BROOKHAVEN NATIONAL LABORATORY

Phase 4 Work Plan
Characterization of Per- and Polyfluoroalkyl Substances (PFAS) and 1,4-Dioxane in Select On-Site and Off-Site Monitoring Wells and Off-Site Extraction Wells and Treatment Systems

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1.0 Emerging Contaminants at BNL

A class of chemicals called Per- and Polyfluoroalkyl Substances (PFAS) and the chemical 1,4-dioxane are emerging contaminants of concern across the United States. PFAS are widely manufactured chemicals that 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. In 2017, BNL began investigating the impact that these chemicals are having on groundwater quality at the Laboratory. The results of these investigations are summarized below.

1.1 Per- and Poly Fluoroalkyl Substances

In 2017, BNL's five active potable water supply wells were sampled for PFAS by the Suffolk County Department of Health Services. The samples were analyzed for same the six PFAS compounds that were evaluated under the Third Unregulated Contaminant Monitoring Rule (UCMR3) program. PFAS were detected in samples from three of the five supply wells (BNL-6, BNL-10 and BNL-11). Combined concentrations of the PFAS compounds perfluorooctane sulfonate (PFOS) and perfluorooctanoic acid (PFOA) concentrations in the supply wells were less than the current EPA Lifetime Health Advisory Level (HAL) of 70 ng/L. The NYSDOH recently proposed establishing individual drinking water standards of 10 ng/L for PFOS and PFOA.

Following these detections, a search of available records identified eight areas where firefighting foam had been released to the ground during the period of 1966 through 2008. Starting in 2018, BNL began a multiphase characterization effort to evaluate the impacts from the foam releases:

- 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 were at high enough levels to potentially affect future supply well operations. The results confirmed the presence of PFAS in the source water contributing areas for four of the five active potable supply wells. Combined PFOS/PFOA concentrations of nearly 3,100 ng/L were found in Phase 1 temporary wells installed near BNL's current firehouse, which is located within the 2-year capture zone of supply well #4 (BNL-4). Although this well has only been in limited service for the past 10 years, BNL will for the time being, discontinue using the well. Furthermore, due to observed increases in PFOS/PFOA concentrations in supply well #6 (BNL-6), this well is now limited to "last call" use.

- Phase 2: From August through November 2018, thirty temporary groundwater monitoring wells were installed in the eight areas where firefighting foam had been released (BNL 2018b). PFAS were detected in the groundwater at all eight areas. BNL's current and former firehouse areas were found to have the highest levels of PFAS, with maximum combined concentrations of PFOS and PFOA of 12,440 ng/L and 5,371 ng/L, respectively.

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

  PFAS were detected in most of the on-site extraction wells and monitoring wells, including wells located along the southern and eastern site boundaries. The maximum combined PFOS and PFOA concentration detected at the southern boundary was 69.2 ng/L in monitoring well 122-10. Along the eastern boundary, downgradient of the STP, a combined PFOS/PFOA concentration of 122.9 ng/L was detected in well 061-05. PFAS were also detected in off-site well 000-122 with combined PFOS/PFOA at a concentration of 29.2 ng/L.

PFAS monitoring results for Phases 1 through 3 are summarized in the *2018 BNL Groundwater Status Report* (BNL 2019b).

1.2 1,4-Dioxane

In 2017, BNL began testing for 1,4-dioxane in select on-site and off-site monitoring wells and treatment systems that have or had detectable levels of TCA. 1,4-dioxane was detected in on-site and off-site monitoring wells and groundwater treatment systems, with a maximum concentration of 18.6 µg/L in OU III Industrial Park monitoring well 000-530. 1,4-Dioxane was also detected in four of five groundwater treatment system effluent samples, with a maximum concentration of 7.14 µg/L in the effluent from the Industrial Park treatment system. The current NY State drinking water standard of 50 µg/L for Unspecified Organic Contaminants would apply to 1,4-dioxane. The NYSDOH recently proposed establishing a drinking water standard of 1.0 µg/L for 1,4-dioxane.

1,4-Dioxane monitoring results for 2017 and 2019 are summarized in the *2018 BNL Groundwater Status Report* (BNL 2019b).

2.0 Phase 4 Monitoring

The primary goal of the Phase 4 monitoring effort is to expand upon the monitoring that has been conducted to date, by conducting a comprehensive baseline characterization of PFAS and 1,4-dioxane concentrations in: 1) select on-site and off-site groundwater monitoring wells; and 2) off-site extraction wells and treatment system influent and effluent. The proposed Phase 4 monitoring effort is described below.

2.1 Monitoring Wells

BNL maintains an extensive network of on-site and off-site wells to evaluate the impacts of groundwater contamination from former and current operations and to track cleanup progress. Groundwater monitoring is focused on two general programs: 1) surveillance designed to satisfy DOE and New York State monitoring requirements for active research

and support facilities; and 2) CERCLA monitoring conducted in accordance with the Federal Facilities Agreement.

For the Phase 4 characterization project, approximately 350 on-site and off-site monitoring wells will be sampled for PFAS and 1,4-dioxane. A list of the wells to be sampled is presented in **Table 1**. The locations of the monitoring wells are shown on **Figure 1.** For efficiency and cost savings, sampling of the monitoring wells for PFAS and 1,4-dioxane will be integrated into the existing sampling schedules. Those wells that are not part of a current sampling program (e.g., the former OU V monitoring program wells, and wells used only for water level measurements) will be scheduled separately. In some cases, new permanent sample pumps will have to be installed in wells that are currently only used for collecting water level measurements.

2.2 Off-Site Extraction Wells and Treatment System Influent and Effluent

Six off-site groundwater treatment systems have been constructed to remediate volatile organic compound contamination that has migrated south of the BNL site. These are the Industrial Park, Industrial Park East, LIPA/Airport, North Street, North Street East, and OU VI EDB treatment systems. By 2013, the Industrial Park East system had met its cleanup goals, and the system's extraction wells were decommissioned. The remaining systems have a total of 27 extraction wells; 21 of which are designed to pump contaminated water from the deep portions of the Upper Glacial aquifer, while six wells pump water from the upper portions of the Magothy aquifer. The Industrial Park system consists of seven in-well air stripping treatment wells and two extraction wells. Water treated by each in-well system is recharged to a shallower portion of the aquifer through an upper (recharge) screen. Water from the two extraction wells is treated by liquid phase granular activated carbon and is recharged to the aquifer via nearby injection wells. Groundwater at the remaining off-site systems is treated by liquid phase granular activated carbon, and the treated water is recharged to the aquifer via injection wells.

