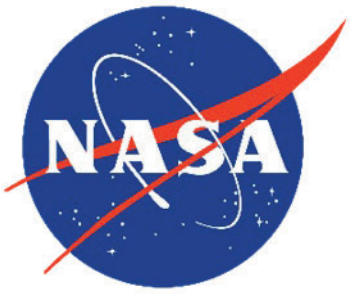
BASE SUPPORT BUILDING (SWMU 014) PLUMESTOP® INJECTION PILOT STUDY WORK PLAN KENNEDY SPACE CENTER, FLORIDA

Prepared for:



Environmental Assurance Branch
National Aeronautics and Space Administration
Kennedy Space Center, Florida

A-E Contract 80KSC019D0010
Task Order 80KSC021F0096

December 2023
Revision: 0

Prepared by:
AECOM Technical Services, Inc.
150 North Orange Avenue, Suite 200
Orlando, Florida 32801
407-843-6552

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In accordance with the provisions of Florida Statutes, Chapter 471, this Pilot Study Work Plan for the Kennedy Space Center located at Merritt Island, Florida, has been prepared under the direct supervision of a Professional Engineer registered in the State of Florida. This work was performed in accordance with generally accepted professional engineering practices pursuant to Chapter 471 of the Florida Statutes. The data, findings, recommendations, specifications, or professional opinions were prepared solely for the use of the National Aeronautics and Space Administration and the Florida Department of Environmental Protection. AECOM Technical Services, Inc. makes no other warranty, either expressed or implied, and is not responsible for the interpretation by others of these data.

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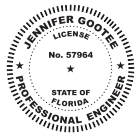

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Jennifer Gootee, P.E. Date
Project Manager
Florida License No. 57964

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ABBREVIATIONS, ACRONYMS, AND SYMBOLS

ADP	Advance data package
AECOM	AECOM Technical Services, Inc.
ASTM	ASTM International
bls	below land surface
BSB	Base Support Building
CAC	Colloidal Activated Carbon
cm^3	cubic centimeters
DEP	Department of Environmental Protection
DoD	Department of Defense
DoE	Department of Energy
DPT	direct push technology
Geosyntec	Geosyntec Consultants, Inc.
HFPO-DA	Hexa-fluoro-propylene Oxide Dimer Acid
IDW	Investigation Derived Waste
KSC	Kennedy Space Center
KSCRT	KSC Remediation Team
NASA	National Aeronautics and Space Administration
PFAS	Per- and Polyfluoroalkyl Substances
PFBS	Perfluorobutanesulfonic acid
PFHxS	Perfluorohexanesulfonic Acid
PFM	Passive Flux Meter
PFNA	Perfluorononanoic acid
PFOA	perfluorooctanoic acid
PFOS	Perfluorooctanesulfonic Acid
PRB	Permeable Reactive Barrier
PSWP	Pilot Study Work Plan
PVC	polyvinyl chloride
QSM	Quality Systems Manual
RCRA	Resource Conservation and Recovery Act
Regenesis	Regenesis Remediation Solutions
RSL	Regional Screening Level
SAP	Sampling and Analysis Plan
SGS	SGS North America, Inc.

SOP	standard operating procedure
SWMU	Solid Waste Management Unit
TOC	Total Organic Carbon
UIC	underground injection control
USEPA	U.S. Environmental Protection Agency

1. INTRODUCTION

1.1 OVERVIEW

This document is a Pilot Study Work Plan (PSWP) for a PlumeStop® permeable reactive barrier (PRB) at the Base Support Building (BSB; the Site) located at the John F. Kennedy Space Center (KSC), Florida. The Site has been designated as Solid Waste Management Unit (SWMU) 014 under KSC's Resource Conservation and Recovery Act (RCRA) Corrective Action program. The Site is located in the northwest corner of the KSC Industrial Area along A Avenue Southeast, between 2nd Street Southeast and 3rd Street Southeast, as shown on **Figure 1**. This document was prepared by AECOM Technical Services, Inc. (AECOM) for the National Aeronautics and Space Administration (NASA) under Indefinite Delivery Indefinite Quantity Contract 80KSC019D0010, Task Order 80KSC021F0096. An Advance Data Package (ADP) presentation of the elements of this Pilot Study Work Plan was presented to the KSC Remediation Team (KSCRT) on November 29, 2023 and is provided as **Appendix A**.

Per- and polyfluoroalkyl substances (PFAS) Phase I, II, and III SWMU Assessment and Confirmatory Sampling were conducted at the BSB from 2019 through 2021 (AECOM, 2022). As part of these activities, soil and groundwater PFAS samples were collected from select monitoring wells, select soil boring locations, and numerous direct push technology (DPT) locations. The results were screened against the United States Environmental Protection Agency (USEPA) Regional Screening Levels (RSLs) for six PFAS compounds, including perfluorooctanoic acid (PFOA), perfluorooctanesulfonic acid (PFOS), perfluorobutanesulfonic acid (PFBS), perfluorononanoic acid (PFNA), perfluorohexanesulfonic acid (PFHxS) and Hexa-fluoro-propylene Oxide Dimer Acid (HFPO-DA). Five PFAS compound concentrations, PFOA, PFOS, PFBS, PFNA, and PFHxS exceeded the RSLs, and the site advanced to confirmatory sampling activities. The results were also screened against the Florida Department of Environmental Protection (DEP) Provisional PFOA and PFOS Cleanup Target Levels/Screening Levels (Florida DEP, 2020). Additional assessment activities were completed in 2022 by HydroGeoLogic Inc. and summarized in the October 2022 PFAS Site Assessment Report ADP; figures showing the results from the sampling activities are provided in **Appendix B**.

This PSWP details the permeable reactive barrier (PRB) being installed at the BSB to decrease concentrations of PFAS in downgradient groundwater using PlumeStop®. PlumeStop® is a colloidal activated carbon (CAC) that PFAS compounds readily adsorb to. A PlumeStop® technical bulletin is provided in **Appendix C**. This PSWP outlines the design criteria, injection plan, and performance monitoring schedule for the proposed PlumeStop® PRB study that will guide the selection for use and design of future full-scale PlumeStop® PRBs at KSC.

1.2 PURPOSE

The purpose of this pilot study is to determine the efficacy of a PlumeStop® PRB at KSC and collect field data to assist in the design of full-scale implementation if PlumeStop® is found to be

a viable solution. PFAS compounds adsorb to the CAC PRB as groundwater flows through the matrix, terminating the migration of impacted groundwater downgradient of the PRB. The pilot study will be completed in the shallow portion of the surficial aquifer from 3 to 13 feet below land surface (bls).

1.3 PILOT STUDY OBJECTIVES

The objectives of this pilot study are to provide information on PRB design characteristics at KSC and to aid in future modeling and remedial designs to prevent PFAS migration in groundwater. The specific goals of the Pilot Study are to:

- Observe changes in PFAS mass flux in groundwater downgradient of the PlumeStop® PRB.
- Determine if groundwater flow is being diverted around or under the PRB.
- Acquire design parameters necessary for future remedial design activities, specifically injection rate, volume, spacing, pressure, PlumeStop® concentration, and any prevalence of daylighting.

In addition to gathering data on injection characteristics, water quality data and groundwater elevations will be observed before, during, and after the injection event to provide additional data for future remedial designs.

1.4 PILOT STUDY WORK PLAN ORGANIZATION

This Pilot Study Work Plan is organized as follows:

Chapter 1 – Introduction
Chapter 2 – Pilot Study Design
Chapter 3 – Pilot Study Field Tasks, Monitoring, and Reporting
Chapter 4 - References

2. PILOT STUDY DESIGN

Injection points completed via Direct Push Technology (DPT) will deliver CAC to the shallow portion of the surficial aquifer and monitoring wells will be installed to monitor the effects of the CAC as detailed in the following sections.

2.1 INJECTION DESIGN SUMMARY

The pilot study consists of injecting CAC into the subsurface through twelve direct push injection points. A DPT rig will push 1.5-inch drill rods to a depth of 13 feet bls. Regenesis Remediation Solutions (Regenesis) will then use pumps to inject CAC into the shallow portion of the surficial aquifer while the DPT rig slowly raises the injection screen up to three feet bls. This process will be completed for each of the 12 injection points. Regenesis may simultaneously inject CAC at multiple injection points depending on field conditions such as pressures, distribution, and daylighting.

Following completion of each injection location, the injection boreholes will be allowed to naturally cave in when the injection tooling is removed. Site soil material and clean sand will be used to fill in any remaining voids. Details of the injection points and PlumeStop® dosage are discussed in the following sections.

2.1.1 Injection Layout

Two parallel rows of six injection points, separated by five feet, will be completed to form a 30-foot-wide arc as depicted on **Figure 2**. The orientation of the PRB is designed to be perpendicular to the average shallow groundwater flow direction through the site. The shallow groundwater flow direction at the site is variable; however, the average flow direction was observed to be west-northwest as shown in **Appendix A**. The average depth to water at the BSB shallow monitoring wells is approximately 3.0 feet bls. Therefore, the injection interval was set at 3 to 13 feet bls.

2.1.2 Design Criteria and PlumeStop® Dosage

The proposed injection design, developed by Regenesis, is based on historical data and general assumptions about the site's hydrogeological parameters. Seepage velocity and mass flux are the primary variables in determining the required PlumeStop® dosing. A hydraulic conductivity of 20 feet per day was measured from slug tests performed in 1991 at the BSB. Based on the site hydraulic conductivity, a seepage velocity of 82.5 feet per year was calculated.

Regenesis used the seepage velocity, soil type, porosity, and hydraulic gradient of the groundwater to calculate their recommended product dosing as shown in **Table 1**. Each injection location will utilize 367 pounds of PlumeStop® mixed with 360 gallons of water, totaling 400 gallons of application solution. The PlumeStop® solution will be applied uniformly at intervals between 3 and 13 feet bls.

Table 1: PlumeStop® Injection Design Criteria

Design Summary

Design Parameters	Units	Value
Treatment Type		Barrier
Distance Perpendicular to Flow	feet	30
Top Application Depth (feet bls)	feet bls	3
Bottom Application Depth (Feet bls)	feet bls	13
Vertical Treatment Interval	feet	10
Soil Type		Silty Sand
Porosity	cm^3/cm^3	0.33
Effective Porosity	cm^3/cm^3	0.23
Hydraulic Gradient	feet/foot	0.026
Groundwater Velocity	feet/year	82.5
Effective Pore Volume Occupancy		71%
Application Summary		
Spacing Within Rows	feet	5
Number of Rows		2
DPT Injection Points		12
Product Dosage		
PlumeStop®	pounds	4,400
Water Required	gallons	4,305
Total Volume Applied	gallons	4,793

Abbreviations:
bls – below land surface
cm3 – cubic centimeter
DPT – direct push technology

Prior to the injection event, design verification testing will take place. Design verification testing will include soil grain size analysis, groundwater elevation measurements, and baseline groundwater sampling to provide updated soil porosity, groundwater flow, and mass flux data that may be used to modify the final injection design criteria.

2.2 MONITORING WELL INSTALLATION DETAILS

Prior to the injection event, seven monitoring well pairs will be installed within and around the proposed injection locations, as shown in **Figure 2**, to monitor groundwater elevations and PFAS concentrations throughout the pilot study. Design criteria for the monitoring well installations are discussed in the following sections.

2.2.1 Monitoring Well Layout

The monitoring well layout was designed to collect groundwater data upgradient, downgradient, and side-gradient of the PRB. The locations of the seven proposed monitoring well pairs are as

follows: (1) 30 feet upgradient, (1) within the PRB, (1) 10 feet downgradient, (1) 20 feet downgradient, (1) 35 feet downgradient, and (2) 22 feet from the PRB center along the ends of the injection layout. The monitoring well layout is depicted on **Figure 2**.

The proposed monitoring well screen intervals are 3 to 13 feet bls (shallow) and 13 to 23 feet bls (shallow-intermediate). The shallow monitoring wells are designed to collect data within the injection interval and the shallow-intermediate wells are set to collect data directly beneath the injection interval.

2.2.2 Monitoring Well Construction

The monitoring well construction details presented in this section are based on the historical subsurface hydrogeology at the site and guidance provided in the KSC Sampling and Analysis Plan (SAP) (Geosyntec Consultants, Inc. [Geosyntec] 2017). Well installation activities will be completed by a licensed well drilling contractor using rotosonic equipment. The licensed driller will obtain the necessary well installation permits prior to installation. Investigation derived waste (IDW) will be drummed for temporary storage on-site.

Monitoring well construction details are shown on **Figure 3**. Construction details include the following:

- Minimum borehole diameter is 6 inches.
- Each monitoring well will be constructed of 2-inch diameter Schedule 40 polyvinyl chloride (PVC) casing with 0.010-inch slotted Schedule 40 PVC screen.
- Casing sections will be flush joint threaded with a Neoprene O-ring or other means of rendering the joint airtight.
- A filter pack will be installed in the annular space around the well screen and extend approximately 6 inches above the top of screen for the shallow wells and 12 inches for the shallow-intermediate wells. The filter pack will be 20/30 silica sand (ASTM International [ASTM] 2017).
- A filter pack seal, consisting of either 30/65 silica sand or bentonite clay, will be installed above the filter pack. The filter pack seal will be installed to the full borehole diameter achieving a minimum thickness of 1 foot for the shallow wells and 2 feet for the shallow-intermediate wells. The depth of the top of the filter pack seal will be confirmed by direct measurement during installation. The bentonite seal will be left to hydrate for the time recommended by the manufacturer before continuing well installation activities.
- Type I/II Portland cement (grout), mixed with potable water using a 1:1 grout to water ratio, will then be installed from the bentonite seal to land surface.
- The filter pack, filter pack seal, and grout will be installed using a tremie pipe, as necessary, to ensure a continuous filter and seal free of voids.
- The wells pairs will be oriented at 10 degrees (perpendicular to the average shallow groundwater flow direction).

- The wells within each pair will be installed 3 feet apart.
- Flush-mount 8-inch well vaults with a single 2-foot by 5-foot concrete pad will be installed for each well pair.

2.2.3 Well Development

The monitoring wells will be developed using a centrifugal or submersible pump until the development water runs clear. Well development activities will be performed no sooner than 24 hours after installation to allow sufficient time for grout curing. Investigation Derived Waste (IDW) will be drummed for temporary storage on-site.

2.3 IDW MANAGEMENT

IDW will be containerized in 55-gallon steel drums. Soil will be stored in open-top drums while development and decontamination water will be stored in closed-top drums. Following the injection event, the IDW drums will be transported to the Component Cleaning Facility or Paint and Oil Locker IDW storage areas and positioned on the provided secondary containment pallets.

One soil sample will be collected from each drum of drill cuttings. Chemical analysis will be performed by SGS North America, Inc. (SGS), a Department of Defense (DoD) Environmental Laboratory Accreditation Program and Florida National Environmental Laboratory Accreditation Program accredited laboratory. Analyses will be performed in accordance with USEPA Method 537M for 29 PFAS compounds incorporating the requirements of the DoD Department of Energy (DoE) Consolidated Quality Systems Manual (QSM) for Environmental Laboratories, Version 5.3, or the most recent version at the time of sampling. One aqueous sample will be collected from each drum of development and decontamination water and analyzed by SGS in accordance with USEPA Method 537M for 29 PFAS compounds and DoD DoE QSM 5.3, USEPA Method 300.0 for nitrates, and USEPA Method 365.4 for total phosphorus.

The soil wastes will be managed based on comparison of the results for PFOS and PFOA to the State of Florida provisional soil cleanup target levels. The DEP will be notified of results and the proposed method of disposition. Liquid wastes are expected to be treated through NASA's granular activated carbon system for PFAS IDW.

3. PILOT STUDY FIELD TASKS, MONITORING, AND REPORTING

This section details the preliminary and operational details for the pilot study, as well as the reporting activities that will be conducted following the study.

3.1 PRELIMINARY FIELD ACTIVITIES

The following administrative tasks will be performed prior to the monitoring well installations, soil core collection, and injection event.

3.1.1 Permitting and Utility Locate

Prior to implementing any intrusive activities, a dig permit will be obtained for clearing and ground penetrating work by submitting an Excavation/Utility Locate Permit Request to KSC's permit office. Upon approval, activities will commence in adherence to any comments attached to the approved Dig Permit. Utility locates by both the KSC Utility Locate office and Florida's Sunshine 811 will be completed with enough lead time to allow for any changes that may become apparent during utility locate efforts. In addition, dig permit applications will include in-person marking of the locations for intrusive work and presence on-site during the locate. Intrusive activities will not commence until utility locates are complete and the Excavation/Utility Locate Permit Request is signed by a KSC locator.

Prior to the injection event, an underground injection control (UIC) permit will be obtained from the Florida DEP for injecting PlumeStop® into the subsurface. In accordance with the UIC permitting guidelines for PlumeStop®, aluminum will be monitored in the groundwater from two pairs of monitoring wells: the central PRB well pair and the furthest downgradient well pair. Aluminum will be monitored quarterly for a minimum of four quarters and screened against the Florida DEP secondary drinking water standard or the background concentration (whichever is less stringent). The UIC permit notification and regulatory guidelines for PlumeStop® are included in **Appendix D**.

3.1.2 Ecological Survey

The monitoring well, soil boring, and injection locations will be marked for inspection by KSC ecological staff. Pilot study locations may be shifted as necessary based on the results of the ecological survey; however, the marked locations are expected to remain as designed since no tortoise burrows or other potential ecological receptors were present during initial site visits.

3.1.3 Vegetation Clearing

Grass mowing activities occur regularly through the KSC landscaping contractor. No additional clearing is required.

3.2 DESIGN VERIFICATION TESTING

Design verification testing will occur prior to the injection event. The following activities are intended to verify the injection design parameters. Data collected through verification testing may warrant final design adjustments prior to the injection event.

3.2.1 Soil Core

AECOM will complete a soil core to a depth of 50 feet bls within the proposed PRB area. The proposed soil core location is shown on **Figure 2** as one of the soil boring locations. Lithology details will be recorded, and soil samples will be collected from 8 and 18 feet bls, or within different soil types based on field observations. The soil samples will be submitted to SGS for grain size analysis by ASTM D422 and total organic carbon (TOC) by USEPA SW9060A to aid in verifying hydrogeological design parameters and establish background TOC concentrations prior to the carbon injection activities.

3.2.2 Vadose Soil Sampling

The vadose zone at the Site is from ground surface to the smear zone, or approximately three feet bls. Two vadose soil samples will be collected at the pilot study site from a depth of 2 to 3 feet bls, or one foot above the apparent water table based on field observations. One sample will be collected at the well pair location within the proposed PRB, and the second sample will be collected from the well pair location 20 feet downgradient of the PRB. The vadose soil sample locations are depicted on **Figure 2**. The vadose soil samples will be submitted to SGS and analyzed in accordance with USEPA Method 537M for 29 PFAS compounds incorporating the requirements of DoD DoE QSM 5.3. These soil samples will be used to measure PFAS concentrations in the vadose zone that may leach into the groundwater during the pilot study.

3.2.3 Monitoring Well Installations and Baseline Groundwater Sampling

Seven pairs of monitoring wells will be installed prior to the injection event. The monitoring wells will be positioned upgradient, downgradient and side-gradient of the proposed injection area and constructed as detailed in Section 2.2.

Baseline groundwater sampling will be completed at the 14 pilot study monitoring wells. The samples will be submitted to SGS and analyzed in accordance with USEPA Method 1633 for 40 PFAS compounds incorporating the requirements of DoD DoE QSM 5.3, and USEPA Method SW9060A for TOC analysis. Samples collected from the monitoring well pair within the proposed PRB and the furthest downgradient well pair will also be analyzed for aluminum by USEPA SW-846 6010D to comply with UIC regulations for PlumeStop® injection sites. Additionally, groundwater parameters like pH, temperature, dissolved oxygen, conductivity, turbidity, and salinity will be recorded to establish baseline readings.

