2020
SITE ENVIRONMENTAL REPORT
VOLUME II
GROUNDWATER STATUS REPORT

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Environmental Protection Division
Groundwater Protection Group

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Contents

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List of Appendices

List of Figures

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List of Tables

Acronyms and Abbreviations

These acronyms and abbreviations reflect the typical manner in which terms are used in Volume II of this document, and may not apply to all situations.

AGS	Alternating Gradient Synchrotron
AOC	Area of Concern
AS/SVE	Air Sparge/Soil Vapor Extraction
AWQS	NYS Ambient Water Quality Standards
BGD	Below Ground Ducts
BGRR	Brookhaven Graphite Research Reactor
BLIP	Brookhaven Linac Isotope Producer
bls	below land surface
BMRR	Brookhaven Medical Research Reactor
BNL	Brookhaven National Laboratory
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
cfm	cubic feet per minute
CFR	Code of Federal Regulations
Ci	curies
COC	Chain of Custody
Co-60	cobalt-60
CRDL	Contract Required Detection Limit
CSF	Central Steam Facility
DCA	1,1-dichloroethane
DCE	1,1-dichloroethylene
DCG	Derived Concentration Guide
DAR	Division of Air Resources
DOE	United States Department of Energy
DQO	Data Quality Objective
DTW	Depth to Water
DWS	Drinking Water Standards
EDB	ethylene dibromide
EDD	Electronic Data Deliverable
EIMS	Environmental Information Management System
EM	Environmental Management
EMS	Environmental Management System
EPA	United States Environmental Protection Agency
EPD	Environmental Protection Division
ER	Emissions Rate
ERP	Emissions Rate Potential
ES	Environmental Surveillance
ESD	Explanation of Significant Differences
EW	extraction well
FFA	Federal Facility Agreement
Freon-11	Trichlorofluoromethane
Freon-12	Dichlorodifluoromethane
ft	feet
ft msl	feet relative to mean sea level
GAC	granular activated carbon
gal/hr	gallons per hour
gpm	gallons per minute
HFBR	High Flux Beam Reactor
HWMF	Hazardous Waste Management Facility
IAG	Inter Agency Agreement
ID	identification
IPE	Industrial Park East
lb/gal	pounds per gallon
lb/hr	pounds per hour
lbs	pounds
LIE	Long Island Expressway
Linac	Linear Accelerator
LIPA	Long Island Power Authority
LISF	Long Island Solar Farm
mCi	milliCuries
MCL	Maximum Contaminant Level
MDA	Minimum Detectable Activity
MDL	Minimum Detection Limit
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
MGD	millions of gallons per day
MPF	Major Petroleum Facility
mrem/yr	millirems per year
MS/MSD	Matrix Spike/Matrix Spike Duplicate
msl	mean sea level
MTBE	methyl tertiary-butyl ether
MW	monitoring well
Na-22	Sodium-22
NPL	National Priorities List
NSE	North Street East
NSLS-II	National Synchrotron Light Source II
NSRL	NASA Space Radiation Laboratory
NYCRR	New York Code of Rules and Regulations
NYS	New York State
NYSDEC	New York State Department of Environmental Conservation
NYSDOH	New York State Department of Health

O&M	Operation and Maintenance
OU	Operable Unit
PCBs	polychlorinated biphenyls
PCE	tetrachloroethylene
pCi/L	picoCuries per liter
PFS	Pile Fan sump
PLC	programmable logic controller
QA/QC	Quality Assurance and Quality Control
RA V	Removal Action V
RCRA	Resource Conservation and Recovery Act
RHIC	Relativistic Heavy Ion Collider
RI	Remedial Investigation
RI/FS	Remedial Investigation/Feasibility Study
ROD	Record of Decision
RPD	Relative Percent Difference
RTW	Recirculating Treatment Well
RW	remediation well
SBMS	Standards Based Management System
SCDHS	Suffolk County Department of Health Services
SCWA	Suffolk County Water Authority
SDG	Sample Delivery Group
SDWA	Safe Drinking Water Act
SOP	Standard Operating Procedure
SPCC	Spill Prevention Control and Countermeasures
SPDES	State Pollutant Discharge Elimination System
Sr-90	strontium-90
STP	Sewage Treatment Plant
SU	standard unit
SVOC	semivolatile organic compound
TCA	1,1,1-trichloroethane
TCE	trichloroethylene
TVOC	total volatile organic compound
TW	temporary well
USGS	United States Geological Survey
UST	underground storage tank
UVB	Unterdruck-Verdampfer-Brunnen Technology (vacuum vaporizing well)
VOC	volatile organic compound
VP	vertical profile
µg/L	micrograms per liter
WCF	Waste Concentration Facility
WLA	Waste Loading Area
WMF	Waste Management Facility
WSB	Western South Boundary

2020 BROOKHAVEN NATIONAL LABORATORY

GROUNDWATER STATUS REPORT

Executive Summary

The *2020 BNL Groundwater Status Report* is a comprehensive summary of data collected during the 2020 calendar year supplemented with relevant investigation data collected during the first quarter 2020, an evaluation of Groundwater Protection Program performance, and recommendations for program changes. This is the twenty fifth annual groundwater status report issued by BNL. This document examines the performance of the program on a project-by-project basis.

GROUNDWATER RESTORATION (COMPREHENSIVE ENVIRONMENTAL RESPONSE, COMPENSATION AND LIABILITY ACT - CERCLA)

Table E-1 summarizes the status and progress of groundwater cleanup at BNL under the provisions of CERCLA. As of December 2020, seven volatile organic compound (VOC) groundwater remediation systems were in operation, along with one strontium-90 (Sr-90) treatment system. In 2020, 44 pounds of VOCs were removed from the Upper Glacial and Magothy aquifers by the treatment systems. To date, 7,700 pounds of VOCs have been removed from the aquifers. The Sr-90 treatment systems removed 0.4 milliCuries (mCi) of Sr-90 from the Upper Glacial aquifer in 2020, for a total of 34 mCi since operations began. Approximately 0.8 billion gallons of groundwater were treated in 2020.

There were 698 monitoring wells and 102 temporary wells sampled as part of the CERCLA Groundwater Monitoring Program, comprising a total of 1,674 groundwater samples. Groundwater remediation activities will continue until the cleanup objectives for the plumes are met. The specific goals are as follows:

- Achieve maximum contaminant levels (MCLs) for VOCs in the Upper Glacial aquifer by 2030
- Achieve MCLs for VOCs in the Magothy aquifer by 2065
- Achieve the MCL of 8 pico Curies per liter (pCi/L) for Sr-90 at the BGRR in the Upper Glacial aquifer by 2070
- Achieve the MCL of 8 pCi/L for Sr-90 at the Chemical/Animal Holes in the Upper Glacial aquifer by 2040

The cleanup objectives will be met by a combination of active treatment and monitored natural attenuation. The comprehensive groundwater monitoring program measures remediation progress.

Table E-1.
BNL Groundwater Remediation System Treatment Summary for 1997 – 2020.

	1997 – 2019		2020	
VOCs Remediation (start date)	Water Treated (gallons)	VOCs Removed (pounds)(c)	Water Treated (gallons)	VOCs Removed (pounds)(c)
OU I South Boundary (Dec. 1996) (a)	4,177,473,000	369	(Closed)	0
OU III Carbon Tetrachloride (Oct. 1999) (e)	153,538,000	349	Decommissioned	0
OU III Building 96 (Feb. 2001)	526,697,000	144	32,000,000	1
OU III Building 452 Freon-11 (March 2012) (a)	124,997,000	106	(Closed)	0
OU III Middle Road (Oct. 2001)	3,612,547,000	1,289	154,000,000	16
OU III South Boundary (June 1997)	5,199,151,000	3,055	85,000,000	6
OU III W. South Boundary (Sept. 2002)	1,912,555,000	156	166,000,000	6
OU III Industrial Park (Sept. 1999)	2,577,662,000	1,077	(Standby) 0	0
OU III Industrial Park East (May 2004) (f)	357,192,000	38	Decommissioned	0
OU III North Street (June 2004)	1,680,942,000	342	(Closed)	0
OU III North Street East (June 2004) (g)	1,009,798,000	44	35,000,000	1
OU III LIPA/Airport (June 2004)	3,528,145,000	472	213,000,000	15
OU III HFBR Tritium Plume (May 1997) (a)	721,795,000	180	(Closed)	0
OU IV AS/SVE (Nov. 1997)	NA (b)	35	Decommissioned	0
OU VI EDB (August 2004)	2,360,057,000	NA(d)	138,000,000	NA (d)
Totals	27,942,549,000	7,656	823,000,000	44

	2003 – 2019		2020	
Sr-90 Remediation (start date)	Water Treated (gallons)	Sr-90 Removed (mCi)	Water Treated (gallons)	Sr-90 Removed (mCi)
OU III Chemical Holes (Feb 2003)	65,663,000	4.94	(Shutdown) 0	0
OU III BGRR (June 2005)	178,803,000	28.7	15,800,000	0.4
Totals	244,466,000	33.64	15,800,000	0.4

Notes:
(a) System was approved for closure in 2019.
(b) Air Sparging/Soil Vapor Extraction (AS/SVE) system performance measured by pounds of volatile organic compounds (VOCs) removed. System was decommissioned in 2003.
(c) Values rounded to the nearest whole number.
(d) Ethylene dibromide (EDB) has been detected in the system influent since 2009 at levels slightly above the standard. Therefore, no removal of VOCs is reported.
(e) System was decommissioned in 2010.
(f) System was decommissioned in 2014.
(g) The North Street East System was restarted in July 2020 for treatment of the EDB plume. Pounds removed in 2020 includes EDB and VOCs.
NA – Not applicable

The locations and extent of the primary VOC and radionuclide plumes at BNL, as of the fourth quarter of 2020, are summarized on **Figures E-1** and **E-2**, respectively. The water table elevation declined approximately one foot during 2020 as the annual precipitation was slightly below average. As a result, a decline in source area contaminant concentrations was observed at the BGRR, WCF, Building 96 and former HWMF where a vadose zone flushing effect has been observed in the past. The source area wells will continue to be monitored closely.

Additional information on the groundwater restoration program is summarized in **Table E-2**.

INSTITUTIONAL CONTROLS

Institutional controls are in place at BNL to ensure effectiveness of all groundwater remedies. During 2020, the institutional controls continued to be effective in protecting human health and the environment. In accordance with the *BNL Land Use Controls Management Plan* (BNL 2013e) the following institutional controls continued to be implemented for the groundwater remediation program:

- Groundwater monitoring, including BNL potable supply systems and Suffolk County Department of Health Services (SCDHS) monitoring of Suffolk County Water Authority (SCWA) well fields closest to BNL;
- Implementing controls on the installation of new supply wells and recharge basins on BNL property;
- Continuing to offer private well testing (via SCDHS) for those homes in the previously defined hook-up area with private wells used for drinking water on properties that previously declined DOE's offer of public water hookups; and
- Maintaining property access agreements for treatment systems off the BNL property.

GROUNDWATER STATUS REPORT RECOMMENDATIONS AND HIGHLIGHTS

The data summarized in this report are the basis for optimizing operational and monitoring elements of the cleanup program. A summary of the highlights and significant changes follows (specific details of which are provided in **Section 5**).

- **OU I South Boundary Treatment System/Former Hazardous Waste Management Facility Sr-90 Plume** –
    - The leading edge of the higher concentration Sr-90 plume is approximately 1,000 feet south of the former Hazardous Waste Management Facility (HWMF) source area and continues to slowly migrate to the south. Updated natural attenuation modeling based on current data indicates the plume will reach the site boundary at concentrations just above the Drinking Water Standard (DWS) by approximately 2080.
    - Two new monitoring wells were installed to improve monitoring of the high concentration segments of the plume near the source area.
- **OU III Building 96 Treatment System –**
    - The increased pumping rate of extraction well RTW-1 has been successful in expanding the capture zone westward and cutting off the plume.
    - While significant progress has been made in groundwater quality following the 2010 source area soil removal, concentrations persist in the immediate source area above the system capture goal. Groundwater monitoring of the source area will continue and liquid carbon with zero valent iron in-situ treatment for this area will be evaluated.
- **OU III Middle Road Treatment System**
    - Groundwater monitoring indicated that VOC concentrations in several wells are not declining at a rate that will meet the ROD cleanup goal of DWS by 2030. Conduct a pre-design characterization for VOCs in groundwater between monitoring well 104-

37 and the Middle Road by installing several temporary vertical profile wells. Install two new extraction wells based on data and groundwater modeling.

- **OU III South Boundary Treatment System –**
    - Groundwater monitoring indicated that VOC concentrations in several wells are not declining at a rate that will meet the ROD cleanup goal of DWS by 2030. Conduct a pre-design characterization of VOCs in groundwater upgradient and downgradient of monitoring well 121-54 and the site boundary by installing up to several temporary vertical profile wells. Install up to two new extraction wells based on data and groundwater modeling.
- **OU III North Street Treatment System –**
    - A petition for system closure was submitted to the regulators in February 2020 as this system has met its cleanup goals. The petition was approved in March 2020. Wells and equipment associated with this system will remain in place until a determination can be made on its use for potential PFAS and/pr 1,4-dioxane remediation.
- **OU III North Street East Treatment System –**
    - The system was to remediate recently discovered ethylene dibromide (EDB). Two new extraction wells began operation in July 2020.
- **LIPA/Airport Treatment System –**
    - If monitoring continues to show concentrations below the capture goal for the LIPA system, petition regulators for system shutdown in 2022.
- **BGRR/WCF Sr-90 Treatment System –**
    - Sr-90 concentrations in source area monitoring wells immediately downgradient of the BGGR (Building 701) and Building 801 decreased in response to a lowering of the water table during 2020 following a high elevation in late 2019. BGRR source area well SR-3 will be monitored and place on standby if Sr-90 remains below DWS in SR-3 and monitoring well 075-701 for six consecutive months.
    - Install several temporary wells along Temple Place to supplement monitoring of the downgradient segment of the WCF plume. Install temporary wells as necessary to monitor high concentrations segments of the downgradient portions of the BGRR and Building 701/801/PFS plumes.
- **Chemical/Animal Holes Sr-90 Treatment System –**
    - The extraction wells continue to be maintained in standby. No significant rebound of Sr-90 concentrations in groundwater have been observed since system shutdown in July 2018. If Sr-90 concentrations in the monitoring and extraction wells do not show any significant rebound through 2021, then a Petition for Closure of the treatment system will be prepared.
- **Operable Unit VI EDB Treatment System –**
    - Geologic and groundwater characterization data obtained in 2020/2021 to support and update groundwater modeling efforts revealed different geologic conditions, and the presence of EDB at greater depths in the Upper Glacial aquifer than originally expected. The intent of the groundwater modeling update was originally to determine the ability of this system to achieve the ROD cleanup goal of DWS by 2030. As a result of recently obtained data, the geologic framework of the groundwater model should be upgraded followed

by a determination of the effectiveness of the current system with respect to both cleanup time and capture of deeper EDB. Any negative impact from recharge of the treated effluent near the leading edge of the plume will also have to be evaluated. Prior to performing new groundwater modeling simulations additional data collection is recommended. A deep vertical profile well should be installed downgradient of EW-1E and both geologic and groundwater quality data obtained to determine the presence of deeper EDB in this area. The groundwater modeling results will determine the scope of system modification in the form of additional extraction wells to ensure plume capture and the achievement of ROD cleanup goals.

- **1,4-Dioxane and PFAS –**
  - During 2020, groundwater samples were collected for 1,4-dioxane and PFAS analyses from 360 permanent wells and 76 temporary wells. The results for these samples were presented in the Phase 4 Characterization Report (BNL 2021a) and in the Time Critical Removal Action PFAS Plume Characterization Report (BNL 2021b) and are summarized in Section 3.5.

FACILITY MONITORING

BNL's Facility Monitoring Program includes groundwater monitoring at eight active research facilities (e.g., accelerator facilities) and support facilities (e.g., fuel storage and waste management facilities). Monitoring conducted at the former g-2 experiment area within the Alternating Gradient Synchrotron (AGS) facility and the Brookhaven Linac Isotope Producer (BLIP) is used to verify the effectiveness of CERCLA corrective actions. During 2020, groundwater samples were collected from 104 wells during 142 individual sampling events.

Highlights of the Facility Monitoring Program are as follows:

- Monitoring conducted during 2020 at BNL's major accelerator facilities (e.g., AGS, Relativistic Heavy Ion Collider, National Synchrotron Light Source-II, and BLIP) has not identified any new impacts to groundwater quality.

- Monitoring conducted at support facilities (Sewage Treatment Plant, Waste Management Facility, Major Petroleum Facility and Motor Pool) has not identified any new impacts to groundwater quality.
- During 2020, tritium concentrations in g-2 source area monitoring wells continued to be periodically above the 20,000 pCi/L DWS, with a maximum concentration of 31,900 pCi/L. Tritium concentrations in BLIP source area monitoring wells continued to be less than the DWS.

Table E-2.
Groundwater Restoration Progress.

Project	Target	Mode	Treatment Type	Expected System Shutdown	Highlights
OU I					
OU I South Boundary (RA V)	VOCs	Closed	Pump and Treat (P&T) with Air Stripping (AS)	2013 (Actual)	No rebound in VOC concentrations has been observed. Petition for Closure approved in Sept. 2019.
Current Landfill	VOCs tritium	Long Term Monitoring & Maintenance	Landfill capping	NA	Periodic VOC increases in monitoring well 088-110 adjacent to the landfill.
Former Landfill	VOCs Sr-90 tritium	Long Term Monitoring & Maintenance	Landfill capping	NA	No longer a continuing source of contaminants to groundwater.
Former HWMF	Sr-90	Long Term Monitoring & Maintenance	Monitoring	NA	Temporary wells installed annually to track migration of Sr-90 plume from former source area. Maximum Sr-90 detected in 2020 of 689 pCi/L in a temporary well. Installed two new permanent monitoring wells. Updated the Sr-90 natural attenuation groundwater model simulation.
OU III					
Chemical/Animal Holes	Sr-90	Standby	P&T with ion exchange (IE)	2018 (Actual)	Petition for Shutdown approved and system shut down in July 2018. Continue to monitor Sr-90 groundwater concentrations in former source area which continue to decline.
Carbon Tetrachloride former source area	VOCs (carbon tetra-chloride)	Decommis-sioned	P&T with carbon	2009 (Actual)	Treatment system was decommissioned in 2010.
Building 96	VOCs	Operational (RTW-2, RTW-3 and RTW-4 in standby)	Recirculation wells with AS for 3 of 4 wells. RTW-1 is P&T with AS.	2023	Monitoring persistent elevated PCE immediately downgradient of former source area.
Building 452	VOCs (Freon-11)	Closed	P&T with AS	2017 (Actual)	Petition for Closure approved in August 2019.
South Boundary	VOCs	Operational (EW-3, EW-5, EW-6, EW-7, EW-8 and EW-12 on standby)	P&T with AS	2023	Extraction well EW-17 is capturing and treating deep VOCs at site boundary. EW-4 is in pulsed pumping mode. Plume migration towards EW-17 slower than anticipated which could impact system shutdown timeframe.
Middle Road	VOCs	Operational (RW-1, RW-4, RW-5, and RW-6 on standby)	P&T with AS	2025	Monitoring persistent elevated deep VOCs south of Princeton Avenue. Plume migration towards extraction wells slower than anticipated which could impact system shutdown timeframe.

continued

Project	Target	Mode	Treatment Type	Expected System Shutdown	Highlights
OU III (cont.)					
Western South Boundary	VOCs	Operational (WSB-2 on standby)	P&T with AS	2026	Four new extraction wells became operational in 2019 to address deeper VOCs to the west. The groundwater is treated at the Middle Road/South Boundary air strippers.
Industrial Park	VOCs	Standby	In-well stripping and P&T with carbon	2021	All extraction wells have been in standby since July 2019 due to VOCs below capture goals.
Industrial Park East	VOCs	Decommissi-oned	P&T with carbon	2009 (Actual)	Treatment system was decommissioned in 2014.
North Street	VOCs	Closed	P&T with carbon	2013 (Actual)	Since VOCs remain below capture goal, a Petition for Closure was approved March 2020.
North Street East	VOCs EDB	Closed (VOCs) Operational (EDB)	P&T with carbon	2014 (Actual for VOCs) 2024 (EDB)	Original VOC system closed in 2020. Temporary well characterization for EDB performed 2018. Two new extraction wells became operational in July 2020 to remediate EDB.
Long Island Power Authority (LIPA) / Airport	VOCs	Operational (LIPA wells on standby/ Airport wells RTW-5A on standby, RTW-2A and 3A pulsed pumping).	P&T and recirculation wells with carbon	2017 LIPA (Actual) 2025 Airport	LIPA extraction wells in standby mode. If VOCs remain low will petition for shutdown in 2022. Persistently elevated VOCs in upgradient monitoring wells along Crestwood Drive may impact Airport system shutdown.
HFBR Tritium	Tritium	Closed	Pump and recharge	2012 (Actual)	A Petition for Closure was approved in March 2019. Ten wells continue to monitor the former source area.
BGRR/Waste Concentration Facility (WCF)	Sr-90	Operational (Standby: SR-4, SR-5, SR-6, SR-7. Pulsed SR-8)	P&T with IE	2026	Source area monitoring downgradient of BGRR, Bldg. 801 and WCF continues to evaluate Sr-90 concentrations dependent on position of water table.
OU IV					
OU IV AS/SVE system	VOCs	Decommissioned	Air sparging/ soil vapor extraction	2003 (Actual)	System decommissioned in 2003.
Building 650 Sump Outfall	Sr-90	Long Term Monitoring	Monitored Natural Attenuation (MNA)	NA	Sr-90 plume continues to slowly attenuate. Temporary wells installed in 2019 verified a southeast shift in the plume.
OU V					
STP	VOCs, tritium	Completed	MNA	NA	Monitoring completed in 2014.

continued

Project	Target	Mode	Treatment Type	Expected System Shutdown	Highlights
OU VI					
Ethylene Dibromide (EDB)	EDB	Operational	P&T with carbon	2024	Additional lithology and chemical data collected in 2020/2021. Results indicate that clay originally thought to be present in the deeper zone, was absent. EDB was also identified below depth of extraction wells. Additional data needed to support rerun of groundwater model to determine path forward.
g-2 and BLIP					
g-2 Tritium Plume	Tritium	Long Term Monitoring & Maintenance	MNA	NA	Tritium concentrations in source area were slightly above the DWS.
BLIP Tritium Plume	Tritium	Long Term Monitoring & Maintenance	MNA	NA	Tritium concentrations continue to be less than DWS.

1.0 INTRODUCTION AND OBJECTIVES

The mission of Brookhaven National Laboratory's Groundwater Protection Program is to protect and restore the aquifer system at Brookhaven National Laboratory (BNL). The program is built on four key elements:

- Pollution prevention: Preventing the potential pollution of groundwater at the source
- Restoration: Restoring groundwater that has been affected at the BNL site
- Monitoring: Monitoring the effectiveness of pollution-prevention efforts, as well as progress in restoring the quality of affected groundwater
- Communication: Communicating the findings and results of the program to regulators and stakeholders

The *BNL 2020 Groundwater Status Report* is a comprehensive summary of groundwater data collected in calendar year 2020 that provides an interpretation of information on the performance of the Groundwater Protection Program. This is the 25th annual groundwater status report issued by BNL. This document examines performance of the program on a project-by-project basis, as well as comprehensively.

How to Use This Document. This document is a detailed technical report that includes analytical laboratory data, as well as data interpretations conducted by BNL's Groundwater Protection Group. This document can also be obtained through BNL's website. Data are presented in four key subject areas:

- Improvements to the understanding of the hydrogeologic environment and surrounding areas
- Progress in cleaning contaminated groundwater
- Identification of any new impacts to groundwater quality due to BNL's active operations
- Proposed changes to the groundwater protection program

This document satisfies BNL's requirement to report groundwater data under the Interagency Agreement and partially fulfills the commitment of the Groundwater Protection Program to communicate the program's findings and progress to regulators and stakeholders.

Section 1 discusses the regulatory requirements of the data collection work in 2020, the site's groundwater classification, and the objectives of groundwater monitoring. **Section 2** discusses the hydrogeologic environment at BNL and its surrounding area. It also summarizes the dynamics of the groundwater flow system in 2020. In **Section 3**, the groundwater cleanup data and progress towards achieving the site's cleanup goals are described. **Section 4** outlines the groundwater surveillance data used to verify that operational and engineered controls are preventing further contamination from BNL's active experimental and support facilities. **Section 5** is a summary of the proposed recommendations to the Groundwater Protection Program identified in **Sections 3 and 4**.

Appendices A and **B** include hydrogeologic data that support the discussions in **Section 2**. **Appendix C** contains the analytical results for each sample obtained under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) program. **Appendix D** contains analytical results for each sample obtained under the Facility Monitoring program. Due to the volume of these data, the report appendices are included on a USB flash drive, which significantly reduces the size of this report in printed format. **Appendix E** contains information on sample collection, analysis, and Quality Assurance/Quality Control (QA/QC). **Appendix F** consists of data supporting the remediation system discussions in **Section 3**, **Appendix G** is a compilation of data usability report forms and **Appendix H** includes the *BNL SR-90 Transport Evaluation for OU I*

Former Hazardous Waste Management Facility (Arcadis 2021). In addition to the appendices, this entire report is included on the USB flash drive with active links to tables and figures.

1.1 Groundwater Monitoring Program

1.1.1 Regulatory Requirements

Activities at BNL are driven by federal and state regulations as well as Department of Energy (DOE) Orders.

Comprehensive Environmental Response, Compensation and Liability Act (CERCLA)

On December 21, 1989, BNL was included on the National Priorities List (NPL) of contaminated sites identified for priority cleanup. DOE, the United States Environmental Protection Agency (EPA), and the New York State Department of Environmental Conservation (NYSDEC) created a comprehensive Federal Facility Agreement (FFA) that integrated DOE's response obligations under CERCLA, the Resource Conservation and Recovery Act (RCRA), and New York State hazardous waste regulations. The FFA, also known as the Interagency Agreement (IAG), was finalized and signed by these parties in May 1992, and includes a requirement for groundwater monitoring (USEPA 1992).

New York State Regulations, Permits, and Licenses

The monitoring programs for the Current Landfill and Former Landfill are designed in accordance with post-closure Operation and Maintenance requirements specified in 6 NYCRR (New York Code of Rules and Regulations) Part 360, *Solid Waste Management Facilities*.

BNL's Major Petroleum Facility (MPF) is operated under NYSDEC Bulk Petroleum Storage License No. 01-1700. This license requires BNL to routinely monitor the groundwater. Together with approved engineering controls, the groundwater monitoring program verifies that storage operations for bulk fuel have not degraded the quality of the groundwater. The engineered controls and monitoring program for the MPF are described in the *BNL Spill Prevention, Control and Countermeasure Plan* (BNL 2016a).

BNL's Waste Management Facility (WMF) is a hazardous waste storage facility operated under NYSDEC RCRA Part B Permit No. 1-4722-00032/00102-0. The permit requires groundwater monitoring as a secondary means of verifying the effectiveness of the facility's administrative and engineered controls.

BNL's State Pollution Discharge Elimination System (SPDES) permit (NY0005835) requires the collection of annual groundwater samples in the vicinity of the Sewage Treatment Plant's recharge basins.

DOE Orders

BNL conducts groundwater monitoring at active research and support facilities in accordance with the environmental surveillance requirements defined in DOE Order 458.1, *Radiation Protection of the Public and the Environment* and DOE Order 436.1, *Departmental Sustainability*.   Groundwater monitoring is conducted to: characterize pre-operational conditions; to detect, characterize, and respond to contaminant releases from site operations and activities; evaluate dispersal and attenuation patterns; and to characterize the potential pathways of exposure to members of the public.

1.1.2 Groundwater Quality and Classification

In Suffolk County, drinking water supplies are obtained exclusively from groundwater aquifers (e.g., the Upper Glacial aquifer, the Magothy aquifer, and, to a limited extent, the Lloyd aquifer). In 1978, EPA designated the Long Island aquifer system as a sole source aquifer pursuant to Section 1424(e) of the Safe Drinking Water Act (SDWA). Groundwater in the sole source aquifers underlying the BNL site is classified as "Class GA Fresh Groundwater" by the State of New York (6 NYCRR Parts 700–705); the best usage of Class GA groundwater is as a source of potable water. Accordingly, in establishing the goals for protecting and remediating groundwater, BNL followed federal Drinking Water Standards (DWS), New York State (NYS) DWS, and NYS Ambient Water Quality Standards (AWQS) for Class GA groundwater.

For drinking water supplies, the applicable federal maximum contaminant levels (MCLs) are set forth in 40 CFR (Code of Federal Regulations) 141 (for primary MCLs) and 40 CFR 143 (for secondary MCLs). In New York State, the SDWA requirements relating to the distribution and monitoring of public water supplies are promulgated under the NYS Sanitary Code (10 NYCRR Part 5), enforced by the Suffolk County Department of Health Services (SCDHS) as an agent for the New York State Department of Health (NYSDOH). These regulations apply to any water supply that has at least five service connections or that regularly serves at least 25 individuals. BNL supplies water to approximately 3,000 employees and visitors, and therefore must comply with these regulations. In addition, DOE Derived Concentration Guides (DCGs) are used for radionuclides not covered by existing federal or state regulations (DOE 2011). On August 26, 2020, New York State formally adopted maximum contaminant levels of 10 ng/L for perfluorooctane sulfonate (PFOS), 10 ng/L for perfluorooctanoic acid (PFOA) and 1.0 µg/L for 1,4-dioxane.

BNL evaluates the potential impact of radiological and nonradiological levels of contamination by comparing analytical results to NYS and DOE reference levels. Nonradiological data from groundwater samples collected from surveillance wells usually are compared to NYS AWQS (6 NYCRR Part 703.5). Radiological data are compared to the DWS for tritium, strontium-90 (Sr-90), gross beta; gross alpha, radium-226, and radium-228; and the 40 CFR 141/DOE DCGs for determining the 4 millirems per year (mrem/yr) dose for other beta- or gamma-emitting radionuclides.

Tables 1-1, 1-2, 1-3, and **1-4** show the regulatory and DOE "standards, criteria, and guidance" used for comparisons to BNL's groundwater data.

1.1.3 Monitoring Objectives

Groundwater monitoring is driven by regulatory requirements, DOE Orders, best management practice, and BNL's commitment to environmental stewardship. BNL monitors its groundwater resources for the following reasons:

Groundwater Resource Management

- To support initiatives in protecting, managing, and remediating groundwater by refining the conceptual hydrogeologic model of the site and maintaining a current assessment of the dynamic patterns of groundwater flow and water-table fluctuations.
- To determine the natural background concentrations for comparative purposes. The site's background wells provide information on the chemical composition of groundwater that has not been affected by BNL's activities. These data are a valuable reference for comparison with the groundwater quality data from affected areas. The network of wells also can warn of any contaminants originating from potential sources that may be located upgradient of the BNL site.
- To ensure that potable water supplies meet all regulatory requirements.

Groundwater Facility Monitoring

- Determine pre-operational/baseline groundwater quality at new facilities.
- To verify that administrative and engineered controls effectively prevent groundwater contamination.
- To demonstrate compliance with applicable DOE and regulatory requirements for protecting groundwater resources.

Groundwater - CERCLA Monitoring

- To track a dynamic groundwater cleanup problem when designing, constructing, and operating treatment systems.
- To measure the performance of the groundwater remediation efforts in achieving cleanup goals.
- To protect public health and the environment during the cleanup period.
- To define the extent and degree of groundwater contamination.
- To provide early warning of the arrival of a leading edge of a plume, which could trigger contingency remedies to protect public health and the environment.

The details of the monitoring are described in the *BNL 2020 Environmental Monitoring Plan* (BNL 2020). This plan includes a description of the source area, description of groundwater quality, criteria for selecting locations for groundwater monitoring, and the frequency of sampling and analysis. **Figure 1-1** highlights BNL's operable unit (OU) locations designated as part of the CERCLA program, and key site features. Details on the sampling parameters, frequency, and analysis by well are listed in **Tables 1-5** and **1-6**. Screen zone, total depth, and ground surface elevations have been summarized in **Table 1-7**. **Figure 1-2** shows the locations of wells monitored as part of the Laboratory's groundwater protection program. Detailed groundwater monitoring rationale can be found in the *BNL 2020 Environmental Monitoring Plan* (BNL 2020a). BNL's CERCLA groundwater monitoring has been streamlined into five general phases **(Table 1-8)**:

<u>Start-up Monitoring</u>

A quarterly sampling frequency is implemented on all wells for a period of two years. This increased sampling frequency provides sufficient data while the system's operation is in its early stages.

<u>Operations and Maintenance (O&M) Monitoring</u>

This is a period of reduced monitoring during the time when the system is in a routine operational state. The timeframe for each system varies. This phase is also utilized for several plume monitoring programs not requiring active remediation.

<u>Shutdown Monitoring</u>

This is a two-year period of monitoring implemented just prior to petitioning for system shut down. The increased sampling frequency provides the necessary data to support the shutdown petition.

<u>Standby Monitoring</u>

This is a period of reduced monitoring, up to a five-year duration, to identify any potential rebounding of contaminant concentrations. If concentrations remain below MCLs, the petition for closure and decommissioning of the system is recommended.

<u>Post Closure Monitoring</u>

This is a monitoring period of varying length for approximately 20 percent of the key wells in a given project following system closure. Monitoring continues until the Record of Decision (ROD) goal of meeting MCLs for VOCs in the Upper Glacial aquifer is reached. This is expected to occur by 2030. This phase is considerably longer for the Magothy and Sr-90 cleanups due to greater length of the time to reach MCLs required for those projects.

Since 2001, BNL uses a structured Data Quality Objective (DQO) process to continually review and refine the groundwater monitoring and remediation projects. The results of the DQO reviews are documented annually in updates to the BNL Environmental Monitoring Plan.

Modifications are implemented to specific wells to adjust sample frequencies or parameters in order to account for changing conditions or unexpected results. These modifications may temporarily alter the monitoring of a well from specifications associated with the general phase of monitoring stated for that well.

Table 1-8. CERCLA Groundwater Monitoring Program – Well Sampling Frequency.

Project Activity Phase	Well Type	Phase Duration (yrs.)	Sampling Freq. (events/yr.)****
Start-up Monitoring	Plume Core	2	4x
	Plume Perimeter	2	4x
	Sentinel/Bypass	2	4x
O&M Monitoring	Plume Core	End Start-up to Shutdown*	2x
	Plume Perimeter	End Start-up to Shutdown*	2x
	Sentinel/Bypass	End Start-up to Shutdown*	4x
Shutdown Monitoring	Plume Core	2	4x
	Plume Perimeter	2	4x
	Sentinel/Bypass	2	4x
Standby Monitoring	Key Plume Core	5	2x
	Plume Perimeter	5	1x
	Sentinel/Bypass	5	2x
Post Closure Monitoring***	20% of key wells	Up To 2030**	1x

Notes:
*- Varies by project, see Table 1-5.
** - Magothy: 2065, BGRR Sr-90: 2070, South Boundary Rad: 2038, Chem Holes Sr-90: 2040
*** - Verification monitoring for achieving MCLs.
****- Sr-90 monitoring projects use approximately half the defined sampling frequency.

The groundwater monitoring well networks for each program are organized into background, core, perimeter, bypass, and sentinel wells. The wells are designated as follows:

- Background –water quality results will be used to determine upgradient water quality
- Plume Core – utilized to monitor the high concentration or core area of the plume
- Perimeter – used to define the outer edge of the plume both horizontally and vertically
- Bypass – used to determine whether plume capture performance is being met
- Sentinel – An early warning well to detect the leading edge of a plume.

1.2 Private Well Sampling

In accordance with the OU III and OU VI RODs, DOE formally offers the owners that previously declined DOE's offer of public water hookups free testing of their private drinking water wells on an annual basis. SCDHS coordinates and performs the sampling and analysis. During 2020, there were four known residences within the defined hook-up area south and east of BNL who continue to use their private wells for drinking water purposes. In December 2020 and January 2021, all four homeowners had their wells sampled. One home had their private and agricultural well tested. In addition to the routine analyses typically performed, the wells were also analyzed for six per- and polyfluoroalkyl substances (PFAS) and 1,4-dioxane. The SCDHS transmitted the PFAS results to the homeowners.

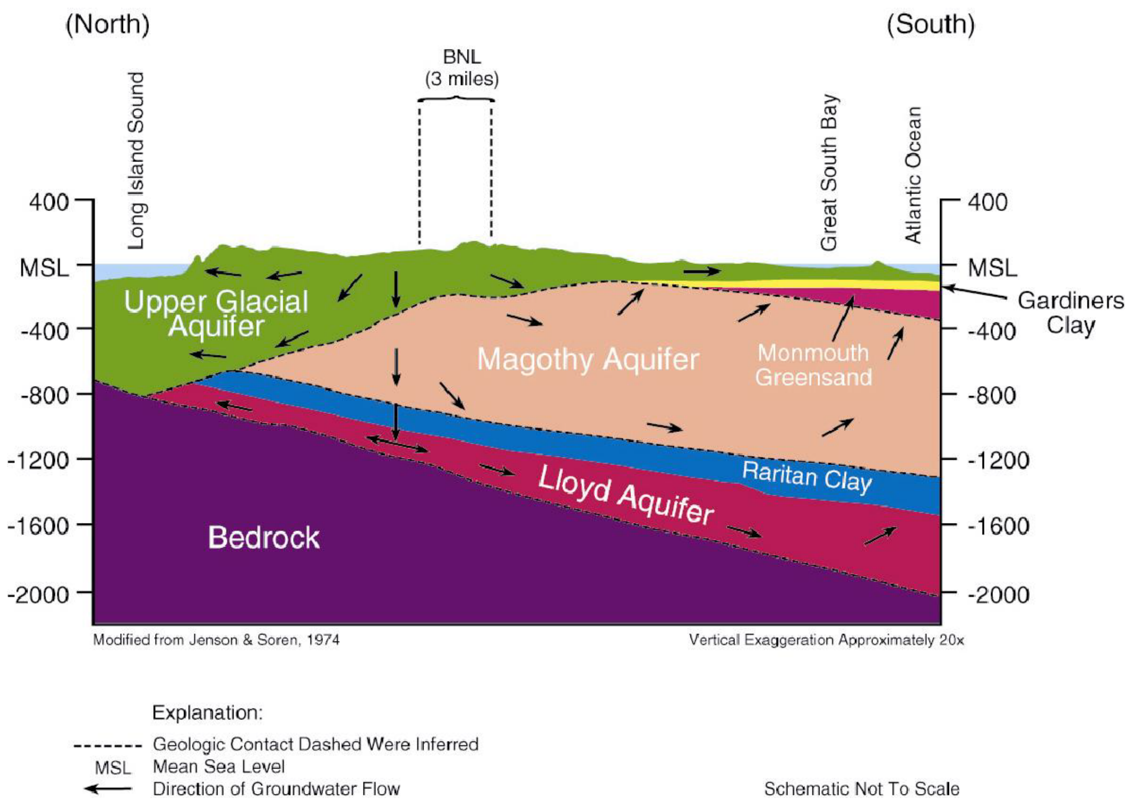
In May 2019, BNL and the SCDHS signed a Technical Services Agreement (TSA) to sample private drinking water supply wells that might be present on 111 properties located south of BNL, in Yaphank, Shirley, and Manorville. This list included the four properties that are part of the routine surveillance program described above. In January 2020, the TSA was modified to include an additional 50 properties, bringing the total to 161 properties to be evaluated. If it was determined that private wells are present on the properties, and the property owner agreed, water samples were collected by SCDHS and analyzed for six PFAS by BNL's contractor laboratory, and for 1,4-dioxane by the Suffolk County Public and Environmental Health Laboratory. During 2019 and 2020, samples were collected from 81 wells that are located on 79 properties. The SCDHS has communicated the analytical results to the property owners.

2.0 HYDROGEOLOGY

This section briefly describes the hydrogeologic environment at BNL and the surrounding area. It also summarizes the dynamics of the groundwater flow system in 2020, along with on-site pumping rates and rainfall recharge.

Detailed descriptions of the aquifer system underlying BNL and the surrounding areas are found in the U.S. Geological Survey (USGS) report by Scorca and others (1999), *Stratigraphy and Hydrologic Conditions at the Brookhaven National Laboratory and Vicinity, Suffolk County, New York, 1994–97,* and the USGS report by Wallace deLaguna (1963), *Geology of Brookhaven National Laboratory and Vicinity, Suffolk County, New York.* The stratigraphy below BNL consists of approximately 1,300 feet of unconsolidated deposits overlying bedrock (**Figure 2-1**). The current groundwater monitoring program focuses on groundwater quality within the Upper Pleistocene deposits (Upper Glacial aquifer), and the upper portions of the Matawan Group-Magothy Formation (Magothy aquifer).

Figure 2-1.
Generalized Geologic Cross Section in the Vicinity of Brookhaven National Laboratory.



The Pleistocene deposits are about 100–200 feet thick and are divided into two primary hydrogeologic units: undifferentiated sand and gravel outwash and moraine deposits, and the finer-grained, more poorly sorted Upton Unit. The Upton Unit makes up the lower portion of the Upper Glacial aquifer beneath several areas of the site. It generally consists of fine- to medium-grained white to greenish sand with interstitial clay. In addition to these two major hydrogeologic units, there are several other distinct hydrogeologic units within the Upper Glacial aquifer. They include localized, near-surface clay layers in the vicinity of the Peconic River (including the Sewage Treatment Plant [STP] area), and reworked Magothy deposits that characterize the base of the aquifer in several areas. The Gardiners Clay is a regionally defined geologic unit that is discontinuous beneath BNL and areas to the south. Typically, it is characterized by variable amounts of green silty clay, sandy and gravelly green clay, and clayey silt.

Where it exists, the Gardiners Clay acts as a confining or semi-confining unit that impedes the vertical flow and migration of groundwater between the Upper Glacial aquifer and the underlying Magothy aquifer.

The Magothy aquifer is composed of Cretaceous aged continental deltaic deposits. The Magothy aquifer at BNL is approximately 800 feet thick, and because it is composed of fine sand interbedded with silt and clay, it is generally less permeable than the Upper Glacial aquifer. The Magothy aquifer is highly stratified. Of particular importance at BNL is that the upper portion of the Magothy contains extensive, locally continuous layers of grey-brown clay (referred to herein as the Magothy Brown Clay). Regionally, the Magothy Brown Clay is not interpreted as being continuous; however, beneath BNL and adjacent off-site areas, it acts as a confining unit (where it exists), impeding the vertical flow and movement of groundwater between the Upper Glacial and Magothy aquifers.

Regional patterns of groundwater flow near BNL are influenced by natural and artificial factors. **Figure 2-2** shows the locations of pumping wells and recharge basins. Under natural conditions, recharge to the regional aquifer system is derived solely from precipitation. A regional groundwater divide exists immediately north of BNL near Route 25. It is oriented roughly east–west, and appears to coincide with the centerline of a regional recharge area. Groundwater north of this divide flows northward, ultimately discharging to the Long Island Sound (**Figure 2-1**). Shallow groundwater in the BNL area generally flows to the south and east. During high water-table conditions, groundwater can discharge into local surface water bodies such as the Peconic River and adjacent ponds. The BNL site is within a regional deep-flow recharge area, where downward flow helps to replenish the deep sections of the Upper Glacial aquifer, the Magothy aquifer, and the Lloyd aquifer. South of BNL, groundwater flow becomes more horizontal and ultimately flows upward as it moves toward regional discharge areas such as the Carmans River and Great South Bay. Superimposed on the natural regional field of groundwater flow are the artificial influences due to pumping and recharge operations.