To date, the individual off-site extraction wells have not been sampled for PFAS or 1,4-dioxane. On-site extraction wells and treatment systems were sampled for PFAS during the Phase 3 characterization effort (BNL 2018c). As part of the Phase 4 characterization effort, samples will be collected for PFAS and 1,4-dioxane analyses from nine active and eighteen inactive extraction wells associated with the IP, LIPA/Airport, North Street, North Street East, and OU VI EDB treatment systems. While monitoring conducted in 2017 verified that 1,4-dioxane is present in the off-site treatment systems sampled (e.g., IP and LIPA/Airport), the Phase 4 sampling of the individual extraction wells and influent and effluent from the treatment systems will provide important information about whether PFAS contaminated groundwater is being captured by these systems. A list of the off-site extraction wells and treatment systems to be sampled is presented in **Table 2**. The locations of the extraction wells are shown on **Figure 2.**

3.0 Sample Collection and Analysis

Groundwater samples will be collected from existing on-site and off-site monitoring wells, off-site extraction wells and treatment systems using standard BNL protocols.

3.1 Monitoring Wells

Sampling details for the monitoring wells are described below:

- For most wells, groundwater samples will be collected using the existing Teflon®-containing bladder pumps and discharge tubing.[1]
- The wells will be sampled in accordance with BNL procedure EM-SOP-302, *Groundwater Sampling – Low Flow Purging and Sampling Using Dedicated Bladder Pumps*.
- Groundwater samples for PFAS analyses will be collected using analytical laboratory supplied 250 ml polypropylene sample bottles containing Trizma. Groundwater samples for 1,4-dioxane will be collected using analytical laboratory supplied 250 ml amber glass sample bottles containing sodium bisulfate.
- Except for utilizing existing sample pumps and discharge lines that contain Teflon®, all other precautions described in **Section 4** will be followed to prevent potential cross contamination of the samples. Sample containers for 1,4-dioxane contain Teflon®-lined caps. Therefore, as a precaution, at each well location, PFAS samples will be collected first, followed by 1,4-dioxane. PFAS and 1,4-dioxane sample bottles will be kept in separate coolers during sample collection and shipment to the analytical laboratory.
- All purge water will be treated using a portable granular activated carbon unit before being discharged to the ground at the collection site.

3.2 Treatment System Extraction Well and Effluent Samples

Sampling details for the extraction wells and treatment system influent and effluent are described below:

- At extraction wells that are currently in full-time operation, water samples can be collected directly, without any modifications to pumping operations.
- Extraction wells that are currently in standby mode will be pumped for a minimum of one (1) hour prior to sampling.
- Raw water samples will be collected at the sample ports identified in the *O&M Manuals*. Sample ports will be purged until the water runs clear (typically after purging 1 to 2 liters of water) prior to collecting the samples.
- All sample ports will be inspected prior to sampling to determine whether Tygon® or other tubing suspected of being made with fluoropolymer chemicals is connected to the sampling port. If present, it will be replaced with HDPE or silicon tubing.
- Groundwater samples for PFAS will be collected using analytical laboratory supplied 250 ml polypropylene sample bottles containing Trizma. Groundwater samples for 1,4-dioxane will be collected using analytical laboratory supplied 250 ml amber glass sample bottles containing sodium-bisulfate.

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[1] To evaluate potential cross contamination issues with the Teflon®-containing pumps and discharge lines, during previous characterizations efforts BNL collected a limited number of groundwater samples from "background" wells located in areas that were thought not to be impacted by PFAS. The analytical results ranged from non-detectable to trace levels of PFAS (e.g., PFOA and PFBA) that may be attributable to the Teflon® pump components (BNL 2019a). Furthermore, there are concerns that switching to Teflon®-free pumps and tubing may have unintended consequences related to sorption of volatile organic compounds to non-Teflon ® coated sampling materials.

- Sample containers for 1,4-dioxane analysis contain Teflon®-lined caps. Therefore, as a precaution, at each sample interval PFAS samples will be collected first, followed by 1,4-dioxane. PFAS and 1,4-dioxane sample bottles will be kept in separate coolers during sample collection and shipment to the analytical laboratory.
- All purge water will be treated using a portable granular activated carbon unit before being discharged to the ground at the collection site.

3.1 Sample Analyses and Reporting

Water samples from all monitoring wells, extraction wells and treatment system effluent will be analyzed using EPA Method 537.1 for twenty-three (23) PFAS compounds and by EPA Method 522 for 1,4-dioxane (**Tables 3 and 4**). The samples will be sent to General Engineering Laboratories (GEL), Charleston, SC, with a requested 30-day turnaround time. A full (Category B) data package will be provided by GEL for both analyses. **Tables 5 and 6** provide summaries of the analytical methods and quality assurance aspects for this effort. An assessment of the analytical results and a Data Usability Summary Report will be provided in a final project report, and further documented in the *2020 BNL Groundwater Status Report*.

4.0 Decontamination and Cross Contamination Prevention Procedures

In addition to adhering to BNL standard operating procedures for the collection of groundwater samples described above, the following procedures shall be adhered to:

1. New nitrile gloves shall be worn between each sample location.
2. Only clean cotton or synthetic clothes shall be worn – preferably washed more than six times, and without the use of fabric softeners. No waterproof or insecticide treated clothing, boots or rain jackets made or treated with Teflon products shall be used at the collection site. This includes all Gore-Tex® and Tyvek® products.
3. Do not apply moisturizers or hand creams to hands or face on the day of sampling. No sunblock or insect repellants. Do not bring packaged food to the work site or use aluminum foil.
4. Field notes shall be taken using a computer tablet or by using ink pens on non-waterproof plain paper attached to a metal clipboard. Do not use Sharpies or markers. Transcribe field notes to Chain-of-Custody forms and official field books when back in the office after the collection process.
5. Use only GEL supplied sample bottles.
6. Print labels before going into the field and apply to the sample containers.
7. Use only GEL supplied PFAS-free water for field reagent blanks and equipment blanks.
8. Place each sample container in a separate polypropylene zip-lock bag.
9. For the shipping coolers, use only regular crushed ice packaged in polypropylene zip-lock plastic bags.
10. Use only GEL shipping coolers that were used to ship sample containers for this project. Tape and band the cooler shut before shipping samples to GEL.

5.0 References

BNL 2018a. Work Plan for the Characterization of Per-fluorinated Compounds in Groundwater within the Source Water Contributing Areas of BNL Supply Wells. Brookhaven National Laboratory, Upton, New York. March 26, 2018.

BNL 2018b. Phase 2 Work Plan for the Characterization of Per- and Polyfluoroalkyl Substances (PFAS) in Known or Suspected Firefighting Foam Release Areas. Brookhaven National Laboratory, Upton, New York. July 31, 2018.