Groundwater elevations will be collected at the 14 pilot study monitoring wells and four existing shallow monitoring wells at the Site (M_O-SCA-IW0001S, M_O-WOS-IW0001S, M_O-PI-IW0002S, and M_O-OWS-IW0003S) The four existing shallow monitoring well locations are shown in **Appendix E**. Based on the comprehensive shallow groundwater flow map generated from the 18 monitoring wells, the injection layout orientation may be adjusted slightly to be perpendicular to the updated groundwater flow direction.

After the baseline groundwater samples are collected, two passive flux meters (PFMs), consisting of five two-foot-long canisters, will be installed in the monitoring well pair within the proposed PRB. The proposed PFM location is depicted on **Figure 2**. The PFMs will be suspended within the screen interval of both monitoring wells and deployed for three weeks before being retrieved and submitted for laboratory analysis. PFAS mass flux and groundwater velocity will be analyzed, providing data at distinct intervals between 3 and 23 feet bls.

Field activities will be performed in accordance with the Florida DEP Standard Operating Procedures (SOPs) (Florida DEP 2005, 2018), PFAS sampling guidelines provided by the Michigan Department of Environmental Quality (2018), and the KSC SAP (Geosyntec 2017).

3.3 INJECTION EVENT AND PLACEMENT VALIDATION

AECOM will provide oversight of the injection event performed by Regenesis and a licensed drilling contractor. AECOM and Regenesis will monitor the injection activities and collect field readings.

3.3.1 Injection Event

Totes of PlumeStop®, drilling equipment, and auxiliary tools and materials will be temporarily stored at the BSB adjacent to the pilot study area. The concentrated PlumeStop® product will be diluted to the injection ratio determined during the design verification testing process and mixed onsite in a remediation trailer provided by Regenesis. Injection dilution water will be sourced from a hydrant located approximately 100 feet northwest of the pilot study area.

The drilling contractor will advance injection tooling with a DPT drill rig to the desired depth interval. Regenesis will then connect the injection tooling to the remediation trailer with pressure rated hose and begin injecting the PlumeStop® solution. When the intended product volume has been injected, the drillers will move the injection tooling to the next interval and Regenesis will repeat the injection procedure. If necessary, product may be simultaneously injected through two or more locations during the event depending on field conditions and injection parameters, like injection pressure and daylighting.

3.3.2 Placement Validation

At the beginning of the injection event, two temporary one-inch piezometers will be installed by Regenesis within the PRB area. The piezometers will have screened intervals of 3 to 8 feet bls

and 8 to 13 feet bls, respectively. Groundwater elevation measurements and water color data will be recorded throughout the injection event to confirm the radius of influence during injections. Filter fabric may be used to cover the piezometer screen sections; however, no additional filter pack or surface seals will be used. The piezometers will be removed at the conclusion of the injection event, and the boreholes will be allowed to naturally cave in. Site soil material and clean sand will be used to fill in any remaining voids.

During the injection event, field readings and observations will be recorded from the injection locations, monitoring wells, and temporary piezometers to evaluate the pilot study design criteria and collect data for full scale implementation. Real-time injection pressure and flow rates will be digitally recorded at the injection locations. Groundwater elevations will be recorded throughout the event to monitor application influence. Groundwater parameters will be analyzed within the pilot study monitoring wells using a water quality meter (e.g. YSI Pro or equivalent), and PlumeStop® concentration field analyses will be performed. A high concentration of PlumeStop® in the adjacent monitoring wells is expected during application; however, it is expected to slowly dissipate.

At the conclusion of the injection event, Regenesis will complete one soil boring within the PRB using Macro-Core® soil sleeves from 3 to 13 feet bls to observe CAC distribution in the soil matrix. The 1.25-inch soil cores will be completed by a licensed driller with a DPT drill rig. The Macro-Core® sleeves, removed from the drill rods after the boring interval is completed, will be opened to gain access to the captured soil core. Since the CAC should darken the soil, the core will be visually evaluated to determine distribution of the CAC. The borehole will be allowed to naturally cave in, and any remaining voids will be filled with site soil material and clean sand.

3.4 PERFORMANCE MONITORING

Following completion of the injection event, performance monitoring will begin. Monthly groundwater sampling will be completed at the 14 pilot study monitoring wells for six months, and then quarterly sampling will proceed for up to two years. The samples will be submitted to SGS and analyzed in accordance with USEPA Method 1633 for 40 PFAS compounds incorporating the requirements of DoD DoE QSM 5.4, and USEPA Method SW9060A for TOC analysis. Groundwater parameters will be recorded during each sampling event. Field analysis of PlumeStop® concentration may be performed if very dark groundwater samples are collected. A high product concentration may affect laboratory analysis; therefore, great care will be taken to ensure the groundwater samples are adequate to submit to the laboratory.

Groundwater samples from the monitoring well pair within the PRB and the furthest downgradient well pair, as shown in Figure 2, will also be analyzed for aluminum by USEPA Method SW-846 6010D on a quarterly schedule to comply with UIC regulations for PlumeStop® injection sites. Aluminum will be analyzed at the two pairs of monitoring wells for a minimum of four quarters and screened against the Florida DEP secondary drinking water standard or the background concentration (whichever is less stringent). The UIC regulatory guidelines for PlumeStop® are included in **Appendix D**.

During each performance monitoring event, groundwater elevations will be collected at the 14 pilot study monitoring wells and four existing shallow monitoring wells at the Site (M_O-SCA-IW0001S, M_O-WOS-IW0001S, M_O-PI-IW0002S, and M_O-OWS-IW0003S). The four existing shallow monitoring well locations are shown in **Appendix E**. The recurring shallow groundwater flow maps generated from the 18 monitoring wells will provide comprehensive groundwater flow patterns within the area of the pilot study.

As a component of the performance monitoring activities, two additional PFMs will be installed in the monitoring well pair within the PRB for approximately three weeks. Timing of the PFM deployment will be determined when PFAS groundwater concentrations begin to decrease, which is expected to occur within the first six months following the injection event. PFAS mass flux and groundwater velocity will be analyzed, providing data at distinct intervals between 3 and 23 feet bls.

3.5 REPORTING

When the injection event is completed, Regenesis will provide AECOM with a detailed injection summary report including injection point data (interval depths, injection pressure/flow rates, reagent volume, time elapsed, and if any daylighting occurred) and field observations. The injection summary report will be evaluated and included the Pilot Study Report.

Following completion of the pilot study performance monitoring, a Pilot Study Report will be prepared documenting soil core lithology and soil sample analysis, results of the baseline groundwater sampling, injection procedures and any problems encountered, results of the performance monitoring, and a summary of the conclusions and recommendations for full-scale implementation. An ADP will also be prepared for presentation to the KSCRT to summarize the results of the pilot study and recommendations for full-scale implementation.

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4. REFERENCES

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FIGURES

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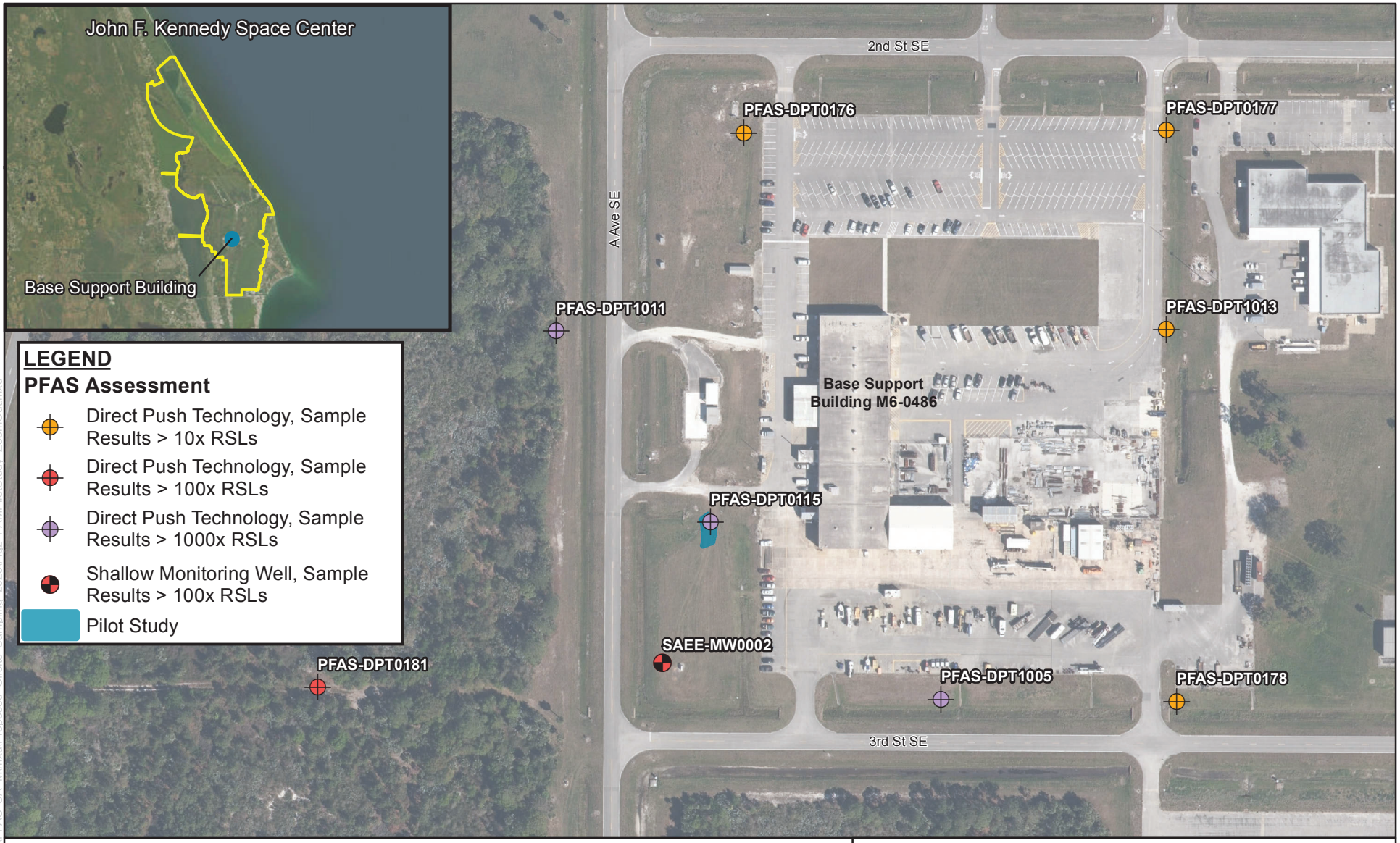

NOTE:
RSL = Regional Screening Level

MAPPING NOTES:
Basemap Source: Orthoimagery from Brevard County, 2018.
Projection Coordinate System: NAD 1983 StatePlane Florida East FIPS 0901
Scale: 1 Inch = 200 Feet

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0 100 200 Feet

FIGURE 1
PlumeStop® Injection Pilot Study Location

JOHN F. KENNEDY
SPACE CENTER
MERRITT ISLAND, FLORIDA

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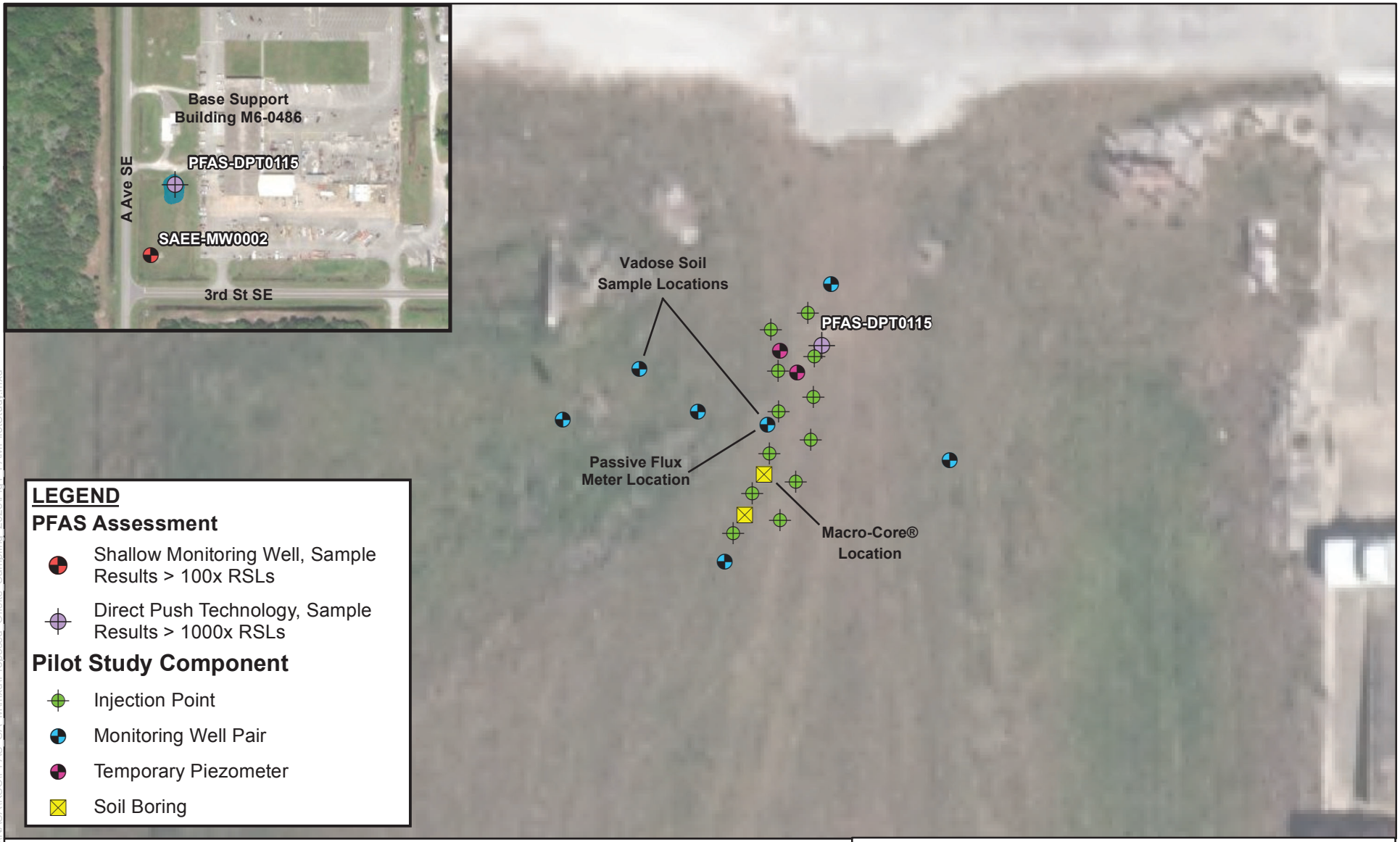

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Projection Coordinate System: NAD 1983 StatePlane Florida East FIPS 0901
Scale: 1 Inch = 20 Feet

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0 10 20 Feet

FIGURE 2
Base Support Building
PlumeStop® Injection Pilot Study Layout
JOHN F. KENNEDY
SPACE CENTER
MERRITT ISLAND, FLORIDA

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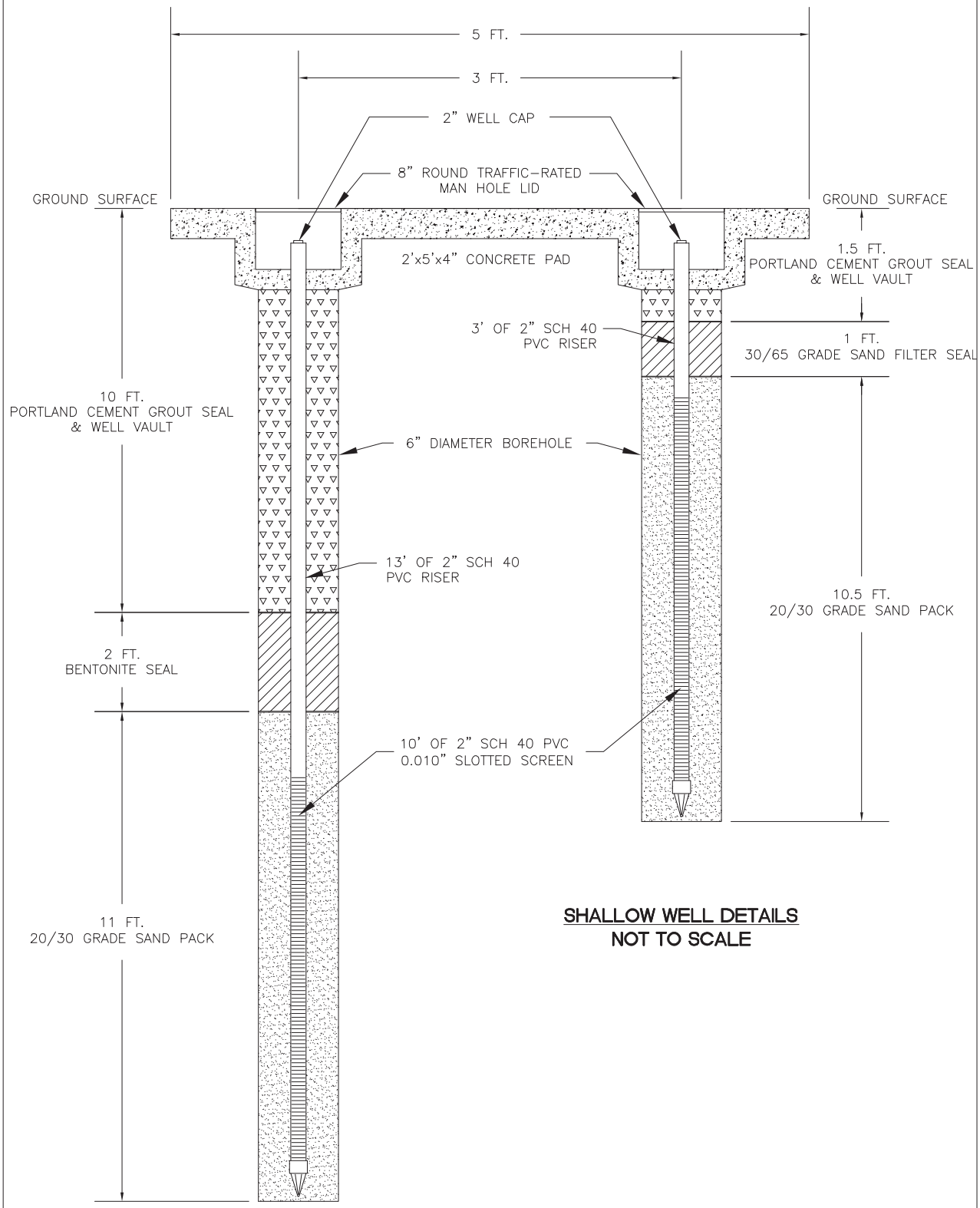

SHALLOW WELL DETAILS
NOT TO SCALE

SHALLOW-INTERMEDIATE WELL DETAILS
NOT TO SCALE

NOTE:
1. Depth of monitoring well screens are provided in feet below land surface (FT BLS).

NASA Kennedy Space Center, Florida
PlumeStop Injection Pilot Study
Base Support Building

Monitoring Well Construction Details

AECOM

Figure: 3

APPENDIX A
PlumeStop® Pilot Study Work Plan Advanced Data Package, November 2023

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Per- and Polyfluoroalkyl Substances (PFAS) Site Assessment and Mitigation

PlumeStop® Injection Pilot Study Work Plan

Base Support Building (Formerly Maintenance & Operations Building)

December 2023

This Advance Data Package (ADP) was prepared for NASA to aid in the evaluation of site conditions and remedial actions. This is not a decision document. New information may come to light that makes this ADP outdated.