2.1 Hydrogeologic Data

Various hydrogeologic data collection and summary activities were undertaken as part of the 2020 Groundwater Protection Program to evaluate groundwater flow patterns and conditions. This work is described in the following sections and includes the results of groundwater elevation monitoring, information on pumping and recharging activities on-site and off-site, and precipitation data.

2.1.1 Groundwater Elevation Monitoring

Synoptic water levels are obtained from a network of on-site and off-site wells screened within the shallow to middle sections of the Upper Glacial aquifer. These data are used to characterize the groundwater flow-field (direction and rate) and to evaluate seasonal and artificial variations in flow patterns.

Due to scheduling delays, the synoptic water-level measurement event for this report was conducted during January 25-28, 2021 using approximately 160 on-site and off-site wells. Water levels were measured with electronic water-level indicators following the BNL *Environmental Monitoring Standard Operating Procedure* EM-SOP-300. **Appendix A** provides the depth-to-water measurements and the calculated groundwater elevations for these measurements. Monitoring results for long-term and short-term hydrographs for select wells are discussed in **Section 2.2**.

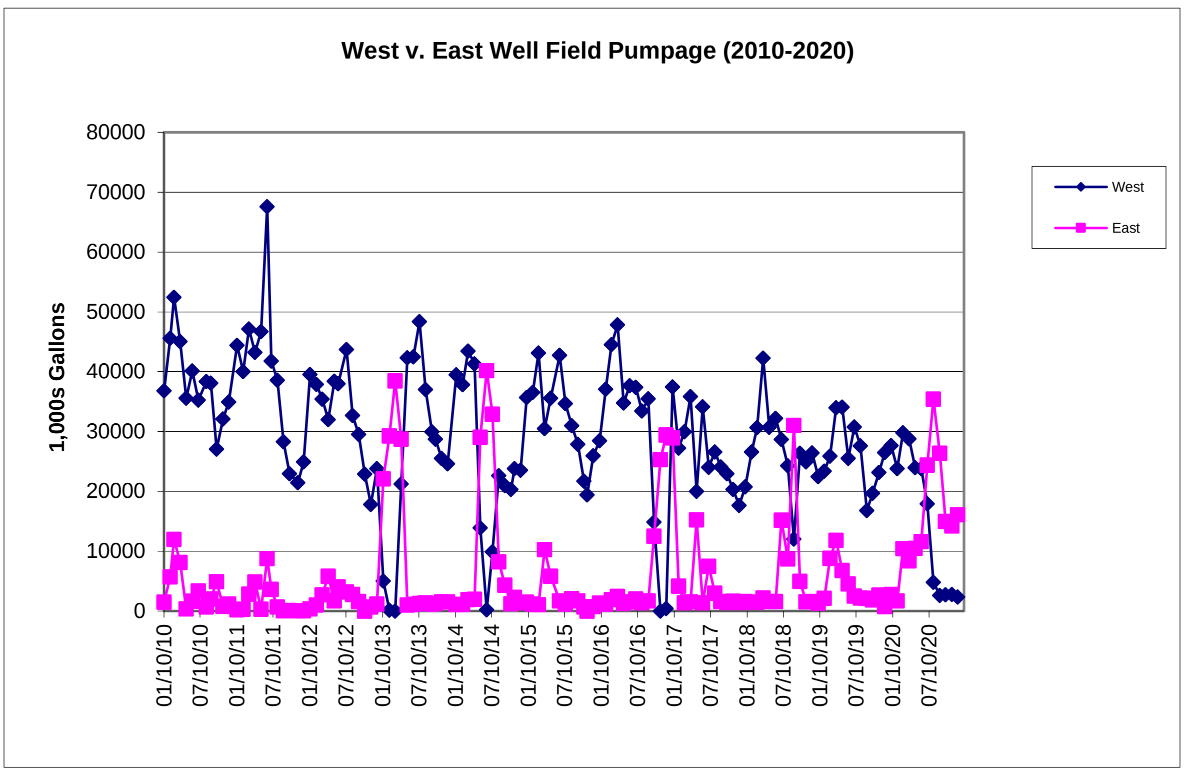
2.1.2 Pumpage of On-Site Water Supply and Remediation Wells

BNL has six water supply wells to provide potable and process cooling water, and 71 treatment wells used for the remediation of contaminated groundwater. All six water supply wells are screened entirely within the Upper Glacial aquifer. Twenty-six of the 71 treatment wells were in operation during some time in 2020 (**See Table 3.0-1**). The location and operational status of the treatment wells (full time operation, pulsed pumping, standby off) and treatment systems (operating, shut down, decommissioned) are shown on **Figure 3.0-1**. **Figure 2-2** show the locations of the water supply and remediation wells. The effects that the groundwater withdrawals have on the aquifer system are discussed in **Section 2.2**.

Table 2-1 provides the monthly and total water usage for 2020 for potable supply wells 4, 6, 7, 10, and 11. It includes information on each well's screened interval and pumping capacity. The variation in monthly pumpage reflects changes in water demand, and maintenance schedules for the water supply system. The western potable well field includes wells BNL-4, BNL-6, and BNL-7; and the eastern field currently includes wells BNL-10 and BNL-11. Eastern supply well BNL-12 has been out of service since October 2008. For the past 10 years, supply well BNL-4 has been of limited use due to low yield resulting from age and iron fouling of the screen. Its future use will be further restricted due to its close proximity to BNL's firehouse, which has been identified as a significant source of per- and polyfluoroalkyl substances (PFAS) contamination. Since June 2018, the use of supply well BNL-6 has been limited due to the detection of PFAS chemicals perfluorooctane sulfonate (PFOS) and perfluorooctanoic acid (PFOA) at combined concentrations that were close to the EPA Lifetime Health Advisory Level (HAL) of 70 ng/L. PFOS concentrations in BNL-6 would also exceed the NYS drinking water standard of 10 ng/L that was established in August 2020.

Water supply operating protocols have been established by the BNL Water and Sanitary Planning Team to help minimize pumping induced changes in groundwater flow directions in the central portion of the BNL site. Under this protocol, the goal is to have the western well field provide 75 percent or more of the site-wide water supply. Water from these wells has naturally high levels of iron, and must be treated before distribution. **Figure 2-3** below summarizes monthly pumpage for the eastern and western well fields.

Figure 2-3.
Summary of Monthly Supply Well Pumpage from the BNL Eastern and Western Well Fields 2010 through 2020.



Since 1999, the implementation of effective water conservation measures has resulted in a significant reduction in the amount of water pumped from the aquifer. During 2020, a total of 368 million gallons of water were withdrawn from the aquifer by BNL's potable supply wells. With the required restrictions placed on the continued operation of western wells BNL-4 and BNL-6, BNL was not able to meet its goal of obtaining more than 75 percent of its total water supply from the western well field, which supplied approximately 52 percent of the water for 2020. **Table 2-2** summarizes the 2020 monthly water pumpage for the groundwater remediation systems. Additional details on groundwater remediation system pumping are provided in **Section 3** of this report.

2.1.3 Off-Site Water Supply Wells

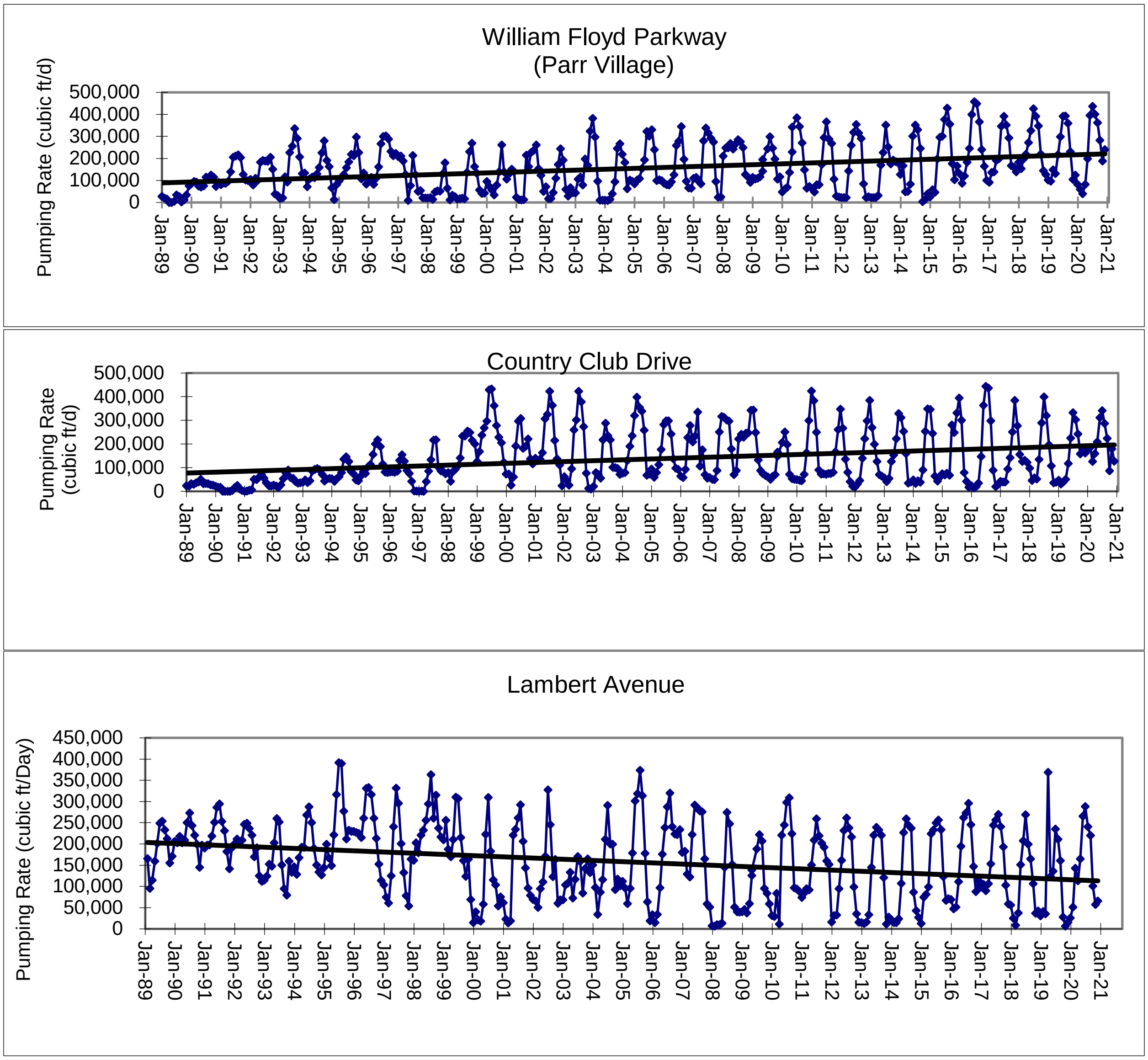
Several Suffolk County Water Authority (SCWA) well fields are located in the vicinity of BNL. The William Floyd Parkway Well Field is west/southwest of BNL (see **Figure 2-2**) and consists of three water supply wells that withdraw groundwater from the mid to deep Upper Glacial aquifer. The Country Club Drive Well Field is south/southeast of BNL, and consists of three water supply wells that withdraw groundwater from the mid-section of the Upper Glacial aquifer. Pumpage information for 1989 through 2020 is provided as **Figure 2-4.** In 2020, the William Floyd Parkway (Parr Village) and Country Club Drive Well Fields produced 634 and 563 million gallons for the year, respectively. The Lambert Avenue Well Field, located south of BNL, produced 396 million gallons for the year.

2.1.4 Summary of On-Site Recharge and Precipitation Data

This section summarizes artificial (i.e., on-site recharge basins) and natural recharge from precipitation. **Table 2-3** summarizes the monthly and total flow of water through 10 on-site recharge basins during 2020. Their locations are shown on **Figure 2-2**. **Section 2.2** (Groundwater Flow) provides a discussion on the effects associated with recharge. Seven of the basins (HN, HO, HS, HT-W, HT-E, HX, and HZ) receive stormwater runoff and cooling water discharges. Flow into these basins is monitored monthly per NYSDEC State Pollutant Discharge Elimination System (SPDES) permit requirements. Generally, the amount of water recharging through the groundwater system to these basins reflects supply well pumpage. Annual water supply flow diagrams show the general relationships between recharge basins and the supply wells. Details on the SPDES program are provided in Volume I of the annual *Site Environmental Report (Chapter 5, Water Quality)*.

The remaining three basins (Removal Action V [RA V], OU III, and Western South Boundary) were constructed to recharge water processed through several of the groundwater remediation systems. **Figure 2-5** provides a comparison of monthly flow rates for basins HO, RA V, OU III and HS over the period of 1999 through 2020. Until September 2001, treated groundwater from the OU III South Boundary Pump and Treat System was discharged solely to the OU III basin along Princeton Avenue. After September 2001, treated groundwater from that system and the OU III Middle Road system was discharged equally to the OU III and RA V basins. Until 2013, water from the OU I South Boundary and the High Flux Beam Reactor (HFBR) system was discharged to the RA V basin. The HFBR and OU I Treatment Systems met their cleanup objectives, and their extraction wells were shut down in May and July 2013, respectively. Because reductions in water discharges to the RA V basin could have resulted in significant changes in local groundwater flow patterns, groundwater modeling was used to determine how to effectively divide the remaining treated water discharges toward the OU III and RA V basins in order to maintain stable groundwater flow directions. Monitoring of groundwater flow patterns demonstrated that this effort was successful for several years. However, with additional reductions in water discharged from the OU III Treatment System, the groundwater flow direction in the Building 650 area has shifted more to the southeast (**Figure 2-2**). Starting in March 2019, the modification to the Western South Boundary Treatment System shifted the treatment of groundwater from this plume to the Middle Road/South Boundary Treatment System. As a result, the treated water has been redirected to the OU III and RA V basins. **Table 2-3** provides estimates of flow to the recharge basins. Other important sources of artificial recharge, not included on **Table 2-3**, include a stormwater retention basin referred to as HW (on Weaver Drive), and the sand filter beds and recharge basins at the STP. Until October 2014, treated water from the STP was discharged to sand filter beds, which contributed to localized mounding of the water table caused by shallow clay and silt deposits. Starting in October 2014, the STP discharge was re-directed to newly constructed groundwater recharge basins located along the eastern portion of the plant. Because the recharge basins are located in an area containing highly permeable soils, these discharges are not causing significant mounding of the water table below the recharge basins. A groundwater mound is still present in the former filter beds due to persistent perched water table conditions resulting from near surface clay and silt deposits.

Figure 2-4.
Suffolk County Water Authority Pumping Near BNL.



Precipitation provides the primary recharge of water to the aquifer system at BNL. Under long-term conditions in undeveloped areas of Long Island, about 50 percent of precipitation is lost through evapotranspiration and direct runoff to streams; the other 50 percent infiltrates the soil and recharges the groundwater system (Aronson and Seaburn 1974; Franke and McClymonds 1972). For 2020, it is estimated that the recharge at BNL was approximately 23 inches. **Table 2-4** summarizes monthly and annual precipitation results from 1949 to 2020 collected on site by BNL Meteorology Services. Variations in the water table generally can be correlated with seasonal precipitation patterns. As shown on **Table 2-4**, total annual precipitation in 2020 was 45.41 inches, which was slightly below the long-term yearly average of 48.94 inches.

2.2 Groundwater Flow

BNL routinely monitors horizontal and vertical groundwater flow directions and rates within the Upper Glacial aquifer by using water-level data collected from a large network of on-site and off-site monitoring wells. Short-term and long-term seasonal fluctuations of water levels are also evaluated using hydrographs for select wells, and trends in precipitation.

2.2.1 Water-Table Contour Map

Figure 2-2 is a groundwater elevation contour map representing the configuration of the water table for January 25-28, 2021. The contours were generated from the water-level data from shallow Upper Glacial aquifer wells. Localized hydrogeologic influences on groundwater flow were considered, including on-site and off-site pumping wells, and on-site recharge basins (summarized in **Section 2.1**).

Groundwater flow in the Upper Glacial aquifer is generally characterized by a southeasterly component of flow in the northern portion of the site, with a gradual transition to a more southerly direction at the southern boundary and beyond. Flow directions in the eastern portion of BNL are predominately to the east and southeast. The general groundwater flow pattern for early 2021 was generally consistent with historical flow patterns. As described in **Section 2.1.2**, the water supply operating protocols established by BNL in 2005 require that the western well field be used as the primary source of water, with a goal of obtaining 75 percent or more of the site's water supply from these wells. Although this goal could not be achieved during 2020, the protocol has generally been effective in maintaining a more stable south-southeast groundwater flow direction in the central portion of the site.

In addition to pumping induced cones of depression near groundwater supply and remediation wells, influences from water recharge activities can be observed as localized mounding of the water table, particularly around recharge basin OU III and the RA V basin (in the center of the site), and the STP. The degree of mounding is generally consistent with the monthly flows to recharge basins summarized in **Section 2.1**. Groundwater mounding is also evident at the Sewage Treatment Plant, and is a result of perched water table conditions resulting from near surface clay and silt deposits.

Other noteworthy features are the influence that surface water bodies have on groundwater flow directions. **Figure 2-2** shows groundwater flowing towards the Carmans River in areas south/southwest of BNL. This pattern is consistent with the fact that the Carmans River is a significant regional discharge boundary.

2.2.2 Well Hydrographs

Groundwater hydrographs are useful in estimating recharge rates and the location of the water table relative to contaminant sources. Long-term (typically 1950–2020) well hydrographs were constructed from water-level data that were obtained for select USGS and BNL wells. These hydrographs track fluctuations in water level over time. Precipitation data also were compared to natural fluctuations in water levels. **Appendix B** contains the well hydrographs, together with a map depicting the locations of these wells.

The long-term hydrographs indicate that typical seasonal water-table elevation fluctuations are on the order of 4 to 5 feet. Some of the water-table elevation changes have occurred during prolonged periods of low precipitation, where a maximum fluctuation of nearly 14 feet was observed during the regional drought of the early 1960s. As shown on the hydrograph for well 065-14, since 2010, when water levels at BNL reached the highest level on record, a nearly 10-foot variation in water table elevations has been observed. Generally, the highest groundwater elevations can be observed during the March-May time period in response to snow melt and spring rains. Normally, the position of the water table drops through the summer and into the fall.

A long-term hydrograph was constructed from historical water-level data from BNL well 065-14 (NYSDEC # S-5517.1; USGS Site Number 405149072532201). This well, installed by the USGS in the late 1940s, is screened in the Upper Glacial aquifer close to the water table. The USGS has collected monthly water-level information from this well from 1948 through 2005. In 2006, the USGS installed a real time continuous water-level recorder in the well. Data from this monitoring station can be accessed on the Web at: http://groundwaterwatch.usgs.gov/AWLSites.asp?S=405149072532201&ncd=rtn.

2.2.3 Groundwater Gradients and Flow Rates

Evaluation of the horizontal hydraulic gradients provides information on the driving force behind groundwater flow. These gradients can be used with estimates of aquifer parameters such as hydraulic conductivity (175 feet per day [ft/day]) and effective porosity (0.24) to assess the velocities of groundwater flow. The horizontal hydraulic gradient at the BNL site is typically 0.001 feet per foot (ft/ft), but in recharge and pumping areas it can steepen to 0.0024 ft/ft or greater. The natural groundwater flow velocity in most of the Upper Glacial aquifer is estimated to be approximately 0.75 ft/day, but velocities can be lower in some portions of the deep Upper Glacial aquifer where finer-grained sands are present. Flow velocities in recharge areas can be as high as 1.45 ft/day, and those in areas near BNL supply wells can be as high as 28 ft/day (Scorca et al. 1999).

2.3 New Geologic Data

During 2020, temporary vertical profile wells were installed for the current firehouse PFAS plume characterization effort. The geologic information on the transition within the Upper Glacial aquifer from shallow coarse-grained sands to the finer-grained Upton Unit was incorporated into the cross section for the Phase 5/Time Critical Removal Action characterization report (BNL 2021b). Additional geologic data was obtained in the off-site OU VI EDB area during the installation of vertical profile wells in September 2020 and March 2021. The geologic data collected during the installation of these wells indicated that the Gardiners Clay is not present in this area as had been previously understood (see **Figure 3.4-2**).

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3.0 CERCLA GROUNDWATER MONITORING AND REMEDIATION

Section 3.0 gives an overview of groundwater monitoring and remediation efforts at BNL during 2020. The section is organized first by Operable Unit, and then by the specific groundwater remediation system and/or plume monitoring program. **Figure 1-2** shows the locations of monitoring wells throughout the site by project. Project specific monitoring well location maps are included throughout **Section 3**.

Report and Data on Flash Drive

Appendices C and D contain the analytical results for each sample. Due to the large volume of data, these appendices are included on a USB flash drive; this significantly reduces the size of the hardcopy of this report. The USB flash drive has a table of contents with active links, such that, by selecting the specific project and analytical suite, the user will be directed to the associated table of results. The groundwater results are arranged by specific monitoring project and then by analytical group [e.g., volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), Per- and Polyfluoroalkyl Substances (PFAS), 1,4-dioxane, metals, chemistry, pesticides/polychlorinated biphenyls (PCBs), and radionuclides]. The data are further organized by well identification (ID) and the collection date of the sample. Chemical/radionuclide concentrations, detection limits, and uncertainties are reported, along with a data verification, validation, and/or usability qualifier (if assigned), and/or a laboratory data qualifier. If a data verification/validation qualifier was not assigned by BSA, the laboratory data qualifier is presented. Results that exceed the corresponding groundwater standard or guidance criteria (**Section 1.1.1**, Regulatory Requirements) are in bold text. The complete analytical results are included to allow the reader the opportunity for detailed analysis.

Plume Maps

Maps are provided that depict the areal extent and magnitude of the contaminant plumes. In most cases, the VOC plumes were simplified by using the total VOC (TVOC) values for drawing the contours, except for those plumes that consist almost exclusively of one chemical, such as the OU III North Street East Ethylene Dibromide (EDB) plume, the OU VI EDB plume, the OU VIII PFOS, PFOA and 1,4-dioxane plumes. TVOC concentrations are a summation of the individual concentrations of VOCs analyzed by EPA Methods 524.2.

The extent of plumes containing VOC contamination was contoured to represent concentrations that were greater than the typical NYS AWQS of 5 micrograms per liter (µg/L) for most compounds. PFOS and PFOA plumes are contoured to the MCL of 10 ng/L and 1,4-dioxane to the MCL of 1.0 µg/L. Radionuclide and EDB plumes were contoured to their appropriate DWS. **Figure 3.0-1** shows the VOC and radionuclide plumes as well as the location and operational status of the groundwater extraction wells and treatment systems.

Following the capping of the landfill areas and the beginning of active groundwater remediation systems in 1997, there have been significant changes in the size and concentrations of several of the VOC plumes. These changes can be attributed to the following:

- The beneficial effects of active remediation systems
- Source control and removal actions
- The impacts of BNL pumping and recharge on the groundwater flow system
- Radioactive decay, biological degradation, and natural attenuation

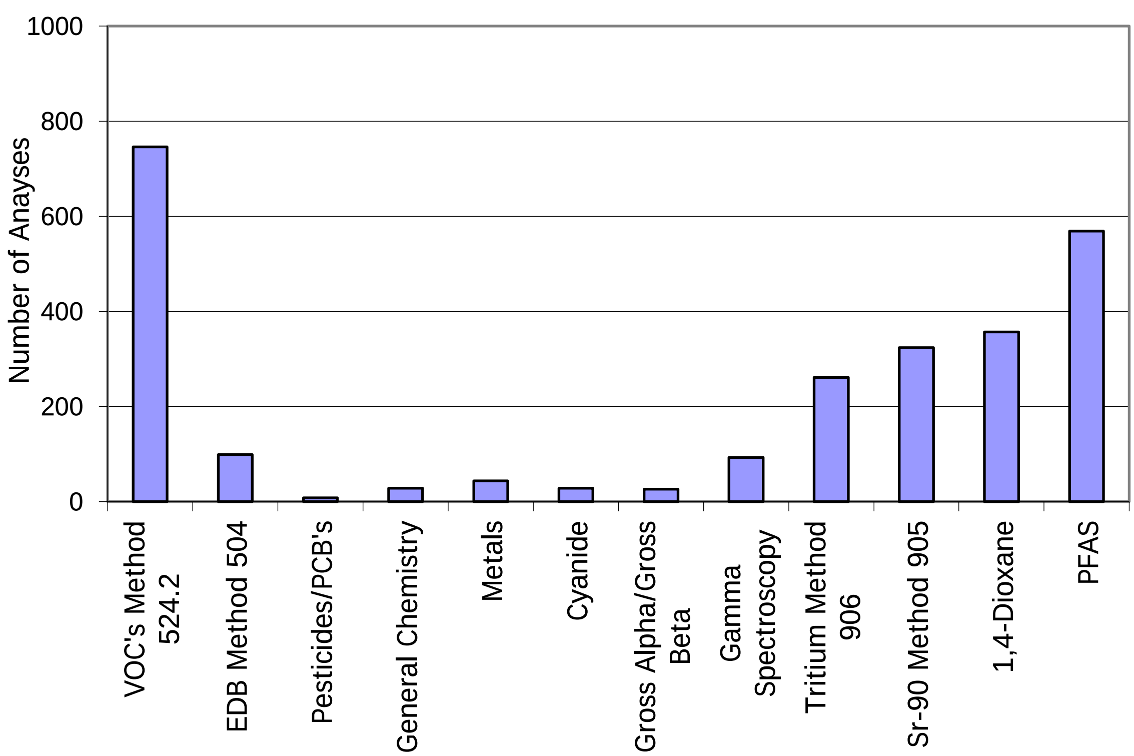
Additionally, BNL's ability to accurately depict these plumes has been enhanced over the years by :

- Installation of additional permanent monitoring wells to the existing well networks
- Installation of temporary wells (vertical profiles and Geoprobes®) that helped to fill in geologic and chemical data gaps as well as characterization of new plumes
- Updates to previous groundwater modeling efforts

During 2020, 1,674 groundwater sampling events from 698 on-site and off-site permanent monitoring wells were used to track the contaminant plumes. From April 1, 2020 through March 31, 2021, 102 temporary wells were installed and 1,116 samples were collected. **Figure 3.0-2** below provides a summary of the number of analyses performed for the permanent monitoring wells arranged by analytical method. Unless otherwise noted, the extent of contamination for a given plume is depicted by primarily using 2020 data from permanent monitoring wells. Contaminant plumes associated with Brookhaven Graphite Research Reactor (BGRR) Sr-90, Building 650 Sr-90, OU I Former Hazardous Waste Management Facility Sr-90, OU VI EDB and PFAS characterization for the former and current firehouses projects were further defined in 2020 using temporary wells (i.e., direct push Geoprobes®) and drilled vertical profile wells.

A single representative round of monitoring data was usually chosen for each plume, typically from the last quarter of the year because it includes the most comprehensive sampling round for the year. This report also serves as the fourth quarter operations report for the remediation systems. Contaminant concentration trend plots for key monitoring wells in each plume are provided to identify significant changes. Data from monitoring wells sampled under BNL's Facility Monitoring Program are evaluated in **Section 4.0**.

Figure 3.0-2.
Summary of Laboratory Analyses Performed for the CERCLA Permanent Monitoring Well Program in 2020.



History and Status of Groundwater Remediation at BNL

Groundwater remediation systems have operated at BNL since 1997 beginning with the OU I South Boundary Pump and Treat System. The goal of groundwater remediation, as defined by the OU III Record of Decision, is to prevent or minimize plume growth and not to exceed MCLs in the Upper Glacial aquifer within 30 years or less (by 2030). Based on additional information obtained during the Strontium-90 Pilot Study, the *OU III Explanation of Significant Differences* (BNL 2005a) identified changes to the cleanup goal timeframes for the Sr-90 plumes. For the BGRR/WCF and Chemical Holes Sr-90 plumes, MCLs must be reached by 2070 and by 2040, respectively. In addition, cleanup of the Magothy aquifer VOC contamination must meet MCLs by 2065.

There are currently eight groundwater remediation systems in operation (as of December 2020). Three systems have met their cleanup goals and have been decommissioned: the OU IV Area of Concern (AOC) 5 Air Sparge/Soil Vapor Extraction System (OU IV AS/SVE); the Carbon Tetrachloride Pump and Treat System; and the Industrial Park East Treatment System. Since 2019, four additional systems, the HFBR Tritium Pump and Recharge System, the Building 452 Freon-11 Treatment System, the OU I South Boundary Treatment System and the North Street Treatment System were approved for closure by the regulators. Although the original North Street East (NSE) Treatment System was approved for an administrative closure in 2020, the carbon filtration units were repurposed for the treatment of the North Street East EDB plume. Furthermore, the HFBR carbon filtration units are being repurposed for treatment of the former firehouse PFAS plume. The air stripper piping for the Building 452 Freon-11 System was reconfigured to treat water from Building 96 extraction well RTW-1. The OU I and North Street systems will be maintained until characterization of PFAS and 1,4-dioxane is complete. **Figure 3.0-1** shows the locations of the treatment systems. In addition to the groundwater treatment systems, two landfill areas (Current and Former) were capped and numerous soil source area removals were conducted, which minimizes the potential for further groundwater contamination.

BNL performs routine maintenance checks on the treatment systems in addition to their routine and non-routine maintenance. In 2020, 703 treatment system samples were obtained from 92 sampling points. The data from the treatment system samples are available in **Appendix F** tables.

In general, BNL uses two types of groundwater remediation systems to treat VOC contamination, air stripping or carbon treatment. Pump and treat remediation consists of pumping groundwater from the plume up to the surface and piping it to a treatment system, where the contaminants are removed by either air stripping or granular activated carbon. Treated water is then introduced back into the aquifer via recharge basins, injection wells, or dry wells. BNL utilizes pump and treat using ion-exchange treatment for remediating Sr-90. Pump and recharge (without treatment for tritium) was utilized to hydraulically contain the HFBR tritium plume. Recirculation well remediation for VOCs consists of pumping the water from a lower well screen, treating it with air stripping or carbon and then reinjecting the clean water into the upper well screen.

Table 3.0-1 summarizes the existing remediation systems. As discussed in the following sections, groundwater modeling is also used as a tool to help determine if remediation of the plumes is proceeding as planned to meet the overall groundwater cleanup goals. When modifications to the remediation systems are necessary, the groundwater model is also used as a tool to aid in the design.

Groundwater Sampling Methodology Summary

Groundwater sampling, analysis methods, quality assurance reviews and database methodologies are detailed in **Appendix E**. A summary of the techniques used are as follows:

Monitoring well groundwater samples are collected using dedicated bladder pumps using a low flow purge technique. A minimum of two times the volume of the sample pump and tubing are purged prior to the sampling of the well. Samples are collected once water quality parameters (pH, specific conductance, and dissolved oxygen) stabilize or when an amount of groundwater equal to 25 percent of a casing volume has been purged. Depending on the parameter, purge flow rates are adjusted to approximately 100 milliliters per minute for sample collection.

The collection of groundwater samples from temporary wells is dependent on the drilling method used. When using an auger rig, hollow stem augers are advanced to the deepest sampling interval. A stainless-steel well screen is connected to two-inch diameter steel well pipe and lowered through the center of the augers to the required sampling depth. The augers are then withdrawn above the well screen. A submersible pump is lowered to the well screen and three well volumes of groundwater are purged prior to sampling. Groundwater samples are collected from the operating pump discharge tubing into laboratory-supplied bottles and preserved according to analysis requirements. This procedure is repeated at each depth interval required by the work plan.

When collecting groundwater samples via a Geoprobe®, a screen is placed inside a sampler sheath and an expendable drive point is attached to the bottom of the sheath and then threaded onto a steel rod. The probe is advanced to the deepest sample collection level and the screen is released using a trip rod. Polyethylene tubing sized to fit inside the probe rods is attached to a check valve. The check valve and tubing are sent down the probe rod until they reach the bottom of the screen, and then withdrawn 12 inches. An inertial pump (e.g., Waterra®) is used to purge the Geoprobe® well. Three casing volumes of groundwater are typically removed prior to sampling. Samples are collected with the inertial pump running continuously.

Since the early 1990's, dedicated bladder pumps have been installed in all BNL monitoring wells that are sampled on a routine basis. The bladder pumps may contain internal components made from polytetrafluoroethylene (PTFE) also referred to as the trade name Teflon®. Furthermore, the pump discharge lines are constructed of PTFE-lined polyethylene. PTFE material is also present in ball valves and pipe sealant that are commonly used in BNL's groundwater treatment system piping, including the sample ports. PTFE has been the preferred material for VOC sampling for many years because, compared to other materials, it does not interact with or adsorb these chemicals.

With the recent need to sample BNL's monitoring wells for Per- and Polyfluoroalkyl Substances (PFAS), there are concerns about potential cross contamination of groundwater samples by the dedicated sample pumps and discharge lines. Although published studies on possible sample cross contamination from PTFE are limited, the preferred current practice for PFAS sampling is not to use products made with PTFE because PFAS (e.g., PFOA) are used during its manufacture and residual amounts of these chemicals may be present in the finished product.

During 2018-2020, BNL conducted a limited comparison study where groundwater samples were collected using existing dedicated bladder pumps and discharge tubing and with PTFE-free pumps and tubing. In addition to collecting samples from monitoring wells and treatment system wells that are screened in aquifer segments impacted by PFAS source areas, samples were also collected from background and downgradient wells not impacted by PFAS. Although ball valves made with PTFE were not replaced at the treatment system piping, existing flexible discharge tubing made with fluoropolymers was replaced with silicone tubing during the sampling events.

Monitoring results for background wells and downgradient wells not impacted by PFAS source areas indicate that PTFE sampling equipment may on occasion release low levels of several PFAS, in particular PFOA, perfluorobutyric Acid (PFBA) and perfluoropentanoic acid (PFPeA). (See detailed discussion in BNL 2021a.) Although PFAS leached from PTFE sampling equipment could result in false-positive results, most PFOA concentrations were well below the 10 ng/L DWS. While PFBA and PFPeA were detected at concentrations >10 ng/L, these chemicals are not currently regulated. The monitoring results suggest that the continued use of PTFE-containing bladder pumps and discharge tubing to collect groundwater samples for PFAS analyses will provide data that are appropriate for decision making. However, the continued use of this sampling equipment should be reevaluated if regulatory standards are established for other PFAS that may leach from PTFE, especially PFBA and PFPeA. When VOCs are not present as a co-contaminant with PFAS in groundwater, BNL will consider utilizing PTFE-free sample pumps and discharge tubing for new wells as they are installed.

Table 3.0-1. 2020 Summary of Existing Groundwater Remediation Systems at BNL.

Operable Unit System	Type	Target Contam	No. of Wells	No. of Wells Oper in 2020[f]	Years in Operation	Recharge Method	Pounds VOCs Removed in 2020/Cumulative
Operable Unit I							
South Boundary[a]	P&T, AS	VOC	2	0	Closed Operated: 16 Standby: 7	Basin	0/369
Operable Unit III							
South Boundary	P&T, (AS)	VOC	8	2	23	Basin	6/3061
HFBR Pump and Recharge[a]	Pump and Recirculate	Tritium	4	0	Closed Operate: 9 Standby: 14	Basin	0/180
Industrial Park	Recirc. Well/ (AS/Carbon)	VOC	7	0	Operate: 16 Standby: 5	Recirc. Well	0/1066
	P&T (Carbon)	VOC	2	0	Operate: 5 Standby: 1	Inj. Wells	0/11
Building 96[d]	Recirc. Well (AS/Carbon)	VOC	4	2	Operate: 16 Standby: 3	Recirc. Well	1/145
Middle Road	P&T (AS)	VOC	7	3	19	Basin	16/1305
Western South Boundary[e]	P&T (AS)	VOC	6	5	18	Basin	6/162
Chemical Holes	P&T (IE)	Sr-90	3	0	Operate: 15 Standby: 2	Dry Well	0[b]/4.94
North Street[g]	P&T (Carbon)	VOC	2	0	Closed Operate: 11 Standby: 5	Inj. Wells	0/342
North Street East	P&T (Carbon)	VOC/ EDB	4	2	Operate:10 Standby: 6	Inj. Wells	1/45
LIPA/Airport	P&T and Recirc. Wells (Carbon)	VOC	10	5	16	Inj. Wells and Recirc. Well	15/487
BGRR/WCF	P&T (IE)	Sr-90	9	5	15	Dry Wells	0.4[b]/29.1
Building 452 Freon-11[a]	P&T (AS)	Freon-11	1	0	Closed Operate: 6 Standby: 2	Basin	0/106
Operable Unit VI							
EDB	P&T (Carbon)	EDB	2	2	16	Inj. Wells	NA[c]
		Total Wells	71	26			

Notes:
AS = Air Stripping
AS/SVE = Air Sparging/Soil Vapor Extraction
EDB = ethylene dibromide
IE = Ion Exchange
LIPA = Long Island Power Authority
NA = Not Applicable
a = Approved for Closure in 2019
P&T = Pump and Treat
g = Approved for Closure in 2020
Recirculation = Double screened well with discharge of treated water back to the same well in a shallow recharge screen
In-Well = The air stripper in these wells is located in the well vault.

b = Sr-90 removal is expressed in mCi.
c = No cumulative EDB calculations are performed based on the low concentrations detected.
d = Well RTW-1 was modified from a recirculation well to surface discharge in May 2008.
e = Four additional extraction wells for the Western South Boundary System became operational in 2019.
f = Includes wells in operation for any time during the year.

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3.1 Operable Unit I

The two sources of VOC groundwater contamination contained within the OU I project are the former Hazardous Waste Management Facility (HWMF) and the Current Landfill. The former HWMF was BNL's central RCRA receiving facility for processing, neutralizing, and storing hazardous and radioactive wastes for off-site disposal until 1997, when a new Waste Management Facility was constructed along East Fifth Avenue. Several hazardous materials spills were documented at the former HWMF. A facility demolition and soil remediation program were completed for this facility in September of 2005.

VOC plumes from the Current Landfill and former HWMF became commingled south of the former HWMF. The commingling was partially caused by the pumping and recharging effects of a spray aeration groundwater remediation system, which operated from 1985 to 1990. This system was designed to treat VOC-contaminated groundwater originating from the former HWMF. The remnants of the VOC plume are depicted on **Figure 3.1-1** and the cross-sectional view on **Figure 3.1-2**.

The on-site segment of the Current Landfill/former HWMF plume was remediated by a groundwater pump and treat system consisting of two wells (EW-1, EW-2) screened in the deep Upper Glacial aquifer at the site property boundary (OU I South Boundary Treatment System). The extracted groundwater was treated for VOCs by air stripping and recharged to the ground at the RA V basin, located northwest of the Current Landfill. A second system (North Street East System) was built to treat the off-site portion of the plume. The off-site groundwater remediation system began operations in June 2004 and was included under the Operable Unit III Record of Decision (**Section 3.2.7**). That system was shut down in 2014 and placed in standby mode. The North Street East System was modified by adding two extraction wells in 2019 to address recently discovered EDB contamination in the deep Upper Glacial Aquifer. Operation of the new wells began in July 2020. A Petition for Shutdown of the OU I South Boundary Treatment System was approved by the regulatory agencies in July 2013. A Petition for Closure was approved by the regulatory agencies in September 2019 as the conditions for closure were satisfied as described in the *OU III ROD* (BNL, 2000a) and the *Operations and Maintenance Manual for the OU I South Boundary Treatment Facility* (BNL 2005b).

3.1.1 OU I South Boundary Treatment System

The OU I South Boundary Groundwater Treatment System was approved for closure by the regulatory agencies in September 2019.

3.1.2 System Description

For a complete description of the former OU I South Boundary Treatment System, see the *Operations and Maintenance Manual for the OU I South Boundary Treatment Facility* (BNL 2005b).

3.1.3 Groundwater Monitoring

Well Network

Six monitoring wells are used for post-closure VOC monitoring of the OU I South Boundary area (**Figure 1-2)**. The Current Landfill Monitoring Program also provides data from one of the primary OU I source areas. A total of 27 permanent wells are used to monitor the former HWMF Sr-90 plume supplemented by sixteen temporary wells installed in 2020. Monitoring wells 098-103 and 098-104 were installed to replace wells 098-101 and 098-102 (installed in 2018) as the wells were inadvertently screened too deep.

Sampling Frequency and Analysis

The wells are monitored for VOCs, and/or Sr-90 as per the schedule provided on **Table 1-5**. During 2020 select wells were analyzed for 1,4-dioxane and PFAS (see **Section 3.5**).

3.1.4 Monitoring Well VOC Results

Figure 3.1-1 shows the remnant of the OU I VOC plume based on samples collected in the fourth quarter of 2020. The data posted on this figure were obtained from the six OU I Post Closure monitoring wells and the Current Landfill monitoring program wells. The primary VOCs detected in this plume consisted of chloroethane and 1,1-dichloroethane (DCA), which originated from the Current Landfill.

The landfill was capped in November 1995. A detailed discussion of the landfill monitoring well data is provided in the *2020 Environmental Monitoring Report, Current and Former Landfill Areas (BNL 2021c).* The downgradient portion of the OU I South Boundary VOC plume (as defined by TVOC concentrations greater than 5 µg/L) has been remediated by a combination of groundwater pump and treat, landfill capping and natural attenuation (**Figure 3.1-1**). The off-site portion of the plume is discussed in **Section 3.2.7**, the North Street East Treatment System.

Figure 3.1-3 gives the historical trends in VOC concentrations for key plume core and bypass wells. **Appendix C** has a complete set of 2020 analytical results. Significant findings for 2020 include:

- TVOC concentrations in Current Landfill source area monitoring well 088-109 have fluctuated largely between ND and 100 µg/L since monitoring of this well began in 1997. Since 2019 concentrations ranged between 1 µg/L and 50 µg/L. This well is located immediately east of the Current Landfill footprint, and approximately 3,500 feet north of the BNL site boundary (**Figure 3.1-1**). All other source area monitoring well TVOC concentrations have remained below 20 µg/L since 2010. Monitoring well 098-99 was installed to provide a sentinel monitoring point approximately 1,200 feet downgradient of the Current Landfill. TVOC concentrations in this well have been less than 10 µg/L since 2018. These data confirm groundwater modeling predictions for the attenuation of VOCs from the Current Landfill.
- Well 107-40 was originally installed to monitor the center line of the plume, approximately 500 feet north of the site boundary. TVOC concentrations in this well have been below the capture goal of 50 µg/L since 2013. In 2017, 1,1-dichloroethylene (1,1-DCE) was the last individual VOC detected above the AWQS in this well.

3.1.5 Radionuclide Monitoring Results

A subset of the OU I Monitoring Program wells is analyzed for tritium annually, Sr-90 semiannually, and gamma spectroscopy annually. The complete results for these wells are provided in **Appendix C**.

Twenty-seven permanent wells are monitored for Sr-90 contamination from the former HWMF **(Table 1-5)**. Two new monitoring wells were installed to replace existing wells as discussed in **Section 3.1.3**. Prior to the installation of these wells, temporary wells were installed to profile Sr-90 concentrations with depth and provide information to guide placement of the well screens. A total of 16 temporary wells were installed in 2020 to supplement the monitoring well network. The highest Sr-90 detected in 2020 was from temporary well GP-40 where a concentration of 689 pCi/L was observed in July 2020 **(Table 3.1-1)**. This is the highest Sr-90 concentration observed in this area historically. The sample in October 2020 from the new monitoring well installed at this location (098-104), had a Sr-90 concentration of 72 pCi/L. Temporary wells have been installed at the same locations previously sampled along a transect at the south edge of the former HWMF (GP-30 and GP-40) and approximately 600 feet to the south in the Long Island Solar Farm (LISF) (GP-71, GP-72, and GP-73). There are two distinct higher concentration plume segments migrating south from the former HWMF. The western segment is monitored by GP-40, GP-72, and GP-73. The eastern segment is monitored by GP-30 and GP-71. Source area well 098-100 located in the central portion of the former HWMF yard was previously represented by temporary well location GP-42. An evaluation of the data from these locations over the previous five years shows that the concentrations in the central portion of the former yard are decreasing. The highest Sr-90 concentrations in the western plume segment are currently located in the vicinity of GP-40 and the leading edge of the higher concentrations has not yet reached GP-72 or GP-73. Sr-90 concentrations in the eastern segment are indicating a decline at GP-30 and that the leading edge of the higher concentrations may be just reaching the GP-71 location. The well locations and plume map are shown on **Figure 3.1-4.** Sr-90 trend plots are provided on **Figure 3.1-5.** It is important to note that the leading edge of the higher Sr-90 concentrations is approximately 1,500 feet north of the site boundary and migrates slowly, at the rate of 20 to 40 feet per year in this area, based on historical monitoring observations.