BNL 2018c. Phase 3 Work Plan, Testing for Per- and Polyfluoroalkyl Substances (PFAS) in Groundwater Treatment Systems, Sewage Treatment Plant Effluent, Landfill Monitoring Wells, and OU V Monitoring Wells. Brookhaven National Laboratory, Upton, New York. November 30, 2018.

BNL 2019a. Addendum to the Phase 3 Work Plan, Testing for Per- and Polyfluoroalkyl Substances (PFAS) in Groundwater Treatment Systems, Sewage Treatment Plant Effluent, Landfill Monitoring Wells, South Boundary Monitoring Wells and OU V Monitoring Wells. Brookhaven National Laboratory, Upton, New York. March 5, 2019.

BNL 2019b. 2018 Site Environmental Report, Volume 2, Groundwater Status Report. Brookhaven National Laboratory, Upton, New York. June 2019.

USEPA 2008. Method 522, Determination of 1,4-dioxane in Drinking Water by Solid Phase Extraction (SPE) and Gas Chromatography/Mass Spectrometry (GC/MS) with Selected Ion Monitoring (SIM). EPA Document #: EPA/600/R-08/101. September 2008.

USEPA 2018. Method 537.1, Determination of Selected Per- and Polyfluoroalkyl Substances in Drinking Water by Solid Phase Extraction and Liquid Chromatography/Tandem Mass Spectrometry (LC/MS/MS). EPA Document #: EPA/600/R-18/352. November 2018.

Table 1

Phase 4 Work Plan for Emerging Contaminants
Brookhaven National Laboratory
List of Monitoring Wells to Be Sampled for PFAS and 1,4-Dioxane

BNL Well Id.	Screen Interval (ft. BLS)	Aquifer Segment	Current Monitoring Project
007-02	252-257	MAG	Site Background/Water Levels
007-04	15-35	SG	Site Background/Water Levels
007-05	200-205	DG	Site Background/Water Levels
013-01	23-43	SG	Site Background/Water Levels
017-01	15-25	SG	Site Background
017-03	115-125	MG	Site Background
017-04	163-168	DG	Site Background
018-01	5-35	SG	Site Background
018-02	65-85	MG	Site Background
018-04	140-150	DG	Site Background
018-05	270-280	MAG	Site Background
025-02	29-39	SG	Site Background/Water Levels
037-02	31-41	SG	Sewage Treat. Plant/OU V
037-03	90-100	MG	Sewage Treat. Plant/OU V
037-04	178-188	DG	Sewage Treat. Plant/OU V
038-01	5-25	SG	Sewage Treatment Plant
038-02	13-23	SG	Sewage Treatment Plant
038-03	6-18	SG	Sewage Treatment Plant
038-05	38-43	SG	Sewage Treatment Plant
038-06	39-44	SG	Sewage Treatment Plant
039-06	5-10	SG	Sewage Treatment Plant
039-07	15-25	SG	Sewage Treatment Plant
039-08	17-27	SG	Sewage Treatment Plant
039-86	15-35	SG	Sewage Treatment Plant
039-87	14-24	SG	Sewage Treatment Plant
039-89	15-30	SG	Sewage Treatment Plant
039-90	15-30	SG	Sewage Treatment Plant
039-91	10-20	SG	Sewage Treatment Plant
039-115	10-25	SG	Sewage Treatment Plant
048-08	10-25	SG	Sewage Treatment Plant
048-09	10-25	SG	Sewage Treatment Plant
048-10	10-25	SG	Sewage Treatment Plant
049-06	175-185	DG	Sewage Treat. Plant/OU V
050-01	205-225	DG	Sewage Treat. Plant/OU V
061-03	6-16	SG	Sewage Treat. Plant/OU V
061-04	90-100	MG	Sewage Treat. Plant/OU V
061-05	195-205	DG	Sewage Treat. Plant/OU V
000-122	240-260	DG	Sewage Treat. Plant/OU V
000-123	150-170	DG	Sewage Treat. Plant/OU V
000-141	37-57	SG	Sewage Treat. Plant/OU V
000-142	145-165	DG	Sewage Treat. Plant/OU V
000-143	240-260	MAG	Sewage Treat. Plant/OU V
000-147	34-54	SG	Sewage Treat. Plant/OU V
600-15	240-260	MAG	Sewage Treat. Plant/OU V
600-16	160-180	DG	Sewage Treat. Plant/OU V

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BNL Well Id.	Screen Interval (ft. BLS)	Aquifer Segment	Current Monitoring Project
600-18	35-55	SG	Sewage Treat. Plant/OU V
600-19	50-70	SG	Sewage Treat. Plant/OU V
600-21	240-260	MAG	Sewage Treat. Plant/OU V
600-22	60-80	SG	Sewage Treat. Plant/OU V
600-24	228-248	MAG	Sewage Treat. Plant/OU V
600-25	52-72	SG	Sewage Treat. Plant/OU V
600-27	240-260	MAG	Sewage Treat. Plant/OU V
054-07	69-79	SG	Alt. Grad. Synchrotron
054-08	27-47	SG	Alt. Grad. Synchrotron
054-62	18-33	SG	Alt. Grad. Synchrotron
054-65	18-33	SG	Alt. Grad. Synchrotron
054-66	18-33	SG	Alt. Grad. Synchrotron
054-124	25-40	SG	Alt. Grad. Synchrotron
054-127	22-37	SG	Alt. Grad. Synchrotron
054-128	22-37	SG	Alt. Grad. Synchrotron
054-130	22-37	SG	Alt. Grad. Synchrotron
054-168	17-33	SG	Alt. Grad. Synchrotron
054-169	17-33	SG	Alt. Grad. Synchrotron
054-191	21-36	SG	Alt. Grad. Synchrotron
055-30	20-35	SG	Alt. Grad. Synchrotron
055-31	45-55	SG	Alt. Grad. Synchrotron
065-126	19-34	SG	Alt. Grad. Synchrotron
064-01	39-59	SG	Water Levels
065-120	22-37	SG	Alt. Grad. Synchrotron
065-192	50-60	SG	Alt. Grad. Synchrotron
065-121	19-34	SG	Alt. Grad. Synchrotron
065-193	50-60	SG	Alt. Grad. Synchrotron
065-123	18-33	SG	Alt. Grad. Synchrotron
065-194	45-55	SG	Alt. Grad. Synchrotron
065-161	90-100	MG	Alt. Grad. Synchrotron
055-03	45-55	SG	Waste Management Fac.
055-10	89-99	MG	Waste Management Fac.
065-04	55-65	SG	OU III - BGRR/WCF Sr-90
065-06	55-65	SG	OU III - BGRR/WCF Sr-90
065-161	90-100	MG	OU III - BGRR/WCF Sr-90
065-361	50-60	SG	OU III - BGRR/WCF Sr-90
065-363	55-65	SG	OU III - BGRR/WCF Sr-90
065-365	75-85	MG	OU III - BGRR/WCF Sr-90
065-402	37-57	SG	OU III - BGRR/WCF Sr-90
075-193	80-90	MG	OU III - BGRR/WCF Sr-90
075-194	140-150	DG	OU III - BGRR/WCF Sr-90
075-666	46-56	SG	OU III - BGRR/WCF Sr-90
075-671	104-114	MG	OU III - BGRR/WCF Sr-90