Outline

1) Introduction
2) Design Criteria
3) Design Verification Testing
4) Injection Event & Placement Validation
5) Performance Monitoring
6) Conclusions

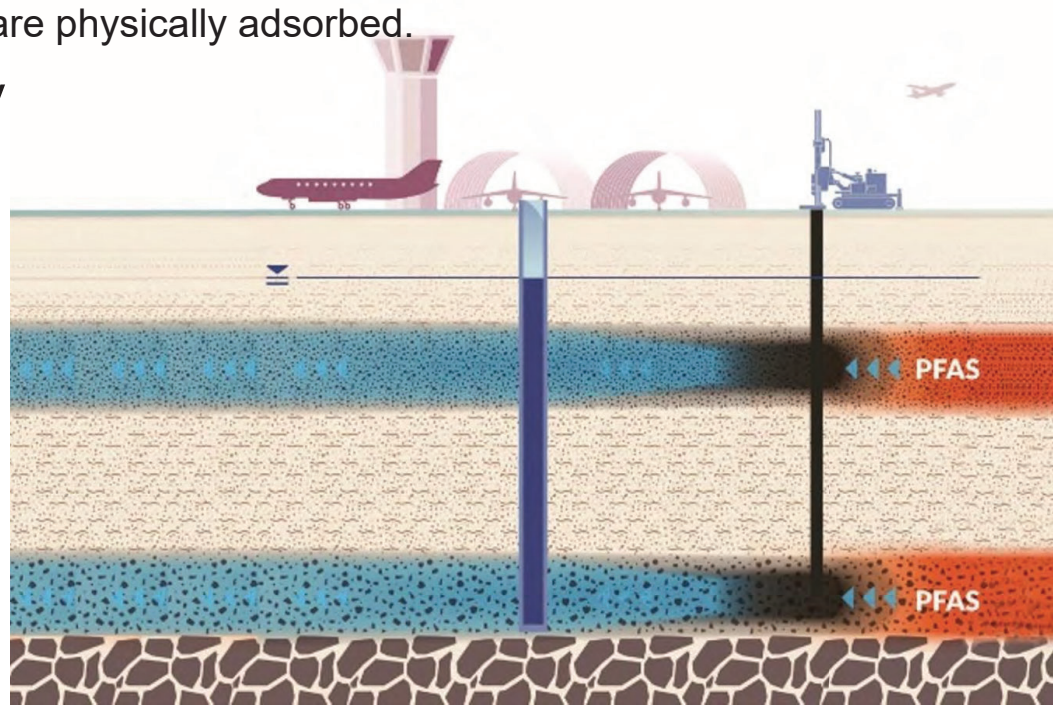
1

Introduction

1

Abatement Concept: PlumeStop® Permeable Reactive Barrier

- Create a groundwater permeable reactive barrier (PRB) for PFAS using PlumeStop®
  - PlumeStop Colloidal Biomatrix: An aqueous, colloidal activated carbon fluid suspended using an organic polymer.
  - Injected into the subsurface under low pressure.
  - Binds to the aquifer matrix where contaminants are physically adsorbed.
- Goal: Demonstrate PlumeStop® efficacy at Kennedy Space Center (KSC).
  - Reduce off-site PFAS migration.
  - Reduce discharge of PFAS to surface water.
- Base Support Building selected as the study site.
  - Relatively high PFAS concentrations.
  - Suspected discharge to surface water.
  - No potential conflicts with concurrent pilot studies.



Picture Source: PlumeStop Pilot Study Proposal, NASA Kennedy Space Center, Florida, Regenesis Remediation Services

aecom.com

Pilot Study Site Description

1

- Base Support Building (formerly known as Maintenance and Operations Building) – Solid Waste Management Unit (SWMU) 014
  - Located at the NW corner of the KSC Industrial Area (IA) at the intersection of Third Street and A Avenue.
  - Constructed in 1964 to support space flight operations at KSC.
  - Previous site activities included painting, carpentry, electrical work, fuel storage and dispensing, metal work, vehicle and heavy equipment maintenance, steam cleaning, and battery maintenance and storage.
  - Approximately 20 gallons of aqueous film-forming foam (AFFF) was released during maintenance repairs on a fire engine on November 2, 2006.
  - Other non-reported AFFF releases likely occurred during routine fire engine maintenance activities.

Figure Source: Confirmatory Sampling Work Plan, Maintenance and Operations Building, SWMU 014, NASA Kennedy Space Center, Florida, HydroGeoLogic Inc.

Base Support Building Site History

- Resource Conservation and Recovery Act Facility Investigation and risk evaluation completed in 2001.
  - Volatile organic compounds (VOCs) and iron exceeded Florida Groundwater Cleanup Target Levels (GCTLs).
  - Treatment strategy: monitored natural attenuation (MNA).
  - Long term monitoring between 2002 and 2018.
    - Iron removed from analyte list in 2004 due to no potential source of iron.
    - VOCs below GCTL in 2018 → MNA discontinued.

Base Support Building Site History

1

- Center-Wide PFAS SWMU Assessment and Confirmatory Sampling
  - PFAS concentrations in groundwater exceeded provisional GCTLs and EPA Regional Screening Levels (RSLs)
  - PFAS concentrations in soil exceeded provisional Soil Cleanup Target Levels (SCTLs) and EPA RSLs
  - PFAS concentrations in surface water exceeded Florida Surface Water Screening Levels (SWSLs)
  - SWMU Assessment and Confirmatory Sampling Report recommended a PFAS site assessment.

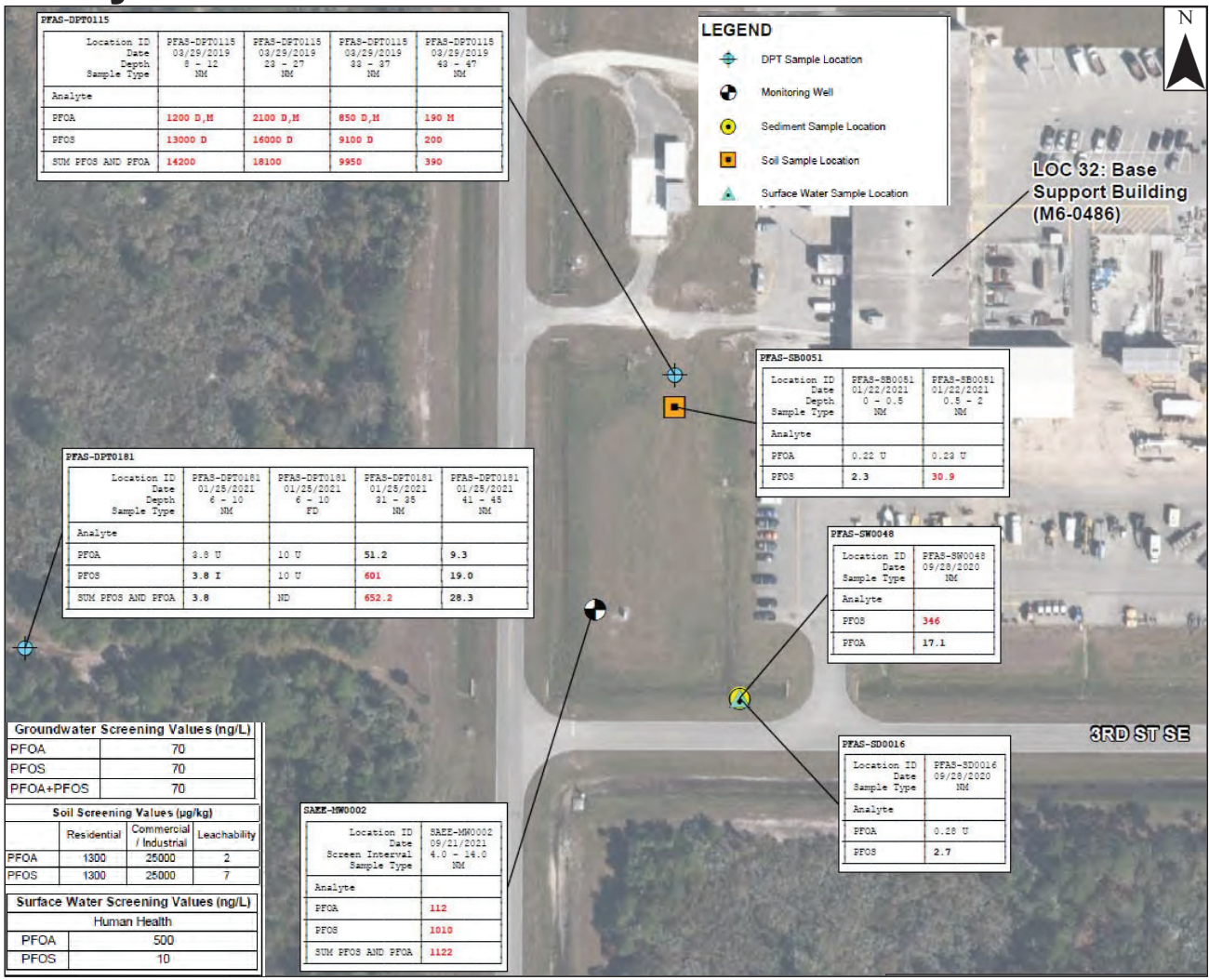


Figure Source: Phase II and III SWMU Assessment and Confirmatory Sampling Report, Center-Wide PFAS, NASA Kennedy Space Center, Florida, AECOM

Base Support Building Site History

1

– 2022 PFAS Investigation Summary (Performed by HydroGeoLogic)
  - Advanced three lithologic borings to 60 feet below land surface (bls).
  - Partial lateral delineation: Impacts were widespread and likely comingled with PFAS plumes from other sites in the IA.
  - Vertical delineation incomplete: Impacts may extend to a depth of at least 55 feet bls. The silt and clay layer around 60 feet bls may serve as a retarding unit.
  - All sampled surface water bodies in the western industrial area exceeded SWSLs.
  - Data supports that there is an exchange of impacted water from surface water to groundwater and groundwater to surface water.

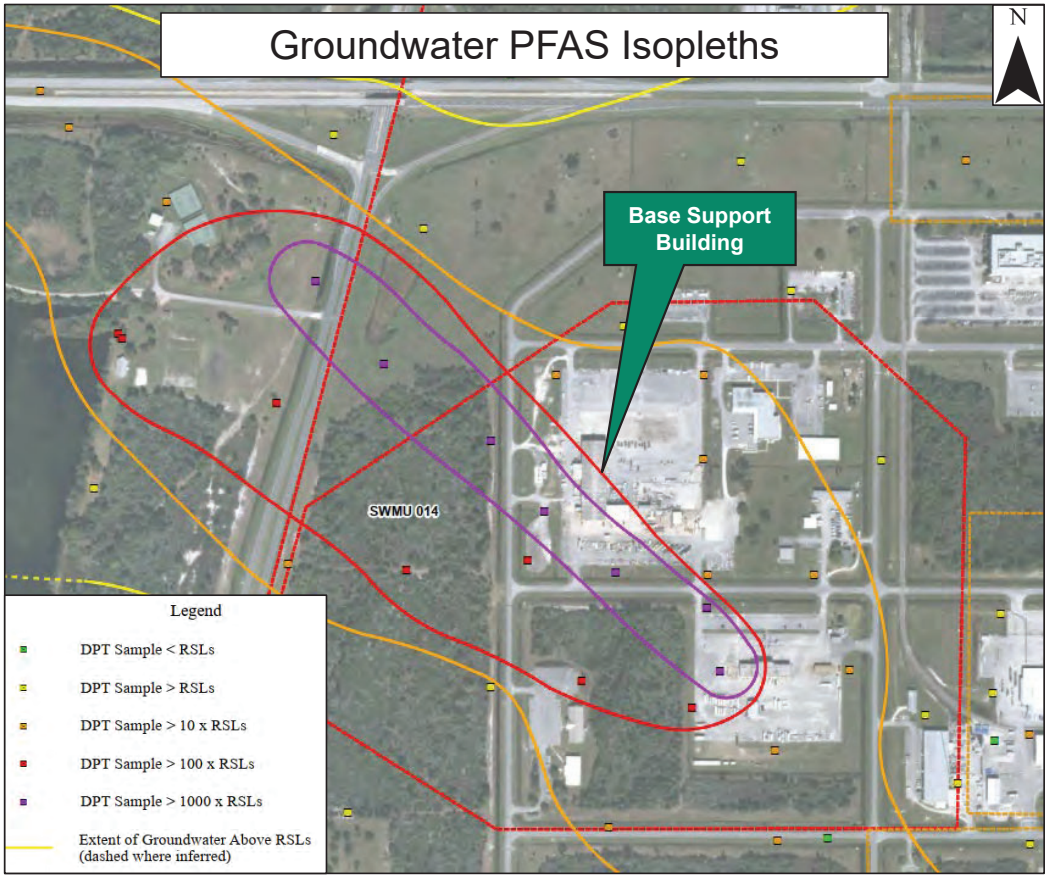


Figure Source: PFAS Site Assessment Report ADP, SWMU-014 and SWMU 118 Base Support Building and KARS Park 2, NASA Kennedy Space Center, Florida, HydroGeoLogic Inc.

Pilot Study Objective

1

- Validate the concept of a PlumeStop® PRB at KSC in the shallow interval.
- Specific goals:
  - Observe changes in PFAS mass flux in groundwater downgradient of the PlumeStop® PRB.
  - Acquire design parameters necessary for future remedial design and implementation activities.
    - Injection rate, spacing, depth, volume, and concentration.
    - Observed backpressure.
    - Prevalence of daylighting.
- Desirable performance metrics:
  - Ease of injection with minimal daylighting and/or short-circuiting of injectate material.
  - No disruption of groundwater flow gradient or pathways compared to pre-injection conditions.
  - Significant reduction in PFAS groundwater mass flux and/or groundwater concentrations.
- Data analysis will include:
  - **Design verification testing** - provides critical data to verify or adjust the design prior to the substrate injection event.
  - **Placement validation** - evaluates the design criteria, like injection spacing and volume, during the injection event.
  - **Performance monitoring** - provides data to determine PRB efficacy after the injection event.

2

Design Criteria

Site Lithology

- Shallow lithology consists of well-graded sands with occasional silty layers.
  - Brown fine sands from the ground surface to approx. 6 feet bls.
  - Light tan to light gray fine sands with some silty layers to approx. 50 feet bls.
- Soil porosity and density are currently estimated based on typical silty sand conditions.

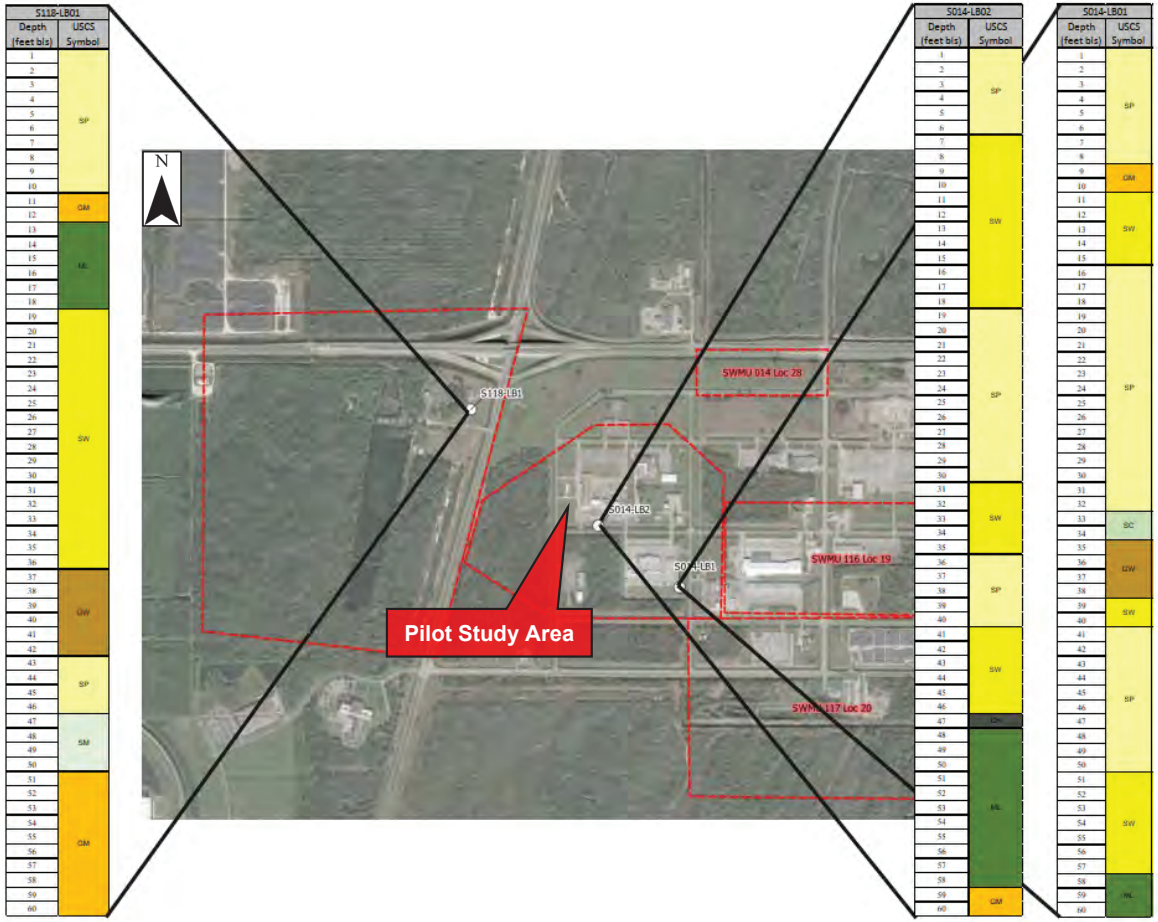


Figure Source: PFAS Site Assessment Report ADP, SWMU-014 and SWMU 118 Base Support Building and KARS Park 2, NASA Kennedy Space Center, Florida, HydroGeoLogic Inc.

Lithologic Borings

Legend	
GW	Well graded gravel
GM	Gravel with silt
GC	Gravel with clay
SW	Well graded sand
SP	Poorly graded sand
SM	Sand with silt
SC	Sand with clay
ML	Inorganic silt with low plasticity
CL	Inorganic clay with low plasticity
CH	Inorganic clay with high plasticity

3

Response to Comment

- HGL Comment #1: Slide 11: Show pilot study location on the slide.
- *Response: The pilot study location will be indicated.*

Site Lithology

– Soil cores from the boring location adjacent to the pilot study area.

S014-LB02 Soil Cores

S014-LB02

Depth (feet bls)	Brief Description
0-46'	Primarily Sand and Shell
46'-58'	Silts and Clay
58'-60'	Shell Hash with Silt

Picture Source: PFAS Site Assessment Report ADP, SWMU-014 and SWMU 118 Base Support Building and KARS Park 2, NASA Kennedy Space Center, Florida, HydroGeoLogic Inc.

Base Support Building Aquifer Characteristics (3.5-13.5 feet bls)

- Shallow GW flow direction is typically west to west-northwest around the pilot study area.
- Average sitewide depth to water is approximately 3 feet bls.
- Hydraulic conductivity is approximately 20 feet/day based on 1991 slug tests at the Base Support Building.