3.1.6 System Operations

This system was approved for closure in September 2019. The extraction wells remain on standby and system equipment is maintained pending an assessment on future use for either PFAS and/or 1,4-dioxane remediation.

The following is a summary of the OU I system operations for 2020:

January–December 2020
The system remained in standby mode for the year. There was no increase in VOC concentrations observed in the extraction or monitoring well network that required the extraction wells to resume pumping.

3.1.7 System Operational Data

Extraction Wells
During 2020, the extraction wells did not operate (**Table F-1 and Figure 3.1-6**).

System Influent and Effluent
There were no influent or effluent samples as the system was approved for closure in 2019 (**Table F-2 and F-3**).

Cumulative Mass Removal
Approximately 369 pounds of VOCs were removed from the aquifer during system operation from 1996 through 2013 (**Figure 3.1-7 and Table F-4**).

Air Discharge
There were no air emissions as the system was in standby in 2020.

3.1.8 System Evaluation

Although the system remains closed, groundwater monitoring continues, and no rebound of VOC concentrations has been observed. The OU I South Boundary Treatment System performance can be evaluated based on the decisions identified by applying the DQO process.

1. Is there a continuing source of contamination? If present, has the source area been remediated or controlled?

Current Landfill
Yes, VOCs continue to be observed immediately downgradient of the Current Landfill which is covered by an engineered cap. Periodic high water table conditions are suspected to periodically flush contaminants from the vadose zone and/or the bottom of the landfilled materials.

Former HWMF Sr-90
Based on the 2020 data there is a continuing source of Sr-90 in the former HWMF yard. Concentrations in source area monitoring well 098-100 have shown a declining trend over the past two years. The highest plume concentrations appear to be near the southern boundary of the former HWMF yard.

2. Were unexpected levels or types of contamination detected?

Current Landfill

No unexpected results were observed. However, PFAS and 1,4-dioxane were detected above the newly promulgated NYS DWS (see **Section 3.5**).

Former HWMF

Although high Sr-90 concentrations were expected at the GP-40 location, the 689 pCi/L observed in that temporary well during 2020 is the highest concentration in this area historically.

3. Has the downgradient migration of the plume been controlled?

Current Landfill VOCs

The OU I South Boundary System was approved for closure in 2019. VOCs periodically released from the Current Landfill are attenuating as they migrate to the south. The groundwater travel time from the Current Landfill to the BNL site boundary is approximately 12-15 years. Modeling simulations indicate that TVOC concentrations from the Current Landfill will attenuate to below 5 µg/L prior to reaching the site boundary. The modeling results continue to be supported by the TVOC concentration data observed in sentinel monitoring well 098-99 over the past several years.

Former HWMF Sr-90

A plume of Sr-90 exceeding the 8 pCi/L DWS extends from the former HWMF yard to an area within the LISF, approximately 2,400 feet to the south. This plume is migrating slowly to the south as verified by monitoring data obtained over the past several years. Sentinel wells downgradient of the leading edge of the plume continue to exhibit low Sr-90 concentrations.

Groundwater model natural attenuation simulations were updated in 2020 based on the latest data set contained in **Appendix H** (*BNL Sr-90 Transport Evaluation* (Arcadis 2021). The simulation shows that Sr-90 reaches the site boundary in the middle of the Upper Glacial Aquifer at a concentration of approximately 20 pCi/L in 2080. The results are similar to those from the modeling simulation performed in 2015.

4. Can individual extraction wells or the entire VOC treatment system be shut down or placed in pulsed pumping operation?

Yes, the system was approved for closure by the regulators in September 2019. There are no downgradient plume core wells exhibiting individual VOCs above the AWQS.

4a. Are TVOC and Sr-90 concentrations in plume core wells above or below 50 µg/L or 8 pCi/L, respectively?

TVOCs

There was a single detection at the capture goal of 50 µg/L in well 088-109 during 2020. TVOC concentrations throughout the downgradient portion of the plume have been less than the system capture goal of 50 µg/L since January 2013.

Sr-90

Sr-90 was detected above 8 pCi/L in both temporary and permanent wells during 2020. The well locations are shown in **Figure 3.1-4**.

4b. Is there a significant concentration rebound in core wells and/or extraction wells following shutdown?
No significant rebound of VOCs has been observed in either monitoring or extraction wells since the system was shut down in July 2013.

5. Has the groundwater cleanup goal of meeting MCLs for VOCs by 2030 been achieved? Has the groundwater cleanup goal of 8 pCi/L for Sr-90 been achieved?

VOCs
No. MCLs have not been achieved for individual VOCs in all wells. Several Current Landfill area wells have displayed individual VOC concentrations in exceedance of MCLs. There were no exceedances of MCLs in the post-closure downgradient wells in 2020. A comparison of groundwater quality in the OU I South Boundary area is shown on **Figure 3.1-8** which compares the VOC plume from 1997 to 2020.

Sr-90
No. Characterization and monitoring are underway and will continue to track the movement and attenuation of the Sr-90 plume.

3.1.9 Recommendations

The following recommendations are presented for the OU I South Boundary Treatment System and groundwater monitoring program:

- Maintain the VOC post-closure groundwater monitoring program of an annual sample collection from post-closure wells: 098-99, 107-40, 107-41, 115-13, 115-16, and 115-51. Maintain quarterly sampling of Current Landfill sentinel well 098-99.
- Install temporary wells as needed to fill monitoring data gaps and characterize extent of Sr-90 plume.

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3.2 OPERABLE UNIT III

There were a number of groundwater issues addressed under the OU III Remedial Investigation/Feasibility Study (RI/FS). VOC plumes originated from several sources, including Building 96, Building 452 Freon, and sources (some unknown) in the north-central developed portion of the site, the Former Landfill, OU IV, and the former carbon tetrachloride underground storage tank (UST). **Figure 3.2-1** is a representation of the plumes based on areas containing TVOC concentrations exceeding 5 µg/L. The eastern portion of **Figure 3.2-1** also includes the North Street (OU I/IV) plumes. **Figure 3.2-2** is cross-section B–B′, which is drawn through the north–south center-line of the primary OU III VOC plumes, as shown in **Figure 3.2-1**.

The primary chemical contaminants found in OU III groundwater are 1,1,1-trichloroethane (TCA), tetrachloroethylene (PCE), and carbon tetrachloride. These three chemicals are the primary VOCs detected in the OU III on-site monitoring wells. Off site, carbon tetrachloride and PCE are the main contaminants detected.

Figure 3.2-3 presents a comparison of the OU III plumes between 1997 and 2020. Several changes in the plumes can be observed in this comparison:

- Significant progress is evident in reducing the higher concentration segments of the plumes both on and off-site. This is due primarily to the source control and groundwater remediation that has been implemented, along with the effects of natural attenuation.
- Hydraulic control of the plumes by the OU III South Boundary Treatment System at the site boundary, Industrial Park and the LIPA/Airport system is evidenced by the segmentation of the plumes in these areas.
- VOC concentrations have been significantly reduced in the vicinity of the North Street System.
- Deeper VOC contamination was characterized in the Western South Boundary area over the past several years. Remediation of this contamination was enhanced by modifying the system to include four new extraction wells.
- While the NSE plume was addressed under OU III, it is the off-site portion of the OU I South Boundary plume and the plume comparison is included on **Figure 3.1-8**. Remediation of the NSE EDB plume was initiated in 2020 with the addition of two new extraction wells.

Three radiological plumes were addressed under OU III. The HFBR tritium plume, at its maximum extent had travelled several thousand feet south from the HFBR. This plume has naturally attenuated and the pump and recharge system received regulatory approval for closure in March 2019. Sr-90 plumes are present downgradient of the former WCF and several sources related to the BGRR. A Sr-90 plume that is downgradient of the Chemical/Animal Holes area has been largely remediated and the system is currently in shutdown mode.

Sections 3.2.1 through **3.2.13** summarize and evaluate the groundwater monitoring and system operations data for the OU III VOC and radiological plumes, including both operational groundwater treatment systems and the monitoring-only programs.

The detection of PFAS and 1,4-dioxane in select OU III groundwater monitoring wells is discussed in **Section 3.5**.

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3.2.1 Building 96 Treatment System

This section summarizes the 2020 operational data from the OU III Building 96 Treatment System, which consists of three recirculation wells and one extraction well with air stripping and vapor-phase carbon treatment. It also presents conclusions and recommendations for future operation of the system. The system began operation in February 2001. For a history of the operation of these wells over the last 20 years, refer to previous Groundwater Status Reports. Starting in 2012, treatment well RTW-1 was used to treat the low-level downgradient portion of the Building 452 Freon-11 plume (See **Section 3.2.2** for further discussion of the Building 452 Freon-11 plume). The Building 452 Freon-11 Treatment System was approved for closure in 2019.

3.2.1.1 System Description

Recirculation wells RTW-2, RTW-3, and RTW-4, draw contaminated groundwater from the aquifer via a submersible well pump in a lower well screen, 48 to 58 feet below land surface (bls), near the base of the contaminant plume. The groundwater is pumped into a stripping tray adjacent to each of the three wells. After treatment, the clean water is recharged in wells RTW-2 through RTW-4 back to the upper screen, 25 to 35 feet bls. In May 2008, well RTW-1 was modified from a recirculation well to a pumping well with air stripping and hexavalent chromium ion exchange treatment, with discharge to the nearby surface drainage culvert. In January 2010 the ion exchange treatment was bypassed following a decline in hexavalent chromium concentrations below the AWQS and was decommissioned in 2018 following regulatory approval. In June 2019 a new pump and motor was installed in RTW-1 in addition to being connected via pipe to the existing Freon 11 building. This building houses a larger air stripper to handle the increased flow. Well RTW-1 was restarted in June 2020 and the pumping rate was increased from 30 gallons per minute (gpm) to 60 gpm to increase capture of VOCs in the western portion of the plume. A complete description of the system is included in the *Operations and Maintenance Manual Building 96 Groundwater Treatment System* (BNL 2009a).

3.2.1.2 Source Area Soil Remediation

The excavation of soil from the VOC contaminated source area in 2010 had a positive impact on groundwater quality as described below. RTW-1 TVOC concentrations have remained below 10 μg/L since 2019. The increased pumping rate of RTW-1 since July 2019 has had the intended effect of reducing the higher VOC concentrations on the western edge of the plume. The ROD cleanup goal for this groundwater plume is to meet drinking water standards by 2030.

Figure 3.2.1-1 shows the location of the excavated soil contamination area in relation to the 2020 VOC groundwater plume. **Figure 3.2.1-2** shows a hydrogeologic cross section of the area.

3.2.1.3 Groundwater Monitoring

A network of 32 wells is used to monitor the VOC plume and the effectiveness of the Building 96 groundwater remediation system (**Figure 3.2.1-1**). Most of the wells are sampled quarterly and analyzed for VOCs as noted in **Table 1-5**. Well 095-159 has been sampled at a monthly frequency since April of 2019 to evaluate the effect of the increase in RTW-1 pumping on the western edge of the plume. During 2020 select wells were analyzed for 1,4-dioxane and PFAS.

3.2.1.4 Monitoring Well Results

Complete VOC results are provided in **Appendix C**. The fourth quarter 2020 plume is shown on **Figure 3.2.1-1** and trends for several wells are presented on **Figure 3.2.1-3**. PCE is the primary component of this plume. A summary of key monitoring well data for 2020 follows:

Former Source Area to RTW-1:

- The historical maximum in monitoring well 085-379 was observed during 2011 with a TVOC concentration of 2,435 µg/L. This well is located immediately south of the 2010 soil excavation area. This well straddles the water table to ensure that the release of any residual groundwater contamination from the former source area is accounted for in this well during water table fluctuations. Concentrations in this well have ranged between 38 µg/L and 135 µg/L since 2016. Following a dramatic decline in TVOC concentrations in the two to three-year period following the source area soil excavation, the trend has slowed considerably.
- TVOC concentrations in core well 095-305, located approximately 100 feet downgradient of the former source area, have declined significantly since mid-2016. The maximum TVOC concentration in this well was 48 µg/L in January 2018 and dropped off to 3 µg/L in October 2020. Well 085-347, located approximately 40 feet downgradient of the source area and screened at the same depth as 095-305, has shown a sharp decline of TVOC concentrations following detections up to 3,000 µg/L in 2010. The TVOC concentration in this well was 20 µg/L in October 2020.
- The maximum TVOC concentration in well 095-84, located immediately upgradient of extraction well RTW-1 was 27 µg/L in August 2020. This is significantly lower than the historical maximum TVOC concentration in this well of 18,000 µg/L in 1998. As noted on **Figure 3.2.1-3**, since 2010, TVOC concentrations have significantly declined. This declining trend is also evident in plume core well 095-306.
- Well, 095-325, was installed in 2019 immediately north of well 095-306 to evaluate a lowering of the plume depth due to changes in RTW-1 pumping over the years. There has been a noticeable decline in TVOCs in this well since it was installed in 2019 from 252 µg/L to 17 µg/L in January 2021.
- TVOC concentrations in monitoring wells 095-294, 095-307, 095-308, and 095-313 have remained at concentrations below 10 µg/L since 2017. These wells monitor the slightly deeper VOC contamination that had been observed west of the main Building 96 plume.

RTW-1 to Downgradient Recirculation Wells RTW-2 through RTW-4:

- TVOC concentrations in well 095-159 decreased from 134 µg/L in August to non-detect in December of 2020. This correlates well with the increased pumping rate for RTW-1 in July 2019 and indicates that capture of the western edge of the plume has been re-established.

Wells Downgradient of RTW-2 through RTW-4:

- TVOC concentrations observed in the six bypass wells, located immediately downgradient of RTW-2, RTW-3, and RTW-4 (095-163, 095-165, 095-166, 095-168, 095-169, and 095-170) ranged from below to slightly above detectable levels in 2019-2020.
- The maximum TVOC concentration in sentinel monitoring well 095-318, located on Weaver Drive, was 6 µg/L in August 2020. TVOC concentrations in this well have been largely below 5 µg/L since 2015.

Freon-11:

- Building 96 extraction well RTW-1 is also being used to address the remaining low-level Freon-11 concentrations. Well 085-386 was transferred from the Building 452 Freon-11 monitoring program to the Building 96 monitoring program in 2020 following the closure of the Building 452 System. This well is located nearby the former EW-18 extraction well. The 2020 result for Freon-11 from this well was < 1 µg/L. The highest concentration of Freon-11 detected in Building 96 monitoring wells during 2020 was 4 µg/L in 095-312.

3.2.1.5 System Operations

Operating Parameters

Extraction well RTW-1 operated full time during 2020. Extraction well RTW-2 operated until May and was placed in stand-by mode on June 2. Well RTW-3 has remained in stand-by mode since January 2016. RTW-4 has been in stand-by mode since October 2012.

January – September 2020

The system was off April 13 to April 16 due to a lightning storm. RTW-2 was placed in stand-by mode on June 2. The system was off from July 9 to August 7 due to damage to the programmable logic controller resulting from a lightning storm. The system operated normally during the remainder of this period and treated approximately 26 million gallons of water.

October – December 2020

The system was off November 3 to November 20 to diagnose and repair a faulty control cable. The system operated normally during the rest of the period. The system treated approximately 6 million gallons of water.

During 2020 the system treated approximately 32 million gallons of water (**Table F-7**).

3.2.1.6 System Operational Data

Recirculation/Treatment Well Influent and Effluent

Table F-5 lists the monthly influent and effluent VOC concentrations for well RTW-1, and the influent concentrations for wells RTW-2 through RTW-4. The highest TVOC concentration from the influent of these wells was 8.3 μg/L in RTW-1 in the second quarter of 2020. TVOC concentrations in the influent declined to 4 μg/L by December 2020. **Figures 3.2.1-4 and 3.2.1-5** show the TVOC concentrations in the treatment wells over time. **Table 3.2.1-1** shows the maximum measured effluent contaminant concentrations compared to the SPDES equivalency permit for well RTW-1(reported under the Building 452 Freon-11 SPDES Equivalency Permit). The system met all equivalency parameters for operation in 2020. RTW-1 was also used to capture lower levels of Freon-11 from the Building 452 area that migrated beyond extraction well EW-18. EW-18 was approved for closure in 2019. Freon-11 concentrations in RTW-1 have declined from a peak of 38 μg/L in 2013 to barely detectable levels in during 2020.

Table 3.2.1-1
OU III Building 96 RTW-1 Treatment Well, 2020 SPDES Equivalency Permit Levels

Parameter	Permit Level (μg/L)	Max. Measured Value (μg/L)
pH range	5.0–8.5 SU	6.1 – 7. 9 SU
tetrachloroethylene	5.0	<0.5
1,1,1-trichloroethane	5.0	<0.5
thallium	Monitor	<0.5
trichlorofluoromethane	5.0	<0.5
methyl bromide	5.0	<0.5
methyl chloride	5.0	<0.5
methylene chloride	5.0	<0.5

Note: Required effluent sampling frequency is monthly following a period of 24 consecutive weekly with no exceedances. *Weekly* for pH.

Note: The discharge is being reported on the Building 452 Freon-11 SPDES Equivalency Permit.

SU = Standard Units

Starting in June 2019, the flow from Bldg. 96 RTW-1 was increased to 60 gallons per minute and the water is being treated at the Building 452 Freon-11 treatment system due to the larger capacity of that system. Beginning with the July 2019 Discharge Monitoring Report (DMR), the RTW-1 discharge is formally reported under the Freon-11 Equivalency Permit.

Table 3.2.1-2
OU III Building 96 Area
2020 Average VOC Emission Rates

Parameter	Allowable ERP* (lb/hr)	Actual** ER (lb/hr)
dichlorodifluoromethane	0.0000187	0
acetone	0.000674	0
methylene chloride	0.000749	0
2-butanone	0.000187	0
benzene	0.000112	0
tetrachloroethylene	0.000165	0.000000332
m,p-xylene	0.0000116	0
isopropylbenzene	0.000243	0
n-propylbenzene	0.0000599	0
1,3,5-trimethylbenzene	0.000375	0
1,2,4-trimethylbenzene	0.000225	0
4-isopropyltoluene	0.00000749	0
naphthalene	0.0000225	0
carbon disulfide	0.0000487	0
styrene	0.00000637	0
trans-1,3-dichloropropane	0.0000157	0

Notes:

ER = Emissions Rate
ERP = Emissions Rate Potential, stated in lb/hr.
* ERP is based on NYSDEC Air Guide 1 Regulations.
** Actual rate reported is the average for the year.

Air Discharge

In 2020, quarterly air sampling was performed from the GAC vessels before treatment (influent), between the two vessels (midpoint), and after the second vessel (effluent). The analytical data are available on **Table F-6**, and the VOC emission rates are summarized on **Table 3.2.1-2.** The findings are utilized to monitor the efficiency of the GAC units and to determine when a carbon change-out is required. Airflow rates, measured for each air-stripping unit inside the treatment building, show that they typically range between 250 and 450 cubic feet per minute (cfm) for each of the four wells. Assuming a total airflow rate of 1,200 cfm, all compounds detected in the carbon effluent during the operating year were well below the New York State Division of Air Resources (DAR)-1 Air Toxics Assessment limits for the worst-case potential impacts to the public.

Cumulative Mass Removal

Table 3.2.1-3 shows the monthly extraction well pumping rates. The annual average pumping rate for the system was 59 gpm. The pumping and mass removal data are summarized on **Table F-7**. In 2020, approximately 1.4 pounds of VOCs were removed. Since February 2001, the system has removed approximately 144.9 pounds of VOCs.

3.2.1.7 System Evaluation

The Building 96 Treatment System performance can be evaluated based on the decisions identified by applying the DQO process.

1. Is there a continuing source of contamination? If present, has the source area been remediated or controlled?

Yes, TVOC concentrations in source area groundwater declined significantly following the excavation effort, but have been fluctuating in the range of 38 μg/L to 100 μg/L in well 085-379 over the past several years. The detection of 38 μg/L in a October 2020 sample is the lowest value observed in this well since it was installed in 2010. The concentrations in the subsequent January 2021 sampling round was 59 μg/L. The water table elevation decline in 2020 resulted in the inability to sample monitoring wells 085-349, 085-351, 085-354, and 085-378. Well 085-378 was sampled two of the four sampling rounds.

2. Were unexpected levels or types of contamination detected?

No, there were no unexpected VOC levels detected. However, PFAS and 1,4-dioxane were detected above the newly promulgated NYS DWS (see **Section 3.5**).

3. Has the downgradient migration of the plume been controlled?

Yes, the installation of a larger capacity pump and increased pumping rate in RTW-1 has expanded the capture zone to the west. This is evidenced by the steep decline in in well 095-159 TVOC concentrations. See **Figure 3.2.1-6** for a comparison of the plume from 2000 to 2020. TVOC concentrations have remained low in sentinel well 095-318, located on Weaver Drive, indicating the plume is not reaching this location.

4. Can individual extraction wells or the entire treatment system be shut down or placed in pulsed pumping operation?
The system has not met all shutdown requirements. RTW-1 did not exceed the TVOC capture goal in 2020. Influent TVOC concentrations in downgradient recirculation wells RTW-3 and RTW-4 have been below 50 µg/L since 2008. TVOC concentrations in RTW-2 briefly increased up to 65 µg/L in 2018 followed by a steep decline and a maximum concentration of 3 µg/L observed in 2020. Due to the consistently low VOC levels, extraction wells RTW-3 and RTW-4 have remained in standby mode.

4a. Are TVOC concentrations in plume core wells above or below 50 µg/L?
TVOC concentrations in two of 21 core wells were above 50 µg/L in 2020 which is a decrease from six wells in 2018. The highest TVOC concentration in 2020 was 98 µg/L in well 095-159 during April.

4b. Is there a significant concentration rebound in core wells and/or extraction wells following shutdown?
Concentrations in the downgradient extraction wells have remained below 5 µg/L since 2018. RTW-1 has been kept in operational mode given the elevated VOC concentrations in well 085-379.

5. Has the groundwater cleanup goal of meeting MCLs been achieved?
MCLs have not been achieved for individual VOCs in all plume core wells. The highest individual VOC concentrations observed during 2020 was 97 µg/L in 085-379.

3.2.1.8 Recommendations
The following are recommendations for the OU III Building 96 Groundwater Remediation System and monitoring program:

- Maintain full time operation of extraction well RTW-1. Monitor VOC concentrations in well 085-379 to determine when this well can be shut down. Maintain a monthly sampling frequency of the influent and effluent.
- As per a recommendation in the *2021 CERCLA Five-Year Review Report* (BNL, 2021c), closely monitor TVOC concentrations in the plume source area and evaluate/implement a liquid carbon with zero-valent iron in-situ treatment for the immediate source area.
- Reduce the monitoring frequency for well 095-159 from monthly to quarterly as concentrations in this well have decreased because of increased RTW-1 pumping. Reduce the sampling frequency of bypass wells 095-163, 095-165, 095-166, 095-168, 095-169, and 095-170 from quarterly to semi-annual as extraction wells RTW-2, RTW-3, and RTW-4 are in standby mode and TVOC concentrations in these wells have been near to below detectable levels over the previous two years. Reduce sampling frequency for well 085-293 from quarterly to semi-annual as TVOCs have been below 5 µg/L since 2014.
- Maintain treatment wells RTW-2, RTW-3, and RTW-4 in standby mode, and restart the wells if extraction or monitoring well data indicate that TVOC concentrations exceed 50 µg/L.

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3.2.2 Middle Road Treatment System

The Middle Road Treatment System began operating in October 2001. This section summarizes the operational data from the Middle Road System for 2020 and presents conclusions and recommendations for future operation. The analytical data from the monitoring wells are also evaluated in detail.

3.2.2.1 System Description

The Middle Road Treatment System has seven extraction wells and air-stripping treatment to remove VOCs from the groundwater. The system is currently operating utilizing wells RW-2, RW-3, and RW-7. During 2019 the Middle Road system was interconnected with the Middle Road/South Boundary and Western South Boundary systems combining them into a single air treatment system. During this modification four new and two existing Western South Boundary extraction wells were tied in and effluent water discharge is now being monitored under the Middle Road and South Boundary Treatment System SPDES equivalency permit. A complete description of the system is included in the *Operation and Maintenance Manual for the OU III Middle Road and South Boundary Groundwater Treatment Systems, Revision 2* (BNL 2014a) and *Operations and Maintenance Manual for the Western South Boundary Treatment System* (BNL 2020c).

3.2.2.2 Groundwater Monitoring

The Middle Road Monitoring Program consists of a network of 33 monitoring wells (**Figure 1-2**). The locations of these wells are shown on **Figure 3.2.2-1**. The wells are sampled and analyzed for VOCs as shown on **Table 1-5**. During 2020 select wells were analyzed for 1,4-dioxane and PFAS (see **Section 3.5**).

3.2.2.3 Monitoring Well Results

The complete VOC results are provided in **Appendix C**. The highest plume concentrations are generally found in the area between extraction wells RW-7 and RW-2 (**Figure 3.2.2-1**). TVOC concentrations in monitoring wells east of RW-2 are well below the 50 µg/L capture goal for this system. The highest TVOC concentration in Middle Road monitoring wells during 2020 was 268 µg/L in well 105-68 during the January sampling round. This monitoring well is located approximately 500 feet north of extraction well RW-7.

Figure 3.2.2-2 shows the vertical distribution of contamination running along an east–west line through the extraction wells; the location of this cross section (E–E') is shown on **Figure 3.2.2-1**. VOC contamination in the western portion of the remediation area (RW-7 through RW-3) extends to the deep Upper Glacial aquifer/shallow portions of the Magothy aquifer. **Figure 3.2.2-3** shows plots of the VOC concentrations versus time for key monitoring wells. Results for key monitoring wells are as follows:

- Plume core well 104-37 (screened in the deep Upper Glacial aquifer) is approximately 2,000 feet upgradient of RW-7, just south of Princeton Avenue. The TVOC concentration in January 2020 was 95 µg/L. TVOC concentrations in this well were much higher historically, followed by a significant decline. They have remained at its current level for the past few years.
- Well 105-68 is approximately 500 feet north of the extraction well RW-7 in 2013. This well contains elevated TVOC concentrations with the highest concentration of 268 µg/L in January 2020. The data from this location along with data from monitoring wells 104-37 and 121-49 indicate that there is a zone of higher concentration VOC contamination, primarily PCE and carbon tetrachloride, in the deep Upper Glacial aquifer extending from Princeton Avenue to the Middle Road and then south of RW-7 to the South Boundary (**Figure 3.2.2-1** and **Figure 3.2.2-4**).
- Plume core monitoring wells 105-66 and 105-67 continued to show elevated TVOC concentrations in 2020 with maximum values of 214 µg/L and 70 µg/L, respectively.

- TVOC concentrations in monitoring wells in the vicinity of extraction wells RW-4, RW-5, and RW-6 were well below the system capture goal of 50 µg/L in 2020.
- Wells 095-322 and 095-323 are located along Weaver Drive (**Figure 3.2.2-1**). These wells were installed in 2014 to monitor VOCs in the deep Upper Glacial aquifer. Well 095-322 and well 095-323 had TVOC concentrations in November 2020 of 42 µg/L and 22 µg/L, respectively.

3.2.2.4 System Operations

The effluent sampling parameters for pH and VOCs follow the requirements for monthly sampling, as per the SPDES equivalency permit (**Table 3.2.2-1**). The effluent concentrations from the treatment system during this period of operation were below equivalency permit levels. Approximately 154 million gallons of water were treated in 2020 by the Middle Road Treatment System.

The following is a summary of the Middle Road System operations for 2020.

January – September 2020

The system operated normally with RW-2, RW-3 and RW-7 operating full time, and RW-1, RW-4, RW-5 and RW-6 in standby mode. The system was down for approximately five days for maintenance in January. In March, well RW-2 was shut down for 10 days for maintenance. In September RW-7 was down for a week for maintenance. Approximately 128 million gallons of water were treated.

Table 3.2.2-1.
Middle Road Air Stripping Tower
2020 SPDES Equivalency Permit Levels

Parameters	Permit Limit (µg/L)	Max. Observed Value (µg/L)
pH range (SU)	6.5–8.5	6.6 – 7.5
carbon tetrachloride	5	<0.5
chloroform	7	<0.5
dichlorodifluoromethane	5	<0.5
1,1-dichloroethane	5	<0.5
1,1-dichloroethylene	5	<0.5
methyl chloride	5	<0.5
tetrachloroethylene	5	<0.5
toluene	5	<0.5
1,1,1-trichloroethane	5	<0.5
1,1,2-trichloroethane	5	<0.5
trichloroethylene	10	<0.5

Notes: SU = Standard Units
Required sampling frequency is monthly for VOCs and pH.

October – December 2020

The system was off in November for approximately 2 weeks for lift station upgrades at Building 517/518. RW-7 was down for November and December for repairs. During the fourth quarter the system pumped and treated approximately 26 million gallons of water.

3.2.2.5 System Operational Data

System Influent and Effluent

Figure 3.2.2-6 plots the TVOC concentrations in the extraction wells versus time. Results of the extraction well samples are found on **Table F-8.** The influent VOC concentrations showed slight variations and values ranged from 0 to 18.8 µg/L. The results of the influent and effluent sampling are summarized in **Tables F-9** and **F-10**, respectively.

Cumulative Mass Removal

Mass balance was calculated for the period of operation to determine the mass removed from the aquifer by the extraction wells. Average flow rates for each monthly monitoring period were used, in combination with the TVOC concentration in the air-stripper influent, to determine the pounds removed. Flow averaged 293 gpm during 2020 (**Table 3.2.2-3**, and **Table F-11**), and approximately 16 pounds of VOCs were removed. Approximately 1,307 pounds of VOCs have been removed since the system began operations in October 2001. The cumulative total of VOCs removed vs. time is plotted on **Figure 3.2.2-5.**

Air Discharge

Table 3.2.2-2 shows the air emissions data from the system for the OU III Middle Road air stripper tower during 2020 and compares the values to levels stipulated in NYSDEC DAR-1 regulations. Emission rates are obtained through mass-balance calculations for the water treated during that time (**Table F-9**). The concentration of each constituent was averaged for 2020, and those values were used in determining the emissions rate. The air emissions for the Middle Road system were below permitted limits. These emissions on **Table 3.2.2-2** are from the Middle Road system. However, the Middle Road/South Boundary and Western South Boundary systems are currently being co-treated in a singular air-stripper tower and the cumulative total emissions are provided and are still well below permitted levels.

Table 3.2.2-2.
OU III Middle Road Air Stripper
2020 Average VOC Emission Rates

Parameter	Allowable ERP*	Actual** ER	MR/SB/WSB Total ER****
carbon tetrachloride	0.016	0.0001	0.0004
chloroform	0.0031	0	0.0001
chloroethane	10***	0	0
1,1-dichloroethane	10***	0	0
1,2-dichloroethane	0.008	0	0
1,1-dichloroethylene	0.034	0	0.0005
cis-1,2-dichloroethylene	10***	0	0
trans-1,2-dichloroethylene	10***	0	0
tetrachloroethylene	0.387	0.0016	0.0022
1,1,1-trichloroethane	10***	0.0001	0.0004
trichloroethylene	0.119	0	0.0001

Notes:
ERP = Emissions Rate Potential, stated in lb/hr.
* ERP is based on NYSDEC DAR-1 Regulations. Conservative value used from MR/SB/WSB.
** Actual Emission Rate (ER) reported is the average for the year.
*** 6 NYCRR Part 212 restricts emissions of VOCs to a maximum of 10 lb/hr without controls.
**** MR/SB/WSB Total ER =Cumulative Total for MR/SB/WSB.

Extraction Wells

The system is currently operating utilizing wells RW-2, RW-3, and RW-7. Extraction wells RW-4 and RW-5 were shut down in September 2003 and placed on standby due to low concentrations of VOCs. RW-6 was shut down in September 2006. Well RW-1 was shut down in November 2015. The extraction wells are sampled quarterly. TVOC concentrations in wells RW-1, RW-4, RW-5 and RW-6 were all below the capture goal of 50 µg/L in 2020 with a maximum concentration of 6 µg/L in well RW-6 in January. The maximum concentration observed in the operating wells in 2020 was in well RW-7 with a peak TVOC concentration of 39 µg/L in October. See **Figure 3.2.2-6** for a plot of the TVOC concentrations for the seven extraction wells. **Table 3.2.2-3** shows the monthly extraction well pumping rates.

3.2.2.6 System Evaluation

The Middle Road Treatment System performance can be evaluated based on the decisions identified for this system from the groundwater DQO process.

1. Were unexpected levels or types of contamination detected?

No. Unexpected concentrations were not detected. However, PFAS and 1,4-dioxane were detected above the newly promulgated NYS DWS (see **Section 3.5**).

2. Has the downgradient migration of the plume been controlled?

Yes, the plume in the deep Upper Glacial aquifer is being captured by extraction wells RW-2, RW-3 and RW-7. The VOCs that have migrated past Middle Road prior to the installation of RW-7 will be captured by the South Boundary Treatment System.

3. Can individual extraction wells or the entire treatment system be shut down or placed in pulsed pumping operation?
Extraction wells RW-1, RW-4, RW-5 and RW-6 have been in standby. Low TVOC concentrations below the 50 µg/L capture goal continued to be observed in the vicinity of these wells. Extraction wells RW-2, RW-3 and RW-7 will continue operating.

3a. Are TVOC concentrations in plume core wells above or below 50 µg/L?
Five plume core wells have TVOC concentrations above the capture goal of 50 µg/L.

3b. Is there a significant concentration rebound in core wells and/or extraction wells following shutdown?
There has been no rebound in the extraction wells currently in standby mode and no rebound in the monitoring wells in this area.

4. Has the groundwater cleanup goal of meeting MCLs been achieved?
Groundwater contaminant concentrations and areal extent of the OU III plume have decreased significantly due to the operation of the Middle Road Treatment System. However, several monitoring wells are not declining at a rate that will definitively achieve the cleanup goal of 5 µg/L for PCE by 2030. These monitoring wells include 104-37, 105-68, and 105-66.

3.2.2.7 Recommendations

The following recommendations are made for the Middle Road Treatment System and groundwater monitoring program:

- Maintain extraction wells RW-1, RW-4, RW-5 and RW-6 in standby mode. Restart the well(s) if extraction or monitoring well data indicate that TVOC concentrations exceed the 50 µg/L capture goal.
- Continue operation of RW-2, RW-3 and RW-7.
- In order to meet the OU III ROD cleanup goal:
    - Install one or two vertical profile borings (VPBs) to confirm distribution of VOC concentrations in the area of the potential additional extraction well(s).
    - Perform groundwater modeling simulations to help determine the best location, extraction rates, and number of extraction wells to optimize the system and achieve cleanup goals.
    - Install an additional extraction well downgradient of monitoring well 104-37 and an additional extraction well immediately upgradient of 105-68 based on results of characterization and groundwater modeling.

3.2.3 OU III South Boundary Treatment System

This section summarizes the operational data from the South Boundary Treatment System for 2020, and provides conclusions and recommendations for future operation. Also included within this section is an evaluation of the extraction and monitoring well sampling data.

3.2.3.1 System Description

This system began operation in June 1997. It utilizes air-stripping technology for treatment of groundwater contaminated with chlorinated solvents. There are eight extraction wells. The system is currently operating utilizing two extraction wells. The system is currently operating with wells EW-4 and EW-17. EW-4 was placed into a pulsed pumping mode in October 2017. The remainder of the wells are in standby mode. During 2019 the South Boundary system was interconnected with the Middle Road/South Boundary and Western South Boundary systems combining them into a single air treatment system. During this modification four new and two existing Western South Boundary wells were tied in and effluent water discharge is now being monitored under the Middle Road and South Boundary Treatment System SPDES Equivalency permit. A complete description of the system is included in the *Operation and Maintenance Manual for the OU III Middle Road and South Boundary Groundwater Treatment Systems, Revision 2* (BNL 2014a) and *Operations and Maintenance Manual for the Western South Boundary Treatment System* (BNL 2020c).

3.2.3.2 Groundwater Monitoring

The OU III South Boundary monitoring well network consists of a total of 36 monitoring wells and was designed to monitor the VOC plume(s) in this area of the southern site boundary, as well as the efficiency of the groundwater remediation system (**Figure 3.2.3-1**). During 2020, 36 South Boundary wells were sampled and analyzed for VOCs at frequencies detailed in **Table 1-5**. During 2020 select wells were analyzed for 1,4-dioxane and PFAS (see **Section 3.5**).

3.2.3.3 Monitoring Well Results

The South Boundary segment of the OU III VOC plume continued to be bounded by the existing monitoring well network. VOCs were detected in the deep Upper Glacial aquifer in the vicinity of the site boundary, as depicted on **Figure 3.2-2, Figure 3.2.3-1,** and **Figure 3.2.3-2. Appendix C** has the complete groundwater monitoring well results for 2020.

Elevated VOC concentrations remain in the deep Upper Glacial aquifer upgradient of wells EW-4 and EW-17, as can be seen on **Figure 3.2.3-2**, which is a cross section (G–G') drawn along the south boundary. The VOC concentration trends for specific key wells are shown on **Figure 3.2.2-3**. Results for key monitoring wells are as follows:

- Bypass well 121-43, located several hundred feet south of extraction wells EW-4 and EW-17, historically had shown **e**levated levels of VOCs (**Figure 3.2.3-1**). Extraction well EW-17 was installed in July 2012 to address the historical high VOC concentrations that had been observed in well 121-43 and capture the deeper portion of the VOC plume at the boundary. In April 2011 the TVOC concentration in well 121-43 was 338 µg/L and has declined to 1.4 µg/L in November 2020.
- In addition to 121-43, three monitoring wells are used to monitor the performance of extraction well EW-17. They are 121-47 a western plume perimeter well, 121-48 an eastern plume perimeter well, 121-49 located upgradient of this extraction well. The upgradient monitoring well 121-49 showed elevated TVOC concentrations in 2020 with the highest concentration in September at 279 µg/L. However, TVOC concentrations show an overall decreasing trend from 740 µg/L in 2017 to 90 µg/L in November 2020 (**Figure 3.2.2-3**).
- Monitoring well 121-45 was installed to monitor the plume between the Middle Road and South Boundary. TVOC concentrations were at 11 µg/L in November. This is a significant reduction from the initial concentration of 613 µg/L in 2006 (**Figure 3.2.2-3**).

- Well 121-54 was installed in 2014 to monitor VOC concentrations upgradient of extraction well EW-17. This well has had persistent TVOC concentrations between 100 and 250 µg/L since 2014 and a concentration of 177 µg/L in May 2020. Well 121-53 was also installed upgradient of EW-17 and it showed a peak TVOC concentration of 71 µg/L in May.
- Well 122-05 is a Magothy monitoring well west of EW-8. TVOC concentrations in this well showed a slight increase to 26 µg/L in 2018 and since dropped to a concentration of 9.3 µg/L in May 2020.

3.2.3.4 System Operations

The individual extraction wells are sampled quarterly and analyzed for VOCs. The effluent sampling parameters of pH and VOCs are obtained monthly, in accordance with SPDES equivalency permit requirements (**Table 3.2.3-1**). In addition, samples are analyzed for tritium with each system-sampling event. Tritium from these samples continues to be non-detect. Effluent VOC concentrations from the treatment system during this period of operation were below equivalency permit requirements. In 2020, approximately 85 million gallons of water were treated by the South Boundary System. Well EW-12 has not been sampled since April 2012. This is because the installation of well EW-17 utilized some of the equipment from this well. In the unlikely event this well is needed, a minor modification could be made to make this well operational. This determination will be made based on the monitoring well data in the vicinity of EW-12. The following is a summary of the South Boundary System operations for 2020.

Table 3.2.3-1.
OU III South Boundary Air Stripping Tower
2020 SPDES Equivalency Permit Levels

Parameters	Permit Limit* (µg/L)	Max. Observed Value (µg/L)
pH range (SU)	6.5 – 8.5	6.6–7.5
carbon tetrachloride	5	<0.5
chloroform	7	<0.5
dichlorodifluoromethane	5	<0.5
1,1-dichloroethane	5	<0.5
1,1-dichloroethylene	5	<0.5
methyl chloride	5	<0.5
tetrachloroethylene	5	<0.5
toluene	5	<0.5
1,1,1-trichloroethane	5	<0.5
1,1,2-trichloroethane	5	<0.5
trichloroethylene	10	<0.5

Notes:

*Maximum allowed by requirements equivalent to a SPDES permit. Required sampling frequency is monthly for VOCs and pH.

SU – Standard units.

January – September 2020

Approximately 71 million gallons of water were pumped and treated. In January, extraction well EW-4 was pulsed pumped and continued through the year with a one month on, one-month off schedule. In January EW-4 was down for two weeks for repair. In May EW-17 was off for 3 weeks for repair. In the first three quarters the OU III South Boundary System pumped and treated approximately 71 million gallons of water.

October – December 2020

In November, EW-4 was down with electrical issues for the majority of November. The system was down for approximately two weeks with lift station upgrades at Building 517/ 518. The OU III South Boundary System pumped and treated approximately 14 million gallons of water.

3.2.3.5 System Operational Data

System Influent and Effluent

Figures 3.2.3-3 and 3.2.3-4 plot the TVOC concentrations in the extraction wells versus time. The overall influent water quality and the individual extraction wells show a declining trend in concentrations. System influent and effluent sampling results are summarized on **Tables F-13** and **F-14**, respectively.

Cumulative Mass Removal

Average flow rates for each monthly monitoring period were used, in combination with the TVOC concentration in the air-stripper influent, to calculate the mass removal (**Table F-15**). The cumulative total of VOCs removed by the treatment system versus time is plotted on **Figure 3.2.3-5**. The 2020 total was approximately 6 pounds. Cumulatively, the system has removed approximately 3,061 pounds since it was started in June 1997.

Air Discharge

Table 3.2.3-2 shows the air emissions data from the OU III South Boundary system for 2020 and compares the values to levels stipulated in NYSDEC DAR-1 regulations. Emission rates are obtained through mass-balance calculations for water treated during that time (**Table F-13**). The concentration of each constituent was averaged for 2020, and that value was used in the calculation. System air emissions were below allowable levels. These emissions on **Table 3.2.3-2** are from the South Boundary system. However, the Middle Road/South Boundary and Western South Boundary systems are currently being co-treated in a singular air-stripper tower and the cumulative total emissions are provided and are still well below permitted levels.

Table 3.2.3-2.
OU III South Boundary Air Stripper
2020 Average VOC Emission Rates

Parameter	Allowable ERP*	Actual** ER	MR/SB/WSB Total ER****
carbon tetrachloride	0.016	0.0001	0.0004
chloroform	0.0031	0	0.0001
chloroethane	10***	0	0
1,1-dichloroethane	10***	0	0
1,2-dichloroethane	0.008	0	0
1,1-dichloroethylene	0.034	0	0.0005
cis-1,2-dichloroethylene	10***	0	0
trans-1,2-dichloroethylene	10***	0	0
tetrachloroethylene	0.387	0.0006	0.0022
1,1,1-trichloroethane	10***	0	0.0004
trichloroethylene	0.119	0	0.0001

Notes:
ERP = Emissions Rate Potential, stated in lb/hr.
* ERP is based on NYSDEC DAR-1 Regulations. Conservative value used from MR/SB/WSB.
** Actual Emission Rate (ER) reported is the average for the year.
*** 6 NYCRR Part 212 restricts emissions of VOCs to a maximum of 10 lb/hr without controls.
**** MR/SB/WSB Total ER =Cumulative Total for MR/SB/WSB.