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List of Monitoring Wells to Be Sampled for PFAS and 1,4-Dioxane

BNL Well Id.	Screen Interval (ft. BLS)	Aquifer Segment	Current Monitoring Project
075-672	107-117	MG	OU III - BGRR/WCF Sr-90
075-673	(a)		OU III - BGRR/WCF Sr-90
075-674	70-80	MG	OU III - BGRR/WCF Sr-90
075-675	90-100	MG	OU III - BGRR/WCF Sr-90
075-705	85-95	MG	OU III - BGRR/WCF Sr-90
075-706	90-100	MG	OU III - BGRR/WCF Sr-90
075-707	70-80	SG	OU III - BGRR/WCF Sr-90
075-85	65-70	SG	OU III - BGRR/WCF Sr-90
075-87	105-110	MG	OU III - BGRR/WCF Sr-90
085-399	55-75	SG	OU III - BGRR/WCF Sr-90
085-398	120-140	DG	OU III - BGRR/WCF Sr-90
085-403	110-130	MG	OU III - BGRR/WCF Sr-90
085-402	90-110	MG	OU III - BGRR/WCF Sr-90
075-40	120-125	MG	OU III - AOC 29/HFBR Tritium
076-173	34-54	SG	OU III - AOC 29/HFBR Tritium
077-10	94-114	MG	OU III - AOC 29/HFBR Tritium
085-02	130-160	DG	OU III - AOC 29/HFBR Tritium
085-43	25-31	SG	Water Levels
085-285	64-68	SG	OU III - AOC 29/HFBR Tritium
095-55	135-140	MG	OU III - AOC 29/HFBR Tritium
095-93	170-180	DG	OU III - AOC 29/HFBR Tritium
095-276	165-175	DG	OU III - AOC 29/HFBR Tritium
095-273	130-140	MG	OU III - AOC 29/HFBR Tritium
096-82	100-110	MG	OU III - AOC 29/HFBR Tritium
096-84	129-139	MG	OU III - AOC 29/HFBR Tritium
096-88	135-145	MG	OU III - AOC 29/HFBR Tritium
096-115	85-95	MG	OU III - AOC 29/HFBR Tritium
096-117	85-95	MG	OU III - AOC 29/HFBR Tritium
096-118	84-94	MG	OU III - AOC 29/HFBR Tritium
105-27	28-38	SG	Water Levels
105-29	170-190	DG	OU III - AOC 29/HFBR Tritium
105-43	145-150	DG	OU III - AOC 29/HFBR Tritium
105-44	150-155	DG	OU III - AOC 29/HFBR Tritium
095-85	90-100	MG	OU III - Bldg 96
085-97	15-35	SG	OU III - Bldg 96
085-293	46-56	SG	OU III - Bldg 96
085-349	20-25	SG	OU III - Bldg 96
085-350	32-37	SG	OU III - Bldg 96
085-359	15-25	SG	OU III - Bldg 96
085-378	10-30	SG	OU III - Bldg 96
085-384	30-45	SG	OU III - Bldg 96
095-163	45-55	SG	OU III - Bldg 96
095-166	45-55	SG	OU III - Bldg 96
095-168	44-54	SG	OU III - Bldg 96

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BNL Well Id.	Screen Interval (ft. BLS)	Aquifer Segment	Current Monitoring Project
095-169	44-54	SG	OU III - Bldg 96
095-170	45-55	SG	OU III - Bldg 96
095-171	45-55	SG	OU III - Bldg 96
095-313	45-60	SG	OU III - Bldg 96
076-16	27-47	SG	Major Petroleum Facility
076-17	27-47	SG	Major Petroleum Facility
076-18	23-43	SG	Major Petroleum Facility
076-19	23-43	SG	Major Petroleum Facility
076-378	27-42	SG	Major Petroleum Facility
076-379	28-43	SG	Major Petroleum Facility
076-380	27-42	SG	Major Petroleum Facility
076-10	30-50	SG	OU IV - AOC 6 Sr-90
076-263	70-80	MG	OU IV - AOC 6 Sr-90
087-09	24-34	SG	Current Landfill
087-11	11-21	SG	Current Landfill
087-23	25-40	SG	Current Landfill
087-24	70-80	SG	Current Landfill
087-26	70-80	SG	Current Landfill
087-27	5-20	SG	Current Landfill
088-109	6-21	SG	Current Landfill
088-110	10-25	SG	Current Landfill
088-21	5-20	SG	Current Landfill
088-22	70-80	SG	Current Landfill
088-23	120-130	SG	Current Landfill
086-42	65-75	SG	Former Landfill
097-17	29-39	SG	Former Landfill
106-30	29-44	SG	Former Landfill
097-313	20-40	SG	Chemical/Animal Holes Sr-90
106-122	35-45	SG	Chemical/Animal Holes Sr-90
106-13	29-39	SG	Chemical/Animal Holes Sr-90
106-14	30-40	SG	Chemical/Animal Holes Sr-90
106-64	30-40	SG	Chemical/Animal Holes Sr-90
106-94	28-43	SG	Chemical/Animal Holes Sr-90
073-01	32-52	SG	Water Treatment Plant
083-01	70-100	MG	OU III - Central/Paint Shop
083-02	120-150	DG	OU III - Central/Paint Shop
083-05	65-75	MG	Water Levels
102-12	44-59	SG	Motor Pool
084-28	48-63	SG	Brookhaven Med. Res. Reactor