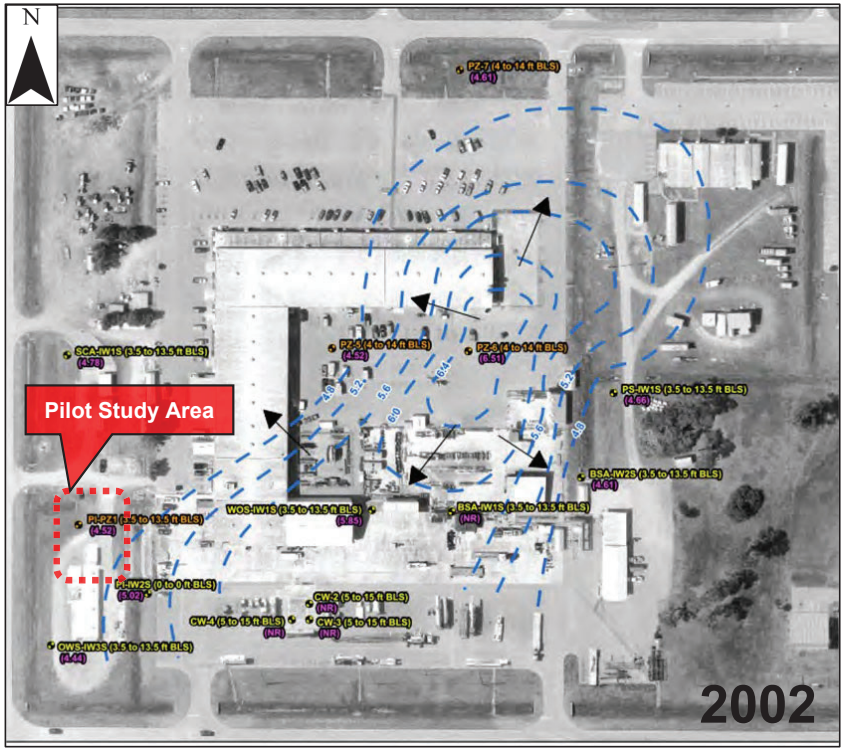
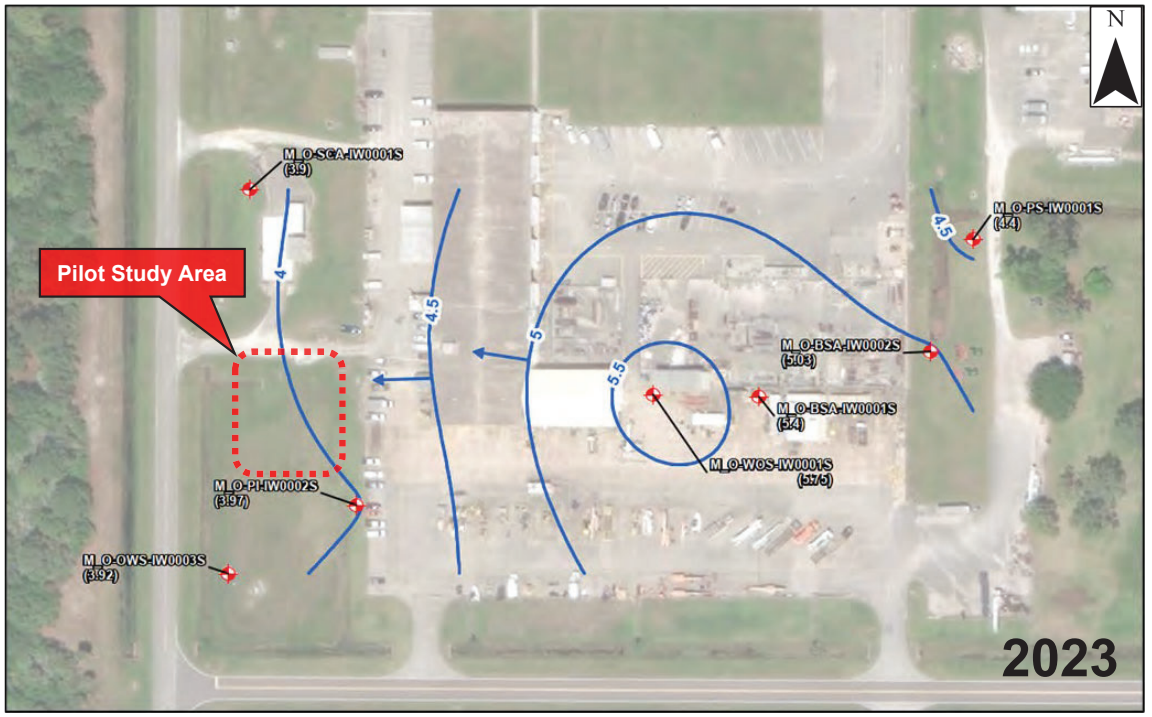


Figure Source: First Annual Long-Term Monitoring Report for the Maintenance and Operations Building, SWMU 014, Kennedy Space Center, Florida, Geosyntec Consultants



Groundwater elevation data collected by HydroGeoLogic in April 2023.
Figure created by AECOM in August 2023.

Response to Comment

- HGL Comment #2: Slide 13: Groundwater elevations are available for additional wells surrounding the Base Support Building area. Consider including these wells for contouring flow directions. Using additional data seems to indicate that there is a groundwater flow divide located in this area where flow is either northwest towards SMWU 118 (like in 2002 or to the southwest, coinciding with the ditch along A Ave SE). The primary plume axis for PFAS appears to follow the northwest flow direction. Verification of the shallow groundwater flow direction described on pages 17 and 18 should help to better define the flow direction through the proposed PRB.
- *Response: AECOM requests the data referenced to be shared. This data will be reviewed prior to implementation of the scope of work.*
- Tetra Tech Comment #1: Slide 13/15 – Please clarify if groundwater flow direction below 13.5 feet bls the same as the 3.5-13.5 feet bls interval. It is implied on Slide 15 but not clearly specified.
- *Response: The monitoring wells utilized for the potentiometric surface maps range in depth from 3.5 to 14 feet bls and have exhibited variable GW flow directions across the site. The intermediate (20-25ft) and deep (35-40ft) zones have had more uniform contour lines and typically exhibit a similar GW flow direction as the shallow zone near the pilot study area.*

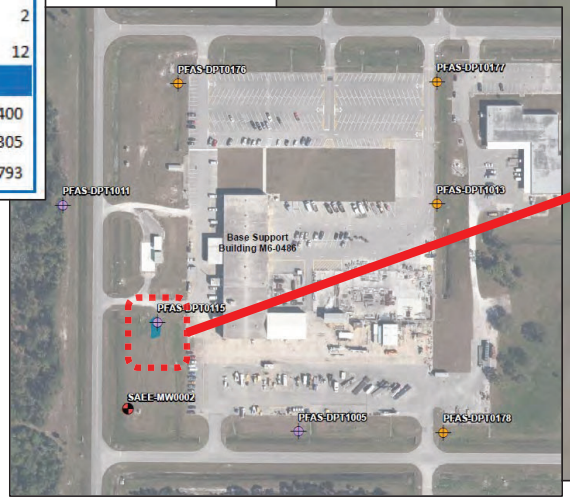
Conceptual Layout

2

Design Summary

Design Parameters	Unit	Value
Treatment Type		Barrier
Distance Perpendicular to Flow (ft)		30
Top Application Depth (ft bgs)		3
Bottom Application Depth (ft bgs)		13
Vertical Treatment Interval	ft	10
Soil Type		silty sand
Porosity	cm3/cm3	0.33
Effective Porosity	cm3/cm3	0.23
Hydraulic Gradient	ft/ft	0.0026
GW Velocity	ft/yr	41
Eff. Pore Voume Occupancy		71%
Application Summary		
Spacing Within Rows (ft)		5
Number of Rows		2
DPT Injection Points		12
Product Dosage		
PlumeStop	lbs	4,400
Water Required	gallons	4,305
Total Volume Applied	gallons	4,793

Dosage per Injection Point
PlumeStop: 367 lbs
Water: 360 gallons
Total Volume: 400 gallons



Response to Comment

- HGL Comment #3: Slide 14. Seepage velocity is 82.5 ft/yr based on hydraulic conductivity of 20 ft/day (7300 ft/yr x .0026 ft/ft)/.23 = 82.5 ft/yr. High seepage velocity (82.5 ft/yr, or 41 ft/yr as in ADP) plus quartz sand aquifer means it is possible that the PlumeStop will be actively transported rather than acting as a “fixed” barrier. Please address that possibility.
- *Response: This question was posed to Regenesis, the supplier of PlumeStop. Their reply is as follows:*

“For the proposed KSC pilot the 7 cm/day (83 ft/yr) seepage would normally not be a concern. A sediment sieve-analysis is useful in predicting any unwanted advection. With the pre-emptive application of a divalent cation solution (i.e. calcium chloride) the carbon set-up can be accelerated to 'park' the PlumeStop in the intended target treatment zone.” Grain size analyses will be performed prior to injection of the PlumeStop. If excessive advection is suspected as a result of these grain size analyses, the application of a calcium chloride solution will be considered.

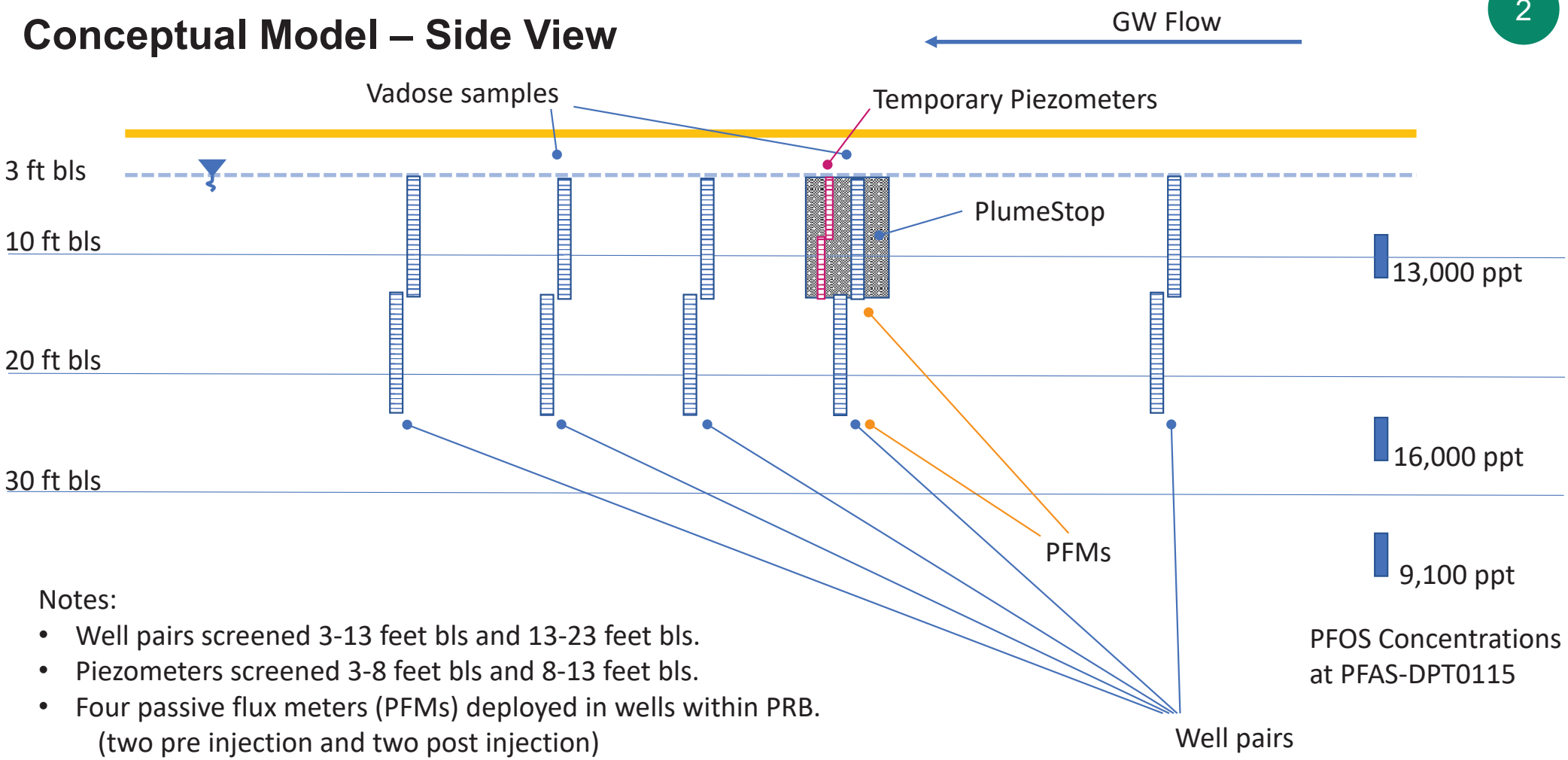
- Tetra Tech Comment #2: Slide 14 – Spacing within rows (5 feet) is listed on the design summary. Specify the spacing between the two rows and the basis for the estimated radius of influence for each injection
- *Response: The spacing between the rows is approximately 5 feet. The radius of influence was recommended by Regenesis as a commonly observed value based on their application experience.*
- Tetra Tech Comment #3: Slide 14 – Please provide the basis for the PlumeStop dosage of 367 lbs per injection point.
- *Response: The dosage was recommended by Regenesis as a typical value based on their application experience.*

3

Response to Comment

- Tetra Tech Comment #4: Slide 14 – With the shape of the 1,000x RSL plume indicating a prevailing flow almost directly northwest, considering orienting the upgradient and downgradient monitoring well pairs more in that direction, or adding one more upgradient well pair southwest of the well currently shown.
- *<u>Response:</u> As indicated on Slide 13, the flow direction can vary between west and northwest. The orientation of the barrier was aligned as an approximate average of the two directions. Additional existing monitoring wells may be gauged during implementation to develop a more comprehensive picture of the shallow potentiometric surface.*

Conceptual Model – Side View



Notes:

- Well pairs screened 3-13 feet bls and 13-23 feet bls.
- Piezometers screened 3-8 feet bls and 8-13 feet bls.
- Four passive flux meters (PFMs) deployed in wells within PRB. (two pre injection and two post injection)

Not to Scale

3

Response to Comment

- HGL Comment #4: Slides 14 and 15: The plan view on page 14 shows two soil boring locations within the downgradient injection line, but the cross-section on page 15 shows one soil sample location within the PRB alignment and the second one downgradient of the PRB. Please resolve this apparent inconsistency between the two slides.
- *Response: The yellow soil borings are to be deployed during the Placement Validation activities, described on Slide 22. The 50 foot soil core will be collected during installation of the monitoring well within the barrier alignment. Vadose zone soil samples will be collected during installation of monitoring wells within, and downgradient of the PRB.*

AECOM

3

Design Verification Testing

Design Verification Testing

- Complete one soil core to a depth of 50 feet bls at a location within the PRB. Collect samples for grain size analysis at 2-foot intervals from 3 to 23 feet bls. Collect samples for total organic carbon (TOC) at 8 feet and 18 feet, or within different soil types based on field observations.
- Collect vadose zone soil samples within and downgradient of the PRB area for PFAS concentrations by USEPA Method 537M.
- Install seven pairs of monitoring wells (14 total monitoring wells) with screen intervals of 3-13 feet bls and 13-23 feet bls and perform baseline sampling. Data to be collected:
  - Field parameters (pH, dissolved oxygen [DO], oxidation reduction potential [ORP], turbidity, conductivity, temperature).
  - PFAS compounds by USEPA Method 537M.
  - TOC by USEPA Method SW9060/SM5310.
- Deploy PFMs in the monitoring wells located within the proposed PRB (discussed on next slide).

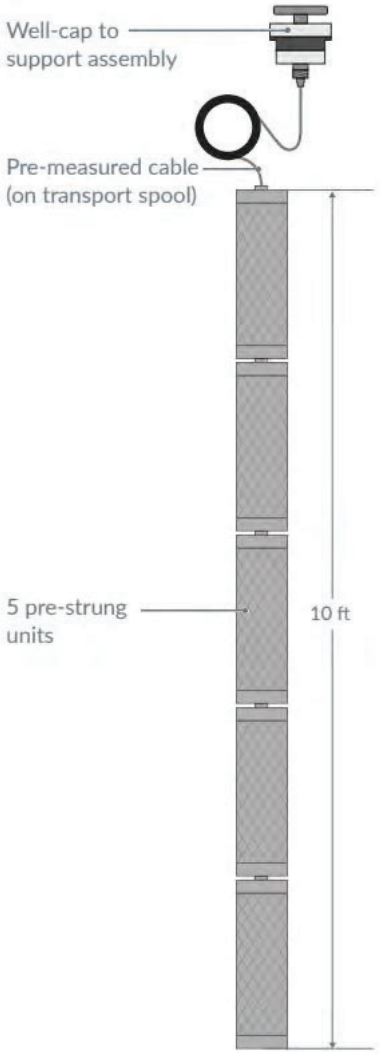
Work Scope	Data Analysis	# of Samples
Soil Core	Grain Size Analysis TOC	2 2
Vadose Soil Baseline Sampling	Vadose Soil PFAS Compounds	2
Install 14 monitoring wells	Lithology	0
Groundwater Baseline Sampling	GW Parameters, PFAS Compounds & TOC	14
Deploy Flux Meters	GW Velocity & PFAS Compounds	2x5

Response to Comment

- HGL Comment #5: Slide 17: Instead of specifying depths for the two TOC samples, suggest selecting the TOC sample interval to target different lithologies based on field observations. For example, 8 ft bgs and 18 ft bgs at SO14-LB01 and SO14-LB02 (Slide 11) would sample the same lithologic type (SP of SO14-LB01 and SW for SO14-LB02). For future designs, it would be helpful to obtain TOC data for the range of lithologies likely to be encountered.
- *Response: Text will be amended to read "…at 8 feet and 18 feet, or within different soil types, based on field observations."*
- Tetra Tech Comment #5: Slide 17 – Slide states soil samples will be collected "within and downgradient of PRB area". However, figure on slide 14 shows both locations within PRB area. Please reconcile.
- *Response: The yellow borings indicated on Slide 17 will be advanced during the Placement Validation phase on Slide 22. The vadose zone soil samples will be collected during installation of monitoring wells.*

Design Verification Testing

- Deploy PFMs in the monitoring well pair located within the proposed PRB.
  - Each PFM made up of five 2-foot sampling canisters.
  - Flux meters are typically deployed for two to three weeks.
  - Used to vertically delineate groundwater velocity.
    - Alcohol tracers are depleted by groundwater flowing past canisters. The net loss of the alcohol tracer is used to determine the average groundwater velocity per interval.
  - Also used to vertically delineate contaminant mass flux.
    - Contaminants are adsorbed onto filter media and analyzed in the laboratory to determine an average contaminant mass flux per interval.
- Remedial design to be finalized based on all data collected during the design verification testing.

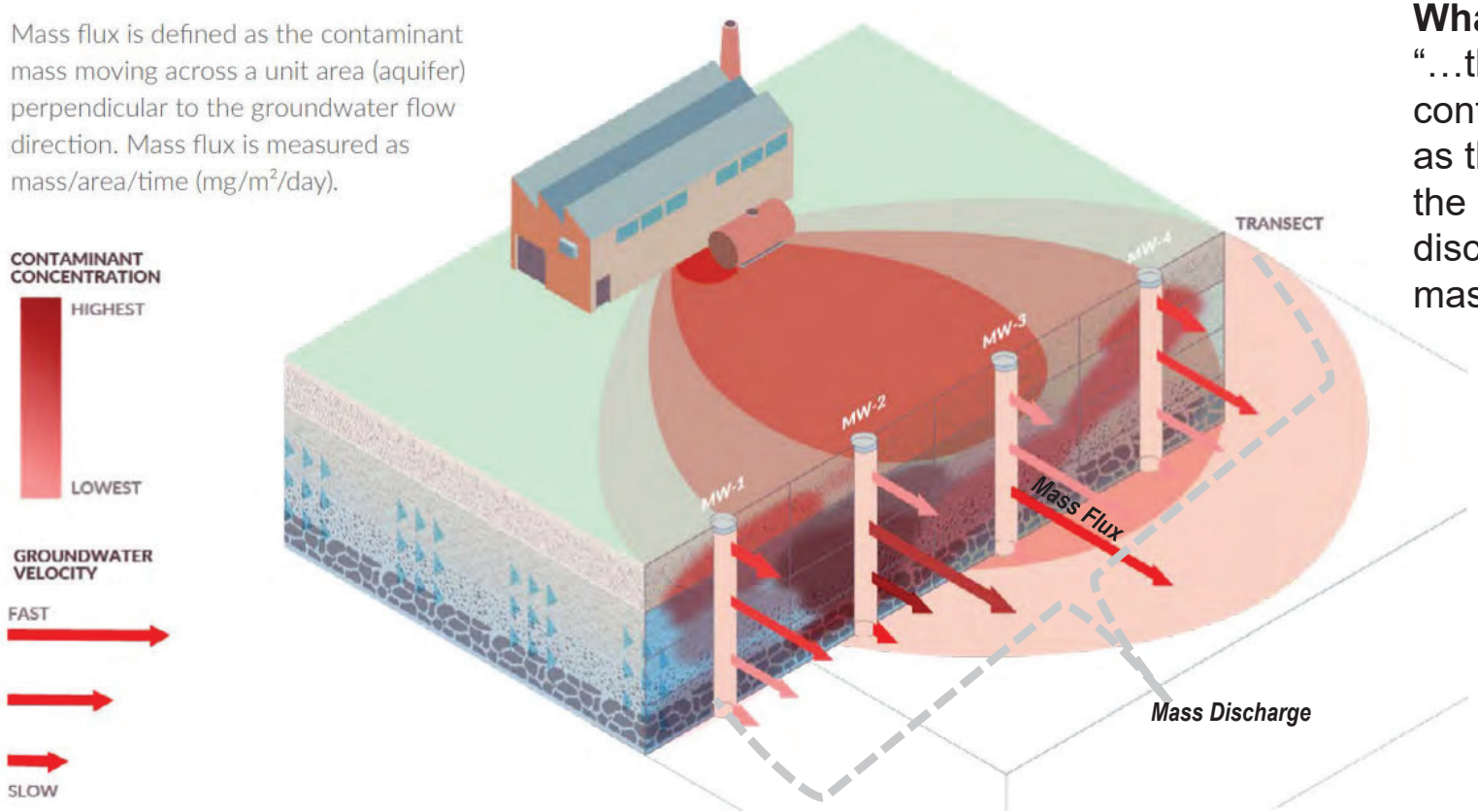


Picture Source: FluxTracer Overview, Regenesis Remediation Services

What is Mass Flux?