Extraction Wells

There are two extraction wells currently operating. Well EW-4 continued to show slowly decreasing TVOC concentrations in 2020 from 4.6 µg/L in April to 1.2 µg/L in October. EW-17 showed TVOC concentrations ranging from 14.1 µg/L in January to 15.8 µg/L in October. This well is located slightly downgradient and deeper than well EW-4. EW-4 was placed into a pulsed pumping mode in October 2017. **Table F-12** summarizes the data for the extraction wells. **Table 3.2.3-3** shows the monthly extraction well pumping rates. The system averaged 162 gpm in 2020.

3.2.3.6 System Evaluation

The OU III South Boundary Treatment System performance can be evaluated based on the major decisions identified for this system resulting from the groundwater DQO process.

<u>*1. Were unexpected levels or types of contamination detected?*</u>

No. Unexpected concentrations were not detected. However, PFAS and 1,4-dioxane were detected above the newly promulgated NYS DWS (see **Section 3.5**).

2. Has the downgradient migration of the plume been controlled?
Yes, extraction well EW-17 is capturing the higher concentrations that were migrating beneath well EW-4 since 2012. This has resulted in reduced VOC concentrations in bypass well 121-43 (**Figure 3.2.3-1**). Western plume perimeter well 121-08 had a TVOC concentration of 2.6 µg/L in November. Eastern perimeter well 114-07 has been non-detect since early 2018. Bypass detection wells 122-20 and 122-35 had TVOC concentrations of 7.7 µg/L and 11.6 µg/L respectively. Individual VOC concentrations in the remaining plume perimeter wells were less than 5 µg/L in the fourth quarter of 2020.

3. Can individual extraction wells or the entire treatment system be shut down or placed in pulsed pumping operation?
Six of the eight extraction wells have been shut down as they have achieved the capture goal for this system. Well EW-17 will continue to operate on a full-time basis to capture VOCs in this area, while Well EW-4 will be placed in standby mode.

4. Are TVOC concentrations in plume core wells above or below 50 µg/L?
There are still three plume core wells with persistent TVOC concentrations above 50 µg/L in the capture zones of wells EW-4 and EW-17.

5. Is there a significant concentration rebound in core wells and/or extraction wells following shutdown?
A significant concentration rebound has not been observed in the monitoring or extraction wells in the eastern segment of this system. Two of the western extraction wells are still operating.

6. Has the groundwater cleanup goal of meeting MCLs been achieved?
Monitoring well 121-49, located near EW-4 and EW-17, has a shown a contaminant concentration decrease from 1,265 ug/L TVOCs in November 2011 to less than 100 ug/L in 2020. However, similar to the Middle Road Treatment System, a monitoring well (121-54) located approximately halfway between the Middle Road and South Boundary Treatment System has VOC concentrations that are not decreasing at a rate that will likely achieve cleanup goals by 2030.

3.2.3.7 Recommendations
The following are recommendations for the OU III South Boundary Treatment System and groundwater monitoring program:

- Maintain wells EW-3, EW-5, EW-6, EW-7, EW-8, and EW-12 in standby mode. The system's extraction wells will continue to be sampled on a quarterly basis, with the exception of EW-12. The wells will be restarted if extraction or monitoring well data indicate TVOC concentrations exceed the 50 µg/L capture goal.
- Continue to operate well EW-17 on a full-time basis. Place EW-4 into standby mode. EW-4 is currently being pulsed pumped (one month on/one month off).
- As per recommendations in **Section 3.2.9**, discontinue sampling of OU III South Boundary/Magothy wells 121-40, 121-44 and 122-41. These wells shown detections well below MCL's during the previous twenty years.
- In order to meet the OU III ROD cleanup goal:
    - Install one or two vertical profile borings (VPBs) to confirm distribution of VOC concentrations in the area of the potential additional extraction well.

- o Perform groundwater modeling simulations to help determine the best location, extraction rates, and number of extraction wells to optimize the system and achieve cleanup goals.
- o Install an additional extraction well downgradient of well 121-54 based on results of characterization and groundwater modeling.

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3.2.4 Western South Boundary Treatment System

The Western South Boundary Treatment System was designed to capture VOCs in the Upper Glacial aquifer along portions of the BNL western south boundary. The capture goal for the system is TVOC concentrations exceeding 20 µg/L. The system was designed to reduce additional off-site migration of the contamination, and potential impacts of the VOC plume to the Carmans River. The system began operating in September 2002 and was changed to pulsed pumping mode in late 2005, one month on and two months off. Based on increasing VOC concentrations in an upgradient monitoring well, extraction well WSB-1 was put back into full-time operation starting in November 2008. Extraction well WSB-2 was placed in standby in October 2016. During 2018 four new extraction wells were added to this system. They began operations in March 2019. Details are provided below on the new extraction wells.

3.2.4.1 System Description

A complete description of the Western South Boundary (WSB) Treatment System is contained in the *Operations and Maintenance Manual for the Western South Boundary Treatment System, Rev. 3* (BNL 2020c). A modification to this system to add four new extraction wells was undertaken beginning in June 2018 (see BNL 2018d) and was completed in March 2019. The four new wells and the two existing wells were connected to the Middle Road/South Boundary Treatment System. A schematic of the new well configuration and piping is included as **Figure 3.2.4-7.** The existing Western South Boundary air stripper is no longer needed and will be decommissioned in the future. The Western South Boundary extraction well effluent water discharge is now monitored under the Middle Road and South Boundary Treatment System SPDES Equivalency permit.

3.2.4.2 Groundwater Monitoring

A network of 35 wells is used to monitor this plume. The well locations are shown on **Figure 3.2.4-1**. A total of 21 temporary vertical profile wells and 17 monitoring wells were installed from late 2016 through 2018 to characterize and monitor the extent of deeper VOC contamination in the WSB plume area. The wells are sampled at the O&M phase frequency (**Table 1-5** for details). During 2020 select wells were analyzed for 1,4-dioxane and PFAS (see **Section 3.5**).

3.2.4.3 Monitoring Well Results

The primary VOCs associated with this plume are dichlorodifluoromethane (Freon-12), TCA, and DCE. These VOCs were first observed in vertical profile wells installed throughout the WSB area in the late 1990s as part of the OU III RI/FS. TVOC concentrations ranging from 20 µg/L to 40 µg/L were encountered at depths between 120-170 ft bls throughout the area at that time.

Monitoring of this plume has identified several specific areas of higher VOC concentrations than were observed during the RI/FS. An area of VOC concentrations higher than previously seen (up to 170 µg/L TVOC concentrations) was characterized beginning in 2008, from the Middle Road area south to WSB-1 at the south boundary. This plume segment of higher concentrations was primarily focused at depths between 130 and 150 feet bls. During 2008 and 2009 an area of Freon-12, with concentrations up to 55 µg/L, was characterized in the deep Upper Glacial aquifer at depths of 180-200 feet bls approximately 800 feet south of Princeton Avenue.

During characterization efforts in 2016-2017 to define the southern extent of the deeper Freon-12, a zone of high VOC concentrations was encountered with most of the plume at slightly greater depths than previously seen in this area (140-210 feet bls). The primary VOCs were TCA, DCE and Freon-12.

Figure 3.2.4-1 presents fourth quarter 2020 monitoring well concentrations. **Figure 3.2.4-2** provides a north-south cross section (H- H') of the plume. **Figure 3.2.4-6** provides an east-west cross section (H1-H1') along the site boundary and **Figure 3.2.4-3** provides trend graphs for key monitoring wells. **Section 3.5.1 and 3.5.2** discuss PFAS and 1,4 Dioxane results from monitoring wells located in the Western South Boundary. A summary of key monitoring well data for 2020 follows:

- Based on the monitoring well and characterization data, the areas of higher TCA and DCE concentrations represent slugs of contamination that may have originated from periodic releases. The deeper zones of elevated Freon-12 are even more isolated. **Figure 3.2.4-2** is a vertical cross section from north to south that depicts the data collected. It clearly shows this area of deeper VOC contamination at the Western South Boundary, with some areas of contamination below the Gardiners Clay.
- **Figure 3.2.4-6** shows an east west cross section near the BNL site boundary. This figure shows that the higher concentrations are slightly deeper than the original extraction well WSB-1 and further to the west.
- Well 126-20 located between WSB-4 and WSB-5 had a peak TVOC concentration in 2020 of 56 µg/L in In February. This is a significant reduction from the 2018 peak of 150 µg/L. These contaminants are expected to be captured by the extraction wells WSB-5 and WSB-6.
- Upgradient monitoring wells 103-18 and 103-19 located near Princeton Avenue showed TVOC concentrations during 2020 up to 10 µg/L in June in well 103-18.
- Monitoring well 126-18 is located upgradient of extraction wells WSB-5 and WSB-6. It is screened at a depth similar to well WSB-5, the shallower of the two extraction wells. TVOC concentrations in this well were 62 µg/L in February but declined to 6 µg/L in November . This is a significant reduction from the peak concentration of 203 µg/L in 2018.
- Downgradient monitoring wells 130-09, 130-10 and 130-11 located south of extraction wells WSB-5 and WSB-6 showed a maximum TVOC concentration of 13 µg/L in well 130-11 in November. The other two wells were below AWQS in 2020.
- The area of higher TCA and DCE concentrations that was identified in 2008-2009, extending at that time from well 119-06 at the Middle Road south to WSB-1, has now decreased to a small area in the vicinity of WSB-1. VOC concentrations in upgradient wells 119-06 and 126-17 are below AWQS. The plume segment has migrated towards WSB-1 as shown on **Figure 3.2.4-1**.
- TVOC concentrations in well 126-14, immediately upgradient of well WSB-1, ranged between 41 µg/L and 70 µg/L in 2020. This well is approximately 200 feet north of WSB-1. The well is showing a downward trend from a peak concentration in 2018 of 170 µg/L.
- Three off-site monitoring wells located on the west end of Carleton Drive and are identified as 000-558, 000-559, 000-560. The maximum TVOC concentration in these wells was 17.3 µg/L in well 000-558 in March. No individual VOCs exceeded the AWQS in 2020 in any of these wells. These wells are monitoring the leading edge of the VOC plume associated with the Western South Boundary.

3.2.4.4 System Operations

During 2020 the extraction well WSB-1 continued full-time operation. Extraction well WSB-2 was in standby mode in 2020 based on the TVOC concentrations being below the capture goal of 20 µg/L. The extraction wells WSB-3, WSB-4, WSB-5, and WSB-6 continued full-time operation through most of 2020. System samples were collected, and extraction wells were sampled monthly until March and switched to quarterly in April and analyzed for VOCs. In addition, the effluent was analyzed for pH monthly in conjunction with the Middle Road and South Boundary pH sample. **Table 3.2.4-1** provides the effluent limitations for meeting the requirements of the SPDES equivalency permit. The Western South Boundary is now operating under the same SPDES equivalency permit as the Middle Road and South Boundary projects. The system's effluent discharges met the SPDES equivalency permit requirements during 2020. The system operations are summarized below.

January – September 2020

The system operated normally except for routine maintenance and repairs. WSB-4 was down for repairs for the most of the third quarter. During the first three quarters, the system treated approximately 132 million gallons of water.

October – December 2020

The system operated normally for the majority of the fourth quarter. WSB-1, WSB-3, WSB-4, WSB-5, WSB-6 remained in operation, and WSB-2 remained in standby mode. WSB-4 was restarted in October. The system was down for approximately two weeks for lift station repairs at Building 517/518 in November. The system treated approximately 34 million gallons of water.

Table 3.2.4-1
Western South Boundary Treatment System (South Boundary and Middle Road) 2020 SPDES Equivalency Permit Levels

Parameter	Permit Level (µg/L)	Max. Measured Value (µg/L)
pH range	6.5–8.5 SU	6.6-7.5 SU
carbon tetrachloride	5	<0.5
chloroform	7	<0.5
dichlorodifluoromethane	5	<0.5
1,1-dichloroethane	5	<0.5
1,1-dichloroethylene	5	<0.5
methyl chloride	5	<0.5
tetrachloroethylene	5	<0.5
toluene	5	<0.5
1,1,1-trichloroethane	5	<0.5
1,1,2-trichloroethane	5	<0.5
trichloroethylene	10	<0.5

Note:

Required effluent sampling frequency is monthly for VOCs and monthly for pH.

SU = Standard units

3.2.4.5 System Operational Data

Extraction Wells

During 2020, the Western South Boundary System treated approximately 166 million gallons of water, with an average flow rate of approximately 315 gpm. **Table 2-2** gives monthly pumping data for the six extraction wells. **Table 3.2.4-2** shows the monthly extraction well pumping rates. VOC concentrations for extraction wells WSB-1, WSB-2, WSB-3, WSB-4, WSB-5, WSB-6 are provided in **Table F-16**. TVOC concentrations for extraction wells WSB-1 and WSB-2 have remained below the capture goal of 20 µg/L since 2006. TVOC concentrations for extraction wells WSB-3, WSB-4, WSB-5, WSB-6 showed a maximum concentration in well WSB-5 of 18 µg/L. All four extraction wells show a decreasing trend since startup in March 2019 as shown on **Figure 3.2.4-4.**

System Influent and Effluent

Influent TVOC concentrations increased with the addition of the four extraction wells to a maximum of 20 µg/L. Individual VOC concentrations were above the AWQS during the year, with a maximum TCA value of 5.3 µg/L in August 2020, and maximum DCE value of 6.2 µg/L in October (**Table F-17**).

The air stripping system effectively removed the contaminants from the influent groundwater. The system's effluent data were below the analytical method detection limit and below the regulatory limit specified in the equivalency permit conditions (**Table F-18**). There were no detections of tritium in the effluent in 2020.

Cumulative Mass Removal

Average flow rates for each monthly monitoring period were used, in combination with the TVOC concentration in the influent, to calculate the pounds of VOCs removed per month (**Table F-19**). The cumulative mass of VOCs removed by the treatment system is provided on **Figure 3.2.4-5**. During 2020, six pounds of VOCs were removed. A total of 163 pounds have been removed since the start-up of the system in 2002.

Air Discharge

Table 3.2.4-3 presents the VOC air emission data for 2020 and compares the values to levels stipulated in NYSDEC DAR-1 regulations. Emission rates are calculated through mass balance for water treated during operation. The VOC air emissions were well below allowable levels. The concentration of each constituent was averaged for 2020, and those values were used in determining the emissions rate. The air emissions for the Western South Boundary system were below permitted limits. These emissions on **Table 3.2.4-3** are from the Western South Boundary system. However, the Middle Road/South Boundary and Western South Boundary systems are currently being co-treated in a singular air-stripper tower and the cumulative total emissions are provided and are still well below permitted levels.

Table 3.2.4-3.
Western South Boundary Air Stripper
2020 Average VOC Emission Rates

Parameter	Allowable ERP*	Actual** ER	MR/SB/WSB Total ER****
carbon tetrachloride	0.016	0.0002	0.0004
chloroform	0.0031	0.0001	0.0001
chloroethane	10***	0	0
1,1-dichloroethane	10***	0	0
1,2-dichloroethane	0.008	0	0
1,1-dichloroethylene	0.034	0.0005	0.0005
cis-1,2-dichloroethylene	10***	0	0
trans-1,2-dichloroethylene	10***	0	0
tetrachloroethylene	0.387	0.0	0.0022
1,1,1-trichloroethane	10***	0.0003	0.0004
trichloroethylene	0.119	0.0001	0.0001

Notes:
ERP = Emissions Rate Potential, stated in lb/hr.
* ERP is based on NYSDEC DAR-1 Regulations. Conservative value used from MR/SB/WSB.
** Actual Emission Rate (ER) reported is the average for the year.
*** 6 NYCRR Part 212 restricts emissions of VOCs to a maximum of 10 lb/hr without controls.
**** MR/SB/WSB Total ER =Cumulative Total for MR/SB/WSB.

3.2.4.6 System Evaluation

The Western South Boundary Treatment System performance can be evaluated based on decisions identified for this system from the groundwater DQO process.

1. Were unexpected levels or types of contamination detected?
There were no unexpected levels or types of contamination. However, PFAS and 1,4-dioxane were detected above the newly promulgated NYS DWS (see **Section 3.5**).

2. Has the downgradient migration of the plume been controlled?
The four new extraction wells are addressing the migration of the recently identified deeper VOC contamination. The bypass wells at the site boundary and sentinel monitoring wells on Carleton Drive continue to remain low indicating the leading edge of the plume is controlled.

3. Can individual extraction wells or the entire treatment system be shut down or placed in pulsed pumping operation?
WSB-2 is currently in standby mode and VOC concentrations in this area are well below the capture goal of 20 μg/L. TVOC concentrations in WSB-1 have declined to below the capture goal. However continued operation of WSB-1 is necessary to ensure the capture of the higher VOC concentrations migrating south from well 126-14. The four new extraction wells began operation in March 2019 and it is too early to evaluate shutdown.

3a. Are TVOC concentrations in plume core wells above or below 20 µg/L?
A number of wells remain above the capture goal of 20 µg/L The 2019 characterization has identified a large area of groundwater contamination significantly above the 20 µg/L capture goal, along with well 126-14 located immediately upgradient of well WSB-1.
3b. Is there a significant concentration rebound in core wells and/or extraction wells following pulsed pumping or shutdown?
No significant rebound was observed during pulsed pumping of extraction well WSB-2 or since the placement of this well in standby.

4. Has the groundwater cleanup goal of meeting MCLs been achieved?
MCLs have not been achieved for individual VOCs in plume core wells. With the addition of the four new extraction wells, the groundwater cleanup goals are expected to be met. There has been a significant reduction in VOC concentrations in the monitoring wells since the start of the new extraction wells in March 2019.

3.2.4.7 Recommendations

The following are recommendations for the OU III Western South Boundary Treatment System and groundwater monitoring program:

- Continue full-time operation of extraction well WSB-1 based on elevated concentrations in well 126-14.
- Based on the low TVOC concentrations below the capture goal of 20 µg/L, maintain extraction well WSB-2 in standby mode. If TVOC concentrations greater than 20 µg/L are observed in WSB-2 or the adjacent monitoring wells, extraction well WSB-2 may be put into full time operation.
- Continue operation of the four new extraction wells. With the operation of these wells the groundwater cleanup goal of meeting MCLs by 2030 are expected to be met.
- Continue the current monitoring frequency for the Western South Boundary monitoring wells as shown in **Table 1-5**.

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3.2.5 Industrial Park Groundwater Treatment System

This section summarizes the operational data from the Industrial Park Groundwater Treatment System for 2020 and presents conclusions and recommendations for its future operation. The Industrial Park system was designed to contain and remediate a portion of the OU III plume between BNL's southern boundary and the Industrial Park. **Figure 3.2.5-1** illustrates the extent of the OU III contaminant plume in the vicinity of the Industrial Park, located south of the Long Island Expressway. The primary VOCs associated with this portion of the OU III plume are TCA, PCE, and carbon tetrachloride.

The system began operation in September 1999. A Petition for Shutdown was submitted to the regulators in February 2013 (BNL, 2013a). After receiving approval from the regulators, the system was shut down in May 2013. In March 2014, wells UVB-3 through UVB-6 were returned to full time operation due to a rebound of VOC concentrations. They were shut down in January 2017.

3.2.5.1 System Description

The original Industrial Park system consisted of a line of seven in-well air stripping treatment wells. Each treatment well is constructed with two well screens separated by an inflatable packer. Contaminated groundwater is withdrawn from the aquifer via submersible pump through a lower screen (extraction) set at the base of the treatment well. The groundwater is pumped to a stripping tray located in a below ground vault over the wellhead. After passing through the stripping tray, treated groundwater flows back down the well and is recharged to a shallower portion of the aquifer through an upper screen (recharge). Some of the treated groundwater that is recharged through the upper screen recirculates through the cell and is drawn back into the extraction screen for further treatment, while the balance flows in the direction of regional groundwater flow.

A closed-loop air system through a single blower keeps the vault under a partial vacuum. The vacuum draws air from below the stripping tray as contaminated groundwater is discharged on top. VOCs are transferred from the liquid phase to the vapor phase as contaminated groundwater passes through the stripping tray. The contaminated air stream is carried from the vault to a treatment and control building, where it is passed through two GAC units in series to remove the VOCs. Treated air is then recirculated back to the wellhead. The carbon units, system blower, and system control panel are all housed in a one-story masonry treatment building. A complete description of the system is included in the *Operations and Maintenance Manual for the OU III Offsite Removal Action* (BNL 2007b).

In 2014 a modification to the Industrial Park System was initiated which included the installation of two new groundwater extraction wells. They are shown on **Figure 3.2.5-1** as IP-EW-8 and IP-EW-9. These wells became operational in January 2015. The wells are screened deeper than the adjacent UVB wells to capture deeper VOC contamination identified just upgradient of this area (**Figure 3.2-2**). These wells are utilizing liquid phase carbon to treat the water rather than in-well air stripping. A complete description of the Industrial Park Modification is included in the *Operations and Maintenance Manual for the OU III Modification to the Industrial Park Groundwater Treatment System* (BNL 2015).

3.2.5.2 Groundwater Monitoring

Well Network

The monitoring well network consists of 48 wells and is designed to monitor the VOCs in the vicinity of the Industrial Park, and the effectiveness of the groundwater treatment system. In February 2021 three wells (122-24, 122-25, and 000-280) that were formerly sampled under the Industrial Park East monitoring program and recently used for water level measurements were abandoned due to pending development of the private property that they were located on.

Sampling Frequency and Analysis

Wells are sampled for VOCs as per the schedule in **Table 1-5**. During 2020 select wells were analyzed for 1,4-dioxane and PFAS (see **Section 3.5**).

3.2.5.3 Monitoring Well Results

The complete analytical results are included in **Appendix C**. VOC concentrations in the plume perimeter wells that monitor the width of the plume remained below AWQS during 2020. Based on these data, the plume is effectively bounded by the current well network. **Figure 3.2.5-1** shows the plume distribution based on fourth quarter 2020 data and the location of cross section I-I'. The vertical extent of contamination is shown on **Figure 3.2.5-2**. Concentration trend graphs for key monitoring wells are shown on **Figure 3.2.5-3.** Significant findings for 2020 include:

Plume Core Wells

- TVOC concentrations in wells 127-08, 127-09, 000-537, and 000-538 located in the northern portion of the industrial park were observed to decline significantly in 2016 (following the initial characterization of this area) from the higher concentrations detected in 2015 (up to 266 µg/L). TVOC concentrations in these wells since 2016 have varied but have largely remained below the capture goal of 50 µg/L. The highest concentration detected in 2020 was 52 µg/L in well 000-537 during the fourth quarter. These wells are monitoring the trailing edge of a deeper VOC slug of contamination originally characterized in 2013, which is located between the Long Island Expressway (LIE) and the Industrial Park Treatment System recirculation well locations.
- Well 000-548 is located between well 000-528 and extraction well IP-EW-9. TVOC concentrations in this well were detected up to 30 µg/L in 2019. Concentrations remained just below 30 µg/L in 2020 with a decrease to 8 µg/L in the December sample.
- Well 000-529 is located 300 feet south of 000-548. TVOC concentrations in this well have been slowly decreasing since 2013. The peak TVOC concentration in this well in 2019 was 28 µg/L. TVOC decreased to 14 µg/L in September 2020.
- Well 000-541 located upgradient of IPE-EW-8 showed a narrow range of TVOC concentrations ranging from 38 µg/L to 45 µg/L in 2020.

Plume Bypass Wells

- Wells 000-432 and 000-544 provide bypass monitoring points downgradient of extraction wells IP-EW-8 and IP-EW-9, respectively. TVOC concentrations have been slightly above detectable levels in 000-432 over the past several years. TVOC concentrations in well 000-544 ranged trended up slightly to levels from 27 µg/L to 40 µg/L.

3.2.5.4 System Operations

In 2020, wells UVB-1 through UVB-7 and extraction wells EW-8 and IP-EW-9 remained in standby mode. These wells and associated monitoring wells had concentrations below the capture goal of 50 µg/L.

System Operations

System extraction well pumping rates are included on **Table 3.2.5-1**. Extraction wells IP-EW-8 and IP-EW-9 operate under a SPDES Equivalency Permit (**Table 3.2.5-2).** The system is sampled on a quarterly basis for VOCs. No effluent VOC samples were taken. The following summarizes the system operations for 2020:

January – December 2020

Wells UVB-1 through UVB-7 and wells IP-EW-8 and IP-EW-9 remained in standby.

3.2.5.5 System Operational Data

Well Influent and Effluent

Water samples were obtained quarterly for wells UVB-1 through UVB-7 and wells IP-EW-8 and IP-EW-9. The samples are analyzed for VOCs.

During 2020, TVOC concentrations in the extraction wells were below the capture goal of 50 µg/L (**Figure 3.2.5-4**). The historical effluent and influent concentrations are shown on **Figure 3.2.5-5**. The removal efficiencies for the air strippers in the extraction wells UVB-1 through UVB-7 for 2020 where not calculated since the wells are not operating. Historical extraction well data are shown in **Table F-23**.

Table 3.2.5.2
OU III Industrial Park Treatment System
2020 SPDES Equivalency Permit Levels

Parameters	Permit Limit (µg/L)	Max. Measured Value (µg/L)
pH (range)	5.0 – 8.5 SU	NS
carbon tetrachloride	5.0	NS
chloroform	7.0	NS
1,1-dichloroethylene	5.0	NS
1,2-dichloroethane	5.0	NS
tetrachloroethylene	5.0	NS
1,1,1-trichloroethane	5.0	NS
trichloroethene	5.0	NS

Notes:
Required sampling frequency is monthly for VOCs and weekly for pH.
SU = Standard Units

Cumulative Mass Removal

The system remained in stand-by mode in 2020. The cumulative mass total of VOCs removed from the aquifer is a total of 1,076 pounds since 1999.

Air Treatment System

Air samples were not collected because UVB-1 to UVB-7 were in stand-by mode (**Table F-22**).

3.2.5.6 System Evaluation

The Industrial Park Treatment System performance can be evaluated based on the major decisions identified for this system resulting from the groundwater DQO process.

1. Were unexpected levels or types of contamination detected?

There were no unusual or unexpected VOC concentrations observed in the monitoring wells or extraction wells associated with the OU III Industrial Park System during 2020. However, PFAS and 1,4-dioxane were detected above the newly promulgated NYS DWS (see **Section 3.5**).

2. Has the downgradient migration of the plume been controlled?

Yes, an analysis of the plume perimeter and bypass well data reveals that there were no TVOC concentrations above the capture goal of the system in 2020. A comparison of the plume from 1997 to 2020 is provided on **Figure 3.2.5-7.** The higher concentration portion of the plume is attenuating as it moves from the northern portion of the industrial park toward wells IP-EW-8 and IP-EW-9.

3. Can individual extraction wells or the entire treatment system be shut down or placed in pulsed pumping operation?

TVOC concentrations in core monitoring well 000-537 was slightly above the capture goal of 50 µg/L during the fourth quarter. The UVB wells have been in stand-by since January 2017.

Two extraction wells were added in 2014 (IP-EW-8 and IP-EW-9) to capture deeper upgradient VOCs. Since operation of these wells was initiated in 2015, the highest TVOC concentrations reported for wells IP-EW-8 and IP-EW-9 are 6 µg/L and 10 µg/L, respectively. Individual VOCs have been below AWQS since 2017. The deeper VOCs seem to be migrating very slowly and attenuating as it moves south. IP-EW-8 and IP-EW-9 were subsequently placed in standby mode in July 2019.

4. Are TVOC concentrations in plume core wells above or below 50 µg/L?
There was one plume core well, 000-537 that had a single TVOC detection over the capture goal at 52 µg/L in 2020. This well is located over 1000 feet upgradient of the extraction wells.

5. Is there a significant concentration rebound in core wells and/or extraction wells following shutdown?

Wells UVB-3 through UVB-6 were restarted in March 2014 due to a rebound in concentrations above the 50 µg/L capture goal. These wells were placed back in standby in January 2017. There was no additional rebound of concentrations in the plume core wells associated with these recirculation wells in 2020. No rebound of concentrations has been observed in the vicinity of wells IP-EW-8 and IP-EW-9 since they were shut down in July 2019.

6. Has the groundwater cleanup goal of meeting MCLs been achieved?
MCLs have not yet been achieved, but are expected to be by 2030.

3.2.5.7 Recommendations

The following are recommendations for the Industrial Park Treatment System and groundwater monitoring program:

- Maintain the seven UVB wells in standby. If TVOC concentrations exceed the 50 µg/L capture goal in these UVB wells or associated monitoring wells, they may be restarted.
- Maintain IP-EW-8 and IP-EW-9 in standby and continue to monitor for rebound of VOCs. If TVOC concentrations approach the capture goal of 50 µg/L in the vicinity of the extraction wells the system will be evaluated for restart.
- If extraction and monitoring wells remain below the capture goal for four consecutive sample rounds, prepare and submit a petition for system closure.

3.2.6 North Street Treatment System

The North Street Treatment System addresses a VOC plume that originated at the Former Landfill/Chemical Holes area. The remnants of the VOC plume is presently located south of the site boundary, with the leading edge extending south to Flower Hill Drive (**Figure 3.2.6-1**). The groundwater treatment system began operating in May 2004. In June 2013, a *Petition for Shutdown OU III North Street Groundwater Treatment System* (BNL 2013c) was submitted to the regulators for review and approval. The system was shut down in August 2013 after receiving approval from the regulators. The system was restarted in June 2014 due to a rebound in VOC concentrations in several monitoring wells above the 50 µg/L TVOC concentration capture goal. The system was again shut down in July 2015 due to a reduction in VOC concentrations. In August 2015, well NS-1 was restarted due to elevated VOC concentrations in a monitoring well located immediately up-gradient of this well. Well NS-1 was shut down in August 2016 due to a reduction in VOC concentrations. In February 2020, a *Petition for Closure for the OU III North Street Groundwater Treatment System* (BNL 2020b) was submitted to the regulators for review and approval. This document received regulatory approval in March 2020. The document recommended the following "*Seven of the 12 core monitoring wells are proposed for continued annual monitoring until the results for individual VOCs are consistently below MCLs. Sampling of the remaining 11 monitoring wells will be discontinued but the wells will be retained until the completion of the PFAS and 1,4-dioxane characterization at the BNL site. The two extraction wells and system infrastructure (building, carbon units, etc.) will also be retained until PFAS and 1,4-dioxane characterization is complete. The four recharge wells and the building will be used for the recently constructed North Street East Ethylene Dibromide Groundwater Treatment System*". The system is now in a post closure monitoring phase.

The groundwater treatment system consists of two extraction wells, which are now permanently shutdown. The system captured the higher concentration portion of the VOC plume (i.e., TVOC concentrations greater than 50 µg/L) in the Upper Glacial aquifer and minimized additional VOC migration into the Magothy aquifer. The North Street plume has been divided into two segments for remediation purposes. The area to the north of extraction well NS-2 was addressed by the North Street remediation system, whereas the Airport System captures and treats contaminated groundwater in the area to the south (**Figure 3.0-1**). The Airport System was constructed in part to address the leading edge of this plume (**Section 3.2.8**).

3.2.6.1 System Description

The North Street system consisted of two extraction wells. Extracted groundwater was piped through two 20,000-pound GAC units located in Building OS-5 on a parcel of land owned by DOE. Discharged to four injection wells located downgradient along North Street. Both the North Street and North Street East systems share the four injection wells. Extraction wells NS-1 and NS-2 were designed to operate at a rate of up to 200 gpm each. A complete description of the system is contained in the *Operations and Maintenance Manual for the North Street/North Street East Offsite Groundwater Treatment Systems* (BNL 2004).

3.2.6.2 Groundwater Monitoring

Well Network

A network of 18 wells monitors the North Street VOC plume (**Figure 1-2 and Figure 3.2.6-1**). Per the Petition for Closure seven wells are still be monitored the other eleven will remain but are no longer sampled. The seven wells still being sampled are 000-108, 000-154, 000-212, 000-343, 000-465, 000-472, 000-474. In 2020 all the wells were sampled. Wells sampled under the Airport program are also utilized for tracking the downgradient portions of the North Street VOC plume.

Sampling Frequency and Analysis

Sampling of the seven as part of the post closure monitoring program for VOCs is performed as per the schedule on **Table 1-5**. During 2020 select wells were analyzed for 1,4-dioxane and PFAS (see **Section 3.5**).

3.2.6.3 Monitoring Well Results

The primary VOCs associated with this plume are carbon tetrachloride, TCE, TCA, and chloroform. **Figure 3.2-1** and **Figure 3.2.6-1** depict the TVOC plume distribution. The complete groundwater monitoring well data for 2020 are included in **Appendix C**. A north–south hydrogeologic cross section (J–J') of the plume is provided on **Figure 3.2.6-2. Figure 3.2.6-3** shows time-concentration plots for key monitoring wells. A summary of key monitoring well data for 2020 follows:

- Plume core well 000-465 is located 100 feet upgradient of extraction well NS-1. This well had historically shown the highest VOC concentrations (primarily carbon tetrachloride) in the North Street area. TVOC concentrations were as high as 1,796 µg/L in 2004. In November 2020 the concentration was 6.9 µg/L.
- Well 000-472, located in close proximity to extraction well NS-2, had TVOC concentration of 16.7 µg/L in November.
- TVOC concentrations in core well 000-474, located approximately 500 feet upgradient of extraction well NS-2, were 9.7 µg/L in November.
- Plume core well 000-154 had historically shown high VOC concentrations (primarily carbon tetrachloride). TVOC concentrations of approximately 1,000 µg/L were observed in this well in 1997 and 1998. However, they have steadily declined since then, and VOC concentrations have been below AWQS for several years. The trailing edge of the higher concentration segment of this plume has migrated south of this location.
- The plume continues to be bounded as shown on **Figure 3.2.6-1** by the plume perimeter wells.
- **Figure 3.2.6-6** compares the TVOC plume from 1997 to 2020. The southern portion of the plume that migrated south of the North Street system prior to system start-up is being captured by the Airport Treatment system eastern extraction wells.

Table 3.2.6-1
OU III North Street Treatment System
2020 SPDES Equivalency Permit Levels

Parameters	Permit Limit (µg/L)	Max. Observed Value (µg/L)
pH (range)	5.5 – 8.5 SU	NS
carbon tetrachloride	5	NS
chloroform	5	NS
1,1-dichloroethane	5	NS
1,2-dichloroethane	5	NS
1,1-dichloroethylene	5	NS
tetrachloroethylene	5	NS
toluene	5	NS
1,1,1-trichloroethane	5	NS
trichloroethylene	10	NS

Notes:
NS = Not Sampled as the system was not operating.
SU= Standard Units

3.2.6.4 System Operations

Table 3.2.6-1 provides the effluent limitations for meeting the requirements of the SPDES equivalency permit. The extraction wells were sampled once in 2020 for VOCs and tritium. Following this sampling was discontinued.

January – December 2020

Both extraction wells NS-1 and NS-2 remained shut down in 2020.

3.2.6.5 System Operational Data

The system was shutdown in 2020 and is now in a post closure monitoring phase.

Extraction Wells

Table F-24 has monthly pumping data and mass removal data and **Table 3.2.6-2** monthly extraction well pumping rates. There are no new data in these tables for 2020 as the system was in standby/shutdown for the year. Well NS-1 and NS-2 were in standby/shutdown mode in 2020, however they were sampled once in August. **Figure 3.2.6-4** shows the plot of the TVOC concentrations from the extraction wells over time. VOC concentrations for the extraction wells are provided on **Table F-25.** TVOC values in well NS-1 have steadily dropped from a high of 599 µg/L in 2004 to approximately 4 µg/L in 2020. TVOC concentrations in well NS-2 remained below 15 µg/L in 2020 with the highest individual VOC detection of 7.7 µg/L of PCE in August. There was no tritium detected in the extraction wells in 2020.

System Influent and Effluent

There were no influent or effluent samples as the system was in standby mode during 2020 (**Table F-26 and F-27**).

Cumulative Mass Removal

The mass of VOCs removed from the aquifer by the North Street Treatment System was calculated using the average flow rates for each monthly monitoring period, in combination with the TVOC concentration in the carbon unit's influent, to calculate the pounds removed per month. The cumulative mass of VOCs removed by the treatment system vs. time is plotted on **Figure 3.2.6-5**. Since May 2004, the system removed 342 pounds of VOCs. The mass removal is summarized in **Table F-24**. The system is now shutdown and no further operations are expected.

The downgradient portion of the plume that was south of the North Street system prior to start-up is being captured by the Airport Treatment System's eastern extraction wells. Further detail on the Airport system is provided in **Section 3.2.8**.

3.2.6.6 System Evaluation

The North Street Treatment System can be evaluated from the decision rules identified in the groundwater DQO process.

1. Were unexpected levels or types of contamination detected?

There were no unusual or unexpected concentrations of contaminants observed in monitoring wells associated with the North Street plume in 2020. However, PFAS and 1,4-dioxane were detected above the newly promulgated NYS DWS (see **Section 3.5**).

2. Has the downgradient migration of the plume been controlled?

A segment of the plume passing through well 800-90 was beyond the capture zone of the North Street extraction well NS-1 at the time of system start-up. As described in **Section 3.2.8**, this portion of the plume is being addressed by the Airport extraction wells.

3. Can individual extraction wells or the entire treatment system be shut down or placed in pulsed pumping operation?

A Petition for Closure of the system was approved by the regulators in March 2020.

3a. Are TVOC concentrations in plume core wells above or below 50 µg/L?

The 11 plume core wells of the North Street System showed TVOC concentrations less than 50 µg/L during 2020.

3b. Is there a significant concentration rebound in core wells and/or extraction wells following shutdown?
No there has been no rebound, the system is now in a post closure monitoring phase.

4. Has the groundwater cleanup goal of meeting MCLs been achieved?
MCLs have not been achieved for individual VOCs in all North Street plume core wells. During 2020, three of the seven remaining wells had VOCs above the MCL, with a concentration of 8.5 µg/L of tetrachlorethylene in well 000-472 being the highest concentration detected. MCLs are expected to be achieved in all wells by 2030.

3.2.6.7 Recommendations

The following are recommended for the North Street Treatment System and groundwater monitoring program:

- NS-1 and NS-2 will remain shut down until the PFAS and 1,4 dioxane characterization is completed. After the completion of this characterization, a determination of the future use of these wells will be determined.
- Seven of the eighteen monitoring wells will continue on an annual monitoring schedule until the results for individual VOCs are consistently below MCLs. The remaining 11 monitoring wells will be retained until the completion of the PFAS and 1,4-dioxane characterization at the BNL site.

3.2.7 North Street East Treatment System

This section summarizes the 2020 operational and monitoring well data for the OU III North Street East (NSE) Treatment System. The original system operated from 2004 to 2014 to capture and control the downgradient portion of the OU I VOC plume, which migrated beyond the BNL site boundary. This treatment system (which includes extraction wells NSE-1 and NSE-2) met its goals in 2014 with no significant rebound identified (BNL 2014b). A formal petition for closure was not prepared for this system since the infrastructure is being used for remediation of the ethylene dibromide (EDB) plume identified in this area. As recommended in the *2019 Groundwater Status Report* (BNL 2020d), this system is now administratively closed for its originally designed purpose. In September 2019, a modification to the North Street East Groundwater Treatment System was submitted to the regulators. This included the addition of two new extraction wells to remediate the EDB plume that was characterized. This system became operational in July 2020.

3.2.7.1 System Description

The original NSE Treatment System consisted of two extraction wells (NSE-1 and NSE-2), which as noted above was administratively closed in 2020. Two additional extraction wells (NSE-EDB-EW-3 and NSE-EDB-EW-4) were installed and became operational in July 2020 to remediate the EDB plume in this area. These wells are designed to operate at approximately 100 gpm. The extracted groundwater water is pumped through two 20,000-gallon GAC units and the treated water is discharged to four injection wells located on North Street. The North Street and NSE carbon treatment units and control systems are located in the same building along North Street. A complete description of the system is contained in the revised *Operations and Maintenance Manual for the North Street/North Street East Offsite Groundwater Treatment Systems* (BNL 2020e) which was submitted to the regulators in August 2020.

3.2.7.2 Groundwater Monitoring

The monitoring network for the EDB plume consists of 12 wells. See **Figure 3.2.7-1** for the location of the wells.

The sampling frequency for the EDB plume monitoring wells is quarterly, except for upgradient perimeter well 115-42 which is sampled semi-annually. Ten of the 12 wells are also sampled annually for VOCs using EPA Method 524.2. See **Table 1-5** for details. During 2020, select wells were analyzed for PFAS and 1,4-dioxane (see **Section 3.5**).

3.2.7.3 Monitoring Well Results

Figure 3.2.7-2 shows the extent of the NSE EDB plume and the location of the two new extraction wells. The trace levels of VOCs identified in the remnants of the original plume are discussed below and the data are provided in **Appendix C.**

Figure 3.2.7-3 depicts the vertical distribution of EDB within the deep Upper Glacial aquifer. The north-south transect line for cross section K–K' is shown on **Figure 3.2.7-2**. **Figure 3.2.7-4** presents the historical trends for EDB in the six monitoring wells that have detected EDB over the last two years. **Appendix C** contains a complete set of 2020 analytical results for the NSE program wells. A summary of key monitoring well data for 2020 follows:

- As shown on **Figure 3.2.7-4**, since August 2015 EDB has consistently been detected above the DWS of 0.05 µg/L in well 000-394, with a maximum concentration of 1.06 µg/L in the fourth quarter 2017. Since then, EDB concentrations have declined with the maximum detection in this well in 2020 of 0.08 µg/L in the fourth quarter. This well is immediately upgradient of extraction well NSE-EDB-EW-4.
- In addition to monitoring well 000-394, EDB was detected above the DWS in four of the 12 plume monitoring wells in 2020 (000-552, 000-553, 000-554 and 000-563). The maximum EDB

concentration in these four wells in 2020 was 0.2 µg/L in the fourth quarter in well 000-563. This well which did not detect EDB in 2019, is located on the western edge of the plume between NSE-EDB-EW3 and NSE-EDB-EW-4.

- Of the three bypass wells, only 000-566 detected EDB slightly above the detection limit at a concentration of 0.02 µg/L in September 2020.
- The two upgradient perimeter wells (115-42 and 000-138) have not detected EDB in 2019 and 2020.
- Three of the six wells sampled annually using Method 524.2 detected VOCs above AWQS in 2020. Wells 000-552 and 000-553, located in the upgradient portion of the plume detected PCE just above the AWQS at 6.9 µg/L and 5.3 µg/L, respectively. Well 000-554 detected methyl tert-butyl ether (MTBE) at 11.3 µg/L. The AWQS for MTBE is 10 µg/L. Historically, there have been sporadic low level detections of MTBE in several of the NSE monitoring wells below the AWQS.

3.2.7.4 System Operations

EDB extraction wells NSE-EDB-EW-3 and NSE-EDB-EW-4 were sampled monthly for EDB and VOCs beginning in July 2020 for the system start-up testing. Due to the construction activities for the system modification, the original extraction wells NSE-1 and NSE-2 have been shut down since July 2019. Therefore, the first two sets of 2020 quarterly samples could not be obtained. These extraction wells were sampled for the last time in August and October 2020 for VOCs. NSE-1 was also sampled for EDB using Method 504. In April 2020, NYSDEC issued a renewal SPDES equivalency permit for the North Street and North Street East Treatment System and included EDB as a discharge parameter. **Table 3.2.7-1** provides the effluent limitations for meeting the requirements of the equivalency permit.