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BNL Well Id.	Screen Interval (ft. BLS)	Aquifer Segment	Current Monitoring Project
084-02	54-64	SG	Water Levels
084-05	179-189	DG	OU III - Central
103-02	45-50	SG	Water Levels
103-10	36-46	SG	Water Levels
103-15	195-205	DG	OU III - Western South Boundary
103-18	165-175	DG	OU III - Western South Boundary
103-19	165-175	DG	OU III - Western South Boundary
111-15	170-180	DG	OU III - Western South Boundary
111-16	168-178	DG	OU III - Western South Boundary
119-11	175-185	DG	OU III - Western South Boundary
119-12	174-184	DG	OU III - Western South Boundary
125-01	40-50	SG	OU III - Western South Boundary
126-14	150-160	DG	OU III - Western South Boundary
126-15	150-160	DG	OU III - Western South Boundary
126-16	130-140	DG	OU III - Western South Boundary
126-18	160-170	DG	OU III - Western South Boundary
126-19	190-200	DG	OU III - Western South Boundary
126-20	135-145	DG	OU III - Western South Boundary
126-21	199-209	DG	OU III - Western South Boundary
127-06	150-160	DG	OU III - Western South Boundary
127-07	146-156	DG	OU III - Western South Boundary
130-03	160-165	DG	OU III - Western South Boundary
130-08	145-155	DG	OU III - Western South Boundary
130-09	135-145	DG	OU III - Western South Boundary
130-10	150-160	DG	OU III - Western South Boundary
130-11	195-205	DG	OU III - Western South Boundary
000-558	160-170	DG	OU III - Western South Boundary
000-559	210-220	DG	OU III - Western South Boundary
000-560	155-165	DG	OU III - Western South Boundary
095-322	175-185	DG	OU III - Middle Road
095-323	200-220	DG	OU III - Middle Road
104-37	204-214	DG/MAG	OU III - Middle Road
105-66	179-189	DG	OU III - Middle Road
105-68	200-210	DG/MAG	OU III - Middle Road
121-53	224-234	DG	OU III - Middle Road
105-23	175-185	DG	OU III - Middle Road
105-25	145-150	DG	OU III - Middle Road
105-44	150-155	DG	OU III - Middle Road
105-67	180-190	DG	OU III - Middle Road
106-56	160-170	DG	OU III - Middle Road
106-58	200-210	DG	OU III - Middle Road
113-17	167-187	DG	OU III - Middle Road
113-19	220-240	MAG	OU III - Middle Road

Table 1

Phase 4 Work Plan for Emerging Contaminants
Brookhaven National Laboratory
List of Monitoring Wells to Be Sampled for PFAS and 1,4-Dioxane

BNL Well Id.	Screen Interval (ft. BLS)	Aquifer Segment	Current Monitoring Project
113-30	185-195	DG	OU III - Middle Road
121-54	(a)		OU III - Middle Road
121-08	180-190	DG	OU III - South Boundary
121-10	160-170	DG	OU III - South Boundary
121-11	200-210	DG	OU III - South Boundary
121-23	180-200	DG	OU III - South Boundary
121-45	190-210	DG	OU III - South Boundary
121-47	224-234	DG	OU III - South Boundary
121-49	210-220	DG	OU III - South Boundary
122-04	200-205	DG	OU III - South Boundary
122-05	269-274	MAG	OU III - South Boundary
122-10	150-160	MG	OU III - South Boundary
122-18	130-150	MG	OU III - South Boundary
122-31	150-160	MG	OU III - South Boundary
122-32	200-210	DG	OU III - South Boundary
087-21	125-135	MG	OU I - South Boundary
088-26	13-23	SG	OU I - South Boundary
098-21	24-34	SG	OU I - South Boundary
098-59	130-140	DG	OU I - South Boundary
098-99	40-50	SG	OU I - South Boundary
098-100	5-20	SG	OU I - South Boundary
098-101	5-20	SG	OU I - South Boundary
098-102	5-20	SG	OU I - South Boundary
000-394	168-188	DG	OU I - South Boundary
107-23	115-125	MG	OU I - South Boundary
107-24	73-83	SG	OU I - South Boundary
107-26	135-145	MG	OU I - South Boundary
107-40	135-145	DG	OU I - South Boundary
107-41	128-138	MG	OU I - South Boundary
107-42	63-73	SG	OU I - South Boundary
108-14	85-105	MG	OU I - South Boundary
108-18	95-115	DG	OU I - South Boundary
108-45	63-73	MG	OU I - South Boundary
108-58	65-75	MG	OU I - South Boundary
108-59	90-100	DG	OU I - South Boundary
115-13	140-150	DG	OU I - South Boundary
115-28	202-212	DG	OU I - South Boundary
115-29	200-210	DG	OU I - South Boundary
115-36	129-134	DG	OU I - South Boundary
115-51	125-145	DG	OU I - South Boundary
116-05	100-110	MG	OU I - South Boundary
116-06	130-140	DG	OU I - South Boundary
000-112	175-185	DG	OU III - Industrial Park

Table 1

Phase 4 Work Plan for Emerging Contaminants
Brookhaven National Laboratory
List of Monitoring Wells to Be Sampled for PFAS and 1,4-Dioxane

BNL Well Id.	Screen Interval (ft. BLS)	Aquifer Segment	Current Monitoring Project
000-245	202-222	DG	OU III - Industrial Park
000-248	230-235	DG	OU III - Industrial Park
000-250	293-303	MAG	OU III - Industrial Park
000-255	165-170	DG	OU III - Industrial Park
000-256	220-225	DG	OU III - Industrial Park
000-259	200-205	DG	OU III - Industrial Park
000-261	130-135	MG	OU III - Industrial Park
000-262	180-185	DG	OU III - Industrial Park
000-265	210-215	DG	OU III - Industrial Park
000-267	158-163	MG	OU III - Industrial Park
000-268	213-218	DG	OU III - Industrial Park
000-271	213-218	DG	OU III - Industrial Park
000-272	181-201	DG	OU III - Industrial Park
000-528	215-225	DG	OU III - Industrial Park
000-529	210-220	DG	OU III - Industrial Park
000-530	205-215	DG	OU III - Industrial Park
000-531	200-210	DG	OU III - Industrial Park
000-537	240-250	MAG	OU III - Industrial Park
000-538	210-220	DG	OU III - Industrial Park
000-541	230-240	MAG	OU III - Industrial Park
000-543	225-235	MAG	OU III - Industrial Park
000-548	230-240	MAG	OU III - Industrial Park
127-08	235-245	MAG	OU III - Industrial Park
127-09	220-230	MAG	OU III - Industrial Park
000-490	245-265	DG/MAG	OU III - Industrial Park East
000-491	215-235	MAG	OU III - Industrial Park East
000-492	245-265	MAG	OU III - Industrial Park East
000-494	300-320	MAG	OU III - Industrial Park East
000-526	330-350	MAG	OU III - Industrial Park East
122-24	250-265	MAG	OU III - Industrial Park East
122-25	220-235	MAG	OU III - Industrial Park East
000-108	215-225	DG	OU III - North Street
000-154	193-203	DG	OU III - North Street
000-213	185-205	DG	OU III - North Street
000-465	185-195	DG	OU III - North Street
000-466	180-190	DG	OU III - North Street
000-472	206-216	DG	OU III - North Street
000-475	187-207	DG	OU III - North Street
000-124	115-125	MG	OU III - North Street East
000-138	158-178	DG	OU III - North Street East
000-477	165-175	DG	OU III - North Street East
000-478	167-177	DG	OU III - North Street East
000-479	165-175	DG	OU III - North Street East