What is Mass Flux?

Mass flux is defined as the contaminant mass moving across a unit area (aquifer) perpendicular to the groundwater flow direction. Mass flux is measured as mass/area/time (mg/m²/day).



Picture Source: FluxTracer Overview, Regenesis Remediation Services

What is Mass Discharge?

"…the total mass crossing a control plane of interest, such as the downgradient edge of the source zone…" Mass discharge is measured as mass/time.

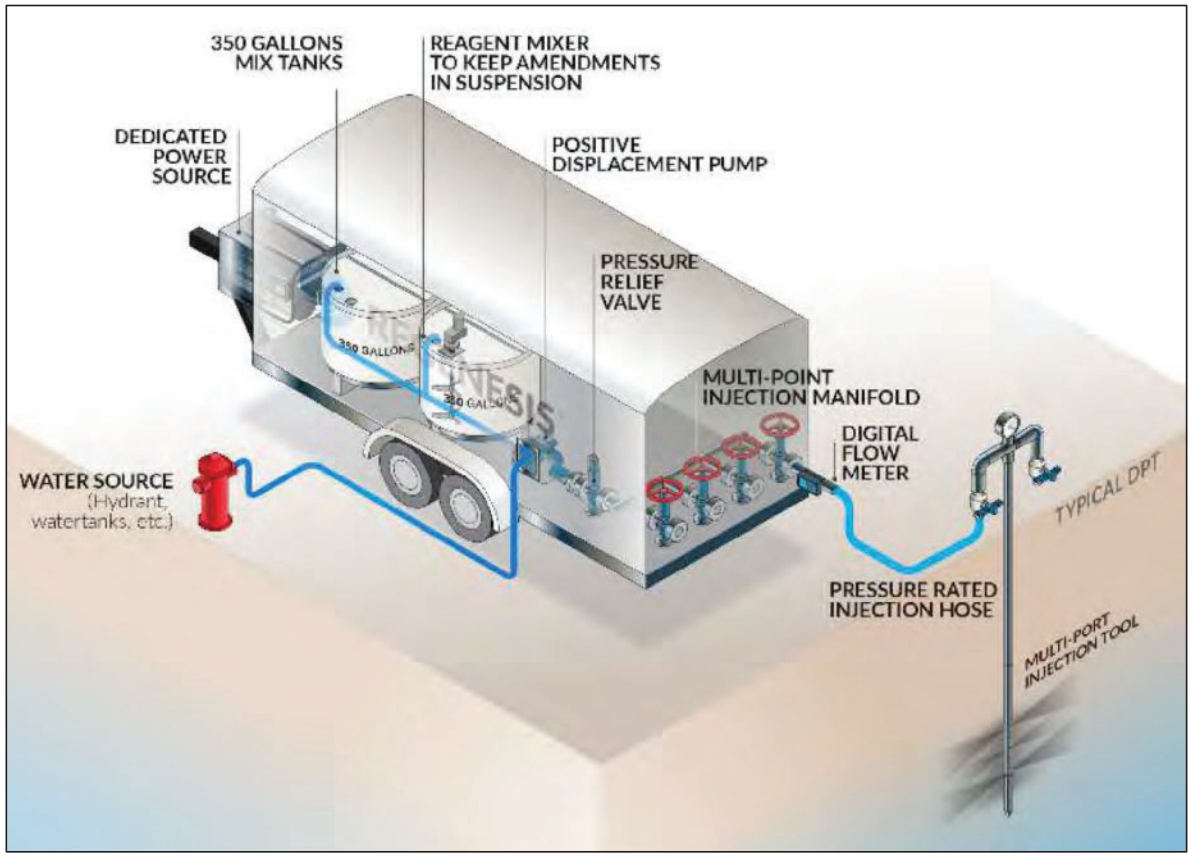
Annable, M. (2022, May 2). Mass flux and mass discharge. Mass Flux and Mass Discharge - Enviro Wiki. https://www.enviro.wiki/index.php?title=Mass_Flux_and_Mass_Discharge#:~:text=Mass%20flux%20is%20the%20contaminant,zone%20or%20a%20property%20boundary.

4

Injection Event & Placement Validation

Injection Event

- Water will be sourced from a hydrant near the Base Support Building.
- PlumeStop® mixed onsite in remediation trailer.
- Injection tooling to be advanced by direct push technology.
- Pressures, flow rates, and injected volumes are monitored and digitally documented for each injection.
- Injection data and field observations are recorded in an injection summary report.



Picture Source: PlumeStop Pilot Study Proposal, NASA Kennedy Space Center, Florida, Regenesis Remediation Services

4

Placement Validation (during injection activities)

– Groundwater Monitoring from Well Clusters and Two Temporary Piezometers
  - Field parameters (pH, DO, ORP, turbidity, conductivity, temperature).
  - Visual indicators, including color, in groundwater
  - Groundwater elevation.
  - Injection concentration field analyses.

– Soil Observations
  - Observe PlumeStop® distribution in the soil matrix via MacroCore collection at two boring locations between 3 and 13 feet bls.

Work Scope	Number	Data Analysis
Install Temporary Piezometers	2	Water Level, Color, Plumestop Presence
Groundwater Monitoring	14	GW Parameters, Water Level, Color, Plumestop Presence
Complete Soil Cores	2	Soil Color, Plumestop Presence

5

Performance Monitoring

Performance Monitoring

- Groundwater sampling at well pairs is recommended on a monthly frequency for the first six months and then quarterly for up to two years. Data to be collected:
  - Field parameters (pH, DO, ORP, turbidity, conductivity, temperature).
  - PFAS compounds by USEPA Method 537M
  - TOC by USEPA Method SW9060/SM5310.
- Deploy PFMs in the monitoring well pair within the PRB.
  - Measure new groundwater velocity across the vertical gradient.
  - Measure new contamination mass flux across the vertical gradient.
  - Timing of installation based on groundwater sampling results

Work Scope	Data Analysis	# of Samples
Groundwater Performance Monitoring	GW Parameters, PFAS Compounds & TOC	168
Deploy Flux Meters	GW Velocity & PFAS Compounds	2x5

3

Response to Comment

- Tetra Tech Comment #6: Slide 24 – Consider collecting soil/PlumeStop samples from the PRB area during select performance monitoring events to confirm the PRB is still intact.
- *Response: This activity will be considered.*
- Tetra Tech Comment #7: Slide 24 – Consider collecting soil/PlumeStop samples from within the PRB at the conclusion of the study to estimate PFAS capture.
- *Response: This activity will be considered.*
- Tetra Tech Comment #8: Slide 24 – Consider using pressure transducers in select wells and nearby surface water to provide a more thorough analysis of groundwater flow horizontally and vertically (and groundwater-surface water interaction) over time and in response to precipitation events. This may provide valuable data for a full-scale design (wall placement, depth, etc.).
- *Response: This activity will be considered.*

6

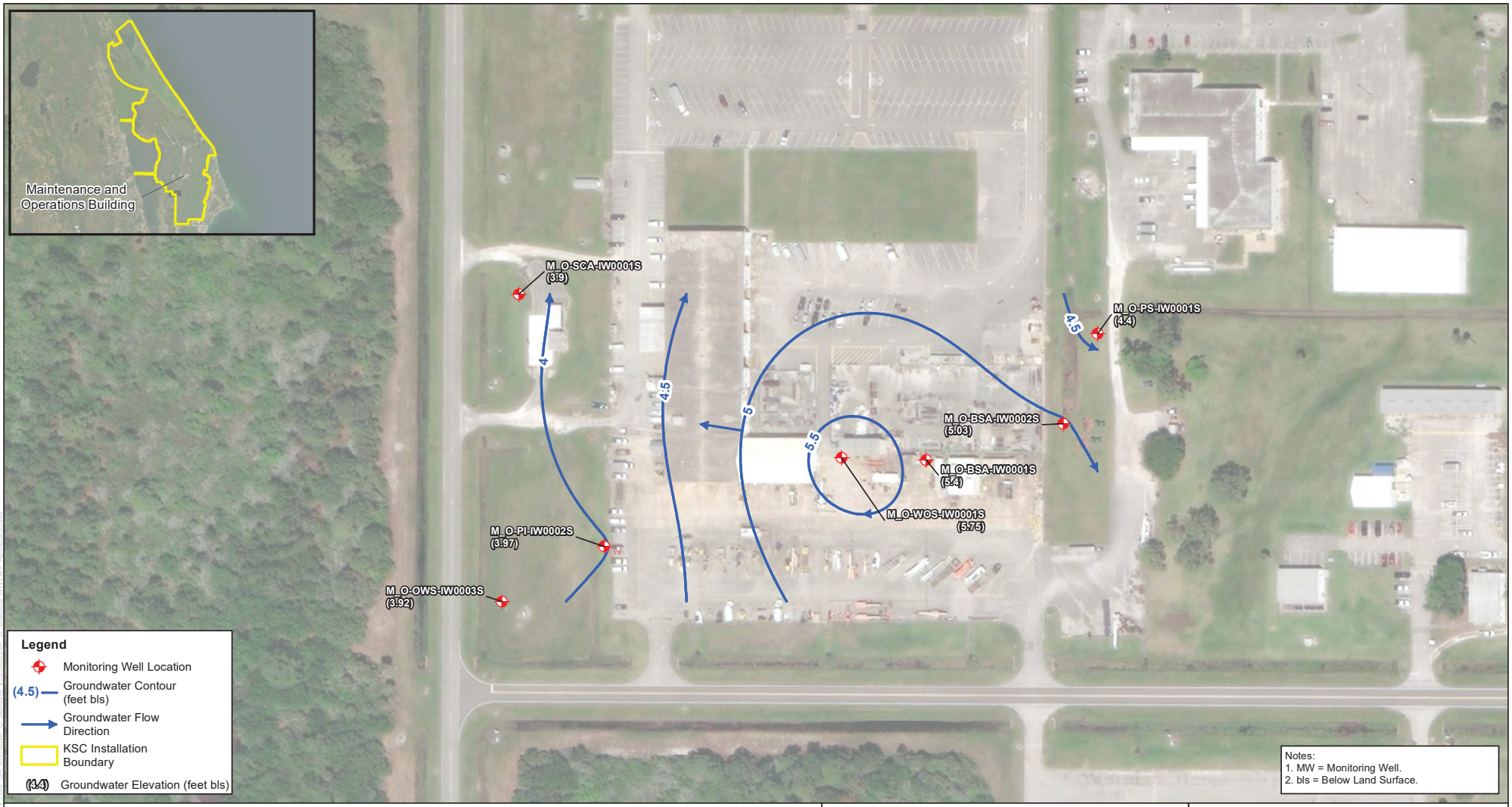
Conclusions

Pilot Study Data Analysis Breakdown

Pilot Study Phase	Work Scope	Data Analysis	# of Samples
Before Injections	• Soil Boring • Vadose Soil Baseline Sampling • Install 14 Monitoring Wells • Groundwater Baseline Sampling • Deploy Flux Meters	• Lithology, Grain Size Analysis, and TOC • Soil PFAS Compounds • Lithology • GW Parameters, PFAS Compounds & TOC • GW Velocity & PFAS Compounds	2 & 2 2 0 14 2x5
During Injections	• Install 2 temporary piezometers • Groundwater Monitoring • Complete 2 Soil Cores	• Water Level, Color, Plumestop Presence • GW Parameters, Color, Water Level, Plumestop • Soil Color, Plumestop Presence	0 0 0
After Injections	• Groundwater Performance Monitoring • Deploy Flux Meters	• GW Parameters, PFAS Compounds & TOC • GW Velocity & PFAS Compounds	168 2x5

– Complete Pilot Study Implementation Report documenting:
  - Pre-injection data summary.
  - Injection procedures and data summary.
  - Post-injection data summary.
  - Recommendations for full-scale implementation.

Thank you.



MAPPING NOTES:
-Basemap Source
Orthoimagery from Brevard County, 2018.
-Projection
Coordinate System: NAD 1983 StatePlane Florida East FIPS 0901
-Scale
1 Inch = 125 Feet

0 62.5 125 250 Feet

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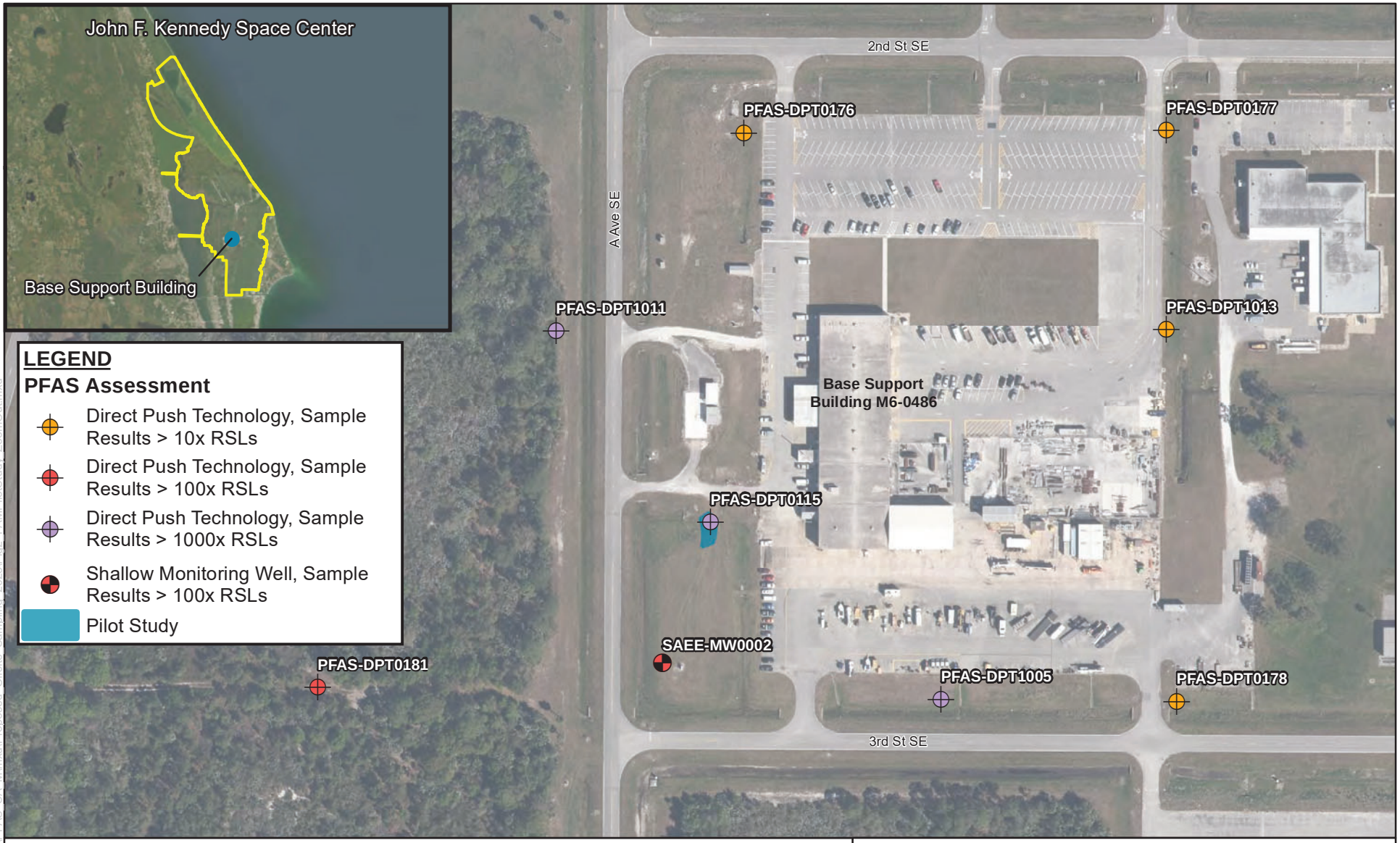
FIGURE 1
GROUNDWATER FLOW
APRIL 2023
MAINTENANCE AND OPERATIONS BUILDING



NOTE:
RSL = Regional Screening Level

MAPPING NOTES:
Basemap Source: Orthoimagery from Brevard County, 2018.
Projection Coordinate System: NAD 1983 StatePlane Florida East FIPS 0901
Scale: 1 Inch = 200 Feet

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0 100 200 Feet

FIGURE 1
Carbon Injection Pilot Study Location

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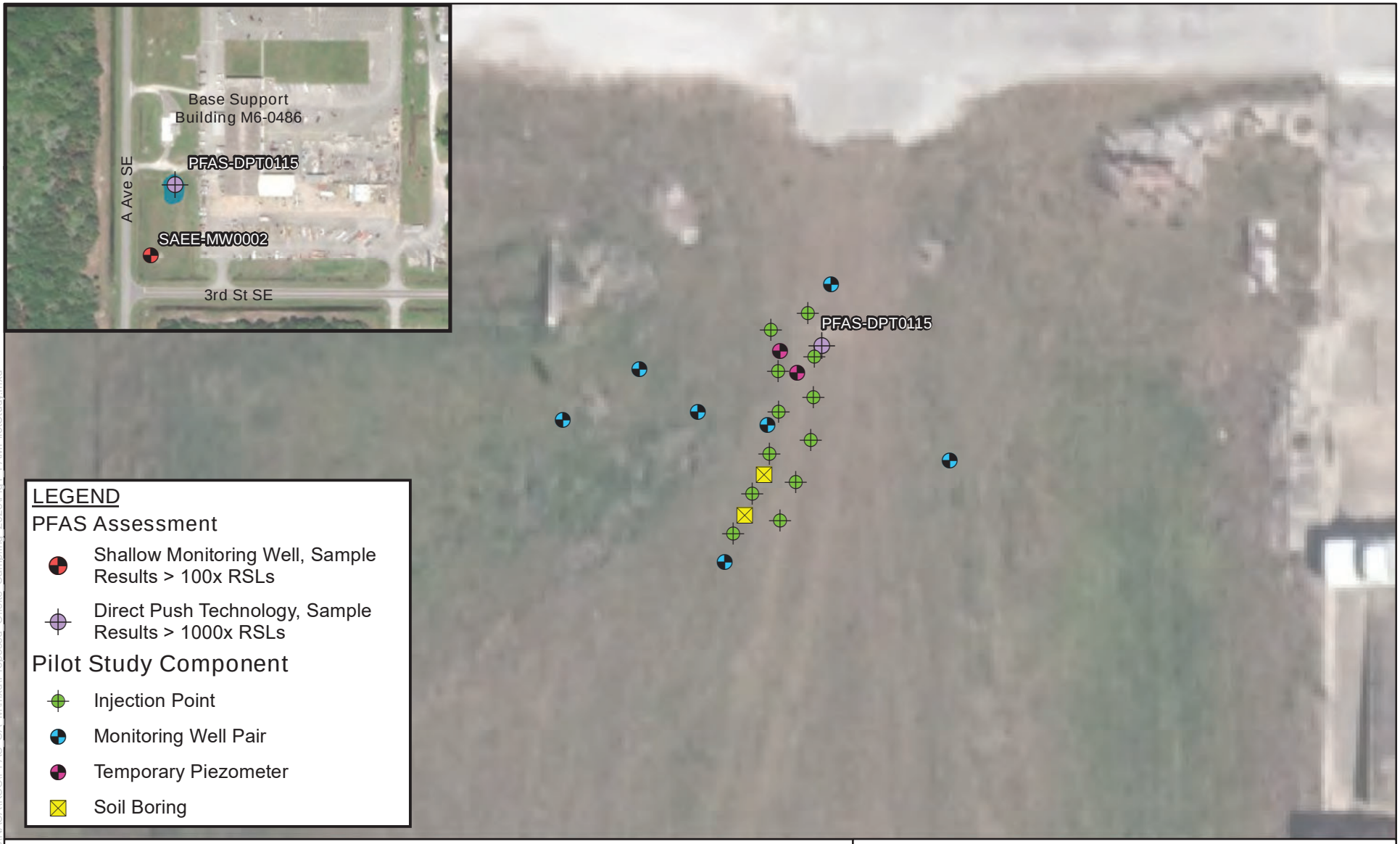

NOTE:
-RSL = Regional Screening Level

MAPPING NOTES:
Basemap Source: Orthoimagery from Brevard County, 2018.
Projection Coordinate System: NAD 1983 StatePlane Florida East FIPS 0901
Scale: 1 Inch = 20 Feet

N

0 10 20 Feet

FIGURE 2
Base Support Building
Carbon Injection Pilot Study Layout
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AECOM
150 North Orange Avenue
Orlando, FL 32801
aecom.com

Project name:
KSCRT Meeting Support

To:
Deda Johansen
Kennedy Space Center, Florida

Project ref:
PFAS Site Assessment and Mitigation – PlumeStop® Injection Pilot Study Work Plan Base Support Building (Formerly Maintenance & Operations Building) ADP

From:
Jennifer Gootee, PE

Date:
November 21, 2023

Memo

Subject: Response to Comments on PFAS Site Assessment and Mitigation – PlumeStop® Injection Pilot Study Work Plan Base Support Building (Formerly Maintenance & Operations Building) ADP

AECOM's responses to comments provided by HydroGeoLogic, and Tetra Tech from their review of the PFAS Site Assessment and Mitigation – PlumeStop® Injection Pilot Study Work Plan Base Support Building (Formerly Maintenance & Operations Building) ADP are provided here.