Table 3.2.7-1.
OU III North Street East Treatment System
2020 SPDES Equivalency Permit Levels

Parameters	Permit Limit (µg/L)	Max. Observed Value (µg/L)
pH range	5.5–8.5 SU	5.7-7.0
carbon tetrachloride	5	<0.5
chloroform	5	<0.5
1,1-dichloroethane	5	<0.5
1,2-dichloroethane	0.6	<0.5
1,1-dichloroethylene	5	<0.5
tetrachloroethylene	5	<0.5
toluene	5	<0.5
1,1,1-trichloroethane	5	<0.5
trichloroethylene	5	<0.5
Ethylene dibromide (EDB)	0.03	<0.02

Notes:
Required effluent sampling freq. is monthly for VOCs and pH.

3.2.7.5 System Operational Data

The two new EDB extraction wells (NSE-EDB-EW-3 and NSE-EDB-EW-4) became operational in July 2020 and the treatment system began start-up testing. As documented in the *2019 Groundwater Status Report* (BNL 2020d), the original VOC system (NSE-1 and NSE-2) is administratively closed for its originally designed purpose. However, the treatment system infrastructure is being used for remediation of the EDB plume.

January through September 2020

Construction was completed and the EDB treatment system began operations in July 2020. The system was off for two days in August for a carbon change-out. The system was off in September due to high differential pressure caused by a blocked cone strainer in the lag carbon vessel. Approximately 13 million gallons of water were pumped and treated.

October through December 2020

Extraction well NSE-EDB-EW-4 was off in November due to replacement of the pump. Approximately 22 million gallons of water were pumped and treated.

Extraction Wells

Extraction wells NSE-EDB-EW-3 and NSE-EDB-EW-4 began start-up testing in July 2020 and were initially sampled for EDB and VOCs on a daily basis for the first week, then transitioned to weekly, and to monthly sampling in September. The maximum EDB concentration detected was 0.14 µg/L in NSE-EDB-EW-4 in July and October. All samples obtained from this extraction well in 2020 exceeded the DWS for EDB. In contrast, EDB concentrations in NSE-EDB-EW-3 exceeded the DWS only twice, in July and October with the maximum concentration of 0.051 µg/L. No other VOCs were detected in these extraction wells above AWQS.

Out of service extraction wells NSE-1 and NSE-2 were sampled in August 2020. EDB was detected in NSE-1 up to 0.06 µg/L. Based on the configuration of the sampling port following the addition of the two new EDB extraction wells, this detection was due to cross contamination from NSE-EDB-3 untreated water. Two follow-up samples of NSE-1 were collected in October 2020 with the valves to new EDB extraction well NSE-EDB-3 closed. EDB was not detected in the samples. No other VOCs were detected in these extraction wells above AWQS. Further sampling of NSE-1 and NSE-2 was discontinued.

Table 2-2 shows the monthly pumping data for the two EDB extraction wells. **Table 3.2.7-2** identify the pumping rates for NSE-EDB-EW-3 and NSE-EDB-EW-4 starting in July 2020. The system averaged 65 gpm in 2020. **Figure 3.2.7-5** plots the TVOC concentrations in all four extraction wells. **Figure 3.2.7-6** plots the EDB concentrations in extraction wells NSE-EDB-EW-3 and NSE-EDB-EW-4. VOC and EDB concentrations for the extraction wells are provided in **Table F-28**. As recommended in the *2019 Groundwater Status Report* (BNL 2020d), sampling for tritium in the extraction wells was discontinued since there have been no detections in the monitoring wells or extraction wells since 2013.

System Influent and Effluent

System influent and effluent sampling results from July through December are summarized on **Tables F-29** and **F-30**, respectively. As noted in **Table 3.2.7-1**, there were no exceedances of the equivalency permit parameters.

Cumulative Mass Removal

The cumulative mass of VOCs removed by the treatment system versus time is noted on **Figure 3.2.7-7**. A cumulative total of approximately 45 pounds of VOCs were removed from the aquifer during system operation (**Table F-31**).

3.2.7.6 System Evaluation

The system began operation in 2004 and was predicted to run for approximately 10 years. The system operated as designed and was shut down in 2014 and administratively closed in 2020. Due to the identification of EDB in the area groundwater in 2015, two new extraction wells were installed and became operational in July 2020 to remediate this plume.

The NSE Treatment System performance can be evaluated based on decisions identified for this system from the groundwater DQO process.

<u>1. Were unexpected levels or types of contamination detected?</u>

No. EDB was detected in the monitoring and extraction wells as expected based on the system design. However, 1,4-dioxane was detected above the newly promulgated NYS DWS (see **Section 3.5**).

2. Has the downgradient migration of the plume been controlled?
Based on the data from the monitoring wells and two new extraction wells, the system is providing effective capture of the EDB plume. Of the three bypass wells immediately downgradient of NSE-EDB-EW-3, only well 000-566 detected EDB slightly above the detection limit at a concentration of 0.02 µg/L.

3. Can individual extraction wells or the entire treatment system be shut down or placed in pulsed pumping operation?
No, the two new extraction wells became operational in July 2020 to remediate the EDB plume. The extraction wells and system influent detect EDB above the DWS.

3a. Are EDB concentrations in plume core wells above or below 0.05 ug/L?
EDB was detected above the DWS in five of the nine plume core monitoring wells in 2020.

3b. Is there a significant concentration rebound in core wells and/or extraction wells following shutdown?
The two new EDB extraction wells became operational in July and have not been shut down. The original VOC system (extraction wells NSE-1 and NSE-2) is administratively closed.

4. Has the groundwater cleanup goal of meeting MCLs been achieved?
No, EDB continues to be detected above MCLs in the monitoring and extraction wells. Of the six monitoring wells sampled annually using Method 524.2, two wells detected VOCs above AWQS in 2020 (PCE up to 6.9 µg/L).

3.2.7.7 Recommendations

The following recommendations are made for the NSE Treatment System and groundwater monitoring program:

- Continue full time operation of the EDB treatment system and maintain monthly sampling of extraction wells NSE-EDB-EW-3 and NSE-EDB-EW-4.
- Maintain the quarterly sampling frequency for the 12 EDB monitoring wells using Method 504, except for upgradient perimeter well 115-42 which is sampled semi-annually. Maintain annual VOC sampling using Method 524.2 for all wells except for 115-42 and 000-138.

3.2.8 LIPA/Airport Treatment System

This section summarizes the 2020 operational and monitoring well data for the LIPA/Airport Treatment System and presents conclusions and recommendations for its future operation. The LIPA system was designed to provide capture and control of the downgradient portion of the plume of VOCs in the Upper Glacial and Magothy aquifers that had migrated south of the Industrial Park System before that system became operational in 1999. The Airport Treatment System was designed to capture the leading edge of the OU III and OU I/IV VOC plumes and to prevent further migration of the plumes, which have migrated past the LIPA extraction wells and the North Street extraction wells.

3.2.8.1 System Description

The three components of the LIPA/Airport Treatment System are as follows:

1. The Magothy extraction well (EW-4L) on Stratler Drive (**Figure 3.2.8-1**) addressed high-level VOCs identified in the Magothy aquifer immediately upgradient of this well on Carleton Drive. The capture goal for this well is 50 µg/L TVOCs. The capture goal for this well has been met and the well is currently in standby mode.
2. The other three LIPA extraction wells (EW-1L, EW-2L, and EW-3L) were installed to address high concentrations of VOCs in the Upper Glacial aquifer that had migrated past the Industrial Park System before that system became operational.. The capture goal for these extraction wells of 50 µg/L TVOC has been met and these wells are in standby mode.
3. The six extraction wells in the Airport System were installed to address the leading edge of the plumes which have migrated past the LIPA extraction wells and the North Street extraction wells prior to their installation. The sixth well (RW-6A) was added in 2007 to address VOCs observed to the west of extraction well RTW-1A. The Airport system wells have a capture goal of 10 µg/L TVOC. RTW-4A also addresses Magothy aquifer contamination. Extraction wells RTW-1A, RTW-4A and RW-6A are in full time operation. Extraction wells RTW-2A, RTW-3A and well RTW-5A are shutdown.

The water from the four LIPA wells was pumped to the treatment plant, about one mile south on Brookhaven [Town] Airport property, where it is combined with the water from the six airport extraction wells (RTW-1A through RW-6A) and treated via granular activated carbon. The treated water is released back to the ground via a series of shallow reinjection wells located on Brookhaven Airport.

A more detailed description of this system is contained in the *Operations and Maintenance Manual for the LIPA/Airport Groundwater Treatment System* (BNL 2008a).

3.2.8.2 Groundwater Monitoring

Well Network

The monitoring network consists of 49 wells. The Magothy extraction well (EW-4L) on Stratler Drive has six monitoring wells associated with its operation. There are 12 wells associated with the Upper Glacial portion of the LIPA plume. The Airport system has 31 monitoring wells, which monitor the portions of the plume south of the LIPA and the North Street systems. All of these wells are used to evaluate the effectiveness and progress of the cleanup associated with these three components of the system. **Figure 1-2 and Figure 3.2.8-1** identify the monitoring wells for these plumes.

Sampling Frequency and Analysis

The monitoring wells for LIPA are currently on a quarterly and semiannual sampling schedule for VOCs. The Airport wells are sampled quarterly for VOCs (**Table 1-5**). During 2020 select wells were analyzed for 1,4-dioxane and PFAS (see **Section 3.5**).

3.2.8.3 Monitoring Results

The primary VOCs associated with these portions of the plume are carbon tetrachloride, TCA, TCE, and DCE. Groundwater monitoring for these systems was initiated in 2004. Fourth quarter 2020 well data are posted on **Figure 3.2.8-1** and **Figure 3.2.8-2**. The complete analytical results are in **Appendix C.** Results for key monitoring wells and extraction wells are as follows:

LIPA Monitoring

- During 2020, TVOC concentrations for the Magothy extraction well EW-4L on Stratler Drive were between 6 µg/L and 9 µg/L. This well was shut down in January 2017 as it achieved its TVOC capture goal of 50 µg/L.
- The Magothy monitoring wells located in the vicinity of extraction well EW-4L all detected TVOC concentrations below 5 µg/L during 2020. The highest TVOC concentration observed was in well 000-425 at 4 µg/L.
- All of the LIPA monitoring wells are below the TVOC capture goal of 50 µg/L. The highest TVOC concentration was 18 µg/L in well 000-131 in June 2020.
- The maximum TVOC concentration in extraction well EW-3L in 2020 was 2 µg/L. Extraction well EW-2L samples detected TVOC concentrations up to 5 µg/L. TVOC concentrations in extraction well EW-1L ranged from 4 µg/L to 7 µg/L. **Figure 3.2.8-3** plots the TVOC trends for the LIPA extraction wells.

Airport Monitoring

- Monitoring wells 800-94 and 800-95, are approximately 1,500 feet north of extraction wells RTW-1A, RTW-2A, and RW-6A. In 2020, well 800-94 had a maximum TVOC concentration of 64 µg/L in December and well 800-95 had a maximum concentration of 16 µg/L in July. Both of these wells have had persistently elevated TVOC concentrations over the past few years. (**Figure 3.2.8-6**)
- **Figure 3.2.8-4** plots the TVOC influent trends for the Airport extraction wells. All six airport extraction wells had TVOC concentrations below the capture goal of 10 µg/L in 2020. Extraction well RW-6A showed the highest TVOC concentrations of about 9 µg/L throughout 2020.
- Well 800-96 detected a maximum TVOC concentration of 67 µg/L in December (**Figure 3.2.8-1**, **Figure 3.2.8-6**).
- None of the bypass wells installed downgradient of this area detected VOCs above AWQS.
- Well 800-92, located upgradient of extraction wells RTW-3A and RTW-4A had TVOC concentrations above the capture goal for the past several years. However, during 2020 the maximum TVOC concentration was 4 µg/L. The concentrations are showing a downward trend. This is a slug of contamination that was south of the North Street extraction wells prior to the system start-up.
- Well 800-101, located directly upgradient of extraction well RTW-4A, has shown an increasing TVOC concentration trend over the past several years. The concentration ranged up to 38 µg/L in 2020. This is above the TVOC capture goal of 10 µg/L for the Airport extraction wells and warrants the continued operation of well RTW-4A, a Magothy extraction well (**Figure 3.2.8.6)**.
- Monitoring well 800-138 was installed adjacent to well 800-59 and screened about 40 feet deeper than this well (from 245 feet to 255 feet bls). This well is used to monitor concentrations of VOCs

identified in upgradient well 800-92. VOC concentrations in this well were below AWQS in 2020.

- Two small areas of VOC contamination remain that are associated with the Airport Treatment System and warrant the continued operation of the treatment system. One area to the west associated with monitoring wells 800-94 and 800-95 and one area to the east associated with well 800-101.

3.2.8.4 System Operations

In 2020, the Airport and LIPA extraction wells were sampled quarterly. The influent, midpoint, and effluent of the carbon units were sampled two times per month. All system samples were analyzed for VOCs. Two of the Airport extraction wells were on a pulsed pumping schedule (RTW-2A, RTW-3A), being pumped one week per month for January and February. In March RTW-2, and RTW-3 were removed from pulsed pumping schedule as per the recommendation in the *2019 Groundwater Status Report* (BNL 2020d). RTW-5A is shut down. Wells RTW-1A, RTW-4A and RW-6A are pumped on a full-time basis. All four LIPA extraction wells are in standby since TVOC concentrations remained below the capture goal of 50 μg/L

The following is a summary of the Airport/LIPA Treatment System operations for 2020:

January – September 2020

The Airport System was operational in the first three quarters with RTW-1A, RTW-4A, and EW-6A operating on a full-time basis. Extraction well RTW-5A, and all four LIPA extraction wells were in standby. Extraction wells RTW-2A and RTW-3A at the Airport System were run one week per month on a pulsed pumping schedule for January and February and were place in standby mode in March as per *2019 Groundwater Status Report* (BNL 2020d) recommendation. RTW-3A pump was pulled and repaired in March. The system was down for a day in June for a scheduled carbon change out. In September RTW- 4A was down for 2 weeks for repairs.

October – December 2020

The Airport/LIPA system operated normally in the fourth quarter.

Extraction Wells Operational Data

During 2020, approximately 213 million gallons of groundwater were treated by the Airport/LIPA system, with an average flow rate of 411 gpm (**Table 3.2.8-2)**. **Table F-32** summarizes the system's mass removal. VOC concentrations for the Airport and LIPA extractions wells are provided in **Table F-35.**

3.2.8.5 System Operational Data

System Influent and Effluent

VOC concentrations for the carbon influent and effluent in 2020 are summarized on **Tables F-34** and **F-35,** respectively.

The carbon vessels for the system effectively removed the contaminants from the influent groundwater. System effluent samples were below the regulatory limit specified in the SPDES equivalency permit (**Table 3.2.8-1**)

Cumulative Mass Removal

The mass of VOCs removed from the aquifer by the Airport/LIPA Treatment System was calculated using the average flow rates for each monitoring period (**Table F-32**) in combination with the TVOC concentration in the carbon unit's influent, to calculate the pounds per month removed. The plot of cumulative mass of VOCs removed vs. time shows that 15 pounds of VOCs were removed during 2020, with a total of 487 pounds removed since system start-up (**Figure 3.2.8-5**).

Table 3.2.8-1
OU III LIPA/Airport Treatment System
2020 SPDES Equivalency Permit Levels

Parameters	Permit Level (µg/L)	Max. Measured Value (µg/L)
pH	5.5–7.5 SU	5.6-6.1 SU
carbon tetrachloride	5	<0.5
chloroform	7	0.78
1,1-dichloroethane	5	<0.5
1,1-dichloroethylene	5	<0.5
methylene chloride	5	<0.5
1,1,1-trichloroethane	5	<0.5
trichloroethylene	10	<0.5

Notes:
ND = Not detected above method detection limit of 0.50 µg/L.
Sampling required an a monthly basis
SU= Standard Units

3.2.8.6 System Evaluation

The Airport/LIPA system performance can be evaluated based on the decision rules identified for this system resulting from the groundwater DQO process.

1. Were unexpected levels or types of contamination detected?
No, there were no unusual or unexpected VOC concentrations observed in the monitoring wells for the LIPA/Airport Treatment System during 2020. However, PFAS and 1,4-dioxane were detected above the newly promulgated NYS DWS (see **Section 3.5**).

2. Has the downgradient migration of the plume been controlled?
Yes. The monitoring data clearly show that the capture goal of 50 µg/L TVOC at the LIPA Upper Glacial and Magothy wells is being met. No TVOC concentrations above the 10 µg/L capture goal have been detected in the bypass monitoring wells at the Airport. Based upon these data, plume migration is being controlled.

3. Can individual extraction wells or the entire treatment system be shut down or placed in pulsed pumping operation?
Yes, currently all four LIPA wells are shut down as they have reached their capture goals. Three of the six Airport extraction wells are shut down.

4. Are TVOC concentrations in plume core wells above or below 50 µg/L for LIPA and 10 ug/L for the Airport?
TVOC concentrations are all below 50 µg/L for all of the LIPA monitoring wells. Several Airport core wells are above a TVOC concentration of 10 µg/L. Well 800-96 located in the vicinity of well RW-6A continues to show levels of TVOC concentrations up to 67 µg/L. Well 800-130 located between well RW-6A and RTW-1A had TVOC concentrations of up to 31 µg/L in July. Wells 800-94 and 800-95 showed maximum TVOC concentrations of 64 µg/L and 16 µg/L, respectively. Well 800-101 is located immediately upgradient of well RTW-4A and showed a peak TVOC concentration of 38 µg/L.

4a. Is there a significant concentration rebound in core wells and/or extraction wells following shutdown?
No, all four LIPA and three Airport extraction wells that are shut down had VOC concentrations below MCLs in 2020.

5. Has the groundwater cleanup goal of meeting MCLs been achieved?
No, the cleanup goal has not been met. Based on monitoring results, MCLs are expected to be achieved by 2030 for the Upper Glacial aquifer, and in the Magothy aquifer by 2065, as required by the OU III ROD and ESD.

3.2.8.7 Recommendations

The following recommendations are made for the LIPA/Airport Treatment System and groundwater monitoring program:

- Continue full time operation of wells RTW-1A, RTW-4A and RW-6A. Keep wells RTW-2A, RTW-3A and RTW-5A in standby mode. If concentrations above the capture goal of 10 µg/L TVOC are observed in any of the extraction wells or the monitoring wells adjacent to wells that are not operating, the well(s) will be put back into full-time operation.
- Maintain LIPA wells EW-1L, EW-2L, EW-3L and EW-4L in standby mode. These extraction wells may be restarted if TVOC concentrations rebound above the 50 µg/L capture goal in either the plume core monitoring wells or the extraction wells. Based upon the low VOC concentrations for the past several years, submit a petition for closure of the LIPA system in 2021.
- No changes to the current monitoring schedule are recommended at this time for the Airport System. Continue the quarterly sampling frequency for the LIPA monitoring wells to support the decision for a petition for closure in 2021.

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3.2.9 Magothy Monitoring

This section provides a brief summary of the Magothy Aquifer Groundwater Monitoring and Cleanup Program and the remedial approach for addressing VOC contamination. The Record of Decision (ROD) states that the cleanup goal for the Magothy aquifer is to reach MCLs by 2065. The forty-four monitoring wells and nine extraction wells used to monitor the Magothy are shown on **Figure 3.2.9-1**. Ten of these wells are no longer sampled due to having achieved AWQS.

Detailed descriptions of the monitoring well analytical results and remediation progress are presented in the following sections of this report: Western South Boundary, Middle Road, LIPA/Airport, North Street, OU III South Boundary, Industrial Park, Industrial Park East and William Floyd Well Field sentinel monitoring. A brief summary of the results is provided in **Table 3.2.9-1 and Figure 3.2.9-2**.

Table 3.2.9-1. Magothy Aquifer Contamination (Historical and 2020).

	Max. TVOC (in µg/L)			
Location	2020	Historical	Primary VOCs	Results
Western South Boundary	<0.5	0.7	None	Magothy not impacted. Monitoring well 130-04 is located near the southwest site boundary and had no detections of VOCs in 2020.
William Floyd Well Field Sentinel	2.2	3.9	DCA	Wells 109-12 and 109-13 serve as outpost sentinel wells for the William Floyd Well Field. There were no detection's of VOCs in well 109-13. Well 109-12 had one low level detection of TVOCs in 2020
Middle Road to South Boundary	58	340	PCE, CCl_4	VOCs identified in upper 20 to 40 feet of the Magothy at the Middle Road area where Magothy brown clay is absent (Figure 3.2-2). Well 113-09 had 58 µg/L TVOC in May, and well 113-19 had 39 µg/L in November. VOCs not detected at the South Boundary beneath the clay.
Industrial Park	52	268	PCE, TCA	VOCs detected in the upper Magothy south of the OU III South Boundary system. Two Magothy extraction wells were installed in the Industrial Park in 2014 to capture and treat this contamination. Maximum TVOC concentrations were detected in well 000-537 at 52 µg/L in December and well 000-541 at 45 µg/L in March.
North Street to Airport	38	123	TCE, DCA	VOCs have been detected in localized areas in the upper 30 feet of the Magothy aquifer along North Street and downgradient near Vita Drive (Figure 3.2.6-2). The leading edge of this contamination is at the eastern portion of the Airport system, with 38 µg/L TVOC in well 800-101 in July, which is adjacent to Airport extraction well RTW-4A. Low VOC concentrations have been detected from the BNL South Boundary to North Street below the Magothy brown clay, at approximately 40 to 150 feet into the upper Magothy. A TVOC concentration of 9 µg/L was detected in well 000-343 in July 2020.
South Boundary to Industrial Park East	9	570	TCA, CCl_4	TVOC concentrations were less than 10 µg/L at the south boundary and off site in the Industrial Park East area, where the Magothy brown clay is absent. Magothy and Upper Glacial contamination is continuous in the industrial park. A TVOC concentration of 9 µg/L was detected in well 122-05 located at the south boundary in May. This is the highest TVOC concentration identified in this area in 2020.
South of Carleton Drive	40	7,200	CCl_4	Historically high VOC concentrations just south of Carleton Drive where the Magothy brown clay is absent. However, data shows these high concentrations are no longer present in this area. Contamination is continuous between Magothy and Upper Glacial aquifers. Well 000-130 which had 7,200 µg/L in 1998, showed a maximum TVOC concentration of 2.5 µg/L in July 2020. Well 000-460 located on Stratler Drive showed VOC concentrations below detection limits in 2020. Well 000-544 showed a high TVOC concentration of 40 µg/L in July. This well is located downgradient of the extraction well IP-EW-9. These concentrations have declined significantly from the historical highs.

The Magothy remedy identified in the *OU III Explanation of Significant Differences* (BNL, 2005a) document calls for the following:

1. Reaching MCLs in the Magothy aquifer by 2065 by active groundwater treatment and natural attenuation.
2. Operation of the nine extraction wells until cleanup objectives are met as part of the treatment systems that provide capture of Magothy VOC contamination at Middle Road (RW-7 and RW-3), South Boundary (EW-17 and EW-8 (shutdown), Airport RTW-3A (shutdown in 2020) and RTW-4A, Industrial Park IP-EW-8 and IP-EW-9 (both shutdown in 2019), and LIPA EW-4L (shutdown).
3. Continued evaluation of monitoring well data to ensure protectiveness. **Table 3.2.9-2** describes how each of the Magothy investigation areas is addressed by the selected Magothy aquifer remedy.
4. Institutional controls and five-year reviews.

Table 3.2.9-2. Magothy Remedy.

Area Investigated	Status of Selected Remedy
Western South Boundary	Continue monitoring and evaluate data.
William Floyd Well Field Sentinel Monitoring	Continue monitoring and evaluate data
Middle Road to South Boundary	Continue operation of the Magothy extraction wells at Middle Road (RW-3 and RW-7). Continue to monitor the three Magothy monitoring wells at Middle Road and five at the South Boundary until cleanup goals are met. Continue to operate South Boundary well EW-17.
North Street to Airport	The Airport extraction well RTW-4A should continue to operate to capture contaminants. Continue monitoring and evaluate data.
North Street East	Continue monitoring and evaluate data.
South Boundary to Industrial Park East	Continue monitoring and evaluate data.
South of Carlton Drive	The LIPA Magothy extraction well (EW-4L) on Stratler Drive has met cleanup goals and is now in standby. Continue monitoring until MCLs are met.
Industrial Park	The two industrial park extraction wells (IP-EW-8 and IP-EW-9) were placed in standby in 2019. Continue monitoring and data evaluation. Wells will be restarted if any significant rebound in concentrations is observed.

3.2.9.1 Monitoring Well Results

See the appropriate sections for detailed discussion of the monitoring well results. During 2020 select wells were analyzed for 1,4-dioxane and PFAS (see **Section 3.5**).

3.2.9.2 Recommendations

The following are recommendations for the Magothy groundwater monitoring program:

- Continue the current monitoring frequency for the Magothy monitoring program. Stop sampling south boundary wells 121-40, 121-44, 122-41 as they have never had any detections of individual VOCs near the MCL's. (**Table 1-5)**.
- Continue pumping the Magothy extraction wells at Middle Road, South Boundary and the Airport. The two IP extraction wells were placed in standby in July 2019 and continue to be monitored for rebound of VOCs. The North Street, OU III South Boundary EW-8 and LIPA and Airport RTW-3A Magothy extraction wells are currently in standby as they have reached the OU

III capture goals identified for shutdown of these wells. The IPE extraction well was abandoned as it had reached its cleanup goal.

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3.2.10 William Floyd Wellfield Sentinel Monitoring

The Suffolk County Water Authority operates the William Floyd Parkway Well Field located west of the BNL site. The well field currently contains three Upper Glacial aquifer supply wells (**Section 2.0**). Because the source water contributing area for this well field extends into the BNL property, four sentinel wells are used to monitor groundwater quality within on-site portion of the contributing area.

3.2.10.1 Groundwater Monitoring

Well Network

The monitoring well network is comprised of Upper Glacial wells 109-03 and 109-04 and Magothy aquifer wells 109-12 and 109-13 (**Figure 3.2.10-1**).

Sampling Frequency and Analysis

Wells 109-03 and 109-04 are jointly sampled by BNL and the SCDHS on a quarterly basis for VOCs, gamma spectroscopy, tritium, and Sr-90 (**Table 1-5**). Wells 109-12 and 109-13 are sampled by BNL quarterly for VOCs. Complete monitoring results are presented in **Appendix C**.

3.2.10.2 Monitoring Well Results

Monitoring results for 2020 are summarized below:

Upper Glacial Wells 109-03 and 109-04: The only parameter detected was chloroform in well 109-03 at a maximum concentration of 0.8 µg/L. The AWQS for chloroform is 7.0 µg/L

Magothy Wells 109-12 and 109-13: No VOCs were detected in either well. However, butylbenzene and naphthalene were detected at trace levels in well 109-12 at 0.58 µg/L and 0.89 µg/L, respectively.

3.2.10.3 Groundwater Monitoring Program Evaluation

The evaluation of the William Floyd Wellfield Sentinel Monitoring Program is based on the decision rule established for this program using the groundwater DQO process.

1. Have the SCWA William Floyd Well Field sentinel wells remained below the MCLs?
Yes. During 2020, no VOCs or radionuclides were detected at concentrations exceeding the MCLs.

3.2.10.4 Recommendation

No changes are recommended for the William Floyd Wellfield Sentinel Monitoring Program.

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3.2.11 BGRR/WCF Strontium-90 Treatment System

The Brookhaven Graphite Research Reactor (BGRR)/ Waste Concentration Facility (WCF) Treatment System addresses the Sr-90 plumes in groundwater downgradient of these facilities. The BGRR/ WCF remedy consists of:

1. Operation of nine extraction wells using ion exchange to remove Sr-90, with discharge of the treated water to dry wells,
2. Operation of the system to minimize plume growth and meet DWS by 2070,
3. Continued monitoring and evaluation of data to ensure protectiveness, and
4. Institutional controls and five-year reviews

The analytical results indicate three primary areas of elevated Sr-90 in groundwater: one extending south from the former WCF area, one extending south from the BGRR (Building 701)/ Below Ground Ducts (BGD) and former Canal House, and another that is south of the former Pile Fan Sump (PFS)/Building 801 Area (**Figure 3.2.11-1**).

3.2.11.1 System Description

Operation of this treatment system began in January 2005. There are two extraction wells (SR-1 and SR-2) located south of the former WCF, and three extraction wells (SR-3, SR-4, and SR-5) located south of the BGRR. SR-4 and SR-5 were placed in standby mode in 2016. Four extraction wells (SR-6, SR-7, SR-8, and SR-9) were installed in 2010 to address higher Sr-90 concentrations located in the downgradient portion of the former WCF plume (in the vicinity of the HFBR) and began operation in 2011. SR-6 was placed in a pulsed pumping mode in 2016. During 2017, wells SR-4, SR-5 and SR-6 were placed in stand-by mode. Wells SR-3 and SR-7 operated on a one month on, one month off pulsed pumping schedule. In October 2018 wells SR-3 and SR-7 were also placed in stand-by mode and well SR-8 was placed in a one month on, one month off pulsed pumping mode. SR-3 was returned to full time operation in January 2019.

Groundwater from the extraction wells is piped to an ion exchange treatment system inside Building 855 (within the BNL Waste Management Facility). The vessels of ion exchange media are designed to treat groundwater contaminated with Sr-90 to below the 8 pCi/L DWS. In addition, the influent is also treated for low-level concentrations (less than 10 µg/L) of VOCs using liquid-phase activated carbon.

Effluent is recharged to the Upper Glacial aquifer via three drywells located approximately 850 feet west of Building 855. A SPDES equivalency permit regulates this discharge. A complete description of the system is included in the *Operations and Maintenance Manual for the Sr-90 BGRR/ WCF/PFS/Building 801 Area Groundwater Treatment System* (BNL 2012).

3.2.11.2 Groundwater Monitoring

Well Network

A network of 72 monitoring wells is used to monitor the Sr-90 plumes associated with the BGRR, former WCF, and PFS/Building 801 areas. Temporary well BGRR-VP01-2020 (see **Figure 3.2.11-1** for locations) was installed in 2020 to provide data for siting of the new sentinel monitoring well (see **Table 3.2.11-1**). New permanent well 095-326 was subsequently installed at the VP-01 location.

Sampling Frequency and Analysis

The well samples are analyzed for Sr-90. As noted in **Table 1-5**, several of the wells are also monitored for other programs. Monitoring well results are tabulated in **Appendix C**. In 2020, the sampling frequency for all three of the Sr-90 plume segments (BGRR, PFS/Building 801 area and former WCF), was either annual or semi-annual for most wells. Source area monitoring wells 075-701 and 075-664 were sampled monthly to monitor Sr-90 releases from underneath Building

701/BGDs resulting from high water table conditions. The sampling frequency was increased to quarterly for monitoring wells 065-325 and 065-405 located downgradient of Building 801. During 2020 select wells were analyzed for 1,4-dioxane and PFAS.

3.2.11.3 Monitoring Well/Temporary Well Results

The Sr-90 plume distribution is shown on **Figure 3.2.11-1**. The distribution of Sr-90 throughout the BGRR, former WCF, and PFS/Building 801 areas is depicted based on groundwater data obtained from the fourth-quarter 2020 sampling round. Hydrogeologic cross-sections drawn along the center line of each of the plumes from the three Sr-90 source areas are shown on **Figures 3.2.11-2, 3.2.11-3, and 3.2.11-4**. In addition, historical Sr-90 concentration trends for key wells are plotted on **Figure 3.2.11-5**.

Historically, the highest Sr-90 concentration observed in these plumes (3,150 pCi/L) was during 2003 in a temporary well installed approximately 185 feet south of Building 701, and slightly upgradient of the location of extraction well SR-3. The highest historical Sr-90 concentration in the former WCF area (1,560 pCi/L) occurred in 2003 in a temporary well installed immediately downgradient of the six former underground storage tanks (USTs A/B), and approximately 25 feet northwest of the former WCF (Building 811). The highest historical Sr-90 concentration associated with the former PFS/Building 801 (566 pCi/L) occurred in 1997 in a temporary well installed immediately downgradient of this area.

A comparison of the plumes from 2004 through 2020 is provided on **Figure 3.2.11-10.** The three Sr-90 plumes were characterized extensively for the first time using numerous temporary wells in 1998. The permanent monitoring network was enhanced significantly in 2004 prior to the startup of groundwater treatment operations. Groundwater flow conditions have changed significantly in this area since the late 1990s. This is due to changes in supply, process, and remediation pumping and recharge in the east-central portion of the site. Flow has shifted from a southerly to southeasterly direction in response to the changes. As a result, a number of permanent wells are no longer in optimal locations for monitoring Sr-90. Some older wells have been dropped from the monitoring network over the years and temporary wells are increasingly required to fill data gaps. A periodic effort to supplement the permanent monitoring network with temporary wells was last carried out during 2018 and 2019. The following is a summary of the 2020 monitoring data for the three Sr-90 plumes:

WCF Plume

The removal of Building 811 and associated radiologically contaminated structures and soils in the WCF yard was completed in 2016. Extraction wells SR-1 and SR-2 have been effective at capturing source area contamination and preventing any southward migration of the plume as can be viewed on **Figure 3.2.11-1**. **Section 3.2.11.6** discusses Sr-90 concentration increases in SR-1 that may have been related to the 2016 remediation activities (these activities including removing above and below ground structures, pavement and contaminated soils). The downgradient portion of this plume has been influenced over the years by an easterly shift in groundwater flow, particularly in the vicinity of the HFBR and areas just to the west of that building.

- Monitoring well 065-175 has historically shown the highest Sr-90 concentrations immediately downgradient of the former WCF source area. Following a slow decline in concentrations since 2000, the Sr-90 concentration in this well increased to 355 pCi/L in April 2014. With the exception of a concentration of 55 pCi/L in May 2018, the Sr-90 concentration in this well has decreased with a detection of 11 pCi/L observed in November 2020 **(Figure 3.2.11-5).** The short-term increase probably resulted from the 2016 Building 811 and yard demolition and remediation work. Well 065-174 located approximately 40 feet to the west also showed a concentration of 16 pCi/L in October of 2019 which was the highest value observed over the past several years. The concentration in this well declined to <MDA in November 2020. Temporary wells installed at the southern edge of the former WCF yard in 2019 showed that the work may have mobilized

residual Sr-90 in very specific locations. At that time, higher concentrations were observed to the east and west of well 065-175.

- Sr-90 concentrations in monitoring wells located immediately downgradient of extraction wells SR-1 and SR-2 were below the 8 pCi/L DWS in 2020, indicating that the extraction wells are capturing Sr-90 migrating south from the source area.
- The downgradient portion of the WCF plume now resides in an area from approximately 200 feet north of the HFBR building, to approximately 150 feet south of Temple Place. There were no temporary wells installed to obtain data from this higher concentration segment of the plume in 2020. Due to the slow migration rate of Sr-90 in groundwater temporary wells will be installed to supplement the monitoring well network every two to three years. These wells will target the higher concentration segment and the location of the leading edge of the plume.

BGRR (Building 701 Area) Plume

- Source area monitoring well 075-701 (screened across the water table from 35-55 ft. msl) has been sampled on a monthly basis since late 2012. The monthly data was collected to evaluate a correlation between water table elevation and Sr-90 concentration increases in the source area as shown on **Figure 3.2.11-6**. This figure plots water table elevation data from a nearby USGS monitoring well against 075-701 Sr-90 concentrations over time and shows a correlation between high water table periods and increased Sr-90 concentrations in well 075-701. When the water table in this area rises to an elevation of approximately 43 feet above mean sea level (msl) there is a corresponding increase in Sr-90 concentrations at source area well 075-701. There is roughly a year lag from the time the water table reaches this level and the corresponding Sr-90 increase in this well due to the distance of the well from the contaminant source. The historical high-water table elevation of almost 47 feet msl in 2019 resulted in a historical high Sr-90 concentration of 1,170 pCiL in this well. Declining water table elevations are then reflected in declining Sr-90 concentrations in well 075-701. This was observed in 2020 as the water table decreased about six feet from its peak in 2019 and by early 2021 the Sr-90 concentration is below 5 pCi/L.

- The BGRR cap monitoring wells have now been in place for nine years. Sr-90 concentrations in monitoring wells 075-699 and 075-700 have been largely below the DWS. Initially, concentrations observed in these wells were 40 pCi/L (April 2012) and 104 pCi/L (April 2013), respectively. Sr-90 concentrations in these wells remained below the DWS in 2020 and were <MDA in the fourth quarter.

- Wells 085-398 and 085-403 monitor the leading edge of the Building 701 Sr-90 plume. Concentrations have been slowly increasing in both wells from barely detectable levels several years ago to 13 pCi/L in 085-398 and 35 pCi/L in 085-403 during October 2019. Concentrations decreased in both wells during 2020 with the fourth quarter results showing 12 pCi/L in 085-93 and 11 pCi/L in 085-403. A new sentinel well 095-326 was installed in 2020 at a location approximately 750 feet further to the south. Sr-90 was <MDA in 2020 in this well following a <MDA result from BGG-VP01-2020 installed previously at this location.

Former Pile Fan Sump/Building 801 Plume

- There was a significant increase in Sr-90 concentrations immediately downgradient of Building 801 in 2019. The sharpest increase was observed in well 065-325 (**Figure 3.2.11-1**) where the concentration ranged from 22 pCi/L in October 2018 up to 186 pCi/L in January 2020, which is a historical high concentration for this well (**Figure 3.2.11-5**). The well was installed in 2002 in response to an incident that had occurred in 2001 resulting in the flooding of the basement of Building 801 with stormwater. Some of this water became contaminated with Sr-90 after coming in contact with the floor and eventually migrated to the water table. This well is immediately upgradient of the former Pile Fan Sump was a formerly contaminated structure which was associated with the BGRR. Underground piping and Sr-90 contaminated soils related to this structure were removed back in 2000 as part of a BGRR removal action. Sr-90 concentrations in this well generally declined during 2020 following the January sample round and the well is now on a monthly sampling frequency. The October result decreased to 31 pCi/L but rebounded to 88 pCi/L in December. Sr-90 in well 065-405 located approximately 40 feet to the south, continued to slowly increase in Sr-90 concentrations from <MDA in 2017 to 80 pCi/L in February 2021. Well 065-37, located approximately 50 feet south of 065-405, has also shown slowly increasing Sr-90 concentrations from 2 pCi/L in 2017 to 41 pCi/L in December 2020.

3.2.11.4 System Operations

In accordance with the SPDES equivalency permit, the required frequency for Sr-90 and VOC sampling is monthly, and the pH measurement is weekly. The influent was also analyzed for tritium. Extraction well Sr-90 concentrations from 2020 are summarized on **Table F-36**. System influent and effluent concentrations are summarized on **Tables F-37** and **F-38**. **Table F-39** contains the monthly Sr-90 removal totals for the system. Operating details are given in the O&M manual for this system (BNL 2012c).

Below is a summary of the system operations for 2020:

January – September 2020

From January to September 2020, wells SR-4, SR-5, SR-6, and SR-7 were in stand-by mode. Well SR-8 operated on a one month on, one month off pulsed pumping schedule. The system was off from March 11th - March 16th to replace a pump and motor in well SR-3. The system was off again from April 7th to April 17th for a alarm that could not be cleared. It was off from July 2nd to August 26th due to a lightning strike that caused damage to multiple electrical components. The system treated approximately 9.5 million gallons of water during this period.

October – December 2020

From October to December 2020, wells SR-4, SR-5, SR-6 and SR-7 were in stand-by mode. Well SR-8 operated in a one month on, one month off pulsed pumping schedule. The system was off from October 19th - October 22nd for a resin change-out. The system was off again from December 3rd to December 21st for repairs. The system treated approximately 3.3 million gallons of water during this period.

Extraction Well Operational Data

During 2020, approximately 12.8 million gallons of water were treated by the remediation system, with an average flow rate of 24 gpm. **Table 3.2.11-2** shows the monthly extraction well pumping rates while **Table F-36** shows Sr-90 concentrations.

3.2.11.5 System Operational Data

During 2020, system influent concentrations of Sr-90 ranged from 2.4 pCi/L to 14.4 pCi/L. The only influent tritium concentration during 2020 was 694 pCi/L in January (**Table F-37**). During 2020, Sr-90 was detected in the effluent at a maximum concentration of 2.4 pCi/L. There were no VOCs or Sr-90 detected above the SPDES Equivalency Permit discharge limits in the 2020 effluent samples (**Table 3.2.11-3**).

Extraction Wells

Maximum Sr-90 concentrations in each of the extraction wells during 2020 were as follows:

- SR-1 27.2 pCi/L in January
- SR-2 9.8 pCi/L in October
- SR-3 41.5 pCi/L in March
- SR-4 0.9 pCi/L in April
- SR-5 3.4 pCi/L in April
- SR-6 2.9 pCi/L in April
- SR-7 3.3 pCi/L in April
- SR-8 3.1 pCi/L in January
- SR-9 8.3 pCi/L in March

Cumulative Mass Removal

Average flow rates for each monitoring period were used, in combination with the Sr-90 influent concentrations, to calculate the number of milliCuries (mCi) removed. During 2020, the flow averaged 24 gpm. Approximately 0.4 mCi of Sr-90 was removed during 2020, for a total of 29 mCi removed since system start-up in 2005 (**Table F-39**). Cumulative mass removal of Sr-90 is shown on **Figure 3.2.11-7**. **Figures 3.2.11-8** and **3.2.11-9** show the Sr-90 concentrations over time for the extraction wells.

Table 3.2.11-3
BGRR Sr-90 Treatment System
2020 SPDES Equivalency Permit Levels

Parameter	Permit Level	Max. Measured Value
pH range	5.5–8.5 SU	6.0–7.2 SU
Sr-90	8.0 pCi/L	2.4
Chloroform	7.0 µg/L	<0.5
1,1-Dichloroethane	5.0 µg/L	<0.5
Ethylbenzene	5.0 µg/L	<0.5
Methyl Chloride	5.0 µg/L	<0.5
Methylene Chloride	5.0 µg/L	<0.5
Toluene	5.0 µg/L	<0.5
1,2,3-Trichlorobenzene	5.0 µg/L	<0.5
1,1,1-Trichloroethane	5.0 µg/L	0.54
1,2,4-Trimethylbenzene	5.0 µg/L	<0.5
Xylene, total	10.0 µg/L	<0.5

Notes:
SU = Standard Units
Required sampling frequency is monthly for Sr-90 and VOCs, and weekly for pH.

3.2.11.6 System Evaluation

The BGRR/ WCF Strontium-90 Treatment System and Monitoring Program can be evaluated in the context of the decisions established for this program using the groundwater DQO process:

1. Is there a continuing source of contamination? If present, has the source area been remediated or controlled?

WCF Plume: Buildings 810 and 811, located in the eastern portion of the former WCF yard, were demolished in 2015. Contaminated piping and soils located underneath and adjacent to the buildings were also removed and sent to an approved disposal facility following the building demolition. Some paved areas were also removed. The excavated areas were backfilled in September 2016. Sr-90 concentration increases were observed in extraction well SR-1 in 2018 and 2019. Source area monitoring well 065-175 has not shown any significant change in Sr-90 levels following the WCF area work in 2015. Source area temporary wells installed in 2019 confirmed that Sr-90 is still present at elevated concentrations in localized portions of the source area. In addition, the Sr-90 concentration in extraction well SR-1 located at the southeast edge of the yard, spiked up briefly to 100 pCi/L in 2017. It has since declined with a December 2020 value of 15 pCi/L. It appears that the remediation work (including removal of building structures and paved areas) resulted in the release of some Sr-90 to the water table. The source area remains controlled by extraction wells SR-1 and SR-2 which capture the plume migrating south from this area.