Table 1

Phase 4 Work Plan for Emerging Contaminants
Brookhaven National Laboratory
List of Monitoring Wells to Be Sampled for PFAS and 1,4-Dioxane

BNL Well Id.	Screen Interval (ft. BLS)	Aquifer Segment	Current Monitoring Project
000-480	167-177	DG	OU III - North Street East
000-481	169-179	DG	OU III - North Street East
000-525	155-165	DG	OU III - North Street East
000-554	190-200	DG	OU III - North Street East
000-555	195-205	DG	OU III - North Street East
000-104	195-215	DG	OU III - LIPA
000-130	275-285	MAG	OU III - LIPA
000-131	220-230	DG	OU III - LIPA
000-445	209-229	DG	OU III - LIPA
000-450	198-218	DG	OU III - LIPA
000-451	188-198	DG	OU III - LIPA
800-101	270-290	MAG	OU III - Airport
800-103	215-235	DG	OU III - Airport
800-104	160-180	DG	OU III - Airport
800-105	222-242	MAG	OU III - Airport
800-106	207-227	DG	OU III - Airport
800-108	206-226	DG	OU III - Airport
800-128	170-190	DG	OU III - Airport
800-129	170-190	DG	OU III - Airport
800-130	175-195	DG	OU III - Airport
800-133	215-235	DG	OU III - Airport
800-138	245-255	MAG	OU III - Airport
800-44	202-222	DG	OU III - Airport
800-59	198-218	DG	OU III - Airport
800-60	200-220	DG	OU III - Airport
800-63	196-216	DG	OU III - Airport
800-92	195-205	DG	OU III - Airport
800-94	175-195	DG	OU III - Airport
800-95	177-197	DG	OU III - Airport
800-96	179-199	DG	OU III - Airport
800-98	174-194	DG	OU III - Airport
800-99	236-256	MAG	OU III - Airport
095-92	116-126	MG	OU III - Carbon tet
000-110	97-107	DG	OU VI - EDB
000-173	106-116	DG	OU VI - EDB
000-175	100-110	DG	OU VI - EDB
000-178	128-138	DG	OU VI - EDB
000-209	94-104	DG	OU VI - EDB
000-284	102-112	DG	OU VI - EDB
000-507	115-135	DG	OU VI - EDB
000-508	110-130	DG	OU VI - EDB
000-519	120-140	DG	OU VI - EDB
000-527	140-150	MAG	OU VI - EDB

Table 1

Phase 4 Work Plan for Emerging Contaminants
Brookhaven National Laboratory
List of Monitoring Wells to Be Sampled for PFAS and 1,4-Dioxane

BNL Well Id.	Screen Interval (ft. BLS)	Aquifer Segment	Current Monitoring Project
000-549	140-150	MAG	OU VI - EDB
100-12	95-105	DG	OU VI - EDB
100-13	65-75	MG	OU VI - EDB
000-343	320-340	MAG	OU III - Magothy
000-427	265-285	MAG	OU III - Magothy
000-429	290-310	MAG	OU III - Magothy
000-458	291-311	MAG	OU III - Magothy
122-41	315-335	MAG	OU III - Magothy
800-90	250-260	MAG	OU III - Magothy

SG=Shallow Upper Glacial, MG=Middle Upper Glacial, DG= Deep Upper Glacial
MAG=Upper Magothy
(a): Need to confirm well screen depth.

Table 2. Phase 4, Off-Site Extraction Wells to be Sampled for PFAS and 1,4-dioxane.

Well ID	Screen Depth (BLS)	Aquifer Segment	Status
Industrial Park Treatment System			
UVB-1 Influent (000-231)	220-240'	Deep Glacial	Standby
UVB-2 Influent (000-233)	195-215'	Deep Glacial	Standby
UVB-3 Influent (000-235)	194-214'	Deep Glacial	Standby
UVB-4 Influent (000-237)	170-190'	Deep Glacial	Standby
UVB-5 Influent (000-239)	180-200'	Deep Glacial	Standby
UVB-6 Influent (000-241)	190-210'	Deep Glacial	Standby
UVB-7 Influent (000-243)	205-225'	Deep Glacial	Standby
IP-EW-8	230-250'	Upper Magothy	Standby
IP-EW-9	220-240'	Upper Magothy	Standby
System Influent (000-534)	--	--	--
System Effluent (000-536)	--	--	--
Airport/LIPA Treatment System			
EW-1L (000-453)	217-237	Deep Glacial	Standby
EW-2L (000-455)	224-244	Deep Glacial	Standby
EW-3L (000-457)	216-236	Deep Glacial	Standby
EW-4L (000-461)	304-324	Upper Magothy	Standby
RTW-1A (800-109)	188-208	Deep Glacial	Active
RTW-2A (800-110)	188-208	Deep Glacial	Active
RTW-3A (800-111)	210-230	Upper Magothy	Active
RTW-4A (800-112)	268-288	Upper Magothy	Active
RTW-5A (800-113)	220-240	Upper Magothy	Standby
RW-6A (800-132)	165-185	Deep Glacial	Active
System Influent (800-122)	--	--	--
System Effluent (800-124)	--	--	--
North Street Treatment System			
NS-1 (000-471)	165-205	Deep Glacial	Standby
NS-2 (000-473)	190-220	Deep Glacial	Standby
System Influent (000-437)			
System Effluent (000-440)	--	--	--
North Street East Treatment System			
NSE-1 (000-487)	161-191	Deep Glacial	Standby
NSE-2 (000-488)	152-182	Deep Glacial	Standby
NSE-EDB-EW3 (000-561)	195-215	Deep Glacial	Note 1
NSE-EDB-EW4 (000-562)	182-202	Deep Glacial	Note 1
System Influent (000-441)			
System Effluent (000-444)	--	--	--
OU VI EDB Treatment System			
EW-1E (000-503)	115-135	Deep Glacial	Active
EW-2E (000-504)	115-135	Deep Glacial	Active
System Influent (000-512)			
System Effluent (000-510)	--	--	--

BLS: Feet below land surface

Note 1: New extraction wells NSE-EDB-EW3 and NSE-EDB-EW4 are expected to be in operation by February 2020.