Responses to HydroGeoLogic Comments

1. Comment: Slide 11: Show pilot study location on the slide.

   Response: The pilot study location will be indicated.

2. Comment: Slide 13: Groundwater elevations are available for additional wells surrounding the Base Support Building area. Consider including these wells for contouring flow directions. Using additional data seems to indicate that there is a groundwater flow divide located in this area where flow is either northwest towards SMWU 118 (like in 2002 or to the southwest, coinciding with the ditch along A Ave SE). The primary plume axis for PFAS appears to follow the northwest flow direction. Verification of the shallow groundwater flow direction described on pages 17 and 18 should help to better define the flow direction through the proposed PRB.

   Response: AECOM requests the data referenced to be shared. This data will be reviewed prior to implementation of the scope of work.

3. Comment: Slide 14. Seepage velocity is 82.5 ft/yr based on hydraulic conductivity of 20 ft/day (7300 ft/yr x .0026 ft/ft)/.23 = 82.5 ft/yr. High seepage velocity (82.5 ft/yr, or 41 ft/yr as in ADP) plus quartz sand aquifer means it is possible that the PlumeStop will be actively transported rather than acting as a "fixed" barrier. Please address that possibility.

   Response: This question was posed to Regenesis, the supplier of PlumeStop. Their reply is as follows:

"For the proposed KSC pilot the 7 cm/day (83 ft/yr) seepage would normally not be a concern. A sediment sieve-analysis is useful in predicting any unwanted advection. With the pre-emptive application of a divalent cation solution (i.e. calcium chloride) the carbon set-up can be accelerated to 'park' the PlumeStop in the intended target treatment zone." Grain size analyses will be performed prior to injection of the PlumeStop. If excessive advection is suspected as a result of these grain size analyses, the application of a calcium chloride solution will be considered.

4. Comment: Slides 14 and 15: The plan view on page 14 shows two soil boring locations within the downgradient injection line, but the cross-section on page 15 shows one soil sample location within the PRB alignment and the second one downgradient of the PRB. Please resolve this apparent inconsistency between the two slides.

   Response: The yellow soil borings are to be deployed during the Placement Validation activities, described on Slide 22. The 50 foot soil core will be collected during installation of the monitoring well within the barrier alignment. Vadose zone soil samples will be collected during installation of monitoring wells within, and downgradient of the PRB.

5. Comment: Slide 17: Instead of specifying depths for the two TOC samples, suggest selecting the TOC sample interval to target different lithologies based on field observations. For example, 8 ft bgs and 18 ft bgs at SO14-LB01 and SO14-LB02 (Slide 11) would sample the same lithologic type (SP of SO14-LB01 and SW for SO14-LB02). For future designs, it would be helpful to obtain TOC data for the range of lithologies likely to be encountered.

   Response: Text will be amended to read "…at 8 feet and 18 feet, or within different soil types, based on field observations."

6. Comment: Figure 1 (Slide 29): Consider including monitoring well sample results in addition to the DPT results. M&O-SCA-IW0002I (17.5-27.5 ft bls) and IW0002D (32.5-42.5 ft bls) had PFOS concentrations of 30,500 ng/L and 37,400 ng/L, respectively in May 2023. This well pair is located just northeast of PFAS-DPT0115 and suggests that the core of the PFAS plume may be located farther to the northeast than the proposed pilot study area.

   Response: AECOM requests the data referenced to be shared. This data will be reviewed prior to implementation of the scope of work.

Responses to Tetra Tech Comments

1. Comment: Slide 13/15 – Please clarify if groundwater flow direction below 13.5 feet bls the same as the 3.5-13.5 feet bls interval. It is implied on Slide 15 but not clearly specified.

   Response: The monitoring wells utilized for the potentiometric surface maps range in depth from 3.5 to 14 feet bls and have exhibited variable GW flow directions across the site. The intermediate (20-25ft) and deep (35-40ft) zones have had more uniform contour lines and typically exhibit a similar GW flow direction as the shallow zone near the pilot study area.

2. Comment: Slide 14 – Spacing within rows (5 feet) is listed on the design summary. Specify the spacing between the two rows and the basis for the estimated radius of influence for each injection.

   Response: The spacing between the rows is approximately 5 feet. The radius of influence was recommended by Regenesis as a commonly observed value based on their application experience.

3. Comment: Slide 14 – Please provide the basis for the PlumeStop dosage of 367 lbs per injection point.

   Response: The dosage was recommended by Regenesis as a typical value based on their application experience.

4. Comment: Slide 14 – With the shape of the 1,000x RSL plume indicating a prevailing flow almost directly northwest, considering orienting the upgradient and downgradient monitoring well pairs more in that direction, or adding one more upgradient well pair southwest of the well currently shown.

Response: As indicated on Slide 13, the flow direction can vary between west and northwest. The orientation of the barrier was aligned as an approximate average of the two directions. Additional existing monitoring wells may be gauged during implementation to develop a more comprehensive picture of the shallow potentiometric surface.

5. Comment: Slide 17 – Slide states soil samples will be collected "within and downgradient of PRB area". However, figure on slide 14 shows both locations within PRB area. Please reconcile.

   Response: The yellow borings indicated on Slide 17 will be advanced during the Placement Validation phase on Slide 22. The vadose zone soil samples will be collected during installation of monitoring wells.

6. Comment: Slide 24 – Consider collecting soil/PlumeStop samples from the PRB area during select performance monitoring events to confirm the PRB is still intact.

   Response: This activity will be considered.

7. Comment: Slide 24 – Consider collecting soil/PlumeStop samples from within the PRB at the conclusion of the study to estimate PFAS capture.

   Response: This activity will be considered.

8. Comment: Slide 24 – Consider using pressure transducers in select wells and nearby surface water to provide a more thorough analysis of groundwater flow horizontally and vertically (and groundwater-surface water interaction) over time and in response to precipitation events. This may provide valuable data for a full-scale design (wall placement, depth, etc.).

   Response: This activity will be considered.

APPENDIX B
Select Figures from the October 2022 PFAS Site Assessment Progress Report ADP

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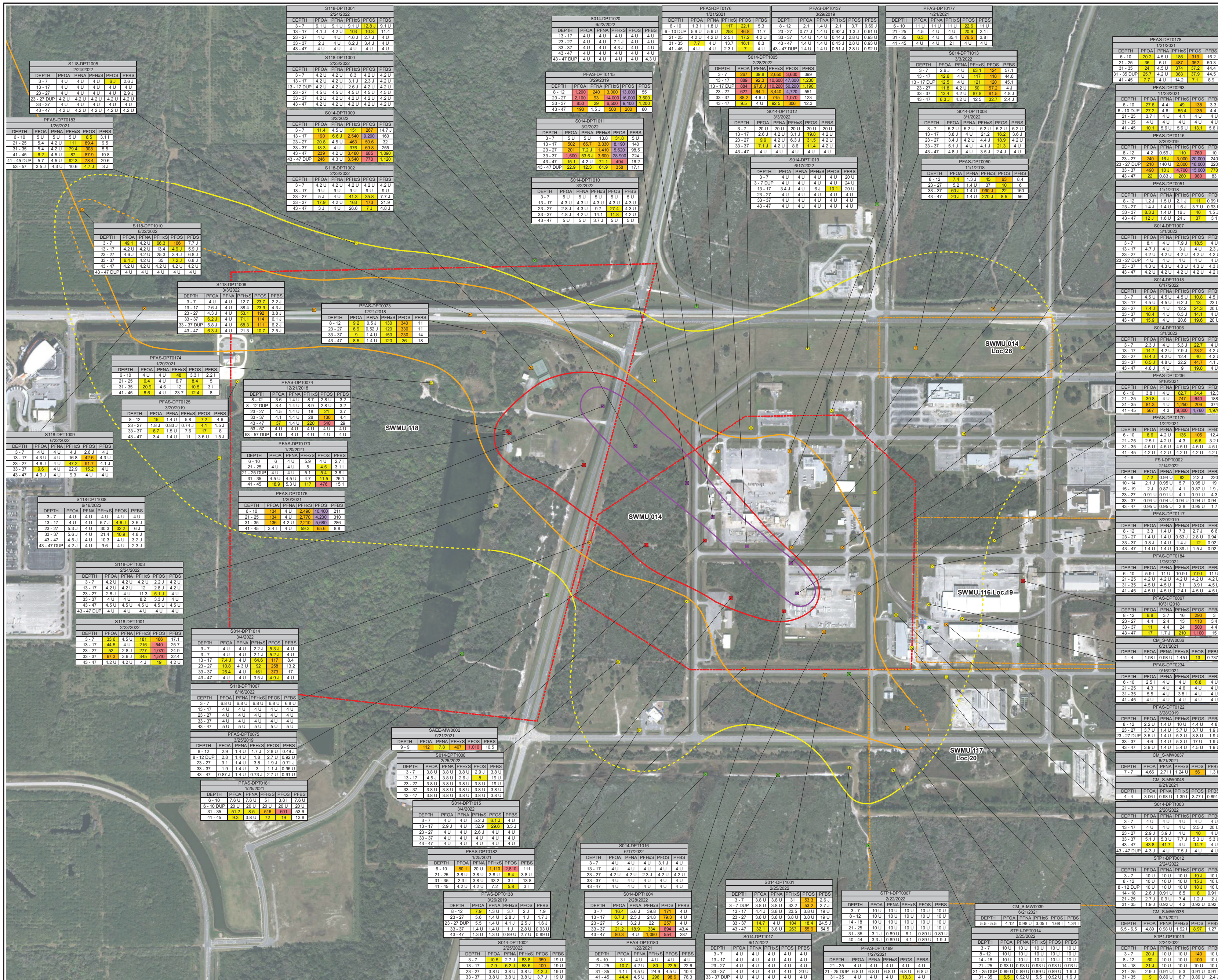
Figure 4
SWMU 014/118
Groundwater Analytical Results



Legend

- DPT Sample < RSLs
- DPT Sample > RSLs
- DPT Sample > 10 x RSLs
- DPT Sample > 100 x RSLs
- DPT Sample > 1000 x RSLs
- Extent of Groundwater Above RSLs (dashed where inferred)
- Extent of Groundwater Above 10 x RSLs (dashed where inferred)
- Extent of Groundwater Above 100 x RSLs
- Extent of Groundwater Above 1000 x RSLs
- SWMU 014/118 Boundaries
- Other SWMU Boundaries

Notes:
Yellow=concentration greater than RSL
Orange=concentration greater than 10 x RSL
Red=concentration greater than 100 x RSL
Purple=concentration greater than 1000 x RSL
Results in nanograms per liter (ng/L)

I=estimated value
J=estimated value
PFOA=perfluorooctanoic acid
PFNA=perfluorononanoic acid
PFHxS=perfluorohexanesulfonic acid
PFOS=perfluorooctanesulfonic acid
PFBS=perfluorobutanesulfonic acid
RSL=regional screening level
SWMU=solid waste management unit
U=not detected

SAMPLE LOCATION					
SAMPLE DATE					
DEPTH	PFOA	PFNA	PFHxS	PFOS	PFBS

RSLs				
PFOA	PFNA	PFHxS	PFOS	PFBS
6	6	40	4	600

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9/14/2022 TB
Source: HGL, ArcGIS Online Imagery

HGL HydroGeoLogic, Inc

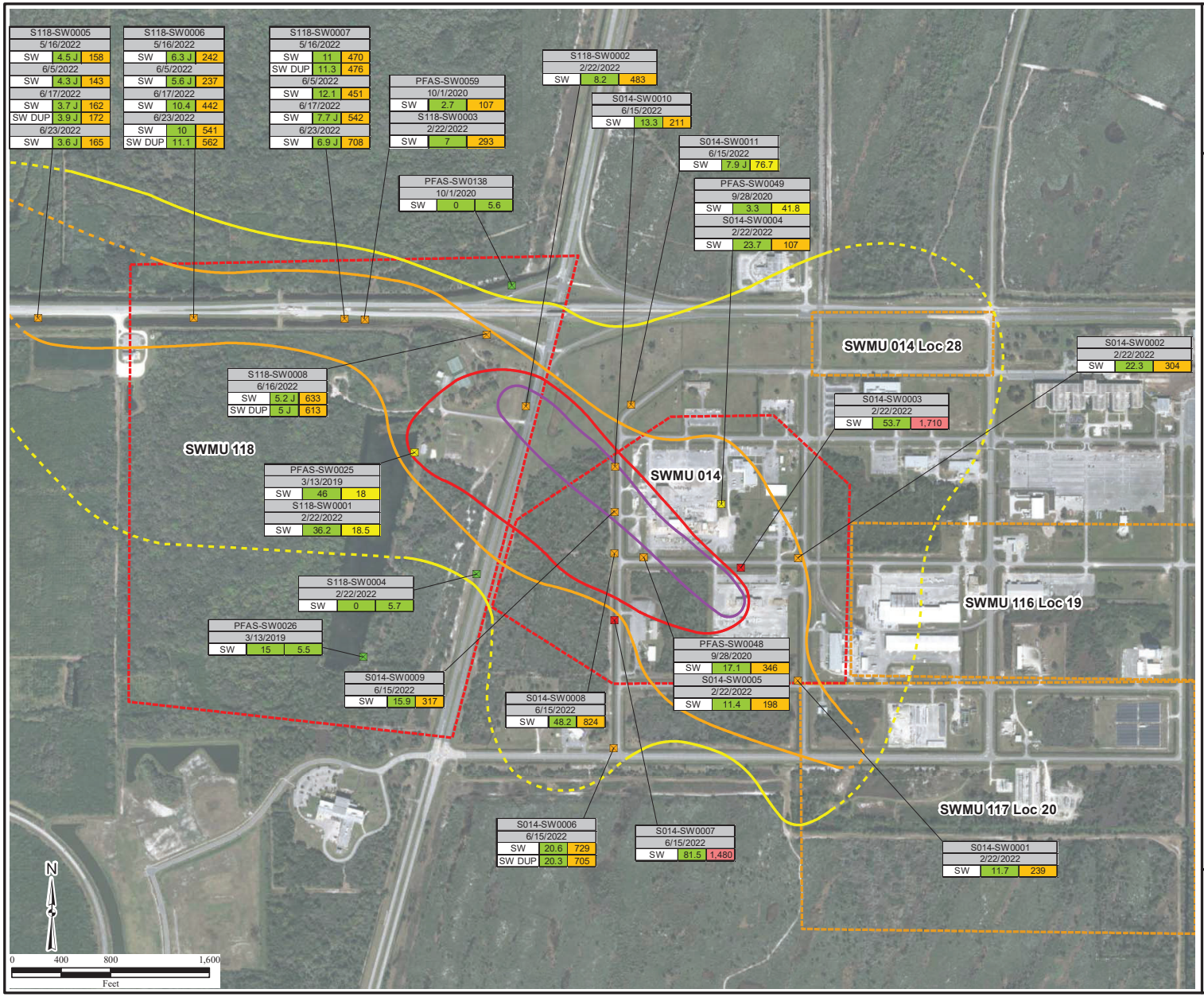

Figure 5
SWMU 014/118
Surface Water
Analytical Results

Legend

- PFOS < 10 ng/L, PFOA < 500 ng/L
- PFOS >10 ng/L
- PFOS > 100 ng/L
- PFOS > 1,000 ng/L
- Extent of Groundwater Above SW SLs (dashed where inferred)
- Extent of Groundwater Above 10 x SW SLs (dashed where inferred)
- Extent of Groundwater Above 100 x SW SLs
- Extent of Groundwater Above 1,000 x SW SLs
- SWMU 014/118 Boundaries
- Other SWMU Boundaries

Notes:
Green=PFOS < 10 ng/L, PFOA < 500 ng/L
Yellow=PFOS >10 ng/L
Orange=PFOS > 100 ng/L
Red=PFOS > 1,000 ng/L
Results in nanograms per liter (ng/L)

J=estimated value
PFOS=perfluorooctanesulfonic acid
PFOA=perfluorooctanoic acid
SWMU=solid waste management unit
SW SL=surface water screening level