BGRR Plume: The source area is capped by Building 701 and an engineered cap that was completed in 2011. Following an historical high water table elevation in 2019, both the water table and Sr-90 concentrations have decreased again to levels below the DWS in the source area. Monthly monitoring will continue in this area in 2021. Until the inventory of Sr-90 in the unsaturated zone beneath Building 701 and the below ground ducts has been depleted, the water table flushing process is expected to continue intermittently. Data from monitoring well 075-701 is a reliable indicator of new Sr-90 releases. The downgradient migration of the Sr-90 plume is controlled by extraction well SR-3. The operation of extraction well SR-3 will be managed going forward based on data from both 075-701 and SR-3 and will be placed in standby mode during periods of lower water table elevation and lower source area concentrations.

PFS/Building 801 Area Plume: The Sr-90 concentration decrease in source area monitoring well 065-325 during 2020 indicates that the source area soil release event has subsided and the small slug of Sr-90 contamination is migrating slowly south as observed in monitoring wells 065-405 and 065-37. Monitoring will continue in this area. It appears that the Sr-90 releases from beneath the building are also related to high water table levels.

2. Were unexpected levels or types of contamination detected?

WCF Plume: No, there were elevated levels of Sr-90 at the source area which were anticipated due to the recent remediation work in the area.

BGRR Plume: No. It was anticipated that once water table levels declined there would be a corresponding reduction in Sr-90 source area groundwater concentrations.

PFS/Building 801 Area Plume: No. While elevated Sr-90 concentrations were observed in 2019 immediately downgradient of the Building 801 area, they declined significantly in 2020. However, PFAS and 1,4-dioxane were detected above the newly promulgated NYS DWS (see **Section 3.5**).

3. Has the downgradient migration of the plume been controlled?

WCF Plume: The downgradient migration of the plume has been largely controlled. The eastward shift in the downgradient segment of this plume over the years has resulted in part of the plume bypassing the capture zone of SR-9. The Sr-90 concentrations to the south and east of SR-9 are well below the system capture goal of 175 pCi/L and are expected to naturally attenuate and meet the ROD cleanup goals.

BGRR Plume: Extraction well SR-3 is positioned to capture the migration of Sr-90 from the source area. This well is currently fully operational due to the elevated Sr-90 concentrations in well 075-701.

PFS/Building 801 Area Plume: This plume is not being actively remediated. Based on source area concentrations, the plume is expected to attenuate and meet the ROD cleanup goals.

4. Can individual extraction wells or the entire treatment system be shut down or placed in pulsed pumping operation?

WCF Plume: The cleanup goal has not yet been met. The extraction wells are capturing source area residual Sr-90 contamination immediately downgradient of the former WCF. Extraction wells SR-6, SR-7, and SR-8 are all below DWS. Extraction well SR-6 is currently in stand-by mode and concentrations remained low in 2020. SR-7 is currently in stand-by mode and Sr-90 concentrations have remained low over the past year. SR-8 is in a pulsed-pumping mode with low concentrations observed in 2020. Concentrations in SR-9 decreased to below the DWS for the second half of 2020.

BGRR Plume: SR-3 has been operational since January 2019 due to increasing source area Sr-90 concentrations. This well will continue to operate but can be placed back on standby if source area concentrations remain below DWS. Extraction wells SR-4 and SR-5 will be maintained in standby mode.

PFS/Building 801 Area Plume: This plume is not being actively remediated.

5. Has the Groundwater Cleanup goal of meeting MCLs been achieved?
The groundwater cleanup goal of meeting MCLs has not been achieved for these plumes.

3.2.11.7 Recommendations

The following are recommendations for the BGRR/WCF Building 801Groundwater Treatment System and Monitoring Program:

- Maintain the monthly sampling frequency of source area monitoring wells 065-325 and 065-405. Continue to monitor the elevated Sr-90 concentrations downgradient of Building 801. Perform groundwater modeling simulation if necessary (based on significant Sr-90 concentration increase), to determine natural attenuation of Sr-90.
- Maintain SR-8 in pulsed pumping mode (one month on and one month off) based on low, but fluctuating, Sr-90 concentrations.
- Maintain a source area monitoring frequency of monthly for BGRR source area well 075-701 and 075-664.
- Maintain SR-3 in full time operational mode. If Sr-90 concentrations in this SR-3 and monitoring well 075-701 remain below DWS for 6 consecutive months, place SR-3 on standby.
- Continue operating wells SR-1, SR-2, and SR-9 in full time operational mode. Maintain wells SR-4, SR-5, SR-6, and SR-7 in standby mode.
- Install several temporary wells along Temple Place to supplement monitoring of the downgradient segment of the WCF plume. Install temporary wells as necessary to monitor high concentrations segments of the downgradient portions of the BGRR and Building 801/PFS plumes.

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3.2.12 Chemical/Animal Holes Strontium-90 Treatment System

This section summarizes the operational data from the Chemical/Animal Holes Strontium-90 Treatment System for 2020 and gives conclusions and recommendations for future operation. This system began operation in February 2003. Due to the declining Sr-90 concentrations, a *Petition for Shutdown of the OU III Chemical Holes Strontium-90 Groundwater Treatment System* (BNL 2018b) was submitted to the regulators in March 2018 and subsequently approved. In July 2018, the system was placed in standby mode.

3.2.12.1 System Description

The Chemical/Animal Holes were located in the south-central portion of the BNL property (**Figure 1-1** and **3.2.12-1**). The area consisted of 55 pits east of the Former Landfill that were used for the disposal of a variety of laboratory chemicals and animal remains. The buried waste was excavated in 1997.

The elements of the Sr-90 groundwater remediation at the Chemical/Animal Holes are:

1. Three extraction wells pumping into an ion exchange treatment system to remove Sr-90 from the extracted groundwater, and on-site discharge of the clean water into two drywells.
2. Operation of the system to minimize plume growth, in conjunction with monitored natural attenuation to meet the 8 pCi/L DWS by 2040.
3. Continued monitoring and evaluation of the data to ensure protectiveness.

Details of operations are provided in the *Chemical/Animal Holes Strontium-90 Groundwater Treatment System Operation and Maintenance Manual* (BNL 2008b).

3.2.12.2 Groundwater Monitoring

Well Network

The Chemical/Animal Holes monitoring network consists of 29 wells. **Figures 1-2** and **3.2.12-1** show the monitoring well locations.

Sampling Frequency and Analysis

The sampling frequency for the monitoring wells was annual (standby phase) in 2020, except for the three upgradient wells that monitor the former source area which were sampled semi-annually (**Table 1-5**). During 2020, select wells were analyzed for PFAS and 1,4-dioxane (see **Section 3.5**).

3.2.12.3 Monitoring Well Results

Figure 3.2.12-1 shows the Sr-90 plume distribution. The plume depiction is derived from third quarter 2020 monitoring well data.

The area of highest Sr-90 concentration is currently located in the former source area upgradient of extraction well EW-1. Monitoring well 097-314 detected 64 pCi/L of Sr-90 in January 2020 and 39 pCi/L in August. Overall, the plume concentrations have significantly decreased since 2006 with no significant rebound identified. To date, the highest Sr-90 concentration observed in groundwater in this area was 4,720 pCi/L at well 106-99 in 2005. Sr-90 concentrations in the plume have been below 50 pCi/L since mid-2015. See **Figure 3.2.12-2** for concentration trends of key monitoring wells and **Figure 3.2.12-3** for a cross-sectional view. The complete monitoring results for all wells in this program are in **Appendix C**.

Sr-90 concentrations in monitoring wells have been significantly reduced over the last ten years. Low precipitation conditions from 2015 through 2017 resulted in the lowering of the water table which may have impacted flushing of Sr-90 from the vadose zone in the former source area during that period. This could have influenced the Sr-90 concentrations in the monitoring wells between the former source area and EW-1. Although there was a significant increase in the water table elevation in 2018, there has not been a significant corresponding rebound in Sr-90 concentrations. Sr-90 concentrations in the monitoring wells in 2020 were generally consistent with 2018 and 2019 results.

A summary of key monitoring well data for 2020 follows:

- Sr-90 concentrations in plume core wells have declined over the past several years as shown in the trend charts. However, since mid-2018, Sr-90 concentrations in well 097-314 began to increase slightly to a maximum of 64 pCi/L in January 2020. Strontium-90 concentrations in this well dropped off in the third quarter to 39 pCi/L. Wells 097-313 and 097-315, also located in the former source area, have not detected Sr-90 above the DWS since 2016. Thus, this a very localized area of contamination.
- Sr-90 concentration trends in plume core wells 106-16,106-94, 106-95 and 106-99 have significantly declined over time and have remained less than 25 pCi/L since 2016. These wells are located immediately upgradient of EW-1. As shown on the plume comparison on **Figure 3.2.12-6**, the plume has become discontinuous and Sr-90 concentrations have been significantly reduced as a result of the groundwater remediation efforts in this area.
- All remaining plume monitoring wells were less than the DWS in 2020 except for 106-103 with a Sr-90 concentration at 8.3 pCi/L.

3.2.12.4 System Operations

The system remained in standby mode in 2020. Therefore, the influent, midpoint, and effluent locations were not sampled (**Tables 3.2.12-1 and 3.2.12-2**). The three extraction wells were sampled quarterly for Sr-90 (**Table F-40**).

The maximum Sr-90 concentration in the extraction wells in 2020 was 19 pCi/L in EW-1 and EW-2.

Tables F-41, 42 and 43 contain no data since the system remained shut down since 2018.

Table 3.2.12-1.
Chemical Holes Sr-90 Treatment System
2020 SPDES Equivalency Permit Levels

Parameter	Permit Level	Max. Measured Value
pH range (SU)	5.0–8.5	NS
Sr-90 (pCi/L)	8.0	NS

Notes:
pCi/L = pico Curies per liter
SU = Standard Units
MDA = Minimal detectable activity
NS = Not sampled since the system was not operating
Required sampling frequencies are monthly for Sr-90 and pH.

3.2.12.5 System Operational Data

Concentrations of Sr-90 in EW-1 have steadily dropped-off since 2009, however there was a slight increase starting in 2019. Sr-90 concentrations in EW-2 have decreased as expected since this well became operational. Upon start-up, up to 139 pCi/L of Sr-90 was detected in EW-2 and the concentration has steadily dropped to less than the DWS since 2012. However, in April 2020 EW-2 detected Sr-90 at 19 pCi/L but concentrations dropped back down in subsequent samples. Sr-90 concentrations in EW-2 and EW-3 have remained below the DWS since 2014, except for the one 2020 detection stated above. **Figure 3.2.12-4** presents the Sr-90 extraction well data over time.

Cumulative Mass Removal

The system remained in stand-by mode in 2020. The cumulative total mass of Sr-90 removed during system operations from 2003 through July 2018 is approximately 4.94 mCi (**Figure 3.2.12-5**).

3.2.12.6 System Evaluation

The Chemical/Animal Holes Sr-90 Treatment System performance can be evaluated based on decisions identified for this system as part of the DQO process.

1. Is there a continuing source of contamination? If present, has the source area been remediated or controlled?
The former Chemical/Animal Holes, located upgradient of extraction well EW-1 were excavated in 1997. The inventory of Sr-90 that remains in the vadose zone in this area is decreasing based on the monitoring data. The temporary well soil and groundwater samples obtained in this area in late 2015 did not identify a continuing source of Sr-90. As shown by the trends in **Figure 3.2.12-2**, Sr-90 concentrations in monitoring wells immediately upgradient of EW-1 have been significantly reduced over the last ten years. This is indicative of the remediation progress. However, there was a slight increase in Sr-90 concentrations in former source area well 097-314 starting in 2018 with a maximum of 64 pCi/L in January 2020. This may be associated with the significant rise in the water table in 2018 following three years of low precipitation conditions, resulting in flushing of Sr-90 from the vadose zone. This area will continue to be monitored in 2021 for potential significant increasing trends.

2. Were unexpected levels or types of contamination detected?
No. There was a temporary increase in Sr-90 concentrations in EW-2 during one sample round in 2020. However, concentrations dropped back off in subsequent samples and no corresponding Sr-90 increases were seen in upgradient monitoring well 106-125. However, PFAS was detected above the newly promulgated NYS DWS (see **Section 3.5**).

3. Has the downgradient migration of the plume been controlled?
Yes. The monitoring data from plume perimeter wells to the west and east as well as the system bypass wells indicate that the main portion of the plume is controlled by extraction well EW-1. The downgradient portion of the plume was previously controlled by operation of EW-2 and EW-3.

4*. Can individual extraction wells or the entire treatment system be shut down or placed in pulsed pumping operation?*
Following regulatory approval, the system was shut down and placed in standby mode in July 2018 and will continue to be monitored for potential rebound.

4a. Are Sr-90 concentrations in plume core wells above or below 8 pCi/L?
Sr-90 concentrations in six of 21 core wells were above 8 pCi/L in 2020 with a maximum of 64 pCi/L in well 097-314. The number of core wells above the MCL have been reduced from the nine identified in 2018.

4b. Is there a significant concentration rebound in core wells and/or extraction wells following shutdown?
There was a slight increase in Sr-90 concentrations in former source area monitoring well 097-314 in the first quarter of 2020, as well as extraction wells EW-1 and EW-2. These concentrations are not considered significant. Monitoring will continue to evaluate any significant rebound and increasing trends.

5*. Has the groundwater cleanup goal of meeting drinking water standards been achieved?*
The DWS has not been achieved for Sr-90 in all plume core wells. However, based on the projected attenuation of the remaining Sr-90, the DWS is expected to be achieved before 2040. Comparison of the current plume with a series of plume snapshots dating back to 2002 is provided in **Figure 3.2.12-6.**

3.2.12.7 Recommendations

The following are the recommendations for the Chemical/Animal Holes Strontium-90 Treatment System and groundwater monitoring program:

- Maintain the system in standby mode and maintain quarterly sampling of the extraction wells. If significant rebound in either the extraction wells or monitoring wells is identified, these extraction wells may be restarted.
- Maintain the annual monitoring well sampling frequency (standby phase), except for wells 097-313, 097-314, 097-315, which will remain at a semi-annual.
- If Sr-90 concentrations in the monitoring and extraction wells do not show any significant rebound through 2021, then a Petition for Closure of the treatment system may be prepared.

3.2.13 HFBR Tritium Pump and Recharge System

In late 1996, tritium was detected in monitoring wells near the HFBR. The source of the release was traced to the HFBR spent fuel pool. In response, the fuel rods were removed and the spent fuel pool was drained. In May 1997, a three-well groundwater pump and recharge system was constructed on the Princeton Avenue firebreak road, approximately 3,700 feet downgradient of the HFBR to capture the leading edge of the tritium plume should it be necessary to prevent off site migration of the plume. Extracted water was recharged at the RA V Recharge Basin. The extraction system was placed on standby status in September 2000, as groundwater monitoring data demonstrated that the plume was attenuating to concentrations well below DWS in the vicinity of the extraction wells.

As described in the OU III ROD, the selected remedy to address the HFBR tritium plume included implementing monitoring and low-flow extraction programs to prevent or minimize the plume's growth. Beginning in June 2000 and ending April 2001, 20 low-flow extraction events removed 95,000 gallons of tritiated water with concentrations greater than 750,000 pCi/L. This water was sent off site for disposal.

The OU III ROD contingencies are defined as either a detection of tritium above 25,000 pCi/L in monitoring wells at the Chilled Water Facility Road, or above 20,000 pCi/L in monitoring wells along Weaver Drive. The OU III ROD contingency of exceeding 20,000 pCi/L at Weaver Drive was triggered with a detection of 21,000 pCi/L in November 2006. In 2007, extraction well EW-16 was installed to supplement the three extraction wells and the system was restarted in November 2007 as per the ROD contingency.

The *Petition For Shutdown, High Flux Beam Reactor, Tritium Plume Pump and Recharge System* (BNL 2013d) was submitted to the regulatory agencies in March 2013 based on satisfaction of the criteria established in the *2008 Groundwater Status Report* (BNL, 2009b) and documented in the *Operations and Maintenance Manual for the High Flux Beam Reactor Tritium Plume Pump and Recharge System (*BNL, 2009c). The petition was approved by the regulatory agencies in May 2013 and the extraction wells were placed in standby mode. A *Petition for Closure* (BNL, 2018c) of this system was submitted to the regulators in July 2018 and approved in March 2019. The extraction wells are now shut down.

3.2.13.1 System Description

Extraction wells EW-9, EW-10, EW-11, and EW-16 are no longer in use and will be decommissioned upon a determination that they will not be needed for use related to PFAS and 1,4-dioxane contamination.

3.2.13.2 Groundwater Monitoring

Well Network

A monitoring well network of 10 wells is utilized to monitor source area tritium concentrations immediately downgradient of the HFBR (**Figure 1-2 and 3.2.13-1**).

Sampling Frequency and Analysis

Sampling details for the well network are provided on **Table 1-5**. During 2020 select wells were analyzed for 1,4-dioxane and PFAS (see **Section 3.5**).

3.2.13.3 Monitoring Well Results

The fourth quarter 2020 data are posted on **Figure 3.2.13-1** for each of the wells in the monitoring network. In 2019 the plume monitoring was scaled back to the area immediately south of the HFBR, due to the attenuation of the downgradient portion of the plume. The highest tritium concentration observed in 2020 was 25,300 pCi/L in well 075-806 in April 2020. **Appendix C** contains the complete set of monitoring well data.

Elevated tritium concentrations in wells located immediately downgradient of the HFBR have been observed to correlate with high water-table elevation events. This results in water table flushing of the remaining tritium inventory in the unsaturated zone beneath the HFBR. The correlation is evident when comparing water table elevations immediately downgradient of the HFBR with peak tritium concentrations in the monitoring wells located in this area as shown in **Figure 3.2.13-2**. Water table elevations declined in 2019-2020 and tritium concentrations declined as well. The correlation between the water table and tritium concentrations is shown on **Figure 3.2.13-2**. The figure demonstrates how the magnitude and frequency of the peak tritium concentrations has diminished over the 23 years of monitoring. The HFBR monitoring time frame has now spanned two of the half-lives for tritium (12 years). Based on the decreasing concentration trend, the inventory of tritium beneath the HFBR has significantly decreased over the past 23 years.

3.2.13.4 System Operations

A petition for closure of this system was approved by the regulators in 2019. No extraction well samples collected in 2020 (**Table F-47**).

3.2.13.5 System Evaluation

The OU III HFBR Tritium Pump and Recharge System and Monitoring Program can be evaluated based on the decision rules established for this program using the groundwater DQO process.

1. Is there a continuing source of contamination? If present, has the source area been remediated or controlled?
Yes. However, the inventory of tritium that remains in the unsaturated zone beneath the HFBR building is decreasing based on monitoring data from groundwater immediately downgradient of the building. The highest concentration observed in the source area during 2020 was 25,300 pCi/L in monitoring well 075-806. The long-term decline in peak tritium concentration trend in wells immediately downgradient of the HFBR and the water table elevation is shown in **Figure 3.2.13-2**.

2. Were unexpected levels of contamination detected?
There were no unusual or unexpected concentrations/types of contaminants observed in the monitoring wells during 2020.

3. Is the plume attenuating as expected?
Yes. Tritium exceeding the 20,000 pCi/L DWS is observed intermittently in individual wells immediately downgradient of the HFBR. **Figure 3.2.13-2** demonstrates the decline in source area concentrations over the years.

4. Has the downgradient migration of the plume been controlled?
Yes. The downgradient segment of the plume has been successfully remediated by a combination of pump and recharge and natural attenuation to levels below the DWS.

5. Can individual extraction wells or the entire treatment system be shut down or placed in pulsed pumping operation?
The regulatory agencies approved the *Petition for Closure* of this system in March 2019.

5a. Are tritium concentrations in extraction wells above or below the 20,000 pCi/L DWS?
The extraction wells are no longer operational as the system has been approved for closure.

5b. Is there a significant concentration rebound in extraction wells following shutdown?
The extraction wells are no longer operational as the system has been approved for closure.

6. Has the groundwater cleanup goal of meeting MCLs been achieved?
MCLs have been attained except for the area immediately downgradient of the HFBR.

3.2.13.6 Recommendations

The following are recommendations for the HFBR Tritium Pump and Recharge System and monitoring program:

- Continue to monitor the source area with the ten wells located immediately downgradient of the HFBR.
- Maintain the downgradient monitoring wells and extraction wells until a determination is made on their utilization related to emerging contaminants.
- Maintain the quarterly sampling frequency.

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3.3 OPERABLE UNIT IV

This section summarizes the data from the Building 650 and Sump Outfall Strontium-90 Monitoring Program that monitors a Sr-90 plume and offers conclusions and recommendations for monitoring.

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3.3.1 Building 650 and Sump Outfall Strontium-90 Monitoring Program

The Building 650 and Sump Outfall Strontium-90 Monitoring Program monitors a Sr-90 plume that derived from a remediated source area known as the former Building 650 Sump Outfall Area. This source area consisted of a depression (sump outfall) at the terminus of a discharge pipe from the building. The pipe conveyed discharges from a concrete pad located approximately 1,200 feet to the west, where radioactively contaminated clothing and equipment were decontaminated beginning in 1959 (**Figure 3.3.1-1**).

3.3.1.1 Groundwater Monitoring

The network consists of 24 wells used to monitor Sr-90 concentrations originating from the former Building 650 Sump Outfall Area (**Figure 1-2 and 3.3.1-1**). During 2020, the monitoring wells were sampled either annually or semiannually, and the samples were analyzed for Sr-90 (**Table 1-5**). During 2020 wells 076-420 and 076-421 were installed to evaluate for potential impacts to groundwater from Demolition and Decommissioning (D&D) of Building 650. These wells were installed prior to any D&D activity and will monitor any releases caused by the disruption of the former foundation and soils during the D&D process. D&D activity is currently underway and is expected to be completed by the end of 2021. Additionally, wells 076-418 and 076-419 were installed downgradient of the Sump Outfall Area where temporary wells in 2019 indicated the need for permanent monitoring wells. These additional wells are incorporated into the monitoring well network and are depicted on **Figure 3.3.1-1.**

3.3.1.2 Monitoring Well Results

The complete monitoring well radionuclide sampling results can be found in **Appendix C**. The Sr-90 plume continues to attenuate as it migrates away from the former Building 650 Sump Outfall Area. The locations of the monitoring wells and the Sr-90 concentrations are shown on **Figure 3.3.1-1**. The leading edge of the plume, as defined by the 8 pCi/L DWS is presently located in the area immediately north of the NSLS II Facility.

Sr-90 concentrations in source area wells 076-13 and 076-168 have remained below DWS over the past year (**Figure 3.3.1-2**). There has been a shift in the groundwater flow direction to the southeast in this area as shown on **Figure 2-2**. This shift is attributable to the reduction of treated water discharging into the RAV basin. This shift could also be contributing to the decrease in concentrations in some of the plume core wells e.g. (076-24, 076-415, 076-182, and 076-416) over the past several years. Furthermore, it is possible a shift back towards the southwest could occur when planned discharges to the RAV basins increase in the future.

Well 076-184, located to the east of wells 076-182 and 076-416, increased to its historical high of 31.6 pCi/L in April of 2020. Well 076-184 showed an increase from 3.8 pCi/L in 2018 to 31.6 pCi/L in 2020. This well decreased to 23.4 pCi/L in October of 2020. However, these Sr-90 concentrations may still be the result of fluctuating groundwater elevations and plume shift in the area.

Monitoring well 076-25 has seen a decrease in Sr-90 concentrations from a high of 12 pCi/L in 2018 to 2.3 pCi/L in 2020. This well is located approximately 160 feet to the south-southeast of Building 650. Again, this decrease in concentrations may be the result of plume shift and fluctuating groundwater elevations.

Wells 076-420 and 076-421 were installed to evaluate for potential impacts to groundwater from D&D of Building 650. These wells were sampled in October of 2020 and results will serve as a baseline. Well 076-420 had an initial result of 0.3 pCi/L. Well 076-421 had an initial result of 0.7 pCi/L.

Wells 076-418 and 076-419 were installed downgradient of the Sump Outfall Area at locations where temporary vertical profile wells installed in 2019. Wells 076-418 and 076-419 located approximately 200 feet and 425 feet southwest of 076-168 had initial results of 11.7 pCi/L and 16.3 pCi/L respectively.

3.3.1.3 Groundwater Monitoring Program Evaluation

The monitoring program can be evaluated based on the decision rules identified from the groundwater DQO process.

1. Is there a continuing source of contamination? If present, has the source area been remediated or controlled?
The source area was remediated in 2002 yet there are still persistent detections of Sr-90 in the Sump Outfall Area at levels near or above the DWS. Based on the Sr-90 concentrations in source area monitoring wells, any residual contamination that may remain at depth in the unsaturated zone above the water table appears to be minimal.

2. Were unexpected levels or types of contamination detected?
No. All Sr-90 detections in 2020 were within the expected concentration range.

3. Is the plume naturally attenuating as expected?
The groundwater modeling conducted in 2010 predicted that the plume will attenuate to below the 8 pCi/L DWS by approximately 2034. The leading edge of the plume, as defined by the DWS, is predicted to advance approximately 250 feet south of Brookhaven Avenue. This is currently where the leading edge of the plume is located.

4. Has the groundwater cleanup goal of meeting MCLs been achieved?
No. There were three monitoring wells exceeding the 8 pCi/L MCL limit in 2020 (076-184, 076-418 and 076-419). Therefore, the performance objectives have yet to be achieved. The groundwater plume continues to degrade due to natural attenuation (i.e., radioactive decay and dispersion).

3.3.1.4 Recommendations

The following are recommendations for the Building 650 and Sump Outfall Strontium-90 Monitoring Program:

- Continue monitoring newly installed wells 076-418, 076-419, 076-420 and 076-421 for potential impacts from D&D activities and from Sump Outfall Area on a semi-annual basis.

3.4 OPERABLE UNIT VI EDB TREATMENT SYSTEM

The OU VI EDB Treatment System addresses an EDB plume in groundwater currently extending off site from south of North Street, southward for approximately 2,500 feet. EDB was used during the 1970s as a fumigant for the BNL Biology Department's biology fields located in the southeastern portion of the site (**Figure 3.4-1**). In the mid-1990s, low levels of EDB were detected in groundwater near the fields. Higher levels were found migrating toward the southern site boundary and off site to the south. In addition, the depth of the plume increased within the Upper Glacial aquifer to the south. EDB has not been detected on BNL property since 2009 and on-site monitoring was discontinued in 2016.

3.4.1 System Description

A groundwater remediation system to address the off-site EDB plume began routine operations in August 2004. The OU VI EDB Treatment System consists of two extraction wells and two recharge wells. A complete description of the system is included in the *Operations and Maintenance Manual for the OU VI EDB Groundwater Treatment System* (BNL 2004).

3.4.2 Groundwater Monitoring

Well Locations

A network of 20 wells monitor the EDB plume from North Street to locations on private property south of North Street and west of Weeks Avenue (**Figure 3.4-1**). These include two monitoring wells (000-567 and 000-568) installed in October 2020.

Sampling Frequency and Analysis

The OU VI EDB plume monitoring program is in the O&M phase (**Table 1-8**). The sampling frequency for nine of the plume core and perimeter wells is semi-annual (**Table 1-5**). Three perimeter wells located upgradient of the plume are sampled annually. The remaining eight wells are sampled quarterly. The wells are analyzed for EDB using EPA Method 504. The federal DWS for EDB is 0.05 µg/L. During 2020 select wells were analyzed for 1,4-dioxane and PFAS (see **Section 3.5**).

3.4.3 Monitoring Well Results

Appendix C contains the complete analytical results of the OU VI EDB monitoring well sampling program. The distribution of the EDB plume for the fourth quarter of 2020 is shown on **Figure 3.4-1**. One temporary vertical profile well was sampled in 2020 and three vertical profile wells were sampled in the first quarter of 2021 (**See Table 3.4-3**). The plume is in the deep Upper Glacial aquifer as depicted on cross section Q–Q' (**Figure 3.4-2)**. See **Figure 3.4-3** for historical EDB trends for key monitoring wells. A summary of key monitoring well data for 2020 follows:

- EDB concentrations declined below the DWS in northern perimeter well 000-173 in 2015. Concentrations have slowly increased over the past several years with the December sample at 0.06 µg/L. Concentrations in 000-175 have remained below the DWS since 2011.
- Core well 000-283, located approximately 1,700 feet upgradient of the extraction wells, detected the maximum historical EDB concentrations in the plume of 7.6 µg/L in 2001. This well has seen a steady drop in EDB concentrations since 2005. However, it continues to show values above the DWS with 0.08 µg/L in the December sample round.
- EDB in well 000-178 increased from late 2006 through 2012, indicating movement of the higher concentration portion of the plume into this area. A 2012 sample detected 4.8 µg/L of EDB, which was an historical high for this well since it was installed in 1998. Since 2012, concentrations have decreased to 0.18 µg/L in December 2020. This well is approximately 1,000 feet upgradient of EW-2E.

- The maximum EDB concentration in the monitoring well network in 2020 was 0.47 µg/L in new well 000-568. This well was installed in December 2020 along the centerline of the plume to enhance the monitoring of EDB upgradient of well 000-507. Approximately 400 feet north of 000-568 is well 000-549, installed in 2019 along the plume centerline. Since that well was installed, the EDB concentration has decreased from 0.45 µg/L to 0.28 µg/L.
- Five temporary vertical profile wells were installed in 2020/2021 (see **Figure 3.4-1**) for the purpose of obtaining updated geologic information as well as groundwater quality data. They were installed in a north-south line, ranging from 500 feet north of EW-2E to 500 feet south of EW-2E (**Figure 3.4-2**). The data from these temporary wells is compiled in **Table 3.4-3**. EDB-VP-01-2020 is located where permanent wells 000-567 and 000-568 were subsequently installed. The highest EDB concentration observed was 0.9 µg/L at a depth of 158 feet bls. EDB-VP-01-2021 was installed between EDB-VP-01-2020 and EW-2E. The highest concentration observed at this location was 1.4 µg/L at a depth of 158 feet. EDB-VP-02-2021 was installed adjacent to EW-2E and the highest concentrations observed at this location was 1.26 at a depth of 178 feet. EDB-VP-03-2021 was installed approximately 400 feet south of EW-2E and no EDB was detected in this profile. EDB-VP-04-2021 was installed adjacent to EW-1E and EDB was also detected significantly below the capture zone of this extraction well. In general, the depth of EDB detections in the VPs installed in 2021 were deeper than anticipated.
- Core well 000-500, located downgradient of well 000-178 and approximately 250 feet upgradient of EW-2E, has shown gradually decreasing levels of EDB since December 2016 when the concentration was 0.5 µg/L. During 2020 the maximum EDB concentration was 0.09 µg/L in March.
- The three bypass monitoring wells have not had any detections of EDB since they were installed in 2005.

The southern migration of the plume is observed by analyzing the trends on **Figure 3.4-3**. Comparing the plume's distribution from 1999 to 2020 (**Figure 3.4-4**), as well as the EDB concentrations in monitoring wells just south of North Street, helps to illustrate the southern movement of the plume as well as the reduction in plume extent. Overall, peak EDB concentrations declined from 7.6 µg/L in 2001 (in well 000-283) to 0.47 µg/L in 2020 (in recently installed well 000-568).

3.4.4 System Operational Data

The sampling frequency of the extraction wells is quarterly. In conformance with the SPDES equivalency permit, the sampling frequency for the influent and effluent is monthly. All OU VI system samples were analyzed for VOCs and EDB, and the effluent sample was analyzed weekly for pH. **Table 3.4-1** provides the effluent limitations for meeting the requirements of the SPDES equivalency permit. During 2020, equivalency permit limits were not exceeded. The system was off approximately 20% of the time for repairs and diffusion well re-development.

January – September 2020

Well EW-1 was off during the month of January to replace a pump and motor. The system was down from August 15th to October 8th for replacement of the programmable logic control panel. The system ran normally for the remainder of this period. The system treated approximately 101 million gallons of water during this period.

October – December 2020

The system was shut down October 13th to October 14th for a routine carbon change-out. The system was off November 10th to November 17th with electrical issues. The system ran normally for the remainder of the period. The system treated approximately 37 million gallons of water for this period.

Extraction Wells

During 2020, the system treated approximately 138 million gallons of water, with an average flow rate of approximately 269 gpm. **Table 2-2** contains the monthly pumping data for the two extraction wells, and **Table 3.4-2** shows the pumping rates. VOC concentrations for EW-1E (000-503) and EW-2E (000-504) are provided on **Table F-44**. In 2020, EDB was detected in all four quarterly samples in EW-2 and in three quarterly samples in EW-1. In 2020, the extraction wells had a maximum EDB detection of 0.051 µg/L in EW-2E in April, which is just above the DWS. No other VOCs were detected in the extraction wells above the AWQS.

Figure 3.4-5 shows the EDB concentrations in the extraction wells over time. EDB levels in EW-1E remained relatively stable from 2008 through 2013, just above the DWS. Since then, concentrations diminished to below the DWS except for one sample event in April. EDB in EW-2E has remained steady since 2011, with detections just below the DWS.

Table 3.4-1
OU VI EDB Treatment System
2020 SPDES Equivalency Permit Levels

Parameters	Permit Limit (µg/L)	Max. Measured Value (µg/L)
pH (range)	5.0 – 8.5 SU	5.1 – 7.6 SU
ethylene dibromide	0.03	<0.02
chloroform	7.0	1.65
1,1-dichloroethene	5.0	<0.50
1,1,1-trichloroethane	5.0	<0.50
methyl chloride	5.0	<0.50
methylene chloride	5.0	<0.50

Notes:
Required sampling frequency is monthly for VOCs and weekly for pH.
SU = Standard Units

System Influent and Effluent

EDB was detected during all the monthly sampling events of the system influent throughout 2020. The maximum influent concentration was 0.049 µg/L. During 2020, the system effluent was below the regulatory limits specified in the SPDES equivalency permit of 0.03 µg/L (**Table 3.4-1**). Influent and effluent results are reported on **Tables F-45** and **F-46,** respectively.

Cumulative Mass Removal

No cumulative mass removal calculations were performed because of the low detections of EDB historically below the DWS in the system influent. The last influent detection exceeding the DWS was 0.051 µg/L in April 2020.

3.4.5 System Evaluation

The OU VI EDB System performance can be evaluated based on decisions identified in the groundwater DQO process.

1. Is there a continuing source of contamination? If present, has the source area been remediated or controlled?

There is no continuing source of EDB.

2. Were unexpected levels or types of contamination detected?

Yes. EDB concentrations in the deeper zones of vertical profile wells installed in 2020/2021 were higher than expected. The deeper contamination was also observed in newly installed monitoring well 000-568 and in the vertical profile borings. In addition, observations of geologic data obtained from 2020/2021 vertical profile wells indicates that the Gardiners Clay unit is not present beneath the southern portion of this plume as was previously understood. This may account for the deeper than expected EDB recently observed.1,4-dioxane was detected above the newly promulgated NYS DWS (see **Section 3.5**).

3. Has the downgradient migration of the plume been controlled?
This issue is currently being evaluated. The detection of EDB in recent temporary and permanent wells in the vicinity of the extraction wells presents the possibility that EDB could be migrating beneath the capture zones. The bottom of the EW-2E well screen is at -64 feet msl. An EDB concentration of 0.48 μg/L was detected at a depth of -108 feet msl in EDB-VP-02-2021, which was installed adjacent to EW-2E. EDB was detected to a depth of -130 feet msl in EDB-VP-04-2021. EDB was not detected in EDB-VP03-2021 which was located approximately 400 feet south of EW-2E. There have been no confirmed EDB detections in bypass monitoring well 000-527 since it was installed in 2013 however, the bottom of this well screen is located at -78 feet msl. EDB was not detected in the remaining three bypass wells since 2005. Additional characterization and groundwater modeling efforts are recommended in this report to address this issue.

4. Can individual extraction wells or the entire treatment system be shut down or placed in pulsed pumping operation?

No, the system has not met all shutdown requirements. Although EDB concentrations in EW-2E are below the DWS, the higher concentration portion of the plume is still evident near well 000-178 and newly installed well 000-549. The plume has moved slower than originally simulated in the 2000 groundwater model update. This slower than expected migration rate may be the result of a fine-grained sand and silt layer in the vicinity of the extraction wells and situated between the depths of -75 msl and -90 msl. This geology was not known prior to 2020 (**Figure 3.4-2**). It was originally envisioned that the system would need to operate between eight to ten years. The system is operating longer because the plume is migrating slower than anticipated. In addition, the presence of deeper EDB contamination that could be migrating under the extraction well capture zone(s) requires evaluation.

4a. Are EDB concentrations in plume core wells above or below 0.05 μg/L?
In 2020, a number of plume core wells continue to show EDB concentrations greater than the 0.05 μg/L DWS.

4b. Is there a significant concentration rebound in core wells and/or extraction wells following shutdown?
The OU VI EDB system has not been pulsed pumped or shut down.

5. Has the groundwater cleanup goal of meeting MCLs been achieved?
The MCL has not been achieved for EDB based on the data from plume core wells and recent vertical profiles.

3.4.6 Recommendations

The following recommendations are made for the OU VI EDB Treatment System and groundwater monitoring program:

- Maintain full time operation of the treatment system and continue quarterly sampling of the extraction wells.
- Geologic and groundwater characterization data obtained in 2020/2021 to support update groundwater modeling efforts revealed different geologic conditions, and the presence of EDB at greater depths in the Upper Glacial aquifer than originally expected. The intent of the groundwater modeling update was originally to determine the ability of this system to achieve the ROD cleanup goal of DWS by 2030.

- As a result of recently obtained data, the geologic framework of the groundwater model should be upgraded followed by a determination of the effectiveness of the current system with respect to both cleanup time and capture of deeper EDB.
- Any negative impact that the diffusion wells may be having on the leading edge of the plume will also have to be evaluated.
- Prior to performing new groundwater modeling simulations additional data collection is recommended. A deep vertical profile well should be installed downgradient of EW-1E and both geologic and groundwater quality data obtained to determine the presence of deeper EDB in this area. The groundwater modeling results will determine the scope of system modification in the form of additional extraction wells to re-establish plume capture and ensure the achievement of ROD cleanup goals.

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3.5 OPERABLE UNIT VIII

A class of chemicals called Per- and Polyfluoroalkyl Substances (PFAS) and the chemical 1,4-dioxane have impacted soil and groundwater quality in numerous areas across the United States. PFAS have been used in a wide variety of common products including non-stick pans, water-repellent clothing, and Class B firefighting foam. 1,4-Dioxane has been broadly used as a stabilizer in chlorinated solvents such as 1,1,1-trichloroethane (TCA), and is present in some paint strippers, greases, waxes, laundry detergents, shampoos, and personal care products.

PFAS have impacted groundwater quality in areas where firefighting foam was used for training, fire suppression systems, and emergency response, whereas 1,4-dioxane has impacted groundwater quality in solvent spill areas. In August 2020, NYS established drinking water standards (referred to as Maximum Contaminant Levels or MCLs) of 10 nanograms per liter (ng/L) for the PFAS compounds perfluorooctane sulfonate (PFOS) and perfluorooctanoic acid (PFOA), and 1.0 microgram per liter (µg/L) for 1,4-dioxane.

Since 2017, BNL has been investigating the impact that these chemicals are having on groundwater quality at the Laboratory and nearby downgradient areas. The results of the investigations conducted from 2017 through early 2020 were summarized in the 2018 and 2019 BNL Groundwater Status Reports (BNL 2019b and BNL 2020d). Results for characterization efforts conducted during 2020 were presented in the Phase 4 Characterization Report (BNL 2021a) and the Time Critical Removal Action Characterization Report (BNL 2021b). and are summarized in **Section 3.5.1** and **Section 3.5.2** of this report.

In response to the impacts that PFAS and 1,4-dioxane are having on groundwater quality at BNL, in early 2021 new Operable Unit VIII and new Areas of Concern 33 and 34 were established to provide the framework for potential future remedial actions under the CERCLA program.

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3.5.1 PFOS AND PFOA IN GROUNDWATER

Per- and Polyfluoroalkyl Substances (PFAS) have impacted soil and groundwater quality across the United States. Although PFAS have been used in a wide variety of industrial processes and commercial products, at BNL the impact that PFAS is having on groundwater quality is primarily the result of the past use of Class B firefighting foam that contained fluorinated surfactants. In 2016, the US EPA has established a Lifetime Health Advisory Level (HAL) of 70 ng/L for the combined concentrations of two PFAS compounds, perfluorooctane sulfonate (PFOS) and perfluorooctanoic acid (PFOA). In August 2020, New York State promulgated individual drinking water standards of 10 ng/L for PFOS and PFOA.

In 2017, the BNL potable water supply wells were sampled for PFAS for the first time. The samples were collected by the Suffolk County Department of Health Services and were analyzed for the same six PFAS compounds that were evaluated under the Third Unregulated Contaminant Monitoring Rule (UCMR3) program. PFAS were detected in samples from three of BNL's five active water supply wells (BNL-6, BNL-10 and BNL-11). Following these detections, BNL searched available records on the use of firefighting foam at the site. This effort identified eight areas where foam had been used for firefighter training or the maintenance of fire suppression systems during the period of 1966 through 2008 (BNL 2019b). To determine whether foam releases at these eight areas had impacted groundwater quality, BNL began a multiphase characterization effort:

Phase 1: In May 2018, BNL installed seven temporary (Geoprobe®) wells to characterize the distribution of PFAS within the 2-year (travel time) source water contributing areas of the BNL supply wells (BNL 2018a). The primary goal of the effort was to determine whether PFAS concentrations in the source water contributing areas are at high enough levels to potentially affect future supply well operations.

Phase 2: From August through November 2018, thirty temporary groundwater monitoring wells were installed in the eight areas where firefighting foam had been released to soil (BNL 2018e).

Phase 3: From December 2018 through January 2019, samples were collected from on-site groundwater treatment systems, monitoring wells downgradient of two closed landfills, the Sewage Treatment Plant (STP) effluent, and in select Operable Unit V monitoring wells located downgradient of the STP (BNL 2018f). In February 2019, BNL sampled 33 existing monitoring wells and installed 11 temporary wells positioned along the southern site boundary (BNL 2019a).

Phase 4: From January through September 2020, groundwater samples were collected from 360 on-site and off-site monitoring wells and extraction wells associated with five off-site groundwater treatment systems (BNL 2021a).

Phase 5/Time Critical Removal Action (TCRA): From July 2020 through January 2021, groundwater samples were collected from 76 temporary wells installed to characterize the high concentration segments of the PFAS plumes associated with the current and former firehouse facilities (BNL 2021b). These data will be used to design groundwater treatment systems for the two plumes.

The monitoring results for Phases 1, 2 and 3 were presented in the 2018 *Groundwater Status Report* (BNL 2019b). Monitoring results for Phase 4 and Phase 5/TCRA were presented in two detailed characterization reports (BNL 2021a and 2021b). The characterization conducted to date has shown that PFOS and PFOA concentrations exceed the recently promulgated DWS of 10 ng/L for PFOS and PFOA in all eight known foam release areas. Furthermore, PFOS and PFOA were also detected in the shallow groundwater near the STP, and PFOA was detected downgradient of the Current Landfill at concentrations that exceed 10 ng/L. To date, the highest PFOS and PFOA concentrations were detected downgradient of the training areas at the current and former firehouse facilities. Downgradient of the current firehouse, PFOS and PFOA were detected at concentrations up to 12,200 ng/L and 602 ng/L, respectively. Downgradient of the former firehouse facility area, PFOS and PFOA were detected at concentrations up to 5,210 ng/L and 1,400 ng/L, respectively. PFOS and PFOA were also detected at concentrations greater than10 ng/L in permanent wells located in several off-site areas.