Table 3. PFAS Analysis Summary

General Engineering Laboratories EPA Method 537.1		Water Detection Limits	
Parameter	**CAS Number**	**MDL ng/L**	**PQL ng/L**
Perfluorooctanesulfonate (PFOS)	1763-23-1	0.66	2
Perfluoroundecanoic acid (PFUdA)	2058-94-8	0.72	2
N-methylperfluoro-1-octanesulfonamidoacetic acid	2355-31-9	1.32	4
Perfluoropentanoic acid (PFPeA)	2706-90-3	0.66	2
Perfluoropentanesulfonate (PFPeS)	2706-91-4	0.66	1.88
N-ethylperfluoro-1-octanesulfonamidoacetic acid	2991-50-6	1.32	4
Perfluorohexanoic acid (PFHxA)	307-24-4	0.66	2
Perfluorododecanoic acid (PFDoA)	307-55-1	0.66	2
Perfluorooctanoic acid (PFOA)	335-67-1	0.66	2
Perfluorodecanoic acid (PFDA)	335-76-2	0.66	2
Perfluorodecanesulfonate (PFDS)	335-77-3	0.66	1.94
Perfluorohexanesulfonate (PFHxS)	355-46-4	0.66	1.82
Perfluorobutyric acid (PFBA)	375-22-4	0.82	2
Perfluorobutanesulfonate (PFBS)	375-73-5	0.8	1.78
Perfluoroheptanoic acid (PFHpA)	375-85-9	0.66	2
Perfluoroheptanesulfonate (PFHpS)	375-92-8	0.66	1.9
Perfluorononanoic acid (PFNA)	375-95-1	0.66	2
Perfluorotetradecanoic acid (PFTeDA)	376-06-7	0.66	2
Perfluorononanesulfonate (PFNS)	68259-12-1	0.7	1.92
Perfluorotridecanoic acid (PFTrDA)	72629-94-8	0.66	2
Perfluorooctanesulfonamide (PFOSA)	754-91-6	0.66	1.86
6:2 Fluorotelomer sulfonate (6:2 FTS)	27619-97-2	0.66	1.9
8:2 Fluorotelomer sulfonate (8:2 FTS)	39108-34-4	1.32	3.84

MDL: Minimum detection limit
PQL: Practical quantitation limit
ng/L: nanograms per liter

Table 4. 1,4-Dioxane Analysis Summary

General Engineering Laboratories EPA Method 522		Water Detection Limits	
Parameter	**CAS Number**	**MDL µg/L**	**PQL µg/L**
1,4-Dioxane	123-91-1	0.1	0.2

MDL: Minimum detection limit
PQL: Practical quantitation limit
µg/L: micrograms per liter

Table 5. Analytical Methods/Quality Assurance Summary for PFAS.

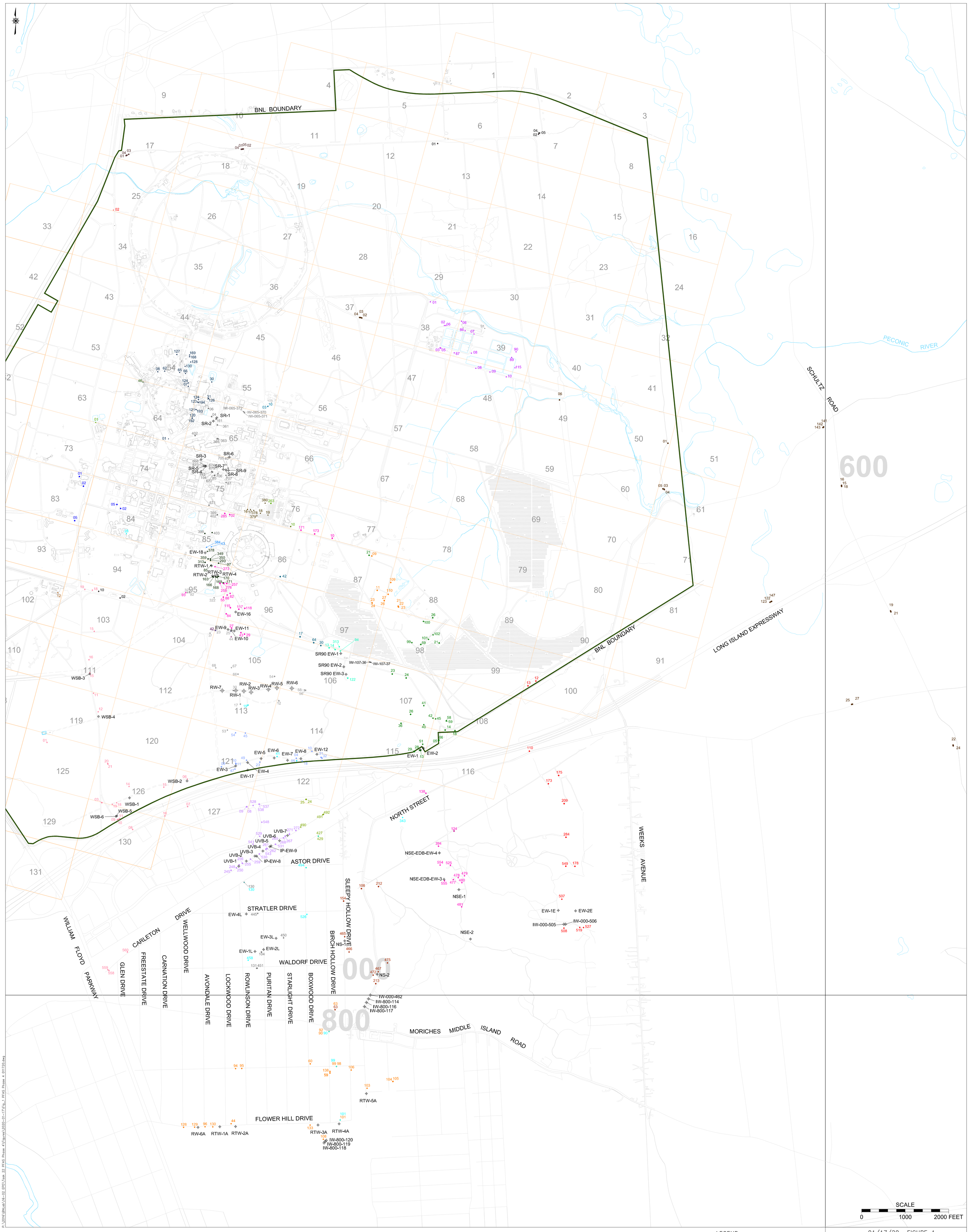
Samples	Parameters/Frequency
Matrix type	Groundwater
Number of samples	Monitoring wells = 354 Extraction wells/effluent = 37 Total samples = 391
Analytical parameters	23 PFAS (see Table 3)
Analytical method	EPA Method 537.1 by LC-MS/MS
Number of equipment blanks	None (Note 1)
Number of field reagent blanks - supplied by GEL.	One per sample shipment
Number of MS/MSDs	One set per every 20 sample locations
Number of duplicate samples	One per every 20 sample locations
Sample preservation	Trizma Samples maintained to ≤10°C (Note 2)
Sample container volume and type	250 ml polypropylene bottles; two bottles per sample location/interval
Sample holding times	Time to extraction = 14 days Time to analyze = 28 days

Note 1: Dedicated sampling equipment will be used for this project.
Note 2: Sample temperature requirements as defined in EPA Method 537.1 (USEPA, 2018). Samples must not exceed 10°C during the first 48 hours after collection, then be maintained by the analytical laboratory at ≤6°C (but not frozen) until extraction. BNL samples typically arrive at GEL Laboratories at temperatures of 1 to 4 °C.