Sample Location		
Sample Date		
Depth	PFOA Concentration	PFOS Concentration

Surface Water Screening Level	
PFOA	500 ng/L
PFOS	10 ng/L

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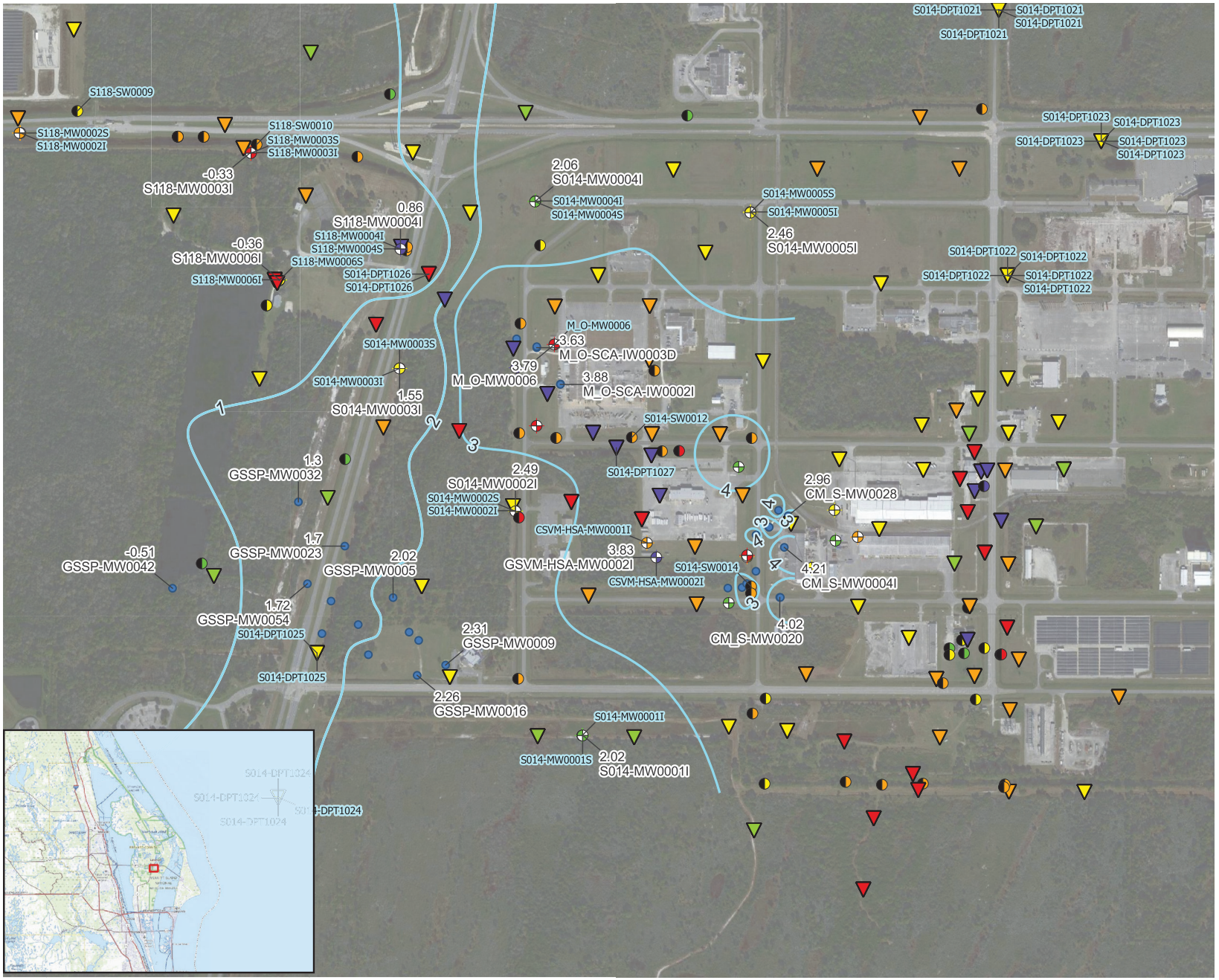
9/14/2022 TB
Source: HGL,
ArcGIS Online Imagery



Legend

- Intermediate GW contour 4-24-2023
- Intermediate GW Gauging
  (elev. ft)
  Location ID

PFAS RSL Exceedances

- DPT < RSL
- DPT >=1x RSL - 10x RSL
- DPT >=10x RSL - 100x RSL
- DPT >=100x RSL - 1000x RSL
- DPT >=1000x RSL
- SW < RSL
- SW >=1x RSL - 10x RSL
- SW >=10x RSL - 100x RSL
- SW >=100x RSL - 1000x RSL
- SW >=1000x RSL
- MW < RSL
- MW >=1x RSL - 10x RSL
- MW >=10x RSL - 100x RSL
- MW >=100x RSL - 1000x RSL
- MW >=1000x RSL

Notes:
Cyan labeled samples collected in 2023
DPT = direct push technology
SW = Surface Water
MW = Monitoring Well
GW = Groundwater
PFAS = per- and polyfluoroalkyl substances

N

0 500 1,000 ft

PFAS Sampling 2023
and
Potentiometric Head Gauging

HGL

APPENDIX C
PlumeStop® Technical Bulletin

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PlumeStop® Technical Bulletin 5.1

In Situ Containment of PFOA and PFOS Using Plumestop® Liquid Activated Carbon™

Introduction and Background

Per- and polyfluorinated alkyl substances (PFAS) are a class of man-made organic chemicals with robust carbon-fluorine bonds that impart chemical, thermal, and biological resistant properties. The stability of these compounds have led to their use in a variety of industrial and consumer products, including stain resistant materials, non-stick surfacing, and aqueous film-forming foams (AFFF) for fire suppression.

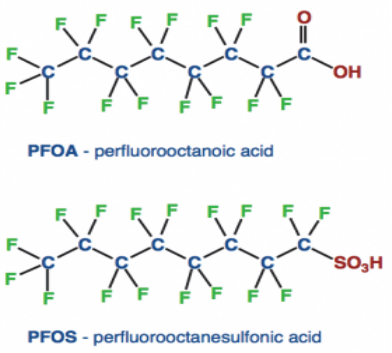

Figure 1: PFOA and PFOS chemical structure

The widespread use of these compounds together with advances in analytical chemistry have resulted in routine, low-level detections of PFAS in water and soil environmental samples as well as in mammals and humans. Once in the environment or exposed to humans, the durability of PFAS becomes problematic as they do not readily degrade or metabolize, making them extremely persistent.

Two of the most commonly encountered PFAS are perfluorooctanesulfonic acid (PFOS) and perfluorooctanoic acid (PFOA), shown in Figure 1. The health effects of PFOA and PFOS for humans are not yet fully understood, however, the US Environmental Protection Agency has considered them emerging contaminants with potential carcinogenic properties. Based on these health risks, the EPA has set a lifetime health advisory limit for the combined concentrations of PFOA and PFOS at 0.07 µg/L, a limit that was lowered in May 2016 from previous levels set in 2009. As a result of these new advisory values, there has been a large focus on effective remediation approaches for PFAS in contaminated soils and groundwater.

To date, conventional *in situ* remediation technologies, e.g. chemical oxidation, have not effectively demonstrated the ability to destroy these contaminants. Additionally, no known microbial strains have been discovered that are capable of biodegrading these

substances. The currently accepted method of treatment for PFAS is through an *ex situ* pump-and-treat system equipped with activated carbon filters. While generally effective, this process can be complicated and expensive due to the large and dilute nature of many PFAS plumes, which are often difficult to treat completely. A recent study[1] reported on the typical characteristics of these PFAS plumes, which include:

- Average plume length is over a mile
- More than 75% of the plume is <10 µg/L
- Large, dilute plumes typically do not have a high concentration source area
- PFOS and PFOA are likely present at the highest concentrations at the leading edge of the plume.

Technology Description

REGENESIS® has developed an *in situ* sorbent technology to physically remove PFOA and PFOS from the aqueous phase in order to prevent further migration of the plume and to remove the inherent risk associated with dissolved phase contaminants. This new *in situ* sorbent technology offers a new tool to address these challenging contaminant plumes. The key elements of this technology include the ability to:

- Distribute a sorbent composed of colloidal activated carbon widely in the aquifer under low pressure injections
- Adsorb contaminants and quickly reduce their groundwater concentrations
- Inhibit further transport of contaminants in the aquifer

PlumeStop® Liquid Activated Carbon™ is comprised of very fine particles of activated carbon (1-2 µm) suspended in water through organic polymer dispersion chemistry. This patented formulation allows PlumeStop to travel through the aquifer under low pressure application without clogging.

Once applied, PlumeStop coats the surface of the soil where contaminants can adsorb and immediately reduce dissolved phase concentrations. For a more extensive review on the ability of PlumeStop to distribute in the subsurface, refer to PlumeStop Technical Bulletin 1.1.

Experimental

To test the adsorption efficacy of PlumeStop, individual adsorption isotherms for PFOA and PFOS were measured in the REGENESIS laboratory. The isotherms were fitted according to the Freundlich model and the parameters were then used to model the expected treatment efficiencies with PlumeStop.

Isotherm samples sets were prepared with a constant contaminant concentration and varied PlumeStop doses. The samples were mixed for a minimum of 48 hours and then a clear aliquot, free of PlumeStop, was sampled and analyzed for the equilibrium contaminant concentration in water. PFOS and PFOA were analyzed by LC/MS/MS (Test America) and LC-ELSD (REGENESIS).

Results and Discussion

The isotherms with Freundlich parameters of PFOA and PFOS are show below in Figures 2 and 3.

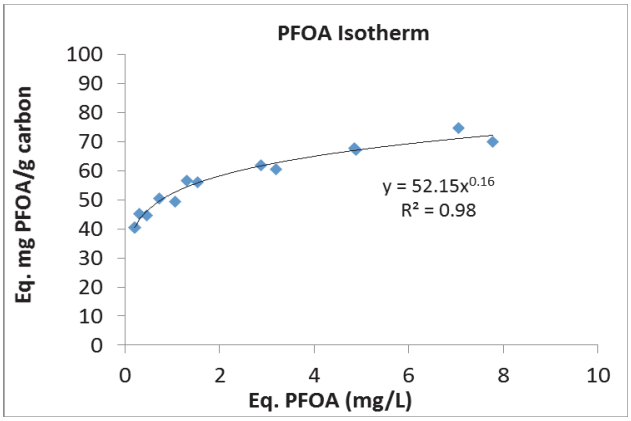

Figure 2: PFOA with PlumeStop isotherm fitted to the Freundlich

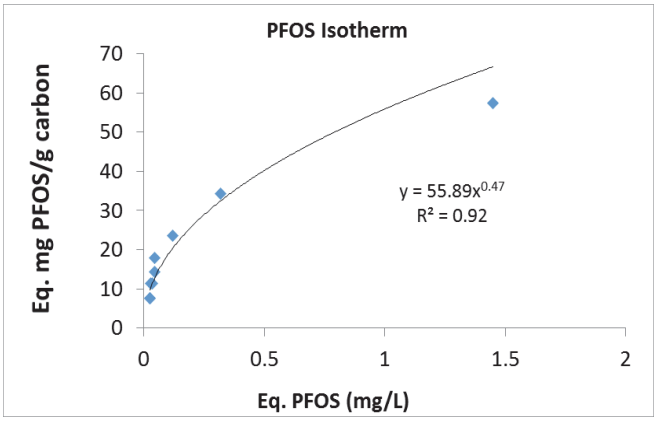

Figure 3: PFOS with PlumeStop isotherm fitted to the Freundlich

Simulated Plume Scenario

A practical way to interpret these isotherm parameters is through a fate and transport model where the capture longevity of a PlumeStop barrier treatment can be estimated by incorporating the isotherm parameters into the model.

In this simulation, a PlumeStop barrier was installed at the leading edge of a plume with the following characteristics:

- Plume contaminant concentration = 5 µg/L
- Target downgradient concentration, maximum = 70 ng/L
- Seepage velocity = 120 ft/yr
- PlumeStop barrier = 25 ft at typical field dose
- Assumes sorption only, no destruction or degradation

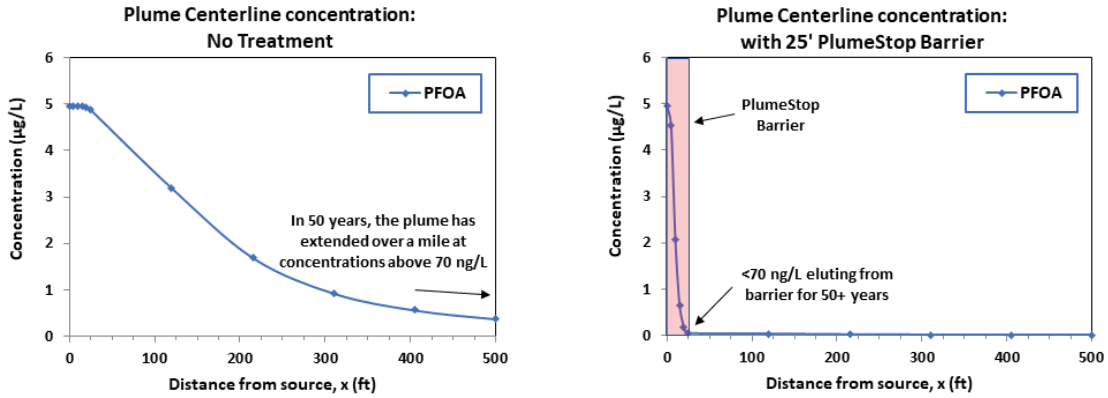

Figure 4: Simulated plume centerline concentration results for PFOA or PFOS. The graph on the left shows the natural migration of the plume after 10 years with no treatment, and the graph on the right demonstrates the capture longevity of a PlumeStop barrier treatment on the same plume.

Outputs from the modeling study are shown in the graphs depicted in Figure 4. The model results indicate that the PFOA/PFOS plume would extend over a mile in 50 years under natural conditions and no treatment. In comparison, when a 25 ft. PlumeStop barrier is installed, the Plume is contained for the 50-year period. It is expected that this timeframe could be extended through re-application of PlumeStop or with a higher initial dose.

Conclusion

The results of this study indicate that PlumeStop is capable of physically removing PFOA and PFOS from the aqueous phase in order to provide an *in situ* approach for

PFAS plumes. The ability to inject and distribute a sorbent within the aquifer allows for improved plume containment over pump and treat systems, with the potential to decrease the operating costs of *ex situ* treatment options. Additionally, future advances in destruction technologies could be applied at a later date in the area of the existing PlumeStop barrier to destroy the contaminants.

Key advantages of a PlumeStop treatment for PFAS

- Avoid or decrease O&M costs associated with *ex situ* approaches like pump and treat
- Ability to inject an *in situ* barrier of colloidal activated carbon that distributes widely and evenly under low pressures in the permeable channels
- Cuts off migrating PFAS plumes
- Rapidly adsorbs PFOS and PFOA from water, even at low concentrations
- Years of sorption capacity with a single application
- Higher doses or reapplications can increase capture longevity

References:

1. Woodward, D.; Chiang, D.; Casson, R. “Lessons Learned from Characterizing Several Dozen Sites Impacted by Perfluorinated Compounds.” In *Bioremediation and Sustainable Environmental Technologies-2015*, Proceedings of the Third International Symposium on Bioremediation and Sustainable Environmental Technologies, Miami, FL, May 2015; Darlington, R. and Barton, A. C., Eds.; Battelle Memorial Institute: Columbus, OH, 2015; B-057.

APPENDIX D
UIC Permit Notification, Florida DEP Approval, and Regulatory Guidelines for PlumeStop®

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Underground Injection Control Notification Memorandum for In Situ Injection-Type Aquifer Remediation Projects: Instructions and Supplemental Information

{This version of UIC Notice memo is for use by staff of the BPSS and District offices}

TO: McKenzie Thomaswalters, Environmental Specialist II
Florida Department of Environmental Protection
Division of Water Resources Management
MS #3530; BMC 545E
2600 Blairstone Road, Tallahassee, Florida 32399-2400

THROUGH: _____
(An employee of Div. of Waste Management or DEP District Office)

FROM: _____
(An employee of Div. of Waste Management or DEP District Office; if another entity then the "Through" must be an employee of Div. of Waste Management or DEP District Office)

DATE: _____

SUBJECT: **Remediation Product Injection Well(s) for In Situ Aquifer Remediation at a PFAS Contaminated Site**

Pursuant to paragraph 62-528.630(2)(c), F.A.C., inventory information is hereby provided in regard to the proposed construction of temporary injection well(s) for the purpose of in situ aquifer remediation at a PFAS contaminated site.

Facility name: NASA Kennedy Space Center
Facility address: Facility M6-0486, Kennedy Space Center, FL 32899
City/County: Merritt Island / Brevard County
Latitude/Longitude: 28.521362, -80.662174
FDEP Facility Number: 058622250

Facility owner's name: NASA
Facility owner's address: KSC Headquarters Building, Kennedy Space Center, FL 32899

Well contractor's name: AECOM Technical Services, Inc.
Well contractor's address: 150 N Orange Avenue, Suite 200
Orlando, FL 32801

Underground Injection Control Notification Memorandum for In Situ Injection-Type Aquifer Remediation Projects: Instructions and Supplemental Information

AFFECTED AQUIFER

Name of aquifer: Surficial

Depth to groundwater (feet): Approximately 3 to 5 feet below land surface

Aquifer thickness (feet): Approximately 50 to 70 feet below land surface

Areal extent of contamination (square feet): 27,250,000

INJECTION WELLS

A site map showing the location and spacing of injection wells, the areal extent of the groundwater contamination plume, and associated monitoring wells is attached. The injection well(s) features are summarized below, and/or a schematic of the injection well(s) is attached.

(Direct-push) or HSA/Mud rotary *(circle the appropriate well type)*

Diameter of well(s) (i.e., riser pipe & screen) (inches): N/A

Total depth of well(s) (feet): N/A

Screened interval: N/A to N/A feet below land surface

Grouted interval, if applicable: N/A to N/A feet below land surface

Casing diameter, if applicable (inches): N/A

Cased depth, if applicable: N/A to N/A feet below land surface

Casing material, if applicable: N/A

If a remediation product will be injected as a DP rod is inserted, indicate injection interval: 3 to 13 feet below land surface.

PROJECT DESCRIPTION

The in situ, injection-type aquifer remediation product/process remediates contaminants by:
(check those that apply)

- ☐ use of a bioremediation product,
- ☐ use of a chemical oxidation product,
- ☐ recirculation of partially treated contaminated groundwater, or
- ☒ other (describe) Permeable Reactive Barrier

Brief description of the project: Colloidal activated carbon (CAC) permeable reactive barrier pilot study for PFAS-impacted groundwater. The CAC will provide surface for the adsorption of PFAS compounds.

Summary of major design considerations and features of the project:

Number of injection wells: 12

Injection volume per well (gallons): 400 (41 PlumeStop + 359 water)

Single or multiple injection events: Single

Injection volume total (all wells, all events): 4800 (492 PlumeStop + 4308 water)

For continuous recirculation of partially treated water, indicate total daily design flow rate: NA gallons per day

FLUID TO BE INJECTED

Brand name of remediation product(s): PlumeStop® Colloidal Biomatrix

Has an innovative technology acceptance letter been issued for this product by the BPSS: (yes) no (Note: it is not required that an innovative technology acceptance letter be issued for the technology or product to be proposed in a RAP)

> If product formula is proprietary then non-disclosure of the formula to the PE reviewing the RAP for the Department is only acceptable if there is an innovative technology acceptance letter issued by the BPSS with an attached proprietary voucher of confidential disclosure and it is verified that the proposed application rates (dosage) is limited to the rates specified in the innovative technology acceptance letter.

Is product formulation proprietary? (yes) no.

If product formulation is proprietary are proposed application rates limited to that indicated in innovative technology acceptance correspondence? (yes) no N/A

Composition of injected fluid (e.g. ingredient, wt. %): Colloidal Activated Carbon [7440-44-0] (<25%); Water [7732-18-5] (>75%); and Proprietary Additives (<2%).

TEMPORARY INJECTION ZONE OF DISCHARGE (ZOD)

(check those that apply)

☐ No ZOD needed. The fluid to be injected meets the primary and secondary groundwater standards of Chapter 62-550, F.A.C., and the minimum groundwater criteria of Chapters 62-520 and 62-777, F.A.C.

☒ ZOD permission by rule 62-520.310(8)(c)†, F.A.C., for reagent chemical species and/or parameter(s) in the fluid to be injected (or re-injected) that exceed secondary groundwater standards. ZOD permission by this rule also applies to chemical species in the fluid to be injected that exceed primary groundwater standards or minimum groundwater criteria, provided those species are prime constituents of the reagents used to remediate site contaminants. The chemical species and parameters for which the approved Remedial Action Plan identifies zone size and duration, and addresses groundwater monitoring are summarized below.