3.5.1.1 PFOS/PFOA Monitoring

Well Network

A permanent monitoring program has not been established specifically for tracking PFAS. During 2020, BNL conducted two characterization projects utilizing available permanent wells and by installing temporary wells. During the Phase 4 project, 360 wells out of BNL's network of nearly 1,200 on-site and off-site monitoring wells and five off-site treatment systems were sampled to obtain baseline characterization data on the presence of PFAS in groundwater (BNL 2021a). During the Phase 5/TCRA project, BNL installed 76 temporary wells to characterize the high concentration (>100 ng/L) segments of the PFOS/PFOA plumes located downgradient of the current and former firehouse facilities (BNL 2021b).

Sampling Frequency and Analysis

For the Phase 4 characterization project, approximately 360 on-site and off-site monitoring wells and five off-site treatment systems were sampled to further characterize the extent of PFAS contamination within the Upper Glacial aquifer and upper portions of the Magothy aquifer (BNL 2021a). For the Phase 5/TCRA characterization project, 76 temporary wells were installed to characterize the high concentration segments of the PFOS/PFOA plumes within the Upper Glacial aquifer downgradient of the current and former firehouse facilities. To evaluate the vertical distribution of PFOS and PFOA in the aquifer, samples were collected approximately every 10 feet, at a total of approximately 745 sample intervals. The groundwater samples were analyzed by EPA Method 537.1 for 23 PFAS.

3.5.1.2 Monitoring Results

Comprehensive reports have been prepared for the Phase 4 and Phase 5/TCRA monitoring results (BNL 2021a and 2021b). The Phase 4 and Phase 5/TCRA monitoring data for PFOS and PFOA are summarized in **Tables 3.5.1-1**, **3.5.1-2**, **3.5.1-3**, and **Appendix C**. The monitoring results are also presented on **Figures 3.5.1-1** through **3.5.1-5**.

3.5.1.3 PFOS and PFOA Groundwater Monitoring Program Evaluation

The 2020 monitoring data were evaluated using the following general DQO statement.

Is there a continuing source of PFOS/PFOA contamination? If present, has the source been remediated or controlled?

Yes, there are continuing sources of PFOS and PFOA. PFOS and PFOA are detected in the groundwater downgradient of the eight identified firefighting foam release areas, in the STP area, and downgradient of the Current Landfill at concentrations that exceed the 10 ng/L MCLs. The persistent, long-term impacts to soil and groundwater quality from the release of firefighting foam at BNL has been verified by the sampling conducted to date. BNL is in the early stages of the PFAS characterization effort. As agreed to with the regulatory agencies, the TCRA project will be the first step under the CERCLA process to control PFOS/PFOA contamination with the installation of two groundwater remediation systems to address the high concentration plume segments downgradient of the current and former firehouse facilities. The need for source controls and remediation of contaminated groundwater in other on-site and off-site areas will be determined following completion of the planned Remedial Investigation/Feasibility Study (RI/FS), and discussions with the regulatory agencies.

3.5.1.4 PFOS/PFOA Monitoring Recommendations

The following are recommended for the PFOS/PFOA monitoring program for 2021:

- Develop path forward for conducting an RI/FS and for long-term monitoring of PFOS and PFOA in groundwater.

- Using the results of the Phase 5/TCRA Characterization effort (BNL 2021b), design and install groundwater treatment systems for focused remediation of the high concentration PFOS/PFOA plume segments downgradient of the current and former firehouse facilities (BNL 2021c).

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3.5.2 1,4-DIOXANE IN GROUNDWATER

The chemical 1,4-dioxane is an emerging contaminant of concern in areas across the United States. It has been broadly used in numerous commercial and personal care products, including as a stabilizer for the solvent 1,1,1-trichloroethane (TCA). At BNL, past releases of TCA have impacted groundwater quality in several on-site and off-site areas. In August 2020, New York State promulgated a drinking water standard (referred to as a Maximum Contaminant Level or MCL) for 1,4-dioxane of 1.0 µg/L. To date, only trace levels of 1,4-dioxane are periodically detected in samples from BNL's potable water supply wells. Following a request from the NYSDEC to obtain baseline data for the presence or absence of 1,4-dioxane in the groundwater, in 2017 BNL began a multiphase characterization effort.

In January 2017, twenty-two on-site and off-site groundwater monitoring wells that have or had detectable levels of TCA were sampled (BNL 2018g). Seventeen of the 22 samples collected had detectable levels of 1,4-dioxane, with a maximum concentration of 18.6 µg/L in OU III Industrial Park monitoring well 000-530. In late 2017 and early 2018, BNL collected additional samples from groundwater treatment system effluent, the Sewage Treatment Plant (STP) effluent, and from monitoring wells downgradient from the Former Landfill, the Current Landfill and the STP. The highest 1,4-dioxane concentration was 9.1 µg/L, detected in off-site monitoring well 000-122 located in the former OU V monitoring program area. 1,4-Dioxane was detected in four of the five treatment system effluent samples, with a maximum concentration of 7.14 µg/L detected in the effluent from the OU III Industrial Park Treatment System. 1,4-Dioxane was not detected in the STP effluent.

In early 2019, samples were collected from 33 permanent wells and 11 temporary wells positioned along the southern boundary (BNL 2019). The highest 1,4-dioxane concentrations were detected in the OU III Western South Boundary area, with a maximum concentration of 15.2 µg/L in deep Upper Glacial monitoring well 126-18. In the OU III South Boundary area, the maximum 1,4-dioxane concentration was 6.2 µg/L in deep Upper Glacial monitoring well 121-47.

During the 2020 Phase 4 and Phase 5/Time Critical Removal Action (TCRA) characterization projects, samples collected from 360 permanent on-site and off-site monitoring wells, 35 on-site temporary wells, and extraction wells and effluent samples from on-site and off-site treatment systems were tested for 1,4-dioxane (BNL 2021a and 2021b). 1,4-Dioxane was detected in several on-site and off-site areas at concentrations exceeding the 1.0 µg/L DWS. The highest 1,4-dioxane concentration was detected in Western South Boundary monitoring well 119-11 at 23.9 µg/L.

3.5.2-1 1,4-Dioxane Groundwater Monitoring

Well Network

A permanent monitoring program has not been established specifically for tracking 1,4-dioxane. During 2020, BNL conducted two characterization projects utilizing available permanent wells and by installing temporary wells. During the Phase 4 project, 360 of BNL's network of approximately 1,200 on-site and off-site monitoring wells, and two on-site and five off-site treatment systems were sampled to establish a baseline for 1,4-dioxane in groundwater (BNL 2021a). During the Phase 5/TCRA project, 1,4-dioxane was tested for in 35 of the 75 temporary wells installed to characterize the high concentration segments of the PFAS plumes downgradient of the current and former firehouse facilities (BNL 2021b).

Sampling Frequency and Analysis

For the Phase 4 characterization project, approximately 360 on-site and off-site monitoring wells and two on-site and five off-site treatment systems were sampled to further characterize the extent of 1,4-dioxane contamination within the Upper Glacial aquifer and upper portions of the Magothy aquifer (BNL 2021a). For the Phase 5/TCRA characterization project, 298 samples from 35 temporary wells were tested to evaluate the vertical distribution of 1,4-dioxane in the Upper Glacial aquifer. The samples from permanent monitoring wells and treatment systems were analyzed for 1,4-dioxane using EPA Method 522, whereas samples from temporary wells were analyzed by Method 8270D SIM.

3.5.2-2 Monitoring Results

Comprehensive reports have been prepared for the Phase 4 and Phase 5/TCRA monitoring results (BNL 2021a and 2021b). The Phase 4 and Phase 5/TCRA monitoring data for 1,4-dioxane are summarized in **Tables 3.5.2-1**, **3.5.2-2**, 3.5.2-3, and tables in **Appendix C**. The monitoring results are also presented on **Figures 3.5.2-1** through **3.5.2-5**.

3.5.2-3 1,4-Dioxane Groundwater Monitoring Program Evaluation

The monitoring data were evaluated using the following general DQO statement.

1. Is there a continuing source of 1,4-dioxane contamination? If present, has the source been remediated or controlled?

BNL is still in the early stages of the 1,4-dioxane characterization effort. The 1,4-dioxane detected in groundwater is likely to have originated from the previously identified VOC source areas where the solvent TCA had been released. These source areas have been undergoing various remediation efforts for the past 20 years, and significant progress has been made in reducing or eliminating continued contaminant releases from these areas. Although 1,4-dioxane concentrations near many of the former TCA source areas that were located in the central portions of the BNL site do not exceed the 1.0 µg/L MCL, it is present in several on-site and off-site areas at concentrations above 1.0 µg/L. The need for source controls and/or remediation of 1,4-dioxane contaminated groundwater will be determined following completion of the planned Remedial Investigation/Feasibility Study (RI/FS), and discussions with the regulatory agencies.

3.5.2-4 1,4-Dioxane Monitoring Recommendations

The following are recommended for the 1,4-dioxane monitoring program:

- Develop a path forward for conducting the RI/FS and for long-term monitoring of 1,4-dioxane in groundwater.

3.6 SITE BACKGROUND MONITORING

Background water quality has been monitored since 1990. Historically, low levels of VOCs were routinely detected in several background wells that are screened in the deeper portions of the Upper Glacial aquifer. Background monitoring is used to define the quality of groundwater that is completely unaffected by BNL operations.

3.6.1 Groundwater Monitoring

Well Network

The 2020 program included 9 wells in the northwestern portion of the BNL property (**Figure 1-2**) hydraulically upgradient of Laboratory operations. In accordance with the recommendation in the 2019 Groundwater Status Report, sampling of well 063-09 was discontinued since it was originally installed to monitor the Water Treatment Plant recharge basin that receives filter backwash water. It was previously documented that the plant operations have not impacted groundwater. Except for aluminum, iron and manganese detections above AWQS in 2001, well 063-09 has not detected any compounds exceeding AWQS since the well was installed in 1994.

Sampling Frequency and Analysis

The samples are collected annually and analyzed for VOCs (**Table 1-5**). During 2020, 12 background wells were tested for PFAS and 1,4-dioxane as part of the Phase 4 Characterization Project (**Section 3.5**).

3.6.2 Monitoring Well Results

The complete groundwater analytical data are provided in **Appendix C**. There was one low level detection of Methyl tert-butyl ether (MTBE) in well 017-03 at a concentration of 0.94 µg/L (AWQS of 10 µg/L). Sampling results for PFAS and 1,4-dioxane are discussed in **Sections 3.5.1 and 3.5.2**.

While radionuclides are no longer analyzed in background wells, historic results are presented for reference purposes. **Table 3.6-1** summarizes the range of radionuclide values detected in background wells from 1996 through 2001.

Table 3.6-1.
Radiological Background Monitoring, 1996 – 2001

Parameter	Activity Range (pCi/L)	Contract-Required Detection Limit (pCi/L)
Cesium-137	<MDA to 7.24	12.0
Gross alpha	<MDA to 2.66	2.0
Gross beta	<MDA to 6.41	4.0
Strontium-90	<MDA to 3.84	0.8
Tritium	<MDA to 835	500.0

Note:
<MDA = Less than minimum detectable activity

3.6.3 Groundwater Monitoring Program Evaluation

The program can be evaluated using the decision rule developed as part of the groundwater DQO process.

1. Were unexpected levels or types of contamination detected?

There were no VOCs detected in site background wells above AWQS during 2020.. However, low levels of PFAS were detected in several of the background area wells (**Section 3.5.1**). 1,4-dioxane was not detected in any of the background wells sampled during the Phase 4 Characterization Project.

3.6.4 Recommendation

The following are recommended for the site background groundwater monitoring program:

- There are no changes proposed to the monitoring program.

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3.7 CURRENT AND FORMER LANDFILL GROUNDWATER MONITORING

Groundwater monitoring data from both the Current and Former Landfills are discussed in detail in the *BNL 2020 Environmental Monitoring Report, Current and Former Landfill Areas* (BNL 2021c). The complete groundwater monitoring results for these programs are included in **Appendix C**.

3.7.1 Current Landfill Summary

Groundwater data shows that in general, contaminant concentrations have been decreasing following the capping of the landfill in 1995. By the end of 2020, the landfill had been capped for 25 years. Groundwater quality has been slowly improving. The trend in the data suggests that the cap is effective in mitigating groundwater contamination. Groundwater monitoring wells for the Current Landfill are shown on **Figure 3.7-1**. The following is a summary of the results from the samples collected during 2020:

- Benzene was detected in downgradient wells 087-27, 088-109, 088-110 and 087-11 at concentrations slightly above the AWQS with a maximum concentration of 1.7 μg/L in well 087-11. The other VOCs detected above the AWQS were chloroethane and 1,1-dichloroethane (DCA) during 2020. DCA was detected in monitoring well 088-109 and 098-99 above the standard of 5 μg/L, with a maximum concentration of 24.5 μg/L in well 088-109. During 2020, chloroethane was detected above AWQS in wells 088-109 and 088-110 with concentrations ranging up to 25.5 μg/L indicating that VOCs continue to emanate from the landfill. These concentrations are naturally attenuating and no landfill related detections at the site boundary are above the drinking water standard **Figure 3.1-1**.
- Concentrations of landfill water chemistry parameters and metals such as ammonia and iron in several downgradient wells were above background values. This suggests that leachate continues to emanate from the landfill into groundwater. Ammonia was detected above the AWQS of 2 mg/L in downgradient wells 087-11 and 088-109 at a maximum concentration of 6.2 mg/L.
- During 2020, iron, chromium and sodium in the background well, and aluminum, arsenic, iron, manganese, and sodium in several downgradient wells were detected above their respective AWQS.
- Strontium-90 and tritium was not detected during 2020. Strontium-90 and tritium have not exceeded the DWS in the Current Landfill wells since 1998.
- Although low levels of contaminants continue to be detected, the cap has been effective at improving the quality of groundwater downgradient of the landfill.

3.7.1.1 Current Landfill Recommendations

The monitoring well network for the Current Landfill is sufficient. No changes to the network or the sampling frequency are warranted at this time.

3.7.2 Former Landfill Summary

Monitoring data shows that contaminant concentrations decreased following the capping of the landfill in 1996. By the end of 2020, the landfill had been capped for 24 years. Contaminant concentrations downgradient of this landfill were relatively low prior to capping. In 2020, eight wells were sampled once for VOCs, pesticides/PCBs, general chemistry, metals and radionuclides. The remaining six wells were sampled once for Sr-90. Groundwater monitoring wells for the Former Landfill are shown on **Figure 3.7-2**. The following is a summary of the results from the samples collected during 2020:

- The Former Landfill is not a source of VOC contamination. No VOCs were detected above groundwater standards since 1998.
- Water chemistry parameters were detected at concentrations approximating those of historic background monitoring well results, indicating that leachate is not being generated. No 2020 results exceeded applicable groundwater standards.
- All metals detections were below AWQS during 2020 except for sodium in background well 086-42 at a concentration of 62,400 ug/L. The sodium is exceedance is most likely from road salting activities from upgradient roadway associated with NSLS II.
- There were no detections of pesticides or polychlorinated biphenyls (PCBs) during 2020. The last detection of pesticides was in 2002 and the last PCB detection was 2008.
- All strontium-90 detections were below the DWS during 2020. Former Landfill wells have not exceeded the strontium-90 DWS since 2001. Tritium was not detected in any of the sampled wells during 2020.

3.7.2.1 Former Landfill Recommendations

With the data presented in *BNL 2020 Environmental Monitoring Report, Current and Former Landfill Areas* (BNL 2021a) and with over two decades of groundwater monitoring data providing evidence that groundwater impact from the Former Landfill area is now essentially nonexistent, it is recommended that groundwater monitoring of the Former Landfill area be discontinued.

3.8 g-2 TRITIUM SOURCE AREA AND GROUNDWATER PLUME

In November 1999, tritium was detected in the groundwater near the former g-2 experiment within the Alternating Gradient Synchrotron (AGS) facility, at concentrations above the 20,000 pCi/L DWS. Sodium-22 was also detected in the groundwater, but at concentrations well below the 400 pCi/L DWS. An investigation into the source of the contamination revealed that the tritium and sodium-22 originated from activated soil shielding located adjacent to the g-2 target building, where approximately five percent of the beam was inadvertently striking one of the beam line magnets (magnet VQ-12). Rainwater was able to infiltrate the activated soils and leach the tritium and sodium-22 into the groundwater. To prevent additional rainwater infiltration into the activated soil shielding, a concrete cap was constructed over the area in December 1999. The g-2 experiment was decommissioned in April 2001.

The g-2/BLIP/former UST ROD (BNL 2007a) requires routine inspections and maintenance of the impermeable cap, and groundwater monitoring of the source area to verify the continued effectiveness of the stormwater controls. Monitoring of the source area will continue for as long as the activated soils have the potential to impact groundwater quality. Contingency actions would be developed if tritium levels in groundwater monitoring wells exceed 1,000,000 pCi/L.

3.8.1 g-2 Tritium Source Area and Plume Groundwater Monitoring

Well Network

The g-2 tritium source area is monitored using two upgradient wells (054-65 and 054-66) and five downgradient wells (054-07, 054-126, 054-184, 054-185, and 064-95) approximately 200 feet downgradient of the source area near Building 912A. Several other nearby wells (054-67, 054-68, 054-124, 054-126 and 065-126) are used to monitor the effectiveness of the cap installed over the adjacent former g-2 beam stop, which is another area that contains activated soil shielding. Twelve wells located approximately 600 feet downgradient of the source area near Building 912 are used to verify the attenuation of tritium released from the source area (**Figure 3.8-1**).

Sampling Frequency and Analysis

During 2020, the source area wells were monitored two times, and the samples were analyzed for tritium (**Table 1-6**). The wells monitoring the former beam stop area and those located near Building 912 were sampled once during the year, and the samples were analyzed for tritium. The water samples are preferentially tested for tritium because it is more leachable than sodium-22, migrates at the same rate as groundwater, and is therefore a better indicator of the effectiveness of the cap. g-2 monitoring well 054-07 was also sampled for PFAS and 1,4-dioxane during the Phase 4 Characterization Project (**Section 3.5).**

3.8.2 g-2 Tritium Source Area and Plume Monitoring Well Results

The extent of the g-2 tritium plume during the fourth quarter of 2020 is depicted on **Figure 3.8-1**.

Source Area Monitoring Results

The maximum tritium concentration in source area wells was 31,900 pCi/L in well 054-185 during the second quarter. Tritium was detected in source area well 054-07 at 20,600 pCi/L during the second quarter. **Figure 3.8-2** provides tritium trend charts for wells that monitor the g-2 source area. Tritium was not detected in the wells that monitor the beam stop area.

Tritium that is traceable to the g-2 source area continues to be detected in monitoring wells located downgradient of Building 912. The maximum tritium concentration in this area was 487 pCi/L in a sample from well 065-123 collected during the fourth quarter.

3.8.3 g-2 Tritium Source Area and Plume Groundwater Monitoring Program Evaluation

The 2020 monitoring data were evaluated using the following DQO statements.

1. Is there a continuing source of contamination? If present, has the source been remediated or controlled?

Although the activated soil shielding remains a potential threat to groundwater quality, the overall reduction in tritium concentrations observed in the groundwater since 1999 indicates that the cap is effectively preventing rainwater from infiltrating the soil. A comparison of tritium levels in the source area monitoring wells and water-table elevation data suggests that periodic natural fluctuations in the water table continue to release residual tritium from the deep vadose zone. There appears to be good correlation between high tritium concentrations detected in monitoring wells immediately downgradient of the source area and the water-table elevation about one year before the sampling (**Figure 3.8-3** and **Figure 3.8-4**). It is believed that this tritium was mobilized to the deep vadose zone soil close to the water table before the cap was constructed in December 1999. Once the cap was in place, the lack of additional rainwater infiltration kept the tritium in the vadose zone from migrating into the groundwater until a significant rise in water table can mobilized it. Over time, the amount of tritium remaining in the vadose zone near the water table will decrease by means of the natural water table flushing mechanism and by natural radioactive decay.

2. Were unexpected levels of tritium detected?

No, the observed tritium levels in the source area monitoring wells are consistent with previous surveillance results.

3. Is the plume naturally attenuating as expected?

Yes. With the effectiveness of the source area controls, the plume segment immediately downgradient of the source area is attenuating as expected.

4. Has the groundwater cleanup goal of meeting MCLs been achieved?

No. Tritium concentrations in groundwater downgradient of the g-2 source area continue to periodically exceed the MCL.

3.8.4 g-2 Tritium Source Area and Plume Recommendations

The following are recommended for the g-2 tritium source area and plume groundwater monitoring program:

- Continue routine inspections of the g-2 cap.
- Continue semiannual monitoring of source area wells near Building 912A, and annual monitoring of wells located downgradient of the former beam stop and Building 912.

3.9 BROOKHAVEN LINAC ISOTOPE PRODUCER (BLIP)

When the Brookhaven Linac Isotope Producer (BLIP) is operating, the Linear Accelerator (Linac) delivers a beam of protons that strike a series of metal targets positioned at the bottom of a 30-foot deep underground tank, referred to as the BLIP target vessel. The targets rest inside a water-filled, 18-inch-diameter shaft that runs the length of the tank, and are cooled by a 300-gallon, closed-loop primary cooling system. During irradiation of the targets, radionuclides are produced in the cooling water and the soil immediately outside the tank by the neutrons created at the target.

In 1998, tritium concentrations of 52,000 pCi/L and sodium-22 up to 151 pCi/L were detected in the groundwater approximately 40 feet downgradient of the BLIP target vessel. The drinking water standard for tritium is 20,000 pCi/L, and the standard for sodium-22 is 400 pCi/L. Due to the activation of the soil shielding surrounding the BLIP target vessel and the detection of tritium and sodium-22 in groundwater, the BLIP facility was designated as sub-AOC 16K under the IAG.

In 1998, BNL made improvements to the stormwater management program at BLIP in an effort to prevent rainwater infiltration into the activated soil below the building. In 2000, BNL undertook additional protective measures by injecting colloidal silica grout (also known as a Viscous Liquid Barrier) into the activated soil. The grout reduces the permeability of the soil, thus further reducing the ability of rainwater to leach tritium and sodium-22 from the activated soils should the primary stormwater controls fail.

In late 2004, BNL constructed a protective cap over the beam line that runs from the Linac to the BLIP facility. The cap was installed because direct soil measurements and beam loss calculations indicated that the tritium and sodium-22 concentrations in soils surrounding this beam line could result in stormwater leachate concentrations that exceed the criteria described in the *Accelerator Safety* SBMS (Standards Based Management System) subject area.[1] During 2015, this cap section was extended in several areas to provide protection of soil shielding that is expected to become activated following planned changes in beam line operations.

A ROD was signed in early 2007 (BNL 2007a). The ROD requires continued routine inspection and maintenance of the impermeable cap, and groundwater monitoring to verify the continued effectiveness of the stormwater controls. Maintenance of the cap and groundwater monitoring will continue for as long as the activated soils have the potential to impact groundwater quality.

3.9.1 BLIP Groundwater Monitoring

Well Network

The monitoring well network for the BLIP facility consists of one upgradient and three downgradient wells (**Figure 3.9-1**).

Sampling Frequency and Analysis

During 2020, the three wells located immediately downgradient of the BLIP facility (064-47, 064-48, 064-67) were monitored twice, and the upgradient well (064-46) was sampled once. The groundwater samples are preferentially analyzed for tritium because it is more leachable than sodium-22, it migrates at the same rate as groundwater, and is the best early indicator of a possible release (**Table 1-6**).

3.9.2 BLIP Monitoring Well Results

Monitoring results indicate that the stormwater controls are effective in preventing the release of tritium from the activated soil surrounding the BLIP target vessel. Since April 2006, tritium levels have remained below the 20,000 pCi/L DWS (**Figure 3.9-1**). During 2020, the maximum tritium

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[1] The BNL *Accelerator Safety* SBMS subject area requires stormwater controls where rainwater infiltration into activated soil shielding could result in leachate concentrations that exceed five percent of the drinking water standard for tritium (1,000 pCi/L) or 25 percent of the drinking water standard for sodium-22 (100 pCi/L).

concentration was 2,070 pCi/L in the second quarter sampling of well 064-67. The maximum tritium concentration during the fourth quarter was 1,320 pCi/L, again in well 064-67.

3.9.3 BLIP Groundwater Monitoring Program Evaluation

The 2020 monitoring data were evaluated using the following DQO statements.

1. Is there a continuing source of contamination? If present, has the source been remediated or controlled?

Yes, however the source is being controlled. Although low levels of tritium continue to be detected in the groundwater downgradient of BLIP, the tritium concentrations have remained below the 20,000 pCi/L DWS since early 2006. The decline in tritium concentrations indicates that the stormwater controls are effectively preventing the leaching of tritium from the activated soils.

2. Were unexpected levels of contamination detected?

No, the observed tritium levels are consistent with previous surveillance results.

3. Has the groundwater cleanup goal of meeting MCLs been achieved?

Yes. However, the activated soil shielding below the BLIP facility needs to be protected from rainwater infiltration. Therefore, the cap needs to be maintained and groundwater surveillance is required to verify the continued effectiveness of the stormwater controls.

3.9.4 BLIP Recommendation

The following is recommended for the BLIP groundwater monitoring program:

- As required by the ROD, BNL will continue to conduct routine inspections of the cap, and to monitor groundwater quality downgradient of the BLIP facility.
- No changes to the groundwater monitoring program are recommended.

4.0 FACILITY MONITORING PROGRAM SUMMARY

During 2020, the Facility Monitoring Program at BNL monitored groundwater quality at eight research and support facilities. New York State operating permits require groundwater monitoring at the Major Petroleum Facility, Waste Management Facility, and the Sewage Treatment Plant; the remaining research and support facilities are monitored in accordance with DOE Orders 458.1 (Radiation Protection of the Public and the Environment) and 436.1 (Departmental Sustainability) or CERCLA Records of Decision. DOE Orders require the Laboratory to establish environmental monitoring programs at facilities that can potentially impact environmental quality, and to demonstrate compliance with DOE requirements and the applicable federal, state, and local laws and regulations. CERCLA Records of Decision define the monitoring requirements and remedial actions for the g-2 tritium source area and plume and the BLIP source area. BNL uses monitoring data to determine whether current engineered and administrative controls effectively protect groundwater quality, determine whether additional corrective actions are needed, and to determine the effectiveness of remedial actions.

During 2020, 95 groundwater monitoring wells were sampled during 125 sampling events for facility surveillance required by state operating permits and DOE Orders. Eleven additional wells were sampled during 22 monitoring events for compliance with CERCLA monitoring requirements for the g-2 Tritium Source Area and Plume and the BLIP facility. **Table 1-6** summarizes the Facility Monitoring Program by project. Complete analytical results from groundwater samples collected in 2020 are provided in **Appendix D**. Monitoring results for the g-2 source area and tritium plume and the BLIP source area are presented in **Sections 3.8, and 3.9**, respectively. Information on groundwater quality at each of the remaining monitored research and support facilities is described below.

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4.1 ALTERNATING GRADIENT SYNCHROTRON (AGS) COMPLEX

The structures that constitute the AGS Complex include the AGS Ring, Linear Accelerator (Linac), BLIP, Building 912, AGS Booster Beam Stop, 914 Transfer Tunnel, former g-2 experimental area, former E-20 Catcher, former U-Line Beam Target, and the J-10 Beam Stop. Activated soil has been created near a number of these areas as the result of secondary particles (primarily neutrons) produced at beam targets and beam stops. A number of radionuclides can be produced by the interaction of secondary particles with the soil that surrounds these experimental areas. Once produced in the soils, some of these radionuclides can be leached from the soils by rainwater, and carried to the groundwater. Of the radionuclides formed in the soil, only tritium (half-life = 12.3 years) and sodium-22 (half-life = 2.6 years) are detected in groundwater. Of these two radionuclides, tritium is more easily leached from activated soils by rainwater, and once tritium enters the water table it migrates at the same rate as groundwater flow (approximately 0.75 feet per day). Sodium-22 does not leach out of the soil as readily as tritium, and migrates at a slower rate in the aquifer. The DWS for tritium is 20,000 pCi/L, and the standard for sodium-22 is 400 pCi/L.

To prevent rainwater from leaching these radionuclides from the soil, impermeable caps have been constructed over the activated soil shielding areas that have the potential to impact groundwater quality. Specifications for evaluating potential impacts to groundwater quality and the need for impermeable caps over beam loss areas are defined in the BNL *Accelerator Safety* subject area.[1] BNL uses 57 groundwater monitoring wells to evaluate the impact of current and historical operations at the AGS beam stop and target areas, and an additional 14 wells to monitor beam loss areas associated with the Relativistic Heavy Ion Collider (RHIC) (discussed in **Section 4.2**). The locations of monitoring wells are shown on **Figure 4.1-1**. The wells are routinely monitored for tritium because it is the best early indicator of a possible release because tritium is more leachable than sodium-22, and it migrates at the same rate as groundwater.

In the late 1990's, BNL detected four tritium plumes that originated from activated soil shielding within the AGS complex: the former g-2 experimental area (**Section 3.8**), the BLIP facility (**Section 3.9**), the former U-Line beam stop (**Section 4.1.8**), and the former E-20 Catcher (**Section 4.1.4**). The subsequent installation of impermeable caps over these soil activation areas resulted in a reduction of tritium levels to less than the 20,000 pCi/L DWS in the BLIP, former U-Line beam stop, and E-20 Catcher areas. Tritium continues to be periodically detected downgradient of the g-2 soil activation area at concentrations that exceed 20,000 pCi/L.

4.1.1 AGS Building 912

Building 912 consists of five interconnected structures that were used to house four experimental beam lines (A, B, C, and D lines). These beam line operations ended in 2002.

Beam losses at the target areas resulted in the activation of the adjacent floor, and probably the soil beneath the floor. The highest levels of soil activation beneath Building 912 are expected at the former C-Line target cave. Stormwater infiltration around the building is controlled by paving and stormwater drainage systems that direct most of the water to recharge basins located north of the AGS complex.

4.1.1.1 AGS Building 912 Groundwater Monitoring

Well Network

Twenty-three shallow Upper Glacial aquifer wells are positioned upgradient and downgradient of Building 912 (**Figure 4.1-1**). Upgradient wells are positioned to monitor potential tritium contamination from sources such as the g-2 area and the former U-Line experimental area. The downgradient wells are

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[1] The BNL *Accelerator Safety* SBMS subject area requires stormwater controls where rainwater infiltration into activated soil shielding could result in leachate concentrations that exceed five percent of the drinking water standard for tritium (i.e., 1,000 pCi/L) or 25 percent of the drinking water standard for sodium-22 (i.e., 100 pCi/L).

positioned to monitor the former beam stop and target areas in Building 912. Some of the downgradient wells are also used to track the leading edge of the g-2 tritium plume that has migrated underneath Building 912 (**Section 3.8**).

Sampling Frequency and Analysis

During 2020, the Building 912 wells were sampled one time. The groundwater samples were analyzed for tritium (**Table 1-6**). Several of the Building 912 wells were also sampled for PFAS and 1,4-dioxane during the Phase 4 Characterization Project (**Section 4.5**).

4.1.1.2 AGS Building 912 Monitoring Well Results

As in past years, tritium that is traceable to the g-2 source area continues to be detected in some of the wells located downgradient of Building 912 (**Figure 4.1-1**). During 2020, tritium from the g-2 plume was detected only in well 065-123, at a concentration of 487 pCi/L. Tritium was not detected in the groundwater samples collected from the remainder of the Building 912 area wells.

4.1.1.3 AGS Building 912 Groundwater Monitoring Program Evaluation

The 2020 monitoring data were evaluated using the following Data Quality Objective statement.

1. Is there a continuing source of contamination? If present, has the source been remediated or controlled?

Activated soils are present below the floor slab at Building 912. Other than tritium associated with the g-2 tritium plume, there were no detections of tritium that could be directly linked to activated soil located at Building 912. This indicates that the building and associated stormwater management operations are effectively preventing rainwater infiltration into the activated soil below the experimental hall.

4.1.1.4 AGS Building 912 Recommendations

The following is recommended for the AGS Building 912 groundwater monitoring program:

- For 2021, continue sampling all Building 912 monitoring wells annually.

4.1.2 AGS Booster Beam Stop

The AGS Booster is a circular accelerator that is connected to the northwest portion of the main AGS Ring and to the Linac. The AGS Booster, which has been in operation since 1994, is used to accelerate protons and heavy ions before injecting them into the main AGS ring. In order to dispose of the beam during studies, a beam stop system was originally constructed at the 10 to 11 o’clock portion of the Booster. In 1999, the beam stop was repositioned to the south side (6 o’clock section) of the Booster ring to allow for the construction of the NASA Space Radiation Laboratory (NSRL) tunnel. A geomembrane cap was constructed over the original beam stop region to prevent stormwater infiltration into the activated soil. When the beam stop was repositioned to the 6 o’clock region of the Booster, a coated concrete cap was constructed over the area.

4.1.2.1 AGS Booster Groundwater Monitoring

Well Network

Two shallow Upper Glacial aquifer monitoring wells (064-51 and 064-52) are used to monitor the Booster beam stop area (**Figure 4.1-1**).

Sampling Frequency and Analysis

Due to access restrictions while the accelerator was in operation during the planned fourth quarter 2019 monitoring period, sampling of the Booster area wells was postponed until February 2020. For the 2020 monitoring period, the Booster area monitoring wells were sampled again during the fourth quarter. The samples were analyzed for tritium (**Table 1-6**).

4.1.2.2 AGS Booster Monitoring Well Results

Although low levels of tritium were detected in the Booster area wells during 2001 and 2002 (up to 1,340 pCi/L in well 064-52), tritium has not been detected in these wells since that time at concentrations above the typical 300 pCi/L method detection limit (**Figure 4.1-2**).

4.1.2.3 AGS Booster Groundwater Monitoring Program Evaluation

The groundwater monitoring results were evaluated using the following Data Quality Objective statement.

1. Is there a continuing source of contamination? If present, has the source been remediated or controlled?

Activated soil shielding is present in the areas of the current and former Booster beam stops. The low levels of tritium detected in groundwater during 2001 and 2002 were related to a short-term uncovering of activated soil shielding near the former booster beam stop during the construction of the tunnel leading from the Booster to the NSRL facility. This work, which began in September 1999 and was completed by October 1999, allowed rainwater to infiltrate the low-level activated soil shielding.[2] Because tritium has not been detected in the Booster area monitoring wells since 2002, it is apparent that the caps have been effectively preventing rainwater infiltration into the activated soil shielding.

4.1.2.4 AGS Booster Recommendation

The following is recommended for the AGS Booster groundwater monitoring program:

- For 2021, the monitoring frequency for the Booster area monitoring wells will continue to be annually.

4.1.3 NASA Space Radiation Laboratory (NSRL)

The NSRL is jointly managed by the U.S. Department of Energy and NASA's Johnson Space Center. The NSRL uses beams of heavy ions extracted from Booster accelerator for radiobiology studies. NSRL became operational in 2003. Although the secondary particle interactions with the surrounding soil shielding are expected to result in only a minor level of soil activation, a geomembrane cap was constructed over the entire length of the beam line and the beam stop region to prevent stormwater infiltration into the soil shielding.

4.1.3.1 NSRL Groundwater Monitoring

Well Network

This facility is monitored by shallow Upper Glacial aquifer monitoring wells 054-08, 054-62 and 054-191 (**Figure 4.1-1**).

Sampling Frequency and Analysis

During 2020, the NSRL monitoring wells 054-62 and 054-191 were sampled one time. Due to access restrictions while the accelerator was in operation during the planned fourth quarter 2019 monitoring period, sampling of well 054-08 was postponed until February 2020. During the 2020 monitoring period, all three wells were monitored during the fourth quarter. The samples were analyzed for tritium (**Table 1-6**). Two of the NSRL wells were also sampled for PFAS and 1,4-dioxane during the Phase 4 Characterization Project (**Section 4.5**).

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[2] Before construction of the NSRL tunnel commenced, soil samples were collected by drilling through the tunnel wall near the former booster beam stop to verify that the tritium and sodium-22 levels were within acceptable limits for worker safety and environmental protection.

4.1.3.2 NSRL Monitoring Well Results
During 2020, tritium was not detected in the NSRL monitoring wells.

4.1.3.3 NSRL Groundwater Monitoring Program Evaluation
The groundwater monitoring results were evaluated using the following Data Quality Objective statement.

1. Is there a continuing source of contamination? If present, has the source been remediated or controlled?
Activated soil shielding at the NSRL is being protected by an impermeable cap. Based on monitoring conducted to date, NSRL beam line operations have not impacted groundwater quality in the area.

4.1.3.4 NSRL Recommendation
The following is recommended for the NSRL groundwater monitoring program:

- For 2021, the monitoring frequency for the NSRL wells will continue to be annually.

4.1.4 Former AGS E-20 Catcher
The E-20 Catcher was in operation from 1984 to 1999, and was located at the 5 o'clock position of the AGS ring (**Figure 4.1-1**). The E-20 Catcher was used to pick up or "scrape" protons that moved out of acceptable pathways.

Following the installation of monitoring wells in late 1999 and early 2000, tritium and sodium-22 were detected at levels greater than their applicable DWS, with concentrations up to 40,400 pCi/L and 704 pCi/L, respectively. In April 2000, a temporary impermeable cap was installed over the E-20 Catcher area, and a permanent cap was constructed by October 2000. Tritium and sodium-22 concentrations in groundwater dropped to below the DWS soon after the cap was installed.

4.1.4.1 Former AGS E-20 Catcher Groundwater Monitoring

Well Network
To verify the continued effectiveness of the impermeable cap over the former E-20 Catcher, the area is monitored by shallow Upper Glacial aquifer wells 064-55, 064-56, and 064-80 (**Figure 4.1-1**).

Sampling Frequency and Analysis
During 2020, the former E-20 Catcher wells were monitored one time, and the samples were analyzed for tritium (**Table 1-6**). Since 2002, groundwater samples from this area have only been analyzed for tritium.

4.1.4.2 Former AGS E-20 Catcher Monitoring Well Results
Following the installation of the cap in 2000, tritium and sodium-22 concentrations decreased to levels below applicable DWS. During 2020, tritium was not detected in any of the wells (**Figure 4.1-3**).

4.1.4.3 Former AGS E-20 Catcher Groundwater Monitoring Program Evaluation
The 2020 monitoring data were evaluated using the following Data Quality Objective statement.

1. Is there a continuing source of contamination? If present, has the source been remediated or controlled?
Activated soil shielding at the former E-20 Catcher is being protected by an impermeable cap. The reduction in tritium concentrations since the impermeable cap was constructed in 2000 indicates that the cap has been effective in preventing rainwater infiltration into the activated soil that surrounds this portion of the AGS tunnel.

4.1.4.4 Former AGS E-20 Catcher Recommendation

The following is recommended for the AGS E-20 Catcher groundwater monitoring program:

- For 2021, the monitoring frequency for the former E-20 Catcher wells will continue to be annually.

4.1.5 AGS Building 914

Building 914 houses the beam transfer line between the AGS Ring and the Booster. Due to beam loss near the facility's extraction (kicker) magnet, the extraction area of Building 914 is heavily shielded with iron. Because the extraction area is housed in a large building, most soil activation is expected to be below the floor of the building, where it is protected from rainwater infiltration.

4.1.5.1 AGS Building 914 Groundwater Monitoring

Well Network

Groundwater quality downgradient of the AGS Building 914 transfer line area is monitored by shallow Upper Glacial aquifer wells 064-03, 064-53, and 064-54 (**Figure 4.1-1**).

Sampling Frequency and Analysis

During 2020, the AGS Building 914 area wells were monitored one time, and samples were analyzed for tritium (**Table 1-6**).

4.1.5.2 AGS Building 914 Monitoring Well Results

Tritium was not detected in the samples collected during 2020, and has not been detected in the Building 914 groundwater monitoring wells since 2008 (**Figure 4.1-4**).

4.1.5.3 AGS Building 914 Groundwater Monitoring Program Evaluation

The 2020 monitoring data were evaluated using the following Data Quality Objective statement.

<u>*1. Is there a continuing source of contamination? If present, has the source been remediated or controlled?*</u>

The lack of detectable levels of tritium since 2008 indicates that the building structure and associated stormwater controls are effectively preventing rainwater infiltration into activated soil below the building. Continued surveillance of groundwater quality in the Building 914 area is required.

4.1.5.4 AGS Building 914 Recommendation

The following is recommended for the AGS Building 914 groundwater monitoring program:

- For 2021, the monitoring frequency for the AGS Building 914 area wells will continue to be annually.

4.1.6 Former g-2 Beam Stop

The g-2 experiment operated from April 1997 until April 2001. The g-2 Beam Stop is composed of iron and is covered by soil shielding. To prevent rainwater from infiltrating the soil surrounding the beam stop, BNL installed a gunite cap over the stop area before the start of beam line operations.

In November 1999, tritium and sodium-22 were detected in groundwater monitoring wells approximately 200 feet downgradient of the g-2 beam stop area (see **Section 3.8**). An investigation into the source of the contamination revealed that the tritium originated from activated soil shielding adjacent to the g-2 beam stop. This section of the beam line was not a designed beam loss area, and therefore was not protected by the gunite cap installed over the beam stop. In December 1999, an impermeable cap was installed over the activated soil shielding, and joined to the beam stop cap. The monitoring program for the g-2 tritium source area and plume are described in **Section 3.8**.

4.1.6.1 Former g-2 Beam Stop Groundwater Monitoring

Well Network

Groundwater quality downgradient of the former g-2 beam stop is monitored using wells 054-67, 054-124, 054-125, and 054-126 (**Figure 4.1-1**). These wells are cross gradient of the g-2 tritium source area monitoring wells described in **Section 3.8**.

Sampling Frequency and Analysis

During 2020, former g-2 Beam Stop wells 054-67 and 054-125 were monitored once, and the samples were analyzed for tritium. Wells 054-124 and 054-126 were sampled twice for tritium under the g-2 tritium plume source area program (**Table 1-6**).   Several of the former g-2 Beam Stop wells were also sampled for PFAS and 1,4-dioxane during the Phase 4 Characterization Project (**Section 4.5**).

4.1.6.2 Former g-2 Beam Stop Monitoring Well Results

During 2020, tritium was not detected in any of the wells.

4.1.6.3 Former g-2 Beam Stop Groundwater Monitoring Program Evaluation

The 2020 monitoring data were evaluated using the following Data Quality Objective statement.

1. Is there a continuing source of contamination? If present, has the source been remediated or controlled?

Overall monitoring results for the past 24 years indicate that the cap over the former beam stop is effectively preventing rainwater from infiltrating the activated soil shielding.

4.1.6.4 Former g-2 Beam Stop Recommendation

The following is recommended for the former g-2 beam stop groundwater monitoring program:

- During 2021, former g-2 Beam Stop area wells 054-67 and 054-125 will continue to be monitored on an annual basis, whereas wells 054-124 and 054-126 will continue to be monitored semiannually under the g-2 tritium plume source area program.

4.1.7 AGS J-10 Beam Stop

In 1998, BNL established a beam stop at the J-10 (12 o’clock) section of the AGS Ring, replacing the E-20 Catcher as the preferred repository for any beam that might be lost in the AGS Ring (**Figure 4.1-1**). The J-10 beam stop area of the AGS Ring is covered by layers of soil-crete (a sand and concrete mixture), which reduce the ability of rainwater to infiltrate the potentially activated soil shielding. A gunite cap was constructed over a small section of the J-10 region that did not have a soil-concrete cover before beam stop operations began.

4.1.7.1 AGS J-10 Beam Stop Groundwater Monitoring

Well Network

The monitoring well network for the J-10 beam stop consists of downgradient wells 054-63 and 054-64 (**Figure 4.1-1**).

Sampling Frequency and Analysis

During 2020, the J-10 beam stop wells were monitored one time and the samples were analyzed for tritium (**Table 1-6**).

4.1.7.2 AGS J-10 Beam Stop Monitoring Well Results

During 2020, tritium was not detected in the J-10 area wells.   (**Figure 4.1-5**).