Table 6. Analytical Methods/Quality Assurance Summary for 1,4-dioxane.

Samples	Parameters/Frequency
Matrix type	Groundwater
Number of well samples	Monitoring wells = 354 Extraction wells/effluent = 37 Total samples = 391
Analytical parameters	1,4-dioxane (see Table 4)
Analytical method	EPA Method 522 by GC-MS/SIM
Number of equipment blanks	None (Note 1)
Number of trip blanks	One per sample shipment
Number of MS/MSDs	One set per every 20 sample locations
Number of duplicate samples	One per every 20 sample locations
Sample preservation	Sodium bisulfate Samples maintained to <10°C (Note 2)
Sample container volume and type	250 ml amber glass bottles, with Teflon septum
Sample holding times	Time to extraction = 28 days Time to analyze = 28 days after extraction

Note 1: Dedicated sampling equipment will be used for this project.
Note 2: Sample temperature requirements as defined in EPA Method 522 (USEPA, 2008). Samples must not exceed 10°C during the first 48 hours after collection, then be maintained by the analytical laboratory at ≤6°C (but not frozen) until extraction.



LEGEND

32	BNL GRID NUMBER
EW-12	BNL REMEDIATION WELL
IW-800-120	BNL INJECTION WELL
481	BNL MONITORING WELL TO BE SAMPLED FOR PFAS AND 1,4-DIOXANE

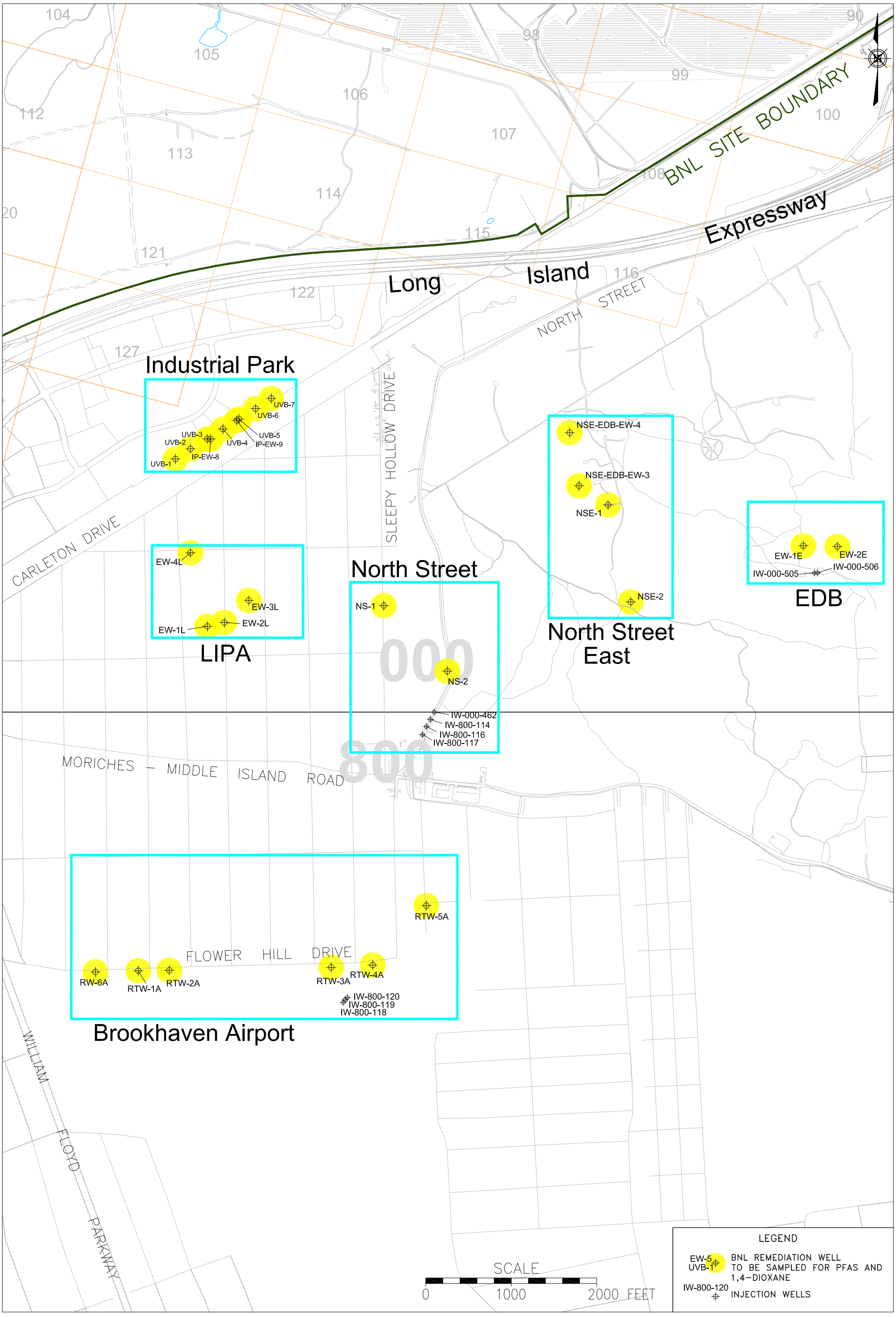
01/17/20 FIGURE 1
PFAS AND 1,4-DIOXANE CHARACTERIZATION

BROOKHAVEN NATIONAL LABORATORY

ENVIRONMENTAL PROTECTION DIVISION

PHASE 4 MONITORING WELL SAMPLING LOCATIONS

P:\2016\BNLab\16-02 EPD\Task 22 PFAS Phase 4\Figures\2020-01-17\Fig_1 PFAS Phase 4 011720.dwg



P:\2016\BNLab\16-02 EPD\Task 22 PFAS Phase 4\Figures\2020-01-17\Fig_2 PFAS 1,4-dioxane Rem Wells Phase 4 011720.dwg

BROOKHAVEN NATIONAL LABORATORY

ENVIRONMENTAL PROTECTION DIVISION

TITLE:

OFF-SITE REMEDIATION WELL AREAS PFAS AND 1,4-DIOXANE CHARACTERIZATION

PHASE 4 OFF-SITE REMEDIATION WELL LOCATIONS

DWN:	VS:HS.:	DATE:	PROJECT NO.:
AJZ	–	01/17/20	–
CHKD: DEP	APPD: DEP	REV.: –	NOTES: –
FIGURE NO.: 2			