4.1.7.3 AGS J-10 Beam Stop Monitoring Program Evaluation

The 2020 monitoring data were evaluated using the following Data Quality Objective statement.

1. Is there a continuing source of contamination? If present, has the source been remediated or controlled?

Groundwater monitoring results indicate that the engineered controls in place at J-10 are preventing significant rainwater infiltration into the activated soil shielding. Continued groundwater monitoring is required to verify the long-term effectiveness of the controls.

4.1.7.4 AGS J-10 Beam Stop Recommendation

The following is recommended for the AGS J-10 Beam Stop groundwater monitoring program:

- During 2021, the J-10 Beam Stop area wells will continue to be sampled on an annual basis.

4.1.8 Former AGS U-Line Beam Target and Stop Areas

The U-Line beam target area was in operation from 1974 through 1986. The entire assembly was in a ground-level tunnel covered with an earthen berm. Although the U-Line beam target has not been in operation since 1986, the associated tunnel, shielding, and overlying soil remain in place.

In late 1999, BNL installed monitoring wells downgradient of the former U-Line target area to evaluate whether residual activated soil shielding was impacting groundwater quality. Low levels of tritium and sodium-22 were detected, but at concentrations well below the applicable DWS. In early 2000, temporary wells were installed downgradient of the former U-Line beam stop, which is approximately 200 feet north of the target area. Tritium was detected at concentrations up to 71,600 pCi/L. Sodium-22 was not detected in any of the samples. During 2000, an impermeable cap was installed over the former U-Line beam stop area to prevent rainwater infiltration and the continued leaching of radionuclides out of the soil shielding.

4.1.8.1 Former AGS U-Line Groundwater Monitoring

Well Network

The former U-Line area is monitored by one upgradient well (054-127), three downgradient wells that monitor the former U-Line target area (054-66, 054-129, and 054-130), and three wells that monitor downgradient of the former U-Line beam stop area (054-128, 054-168, and 054-169) (**Figure 4.1-1**).

Sampling Frequency and Analysis

During 2020, the former U-Line area wells were monitored one time, and the samples were analyzed for tritium (**Table 1-6**). Several of the U-Line area wells were also sampled for PFAS and 1,4-dioxane during the Phase 4 Characterization Project (**Section 4.5**).

4.1.8.2 Former AGS U-Line Groundwater Monitoring Well Results

Former U-Line Target Area

During 2020, tritium was not detected in the former U-Line Target area wells (**Figure 4.1-6**).

Former U-Line Beam Stop Area

Tritium was detected at a concentration of 1,180 pCi/L in the former U-Line Beam Stop area well 054-128 (**Figure 4.1-7**).

4.1.8.3 Former AGS U-Line Groundwater Monitoring Program Evaluation

The 2020 monitoring data were evaluated using the following Data Quality Objective statement.

1. Is there a continuing source of contamination? If present, has the source been remediated or controlled?

The significant decrease in tritium concentrations in groundwater since 2000 indicates that the impermeable cap installed over the former U-Line Beam Stop has been effective in stopping rainwater infiltration into the residual activated soil.

4.1.8.4 Former AGS U-Line Recommendation

The following is recommended for the former AGS U-Line groundwater monitoring program:

- For 2021, the former U-Line area wells will continue to be monitored for tritium on an annual basis.

4.2 RELATIVISTIC HEAVY ION COLLIDER (RHIC)

Beam line interactions at the Relativistic Heavy Ion Collider (RHIC) Collimators and Beam Stops produce secondary particles that interact with soil surrounding the 8 o'clock and 10 o'clock portions of the RHIC tunnel and the W-Line Stop (**Figure 4.2-1**). These interactions can result in the production of tritium and sodium-22 in the nearby soil shielding, which can be leached out of the soil by rainwater. Although the level of soil activation is expected to be minor, before RHIC operations began in 2000 BNL installed impermeable caps over these beam loss areas to prevent potential impact to groundwater quality.

4.2.1 RHIC Groundwater Monitoring

Well Network

Thirteen shallow wells are used to verify that the impermeable caps at the RHIC beam stops and collimators are effective in protecting groundwater quality. Six of the monitoring wells are located in the 10 o'clock beam stop area, six wells are in the collimator area, and one well is downgradient of the W-Line Beam Stop (**Figure 4.2-1**). As part of BNL's Environmental Surveillance program, surface water samples are also collected semiannually from the Peconic River downstream of the beam stop area at sample location HV (sample location 026-03). These monitoring results are used to verify that potentially contaminated groundwater is not entering the Peconic River stream bed as base flow during high water-table conditions.

Sampling Frequency and Analysis

During 2020, groundwater samples were collected from the RHIC monitoring wells on a semiannual schedule, and the samples were analyzed for tritium (**Table 1-6**). Routine analysis for sodium-22 was discontinued starting in 2002 because tritium is the best indicator of possible cap failure (i.e., tritium is more leachable than sodium-22, and it migrates at the same rate as groundwater). Annual surface water samples collected at location HV were analyzed for tritium and by gamma spectroscopy.

4.2.2 RHIC Monitoring Well Results

During the first quarter of 2020, tritium was detected in well 043-02 at a concentration of 4,310 pCi/L. Tritium was not detected in well 043-02 during the third quarter of 2020 or the first quarter of 2021. Tritium was not detected in any of the other RHIC monitoring wells. Furthermore, neither tritium or sodium-22 were detected in the surface water sample collected from downstream location HV.

4.2.3 RHIC Groundwater Monitoring Program Evaluation

The 2020 monitoring data were evaluated using the following Data Quality Objective statement.

<u>*1. Has the source of potential contamination been controlled?*</u>

Groundwater and surface water monitoring data continue to demonstrate that the impermeable caps installed over the RHIC beam stop and collimator areas are effectively preventing rainwater infiltration into the activated soil shielding.

4.2.4 RHIC Recommendation

The following is recommended for the RHIC groundwater monitoring program:

- During 2021, groundwater samples will continue to be collected on a semiannual basis. Surface water samples will also continue to be collected as part of the Environmental Surveillance program.

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4.3 BROOKHAVEN MEDICAL RESEARCH REACTOR (BMRR)

The Brookhaven Medical Research Reactor (BMRR) was a 3-megawatt light water reactor used for biomedical research. Research operations at the BMRR ended in December 2000. All fuel was removed in 2003 and the primary cooling water system was drained.

When it was operating, the BMRR primary cooling water system contained 2,550 gallons of water that contained approximately 5 curies (Ci) of tritium. Unlike the HFBR, the BMRR did not have a spent fuel storage canal or pressurized imbedded piping systems that contained radioactive liquids. Historically, fuel elements that required storage were either stored within the reactor vessel, or they were transferred to the HFBR spent fuel canal. The BMRR primary cooling water system piping is fully exposed in the containment structure, and was accessible for routine visual inspections while it was operating.

In 1997, tritium was detected in groundwater directly downgradient (within 30 feet) of the BMRR. The maximum tritium concentration observed during 1997 was 11,800 pCi/L, almost one-half of the 20,000 pCi/L DWS. The highest observed tritium concentration since the start of groundwater monitoring was 17,100 pCi/L in October 1999. The tritium detected in groundwater is believed to have originated from the historical discharge of small amounts of BMRR primary cooling water to a basement floor drain and sump system that may have leaked. Although the last discharge of primary cooling water to the floor drain system occurred in 1987, the floor drains continued to be used for secondary (non-radioactive) cooling water until 1997. The infiltration of this water may have promoted the movement of residual tritium from the soil surrounding the floor drain piping system to the groundwater. The floor drains were permanently sealed in 1998.

4.3.1 BMRR Groundwater Monitoring

Well Network

The monitoring well network for the BMRR facility consists of one upgradient and three downgradient wells (**Figure 4.3-1**).

Sampling Frequency and Analysis

The BMRR wells are sampled once every two years. Groundwater samples are currently only analyzed for tritium (**Table 1-6**). During 2020, one BMRR well was also sampled for PFAS and 1,4-dioxane for the Phase 4 Characterization Project (**Section 3.5**).

4.3.2 BMRR Monitoring Well Results

Tritium was not detected in the BMRR monitoring wells during 2020. Monitoring conducted since 1997 has shown that tritium concentrations in the BMRR wells have always been below the 20,000 pCi/L DWS (**Figure 4.3-2**). Previous analyses for gamma, gross alpha, and gross beta did not indicate the presence of any other reactor-related radionuclides.

4.3.3 BMRR Groundwater Monitoring Program Evaluation

Monitoring data were evaluated using the following Data Quality Objective statement.

<u>1. Is there a continuing source of contamination? If present, has the source been remediated or controlled?</u>

Tritium concentrations in groundwater downgradient of the BMRR have never exceeded the 20,000 pCi/L DWS. Tritium concentrations were <5,000 pCi/L from September 2000 through 2010, <600 pCi/L during the 2012, 2014 and 2016 sample periods, and tritium was not detected during the 2018 sample period. Groundwater monitoring results indicate that the BMRR structure is effectively preventing rainwater infiltration into the underlying soils, or that the amount of residual tritium in the vadose zone has been significantly reduced.

4.3.4 BMRR Recommendation

The following is recommended for the BMRR groundwater monitoring program:

- The monitoring frequency for the BMRR wells will continue to be once every two years, with the next set of samples being collected in 2022.

4.4 SEWAGE TREATMENT PLANT (STP)

The STP processes sanitary wastewater from BNL research and support facilities. Until October 2014, treated effluent from the STP was discharged to the Peconic River under a NYSDEC SPDES permit (NY-0005835). Treated wastewater from the STP is now released to nearby groundwater recharge basins (SPDES Outfall 001) (**Figure 4.1.1**).

On average, 0.5 million gallons per day (MGD) of wastewater are processed during the summer and 0.3 MGD of water are processed during the rest of the year. Before discharge into the recharge basins, the sanitary waste stream is treated by: 1) primary clarification to remove settleable solids and floatable materials; 2) aerobic oxidation for secondary removal of the biological matter and nitrification of ammonia; 3) secondary clarification; and 4) filtration for final effluent polishing. Oxygen levels are regulated during the treatment process to remove nitrogen biologically, using nitrate-bound oxygen for respiration. As required by the NYS SPDES permit, monitoring wells are used to evaluate groundwater quality near the recharge basins.

Two emergency hold-up ponds are located east of the former sand filter beds. The hold-up ponds are used to store sanitary waste in the event of mechanical problems at the plant or if the influent contains contaminants in concentrations exceeding BNL administrative limits and/or SPDES permit effluent release criteria. The hold-up ponds have a combined holding capacity of nearly six million gallons of water and provide BNL with the ability to divert all sanitary system effluent for approximately one week. The hold-up ponds are equipped with fabric-reinforced plastic liners that are heat-welded along all seams. In 2001, improvements were made with the addition of new primary liners and a leak detection system. The older liners now serve as secondary containment.

4.4.1 STP Groundwater Monitoring

Well Network

In addition to the comprehensive influent and effluent monitoring program at the STP, the groundwater monitoring program is designed to provide a secondary means of verifying that STP operations are not impacting groundwater quality. One upgradient well (039-87) and six downgradient wells (039-88, 039-89, 039-115, 048-08, 048-09 and 048-10) are used to monitor groundwater quality in the recharge basin area (**Figure 4.4-1**). Monitoring results from three wells (039-88, 039-89, and 039-90) are also used to evaluate groundwater quality in the holding pond area, when necessary.

Sampling Frequency and Analysis

In accordance with the SPDES permit, the STP recharge basin area monitoring wells are sampled annually (**Table 1-6**). Samples were collected in November 2019. As required by the permit, the samples are analyzed for the following metals: copper, iron, lead, nickel, silver, zinc and mercury.

In January 2020, samples from STP and downgradient (Operable Unit V) monitoring wells were tested for per- and polyfluoroalkyl substances (PFAS) and 1,4-dioxane as part of Phase 4 of the Laboratory's ongoing characterization of emerging contaminants of concern. The results for the Phase 4 effort are summarized in **Sections 3.5.1 and 3.5.2**. Furthermore, due to periodic exceedances of the SPDES permit discharge limit for the corrosion inhibitor tolyltriazole, the STP recharge basin monitoring wells were sampled for this chemical in July 2020

4.4.2 STP Monitoring Well Results

All metals concentrations tracked under the SPDES permit were below the applicable AWQS. As in previous years, sodium was detected at concentrations above the 20 mg/L AWQS in the STP recharge basin area wells. During 2019, sodium levels exceeded 20 mg/L in six wells, with maximum concentration of 98.6 mg/L in well 039-115. Although tolyltriazole was not detected in groundwater samples collected during 2019, tolyltriazole concentrations exceeded the AWQS of 0.05 mg/L in four of the recharge basin area monitoring wells sampled in July 2020, with a maximum tolyltriazole concentration of 0.453 mg/L in the sample collected from well 039-115 (**Table 4.4-1**).

4.4.3 STP Groundwater Monitoring Program Evaluation

The 2020 monitoring data were evaluated using the following Data Quality Objective statement.

1. Are STP operations impacting groundwater quality?
In addition to the continued detection of sodium at concentrations above the 20 mg/L AWQS, monitoring results for 2020 indicate that tolyltriazole is also impacting groundwater quality near the STP recharge basins.

4.4.4 STP Recommendation

For 2021, the following is recommended for the STP groundwater monitoring program:

- In accordance with the SPDES permit, the STP groundwater monitoring wells will be sampled annually, and the samples will be analyzed for the metals specified in the permit. Consider conducting additional monitoring for tolyltriazole.

4.5 MOTOR POOL AREA

The Motor Pool (Building 423) consists of a five-bay automotive repair shop, which includes office and storage spaces (**Figure 4.5-1**). The facility has been used continuously since 1947.

Potential environmental concerns at the Motor Pool include 1) the use of USTs to store gasoline, diesel fuel, and waste oil, 2) hydraulic fluids used for lift stations, and 3) the use of solvents for parts cleaning. In August 1989, the gasoline and waste oil USTs, pump islands, and associated piping were upgraded to conform to Suffolk County Article 12 requirements for secondary containment, leak detection devices, and overfill alarms. The present tank inventory includes two 8,000-gallon USTs used to store unleaded gasoline, one 260-gallon above ground storage tank used for waste oil, and one 3,000-gallon UST for No. 2 fuel oil. The Motor Pool facility has five vehicle-lift stations. The hydraulic fluid reservoirs for the lifts are located above ground.

4.5.1 Motor Pool Area Groundwater Monitoring

Well Network

The groundwater monitoring program for the Motor Pool's UST area is used to confirm that the current engineered and institutional controls are effective in preventing contamination of the aquifer. Shallow Upper Glacial aquifer wells 102-05 and 102-06 are used to monitor for potential contaminant releases from the UST area (**Figure 4.5-1**). As needed, groundwater quality downgradient of Building 423 can also be monitored using shallow wells 102-10, 102-11, 102-12, and 102-13.

Sampling Frequency and Analysis

During 2020, the two UST area wells were monitored one time, and the samples were analyzed for VOCs (**Table 1-6**). The wells were also checked for the presence of floating petroleum hydrocarbons. The remaining Building 423 monitoring wells were not sampled. Motor Pool area well 102-12 was sampled for PFAS and 1,4-dioxane during the Phase 4 Characterization Project (**Section 3.5**).

4.5.2 Motor Pool Monitoring Well Results

Underground Storage Tank Area

During 2020, chloroform was detected in both wells, with a maximum concentration of 0.59 µg/L in well 102-05. As in previous years, no floating product was detected in the wells.

4.5.3 Motor Pool Groundwater Monitoring Program Evaluation

The 2020 monitoring data were evaluated using the following Data Quality Objective statement.

<u>*1. Is there a continuing source of contamination? If present, has the source been remediated or controlled?*</u>

During 2020, there were no reported gasoline or motor oil losses or spills from the USTs or from Building 423 that could affect groundwater quality. Furthermore, all waste oils and used solvents generated from current operations are being properly stored and recycled. The gasoline USTs have electronic leak detection systems, and there is a daily product reconciliation (i.e., an accounting of the volume of gasoline stored in USTs and volume of gasoline dispensed).

4.5.4 Motor Pool Recommendations

The following are recommendations for the Motor Pool area monitoring program for 2021:

- The sampling frequency for the UST area wells 102-05 and 102-06 will continue to be annually.

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4.6 ON-SITE SERVICE STATION

Building 630 was a commercial automobile service station, privately operated under a contract with BNL. The station was built in 1966 and was used for automobile repair and gasoline sales until January 2018. Potential environmental concerns at the Service Station included the use of USTs for the storage of gasoline and waste oil, hydraulic fluids used for lift stations, and the use of solvents for parts cleaning. In August 1989, the USTs, pump islands, and associated piping were upgraded to conform to Suffolk County Article 12 requirements for secondary containment, leak detection devices, and overfill alarms. The tank inventory included three 8,000-gallon USTs for storing unleaded gasoline and one 500-gallon UST used for waste oil. The facility had three hydraulic vehicle-lift stations. In early 2018, the underground storage tanks were emptied of their contents, and hydraulic oils were draining from the lift stations. In September 2018, the underground storage tanks were excavated and removed from the site for proper disposal. During the removal of the underground storage tanks, there were no reported gasoline or motor oil losses or spills that could affect groundwater quality. Furthermore, no contaminants were detected in end-point soil samples at concentrations above 6 NYCRR Part 375 cleanup guidelines.

4.6.1 Service Station Groundwater Monitoring

Well Network

Groundwater quality in the service station area was monitoring using four shallow Upper Glacial wells. The monitoring program was used to confirm that the engineered and institutional controls in place are effective in preventing contamination of the aquifer and to evaluate continued impacts from historical spills (**Figure 4.6-1**).

Sampling Frequency and Analysis

No groundwater samples were collected during 2020.

4.6.2 Service Station Monitoring Well Results

Although groundwater water quality at the Service Station had been impacted by a variety of VOCs that were related to historical vehicle maintenance and refueling operations, monitoring conducted during 2015 through 2017 indicated a significant drop in VOC concentrations. During 2017, the highest VOC concentration was detected in well 085-17, with tetrachloroethylene at 3.7 µg/L, which was below the NYS AWQS of 5 µg/L.

4.6.3 Service Station Groundwater Monitoring Program Evaluation

Monitoring data collected to date were evaluated using the following Data Quality Objective statement.

1. Is there a continuing source of contamination? If present, has the source been remediated or controlled?

Based upon the last set of monitoring data collected in 2017, VOC concentrations for individual compounds have declined to less than applicable AWQS. During the removal of the underground storage tanks, there were no reported gasoline or motor oil losses or spills that could affect groundwater quality. Furthermore, no contaminants were detected in end-point soil samples at concentrations above 6 NYCRR Part 375 cleanup guidelines.

4.6.4 Service Station Groundwater Monitoring Program Recommendation

Because the Service Station facility has been decommissioned, and recent groundwater monitoring results indicated that VOC concentrations declined to less than the NYS AWQS, the monitoring program has been discontinued. The monitoring wells will be retained for possible future use.

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4.7 MAJOR PETROLEUM FACILITY (MPF)

The MPF is the storage area for fuel oil used at the Central Steam Facility (CSF). The fuel oil is held in a network of seven above ground storage tanks, which have a combined capacity of up to 1.7 million gallons of No. 6 fuel oil and 60,000 gallons of No. 2 fuel oil. The tanks are connected to the CSF by above ground pipelines that have secondary containment and leak detection devices. The fuel storage tanks are positioned in bermed containment areas that have a capacity to hold >110 percent of the volume of the largest tank located there. The bermed areas have bentonite clay liners consisting of either Environmat™ (bentonite clay sandwiched between geotextile material) or bentonite clay mixed into the native soil to form an impervious soil/clay layer. Fuel-unloading operations occur in a centralized building that has secondary containment features. The MPF is operated under NYSDEC Permit #1-1700 and, as required by law, a Spill Prevention Control and Countermeasures (SPCC) Plan and a Facility Response Plan have been developed for the facility. Groundwater quality near the MPF has been impacted by several oil and solvent spills and PFAS: 1) the 1977 fuel oil/solvent spill east of the MPF that was remediated under the FFA (OU IV); 2) a historical fuel/solvent spill discovered in 2013 near MPF storage tank #3; 3) historical solvent spills near the CSF; 4) solvent spills that occurred in the Building 650 area; and 5) firefighter training with PFAS containing foam occurred near several of the storage tanks.

4.7.1 MPF Groundwater Monitoring

Well Network

Eight shallow Upper Glacial aquifer wells are used to confirm that the engineered and institutional controls in place are effective in preventing contamination of the aquifer (**Figure 4.7-1**).

Sampling Frequency and Analysis

Groundwater contaminants from the fuel oil products stored at the MPF can travel both as free product and in dissolved form in groundwater. Based upon these factors, the NYSDEC Special License Conditions for the MPF requires semiannual monitoring for VOCs and SVOCs and monthly monitoring for floating petroleum (**Table 1-6**). During 2020, the MPF wells were also tested for PFAS and 1,4-dioxane during the Phase 4 Characterization Project (**Section 3.5**)

4.7.2 MPF Monitoring Well Results

During 2020, tetrachloroethene (7.2 µg/L), trichloroethene (0.69J µg/L) and chloroform (0.59J µg/L) continue to be detected in upgradient well 076-25 (**Figure 4.7-1**). The tetrachloroethene concentration in upgradient well 076-25 was slightly above the AWQS of 5 µg/L. In the downgradient wells, chloroform was detected in well 076-18 at 1.3J µg/L and tetrachloroethene was detected in well 076-380 at 1.1J µg/L. The trichloroethene and chloroform concentrations were less than the 5 µg/L and 7 µg/L AWQS, respectively. These compounds are believed to originate from historic solvent spills that occurred near the Central Steam Facility and at an adjacent upgradient facility (Building 650). As in previous monitoring periods, no floating petroleum was detected in the MPF monitoring wells. Results for the Phase 4 characterization project indicate that both PFOS and PFOA are present in the groundwater downgradient of the MPF at concentrations >10 ng/L DWS (**Section 3.5.1**).

4.7.3 MPF Groundwater Monitoring Program Evaluation

The 2020 monitoring data were evaluated using the following Data Quality Objective statement.

1. Are the potential sources of contamination being controlled?

Groundwater monitoring at the MPF continues to show that fuel storage and distribution operations are not impacting groundwater quality. VOCs that are periodically detected in the groundwater are likely to have originated from historical solvent spills near the Central Steam Facility (Building 610) and the

Building 650 area to the north. Several historical spill sites near the CSF were identified during the 1990s, and the contaminated soils were excavated and disposed of in accordance with regulatory requirements. The historical use of firefighting foam in the MPF area has also impacted groundwater quality. Long-term impacts from PFAS use at the MPF will be evaluated during the Remedial Investigation.

4.7.4 MPF Recommendation

For 2021, monitoring will continue as required by the NYS operating permit, with semiannual monitoring for VOCs and SVOCs, and monthly testing for floating product.

4.8 WASTE MANAGEMENT FACILITY (WMF)

The WMF is designed to safely handle, repackage, and temporarily store BNL-derived wastes prior to shipment to off-site disposal or treatment facilities. The WMF is a state-of-the-art facility, with administrative and engineered controls that meet all applicable federal, state, and local environmental protection requirements. The WMF consists of three buildings: the Operations Building, Reclamation Building (for radioactive waste), and the RCRA Building.

Groundwater monitoring is a requirement of the RCRA Part B permit issued for WMF operations. The groundwater monitoring program for the WMF is designed to supplement the engineered and institutional controls by providing additional means of detecting potential contaminant releases from the facility. Because of the close proximity of the WMF to BNL potable supply wells 11 and 12, it is imperative that the engineered and institutional controls implemented at the WMF are effective in ensuring that waste handling operations do not degrade the quality of the soil and groundwater in this area. (Note: Potable water supply well 12 has been out of service since 2008.)

4.8.1 WMF Groundwater Monitoring

Well Network

During 2020, groundwater quality at the WMF was monitored using eight shallow Upper Glacial aquifer wells. Two wells (055-03 and 055-10) are used to monitor background water quality. During 2020, six wells were used to monitored groundwater quality near the two main waste handling and storage facilities. Wells 056-21, 066-220 and 066-221 are located near the RCRA Building, and wells 056-22, 066-222 and 066-223 are located near the Reclamation Building. Periodically adjustments are made to the list of downgradient wells that are monitored due to transient changes in groundwater flow directions caused by the operations of the nearby supply wells. BNL discontinued sampling of well 066-224 following the 2012 closure of the former Mixed Waste Building. Locations of the monitoring wells are shown on **Figure 4.8-1**.

Sampling Frequency and Analysis

During 2020, the WMF wells were sampled in February and September. Groundwater samples were analyzed twice for VOCs, tritium, gamma spectroscopy, gross alpha, and gross beta, and one time for strontium-90, metals and anions (e.g., chlorides, sulfates, and nitrates) (**Table 1-6**). A complete set of monitoring data are presented in the *2020 Groundwater Monitoring Report for the Waste Management Facility* (BNL 2021d). During 2020, WMF background wells 055-03 and 055-10 were also sampled for PFAS and 1,4-dioxane for the Phase 4 Characterization Project (**Section 3.5**).

4.8.2 WMF Monitoring Well Results

Radiological Analyses

Gross alpha and beta levels in samples from both upgradient and downgradient monitoring wells were consistent with background concentrations. During 2020, low levels of sodium-22 (at 7.13 pCi/L) and Cs-137 (at 9.1 pCi/L) were reported for samples collected from wells 066-220 and 066-221, respectively. The reported sodium-22 and cesium-137 concentrations were well below the applicable drinking water standards of 400 pCi/L and 200 pCi/L, respectively. Based upon documented waste management operations, neither sodium-22 nor cesium-137 would be associated with the WMF.

A trace level of strontium-90 (Sr-90) was detected in downgradient monitoring well 066-222 at 0.261+/-0.169 pCi/L (MDL = 0.259 pCi/L), which is approximately 3% of the 8 pCi/L DWS. The past detection of Sr-90 in several of the WMF monitoring wells is likely to be historical leakage of wastewater from the main sanitary line that ran through the current WMF area before it was re-routed south of the facility. During construction of the WMF, portions of the old sanitary line were abandoned in place. Low levels of Sr-90 were also detected in pre-operation (baseline) samples collected in May 1997 in both upgradient and downgradient wells at concentrations up to 5.4 pCi/L. The only operation at the WMF that could potentially contribute Sr-90 to the environment is the BGRR/WCF groundwater treatment system located in Building 855. However, the pipeline in the WMF area is double lined, and is monitored by a leak detector. There are no indications that this piping system has leaked.

Non-Radiological Analyses

All anions (chlorides, sulfates, and nitrates) and most metals concentrations were below applicable ambient NYS AWQS or DWS. As in previous years, sodium was detected at concentrations above the 20 mg/L AWQS. Sodium was detected at concentrations above the standard in both upgradient wells at a maximum of 41 mg/L in well 055-10, and in six downgradient wells (056-21, 056-22, 066-220, 066-221, 066-222 and 066-223) at concentrations up to 44 mg/L. Figure 7 provides a summary of sodium concentrations in WMF monitoring wells for the period of 1999 through 2020. The elevated sodium concentrations are likely the result of road salting operations. Although trace levels of chloroform were detected in upgradient well 055-10 during both sample periods, the concentrations were below the AWQS. No VOCs were detected in the downgradient wells.

4.8.3 WMF Groundwater Monitoring Program Evaluation

The 2020 monitoring data were evaluated using the following Data Quality Objective statement.

1. Are potential sources of contamination within the WMF being controlled?

Groundwater monitoring results for 2020 continued to show that WMF operations are not affecting groundwater quality. Furthermore, there were no outdoor or indoor spills at the facility that could have affected soil or groundwater quality.

4.8.4 WMF Recommendation

The following are recommended for 2021:

- Continue monitoring the wells at a semiannual frequency as required by the RCRA Part B Permit.

4.9 NATIONAL SYNCHROTRON LIGHT SOURCE II (NSLS-II)

The NSLS-II is an electron accelerator that began full-time operations in 2014. High-energy particle interactions in water, air, and soil can produce radioactivity from spallation reactions or neutron capture in nitrogen, oxygen, or other materials. In high-energy proton accelerators, such as BNL's AGS, BLIP and RHIC, these interactions can produce significant activation of the soil shielding. However, electron accelerators such as the NSLS-II have significantly reduced potential for environmental impacts and can produce only about one to five percent of the induced activity of a proton accelerator. As required by the BNL SBMS *Accelerator Safety* subject area, analyses have been conducted to estimate the rate of formation of tritium and sodium-22 in the surrounding soils during the operation of the NSLS-II's Linac, Booster, and Storage Ring. The results of these analyses indicate that interactions of neutrons with the soils below the tunnel floor and surrounding soil shielding (berm) have the potential to create very low levels of tritium and sodium-22 in the soil. However, because the soil beneath the concrete floor will not be exposed to rainfall, the potential leaching of radioactive isotopes from the soil to the water table at these locations will be minimal. There is also the potential to create very low levels of tritium in the water used to cool the magnets and other accelerator components.

4.9.1 NSLS-II Groundwater Monitoring

Well Network

Four monitoring wells are located downgradient of the facility's Linac, Booster and Storage Ring area where beam line operations may result in low level activation of the surrounding soil shielding (**Figure 4.9-1**). Two nearby MPF monitoring wells (076-18 and 076-19) are used as upgradient/background wells for the NSLS-II facility.

Sampling Frequency and Analysis

During 2020, the four NSLS-II monitoring wells and the two MPF wells were sampled one time, and the samples were analyzed for tritium (**Table 1-6**).

4.9.2 NSLS-II Monitoring Well Results

No tritium was detected in the groundwater samples collected during 2020.

4.9.3 NSLS-II Groundwater Monitoring Program Evaluation

The 2020 monitoring data were evaluated using the following Data Quality Objective statement.

1. Are the engineered and operational controls effective at preventing or reducing the leaching of radionuclides from activated soils to the groundwater?

Monitoring results for 2020 indicate that NSLS-II beam line operations conducted to date have not affected groundwater quality.

4.9.4 NSLS-II Recommendations

For 2021, the four NSLS-II and two MPF (background) monitoring wells will continue to be monitored annually for tritium.

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5.0 SUMMARY OF RECOMMENDATIONS

This section is provided as a quick reference to recommendations for monitoring and remediation program changes described in **Sections 3** and **4**. **Table 5-1** summarizes the changes to the monitoring well sampling programs.

5.1 OU I South Boundary Treatment System

- Maintain the VOC post-closure groundwater monitoring program of an annual sample collection from post-closure wells: 098-99, 107-40, 107-41, 115-13, 115-16, and 115-51. Maintain quarterly sampling of Current Landfill sentinel well 098-99
- Install temporary wells as needed to fill monitoring data gaps and characterize extent of the Sr-90 plume.

5.2 Building 96 Treatment System

- Maintain full time operation of extraction well RTW-1. Monitor VOC concentrations in well 085-379 to determine when this well can be shut down. Maintain a monthly sampling frequency of the influent and effluent.
- As per a recommendation in the *2021 CERCLA Five-Year Review Report* (BNL, 2021c), closely monitor TVOC concentrations in the plume source area and evaluate/implement a liquid carbon with zero-valent iron in-situ treatment for the immediate source area.
- Reduce the monitoring frequency for well 095-159 from monthly to quarterly as concentrations in this well have decreased because of increased RTW-1 pumping. Reduce the sampling frequency of bypass wells 095-163, 095-165, 095-166, 095-168, 095-169, and 095-170 from quarterly to semi-annual as extraction wells RTW-2, RTW-3, and RTW-4 are in standby mode and TVOC concentrations in these wells have been near to below detectable levels over the previous two years. Reduce sampling frequency for well 085-293 from quarterly to semi-annual as TVOCs have been below 5 µg/L since 2014.
- Maintain treatment wells RTW-2, RTW-3, and RTW-4 in standby mode, and restart the wells if extraction or monitoring well data indicate that TVOC concentrations exceed 50 µg/L.

5.3 Middle Road Treatment System

- Maintain extraction wells RW-1, RW-4, RW-5 and RW-6 in standby mode. Restart the well(s) if extraction or monitoring well data indicate that TVOC concentrations exceed the 50 µg/L capture goal.
- Continue operation of RW-2, RW-3 and RW-7.
- In order to meet the OU III ROD cleanup goal:
    - Install one or two vertical profile borings (VPBs) to confirm distribution of VOC concentrations in the area of the potential additional extraction well(s).
    - Perform groundwater modeling simulations to help determine the best location, extraction rates, and number of extraction wells to optimize the system and achieve cleanup goals.
    - Install an additional extraction well downgradient of monitoring well 104-37 and an additional extraction well immediately upgradient of 105-68 based on results of characterization and groundwater modeling.

5.4 OU III South Boundary Treatment System

- Maintain wells EW-3, EW-5, EW-6, EW-7, EW-8, and EW-12 in standby mode. The system's extraction wells will continue to be sampled on a quarterly basis, with the exception of EW-12. The wells will be restarted if extraction or monitoring well data indicate TVOC concentrations exceed the 50 µg/L capture goal.
- Continue to operate well EW-17 on a full-time basis. Place EW-4 into standby mode. EW-4 is currently being pulsed pumped (one month on/one month off).
  - As per recommendations in **Section 3.2.9**, discontinue sampling of OU III South Boundary/Magothy wells 121-40, 121-44 and 122-41. These wells shown detections well below MCL's during the previous twenty years.
- In order to meet the OU III ROD cleanup goal:
  - Install one or two VPBs to confirm distribution of VOC concentrations in the area of the potential additional extraction well.
  - Perform groundwater modeling simulations to help determine the best location, extraction rates, and number of extraction wells to optimize the system and achieve cleanup goals.
  - Install an additional extraction well downgradient of well 121-54 based on results of characterization and groundwater modeling.

5.5 Western South Boundary Treatment System

- Continue full-time operation of extraction well WSB-1 based on elevated concentrations in well 126-14.
- Based on the low TVOC concentrations below the capture goal of 20 µg/L, maintain extraction well WSB-2 in standby mode. If TVOC concentrations greater than 20 µg/L are observed in WSB-2 or the adjacent monitoring wells, extraction well WSB-2 may be put into full time operation.
- Continue operation of the four new extraction wells. With the operation of these wells the groundwater cleanup goal of meeting MCLs by 2030 are expected to be met.
- Continue the current monitoring frequency for the Western South Boundary monitoring wells as shown in **Table 1-5**.

5.6 Industrial Park Treatment System

- Maintain the seven UVB wells in standby. If TVOC concentrations exceed the 50 µg/L capture goal in these UVB wells or associated monitoring wells, they may be restarted.
- Maintain IP-EW-8 and IP-EW-9 in standby and continue to monitor for rebound of VOCs. If TVOC concentrations approach the capture goal of 50 µg/L in the vicinity of the extraction wells the system will be evaluated for restart.
- If extraction and monitoring wells remain below the capture goal for four consecutive sample rounds, prepare and submit a petition for system closure.

5.7 North Street Treatment System

- If TVOC concentrations in any core monitoring wells increase to over the 50 µg/L capture goal, the extraction well(s) may be restarted.

- NS-1 and NS-2 will remain shut down until the PFAS and 1,4 dioxane characterization is completed. After the completion of this characterization, a determination of the future use of these wells will be determined.
- Seven of the eighteen monitoring wells will continue on an annual monitoring schedule until the results for individual VOCs are consistently below MCLs. Sampling of the remaining 11 monitoring wells will be discontinued but the wells will be retained until the completion of the PFAS and 1,4-dioxane characterization at the BNL site.

5.8 North Street East Treatment System

- Continue full time operation of the EDB treatment system and maintain monthly sampling of extraction wells NSE-EDB-EW-3 and NSE-EDB-EW-4.
- Maintain the quarterly sampling frequency for the 12 EDB monitoring wells using Method 504, except for upgradient perimeter well 115-42 which is sampled semi-annually. Maintain annual VOC sampling using Method 524.2 for all wells except for 115-42 and 000-138.

5.9 LIPA/Airport Treatment System

- Continue full time operation of wells RTW-1A, RTW-4A and RW-6A. Keep wells RTW-2A, RTW-3A and RTW-5A in standby mode. If concentrations above the capture goal of 10 µg/L TVOC are observed in any of the extraction wells or the monitoring wells adjacent to wells that are not operating, the well(s) will be put back into full-time operation.
- Maintain LIPA wells EW-1L, EW-2L, EW-3L and EW-4L in standby mode. These extraction wells may be restarted if TVOC concentrations rebound above the 50 µg/L capture goal in either the plume core monitoring wells or the extraction wells. Based upon the low VOC concentrations for the past several years, submit a petition for closure of the LIPA system in 2021.
- No changes to the current monitoring schedule are recommended at this time for the Airport System. Continue the quarterly sampling frequency for the LIPA monitoring wells to support the decision for a petition for closure in 2021.

5.10 Magothy Monitoring

- Continue the current monitoring schedule for the Magothy monitoring program. Stop sampling south boundary wells 121-40, 121-44, 122-41 as they have never had any detections near the MCL's and are generally non detect.
- Continue pumping the Magothy extraction wells at Middle Road, South Boundary and the Airport. The two IP extraction wells were placed in standby in July 2019 and continue to be monitored for rebound of VOCs. The North Street, North Street East, OU III South Boundary EW-8 and LIPA and Airport RTW-3A Magothy extraction wells are currently in standby as they have reached the OU III capture goals identified for shutdown of these wells. The IPE extraction well was abandoned as it had reached its cleanup goal.

5.11 William Floyd Wellfield Sentinel Monitoring

No changes are recommended for the William Floyd Wellfield Sentinel Monitoring Program.

5.12 BGRR/WCF Strontium-90 Treatment System

- Maintain the monthly sampling frequency of source area monitoring wells 065-325 and 065-405. Continue to monitor the elevated Sr-90 concentrations downgradient of Building 801. Perform groundwater modeling simulation if necessary (based on significant Sr-90 concentration increase), to determine natural attenuation of Sr-90.

- Maintain SR-8 in pulsed pumping mode (one month on and one month off) based on low, but fluctuating, Sr-90 concentrations.
- Maintain a source area monitoring frequency of monthly for BGRR source area well 075-701. Maintain a monthly sampling frequency of 075-664 .
- Maintain SR-3 in full time operational mode. If Sr-90 concentrations in this well and monitoring well 075-701 remain below DWS for six consecutive months, place SR-3 on standby.
- Continue operating wells SR-1, SR-2, and SR-9 in full time operational mode. Maintain wells SR-4, SR-5, SR-6, and SR-7 in standby mode.
- Install several temporary wells along Temple Place to supplement monitoring of the downgradient segment of the WCF plume. Install temporary wells as necessary to monitor high concentrations segments of the downgradient portions of the BGRR and Building 801/PFS plumes.

5.13 Chemical/Animal Holes Strontium-90 Treatment System

- Maintain the system in standby mode and maintain quarterly sampling of the extraction wells. If significant rebound in either the extraction wells or monitoring wells is identified, these extraction wells may be restarted.
- If Sr-90 concentrations in the monitoring and extraction wells do not show any significant rebound through 2021, then a Petition for Closure of the treatment system may be prepared.
- Maintain the annual monitoring well sampling frequency (standby phase), except for former source area wells 097-313, 097-314, 097-315, which will remain at a semi-annual.

5.14 HFBR Tritium Pump and Recharge System

- Continue to monitor the source area quarterly with the ten wells located immediately downgradient of the HFBR.
- Maintain the monitoring and extraction wells until a determination is made on their utilization related to emerging contaminants.

5.15 Building 650 (Sump Outfall) Strontium-90 Monitoring

- Continue monitoring newly installed wells 076-418, 076-419, 076-420 and 076-421 for potential impacts from D&D activities and from Sump Outfall Area on a semi-annual basis.

5.16 Operable Unit VI EDB Treatment System

- Maintain full time operation of the treatment system and continue quarterly sampling of the extraction wells.
- Geologic and groundwater characterization data obtained in 2020/2021 to support updated groundwater modeling efforts revealed different geologic conditions, and the presence of EDB at greater depths in the Upper Glacial aquifer than originally expected. The intent of the groundwater modeling update was originally to determine the ability of this system to achieve the ROD cleanup goal of DWS by 2030.

- As a result of recently obtained data, the geologic framework of the groundwater model should be upgraded followed by a determination of the effectiveness of the current system with respect to both cleanup time and capture of deeper EDB.
- Any negative impact that the recharge of treated water (via diffusion wells) may be having on the leading edge of the plume will also have to be evaluated.
- Prior to performing new groundwater modeling simulations additional data collection is recommended. A deep vertical profile well should be installed downgradient of EW-1E and both geologic and groundwater quality data obtained to determine the presence of deeper EDB in this area. The groundwater modeling results will determine the scope of system modification in the form of additional extraction wells to re-establish plume capture and ensure the achievement of ROD cleanup goals.

5.17 Site Background Monitoring

There are no changes proposed to the monitoring program.

5.18 Current Landfill Groundwater Monitoring

No changes to the monitoring program are warranted at this time.

5.19 Former Landfill Groundwater Monitoring

With the data presented in *BNL 2020 Environmental Monitoring Report, Current and Former Landfill Areas* and with over two decades of groundwater monitoring data providing evidence that groundwater impact from the Former Landfill area is now essentially nonexistent, it is recommended that groundwater monitoring of the Former Landfill area be discontinued.

5.20 g-2 Tritium Source Area and Groundwater Plume

- Continue routine inspections of the g-2 cap.
- Continue semiannual monitoring of source area wells near Building 912A, and annual monitoring of wells located downgradient of the former beam stop and Building 912.

5.21 Brookhaven Linac Isotope Producer (BLIP) Facility

- As required by the ROD, BNL will continue to conduct routine inspections of the cap, and to monitor groundwater quality downgradient of the BLIP facility.
- No changes to the groundwater monitoring program are recommended.

5.22 PFOS and PFOA in Groundwater

- Develop path forward for conducting an RI/FS and for long-term monitoring of PFOS and PFOA in groundwater.
- Using the results of the Phase 5/TCRA Characterization effort, design and install groundwater treatment systems for focused remediation of the high concentration PFOS/PFOA plume segments downgradient of the current and former firehouse facilities..

5.23 1,4-Dioxane in Groundwater

Develop a path forward for conducting the RI/FS and for long-term monitoring of 1,4-dioxane in groundwater.

5.24 Alternating Gradient Synchrotron (AGS) Complex

Continue sampling all Building 912 monitoring wells annually.

5.25 Relativistic Heavy Ion Collider (RHIC) Facility

Groundwater samples will continue to be collected on a semiannual basis. Surface water samples will also continue to be collected as part of the Environmental Surveillance program.

5.26 Brookhaven Medical Research Reactor (BMRR) Facility

The monitoring frequency for the wells will continue to be once every two years, with the next set of samples being collected in 2022.

5.27 Sewage Treatment Plant (STP) Facility

In accordance with the SPDES permit, the STP groundwater monitoring wells will be sampled annually, and the samples will be analyzed for the metals specified in the permit. Additional consideration should be made for the continued monitoring for tolyltriazole.

5.28 Motor Pool Area

The sampling frequency for the UST area wells 102-05 and 102-06 will continue to be annually.

5.29 On-Site Service Station

Because the Service Station facility has been decommissioned, and recent groundwater monitoring results indicated that VOC concentrations declined to less than the NYS AWQS, the monitoring program has been discontinued. The monitoring wells will be retained for possible future use.

5.30 Major Petroleum Facility (MPF) Area

Monitoring will continue as required by the NYS operating permit, with semiannual monitoring for VOCs and SVOCs, and monthly testing for floating product.

5.31 Waste Management Facility (WMF)

Continue monitoring the wells at a semiannual frequency as required by the RCRA Part B Permit

5.32 National Synchrotron Light Source II (NSLS-II)

The four NSLS-II and two MPF (background) monitoring wells will continue to be monitored annually for tritium.

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