Chemical species & parameters: Aluminum – secondary groundwater standard (0.2 mg/L)

Zone size (sq. ft.) 1,500 Duration (mos.) 12 Yes, monitoring addressed. ☒

☐ ZOD permission by rule 62-520.310(8)(c)†, F.A.C., for the following contaminants of concern that exceed their groundwater standards in the fluid to be re-injected as part of a closed-loop re-injection system for which the approved Remedial Action Plan identifies zone size and duration, and groundwater monitoring:

Contaminants of concern:_____

_____

Zone size (sq. ft.)___ Duration (mos.)_____ Yes, monitoring addressed. ☐

☐ ZOD permission by variance because the fluid to be injected contains the following impurities that are not prime constituents of the reagents used to remediate the site's contaminants, and the concentrations of those impurities in the fluid to be injected are in excess of their primary groundwater standards:

Impurities regulated as primary groundwater contaminants:_____

_____

Zone size (sq. ft.)___ Duration (mos.)_____ Yes, monitoring addressed. ☐

☐ A variance needs to be granted before the remediation can be conducted.

☐ A variance has already been granted for the impurities listed above:

Date variance granted: _____

Zone size (sq.ft.): _____

Duration (mos.): _____

☒ If ZOD permission by rule 62-520.310(8)(c)†, F.A.C., or by variance is checked above, then a figure that delineates the ZOD is attached. (Use the lines below to more fully describe the ZOD if a figure alone will not suffice).

PlumeStop to be injected at twelve points (two rows of six) spaced at approximately five-foot intervals. (see attached site figure)

_____

CLEANUP CRITERIA AND ENFORCEABLE APPROVAL ORDER

The in situ injection-type aquifer remediation plan for this contaminated site is intended to meet the groundwater cleanup criteria set forth in Chapter 62-777, F.A.C. Additionally, all other groundwater standards will be met at the time of project completion for any residuals associated with the ingredients of the injected remediation products, and any by-products or intermediates produced as a result of the chemical or biochemical reactions induced by those ingredients or the contaminants of concern during their use. Applicable primary and secondary groundwater standards are set forth in Chapter 62-550, F.A.C., and minimum groundwater criteria are set forth in Chapter~~s~~ 62-520, F.A.C.

The remediation plan estimates that site remediation will take N/A (24mo Pilot Study) months. We will notify you if there are any modifications to the remediation strategy which will affect the injection well design or the chemical composition and volume of the injected remediation product(s).

The proposed remediation plan was approved on N/A (Pilot Study) by an enforceable approval order. A copy is attached. The remediation system installation is expected to commence within 60 days. Please call me at 407-488-7726 if you require additional information.

Florida Department of Environmental Protection

Bob Martinez Center
2600 Blair Stone Road
Tallahassee, Florida 32399-2400

Rick Scott
Governor

Carlos Lopez-Cantera
Lt. Governor

Jonathan P. Steverson
Secretary

August 31, 2015

Via Electronic Mail
Info@Regenesis.com

Craig Sandefur
Regenesis
1011 Calle Sombra
San Clemente, California 92673

Re: **PlumeStop™ Colloidal Biomatrix**

Dear Mr. Sandefur:

The Florida Department of Environmental Protection's Division of Waste Management (Division) hereby accepts PlumeStop™ Colloidal Biomatrix (PlumeStop™) for in-situ biodegradation of petroleum hydrocarbons, chlorinated solvents, and other suitable contaminants in groundwater and soil.

PlumeStop™ is an aqueous mixture of finely ground (micron-scale) activated carbon and proprietary food grade additives that is typically injected into the subsurface as aqueous slurry. As Regenesis has indicated, PlumeStop™ disperses quickly and widely in the subsurface, where it sorbs dissolved contaminants from the groundwater and concentrates them within its structure. It then provides a large amount of surface area for microbial colonization and growth in order to accelerate biodegradation.

The considerations of this letter should be taken into account for the use of PlumeStop™, and a site-specific Remedial Action Plan should be submitted for review and approval by the Department. A voucher for the confidential disclosure of the proprietary ingredients and a chemical analysis of PlumeStop™ is provided in Enclosure 1. Regulatory information is provided in Enclosure 2.

While the Department of Environmental Protection does not provide endorsement of specific or brand name remediation products or processes, it does recognize the need to determine their acceptability from an environmental standpoint with respect to applicable rules and regulations, and the interests of public health and safety. Vendors, upon receipt of an acceptance, must market the product or processes on its own merits regarding performance, cost and safety in comparison to

competing alternatives in the marketplace. This acceptance letter shall not be construed as either an approval of the product or a certification of its performance.

It is not a requirement that a remediation product or process obtain an acceptance from the Department in order to be proposed for use in a site-specific Remedial Action Plan, but the plan must contain sufficient information to show that the product or process meets all applicable and appropriate rules and regulations. For PlumeStop™, a copy of this acceptance letter should be included in the appendix of each site-specific Remedial Action Plan that proposes its use.

The Department reserves the right to revoke its acceptance of a product or process if it has been falsely represented. Additionally, Department acceptance of any product or process does not imply it has been deemed applicable for all cleanup situations, or that it is preferred over other treatment or cleanup techniques in any particular case. A site-specific evaluation of applicability and cost-effectiveness must be considered for any product or process, whether conventional or innovative, and adequate site-specific design details must be provided in a Remedial Action Plan. If you have any questions, contact Rick Ruscito at (850) 877-1133, extension 3722, through Mail Station 4590 at the letterhead address or by E-mail at RRuscito@ene.com.

Sincerely,

Rick Ruscito

Rick Ruscito, P.E.
Ecology & Environment, Inc.
Petroleum Restoration Program Section 6
RRuscito@ene.com

Jamie Luten Lopez
Environmental Consultant
Petroleum Restoration Program
Jamie.L.Lopez@dep.state.fl.us

Enclosure: (1) Voucher for Disclosure of Proprietary Ingredients and a Chemical Analysis of PlumeStop™ Colloidal Biomatrix
(2) Regulatory Information

ec: Andy Lowy - ALowy@Regenesis.com

Burlab 1476
INN 209
PPL 496
ITR 72940
8/31/2015

Florida Department of Environmental Protection

Bob Martinez Center
2600 Blair Stone Road
Tallahassee, Florida 32399-2400

Rick Scott
Governor

Carlos Lopez-Cantera
Lt. Governor

Jonathan P. Steverson
Secretary

Craig Sandefur
Regenesis
1011 Calle Sombra
San Clemente, California 92673

Re: Voucher for Disclosure of Proprietary Ingredients and a Chemical Analysis of PlumeStop™ Colloidal Biomatrix

Dear Mr. Sandefur:

The Division of Waste Management (Division) hereby acknowledges a confidential disclosure by Regenesis dated August, 28, 2014 regarding the specific proprietary additives and their proportions in PlumeStop™, and a supplemental disclosure dated November 20, 2014 providing the results of a chemical assay for metals. Having reviewed the disclosures, the Division hereby vouches for the information provided. The table below is not the detailed confidential information that was provided to the Division but rather the overall chemical composition provided on the Internet as a Material Safety Data Sheet.

PlumeStop™

(Aqueous mixture of activated carbon and other food grade additives.)

Ingredient	CAS No.	Concentration
Colloidal Activated Carbon ≤ 2.5 microns	7440-44-0	< 25%
Water	7732-18-5	> 75%
Proprietary Additives		≤ 2%

Without this voucher for disclosures of the proprietary ingredients and the chemical assay, and the advice provided by the Division in Enclosure 2 based on its review of those disclosures, users of PlumeStop™ would not know how to comply with the requirements of rule 62-520.310(8)(c), Florida Administrative Code (F.A.C.) for a temporary Zone of Discharge.

For underground injection control purposes, aquifer remediation plans proposing the use of PlumeStop™ must indicate the volume and complete chemical composition of the fluid to be injected. Since the identities and proportions of some ingredients are proprietary, as well as the chemical assay, it will suffice to indicate just the overall volume and concentration of PlumeStop™ to be injected, and provide a footnote indicating that one-time confidential disclosures dated August, 28, 2014 and November 20, 2014, identifying all of the ingredients, their proportions, and the results of a chemical assay are already on file with the Division. Please direct questions regarding this voucher to Rick Ruscito at (850) 877-1133, extension 3720.

Sincerely,

Rick Ruscito

Rick Ruscito, P.E.
Ecology & Environment, Inc.
Petroleum Restoration Program Section 6
RRuscito@ene.com

Jamie Luten Lopez
Environmental Consultant
Petroleum Restoration Program
Jamie.L.Lopez@dep.state.fl.us

ENCLOSURE 2

REGULATORY INFORMATION

a. Groundwater cleanup standards: The onus shall be on users of PlumeStop™ to ensure that all applicable groundwater standards will be met at the time of project completion for the contaminants of concern being remediated, and any by-products produced as a result of chemical or biochemical reactions induced or assisted by PlumeStop™. The following chapters of the Florida Administrative Code (F.A.C.) are cited: Chapter 62-550, F.A.C., for primary and secondary water quality standards; Chapter 62-520, F.A.C., for groundwater classes and standards; Chapter 62-522, F.A.C., for groundwater permitting and monitoring requirements; Chapter 62-528, F.A.C., for underground injection control, particularly Part V, for Class V, Group 4 aquifer remediation projects; Chapters 62-780, 62-782, and 62-785 F.A.C., for cleanup criteria; and Chapter 62-777, F.A.C., for cleanup target levels.

b. Injection well permit: Per Rule 62-528.630(2)(c), F.A.C., the issuance of an enforceable, site-specific Remedial Action Plan Approval Order by the Department for injection-type aquifer remediation [by PlumeStop™] constitutes the granting of a Class V injection well construction/clearance permit.

c. Underground Injection Control (UIC): Remedial Action Plans proposing injection-type aquifer remediation shall include the information required by rules 62-528.630(2)(c)1 through 6, F.A.C., for the purposes of the UIC program. Reviewers of those plans, upon issuance of a Department-enforceable Remedial Action Plan Approval Order must transmit this information to the UIC program in Tallahassee by submitting a completed copy of the "UIC Notification". The notification is in the form of a memorandum currently located on the Internet at www.dep.state.fl.us/waste/categories/pcp/pages/innovative.htm.

d. General information about temporary Zones of Discharge (ZOD): For groundwater remediation, the composition of a fluid to be injected must meet the primary and secondary drinking water standards set forth in Chapter 62-550, F.A.C., and the minimum groundwater criteria of Chapter 62-520, F.A.C., pursuant to UIC Rule 62-528.600(2)(d), F.A.C. Aquifer remediation products that do not meet these requirements must seek relief from water quality criteria by one of two mechanisms as follows. Permission for a temporary ZOD may be obtained via rule 62-520.310(8)(c), F.A.C. If permission for a ZOD cannot be obtained by rule, then it will be necessary to seek a variance from Department rules in accordance with Section 120.542, Florida Statutes.

   Rule 62-520.310(8)(c), F.A.C., allows for a temporary ZOD for closed-loop re-injection systems, for the prime constituents of the reagents used to remediate site contaminants, and for groundwater secondary standards. In order to obtain permission for a temporary ZOD by rule, a site-specific Remedial Action Plan must indicate: (a) the chemical ingredients of concern in the fluid to be injected that will be present in excess of groundwater standards; (b) the size of the ZOD that is needed; (c) the amount of time that the ZOD will be needed; and (d) a plan for monitoring the injected chemical ingredients of concern. The size of the temporary ZOD will usually be the injection well radius of influence when the treatment system is a single injection point. For a multiple point system, the ZOD can usually be

expressed and illustrated as the total area covered by all the injection points, located side-by-side with overlapping radii of influence.

e. Site-specific Remedial Action Plans shall indicate the volume and concentration of the aqueous PlumeStop™ slurry that will be injected.

f. Specific ZOD information for PlumeStop™: Obtain permission for a temporary injection ZOD by way of rule 62-520.310(8)(c), F.A.C., for aluminum, a secondary drinking water contaminant in Florida, and monitor the receiving groundwater for aluminum in order to comply with UIC ZOD requirements. For the aluminum, reviewers of Remedial Action Plans, when filling out the UIC Notification memorandum, should check the box labeled "*ZOD permission by rule* 62-520.310(8)(c), F.A.C., for *reagent chemical species and/or parameter(s) in the fluid to be injected (or re-injected) that exceed secondary groundwater standards*".

g. ZOD monitoring advice for PlumeStop™: For the ZOD parameter aluminum, quarterly monitoring of groundwater should suffice in most cases. The current secondary groundwater standard for is aluminum is 0.2 milligrams per liter (mg/L). Upon expiration of the time period granted for the ZOD by way of rule 62-520.310(8)(c), F.A.C., the concentration of aluminum must meet its groundwater standard or its natural-occurring background value at the specific cleanup site, whichever is less stringent.

h. Utilization of wells: If a remediation site happens to have an abundance of monitoring wells, then the Division of Waste Management has no objection to the use of some wells for the injection of PlumeStop™ slurry if the wells are suitable for the purpose. However, no "designated" monitoring well, dedicated to the tracking of remediation progress (by sampling) shall be used to apply PlumeStop™. This will avoid a premature conclusion that the entire site meets cleanup goals. By making sure that designated tracking wells are not used for treatment, there will be more assurance that the treatment process has permeated the entire site and that it did not remain localized to the area immediately surrounding each injection well.

i. Three categories of groundwater monitoring:

1. Active remediation monitoring for a cleanup site's contaminants of concern: During the period of active remediation, groundwater shall be monitored in accordance with the requirements set forth in Section 62-780.700, F.A.C.

2. Post Active Remediation Monitoring for a cleanup site's contaminants of concern: At least one (1) year of quarterly post remediation groundwater monitoring for the contaminants of concern shall be conducted at a minimum of two (2) wells: one located in the area of highest contamination, the other at the downgradient edge of the contamination plume, pursuant to Section 62-780.750, F.A.C.

3. Monitoring of the UIC zone of discharge for aluminum: For PlumeStop™, in order to comply with rule 62-520.310(8)(c), F.A.C., monitor the ZOD for aluminum as discussed in paragraph *g* above.

j. Operation:

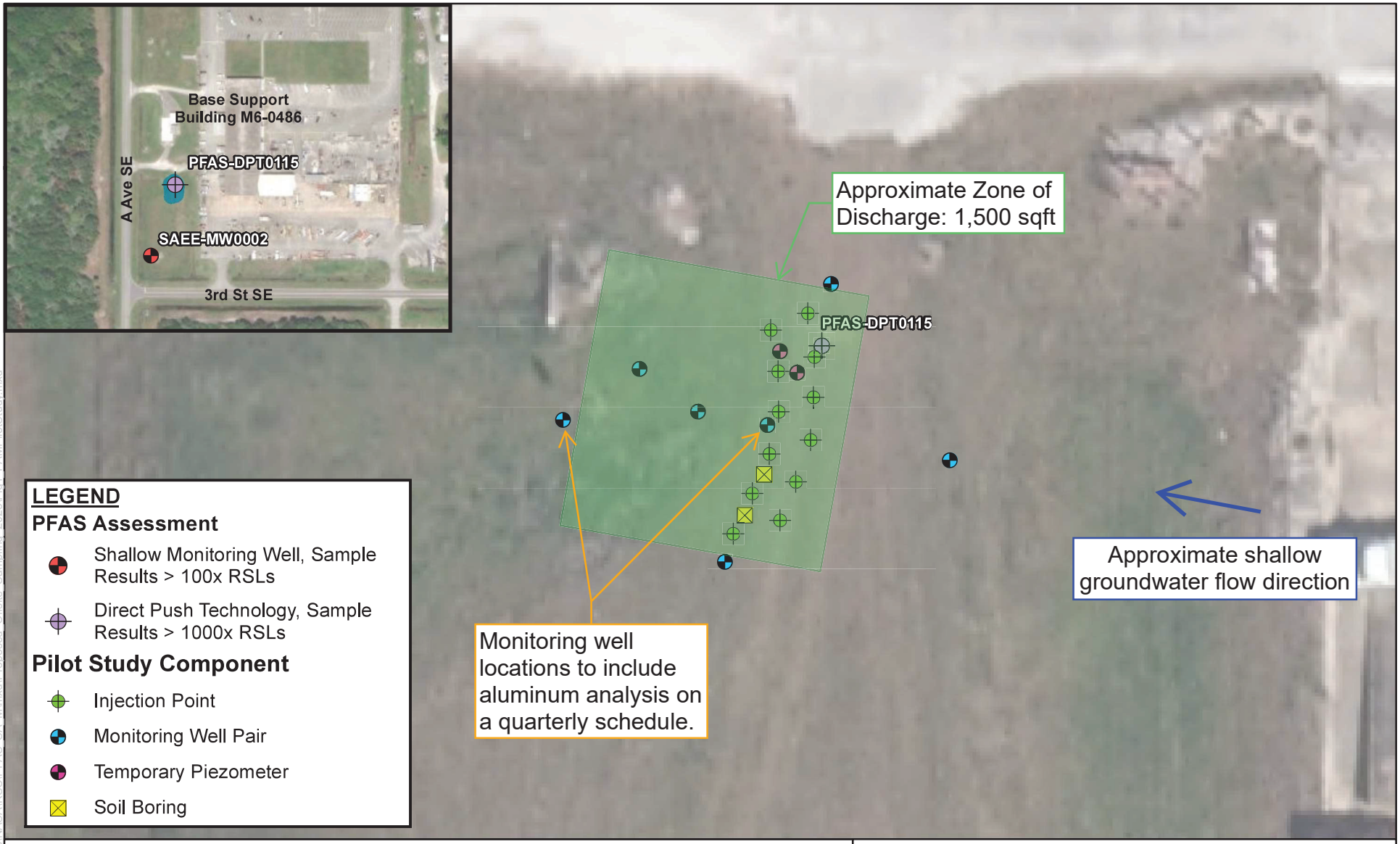
1. Avoidance of migration: For injection-type, in-situ aquifer remediation projects, injection of PlumeStop™ shall be performed in such a way, and at such a rate and volume that no undesirable migration of either the PlumeStop™ or the contaminants of concern in the aquifer results, pursuant to rule 62-528.630(3), F.A.C.

2. Underground Injection Control operating permit: Although an operating permit is not required for aquifer remediation wells pursuant to rule 62-528.640(1)(b), and 62-528.640(1)(c), F.A.C., since no movement of the contamination plume is expected to accompany the treatment process, the Department requests that the information items listed in rule 62-528.640(1)(b), F.A.C., be considered and included in Remedial Action Plan proposals as a matter of good and thorough design practice. Briefly summarized, they are: quality of water in the aquifer; quality of the injected fluid; existing and potential uses of the affected aquifer; and well construction details.

k. Abandonment of wells: Upon issuance of a Site Rehabilitation Completion Order or a declaration of "No Further Action", injection wells shall be abandoned pursuant to Section 62-528.645, F.A.C. The Underground Injection Control Section of the Department shall be notified so that the injection wells can be removed from the inventory-tracking list.

l. Open-pit application: There is no objection to the introduction of PlumeStop™ to an open excavation pit in which the groundwater has been exposed. Open-pit application is not injection, and it is not necessary to notify the Underground Injection Control Section, but this should not be construed as carte blanche to introduce to the pit any substance at any concentration with no regard to potential toxicological effects. The Division of Waste Management therefore recommends that the groundwater in the area of the pit be monitored for the same zone of discharge parameters that would have been monitored (if any) had the application actually been an injection.

m. Limitation: PlumeStop™ is not intended for bulk removal of free product. Remove the bulk of the free product by other means prior to the use of PlumeStop™.



NOTE:
-RSL = Regional Screening Level

MAPPING NOTES:
Basemap Source: Orthoimagery from Brevard County, 2018.
Projection Coordinate System: NAD 1983 StatePlane Florida East FIPS 0901
Scale: 1 Inch = 20 Feet

N

0 10 20 Feet

FIGURE 2-1
Base Support Building
PlumeStop® Injection Pilot Study Layout
JOHN F. KENNEDY
SPACE CENTER
MERRITT ISLAND, FLORIDA

Drawn By: AD	Date Saved: 10/24/2023	AECOM

APPENDIX E
Shallow Aquifer Groundwater Contour Figures

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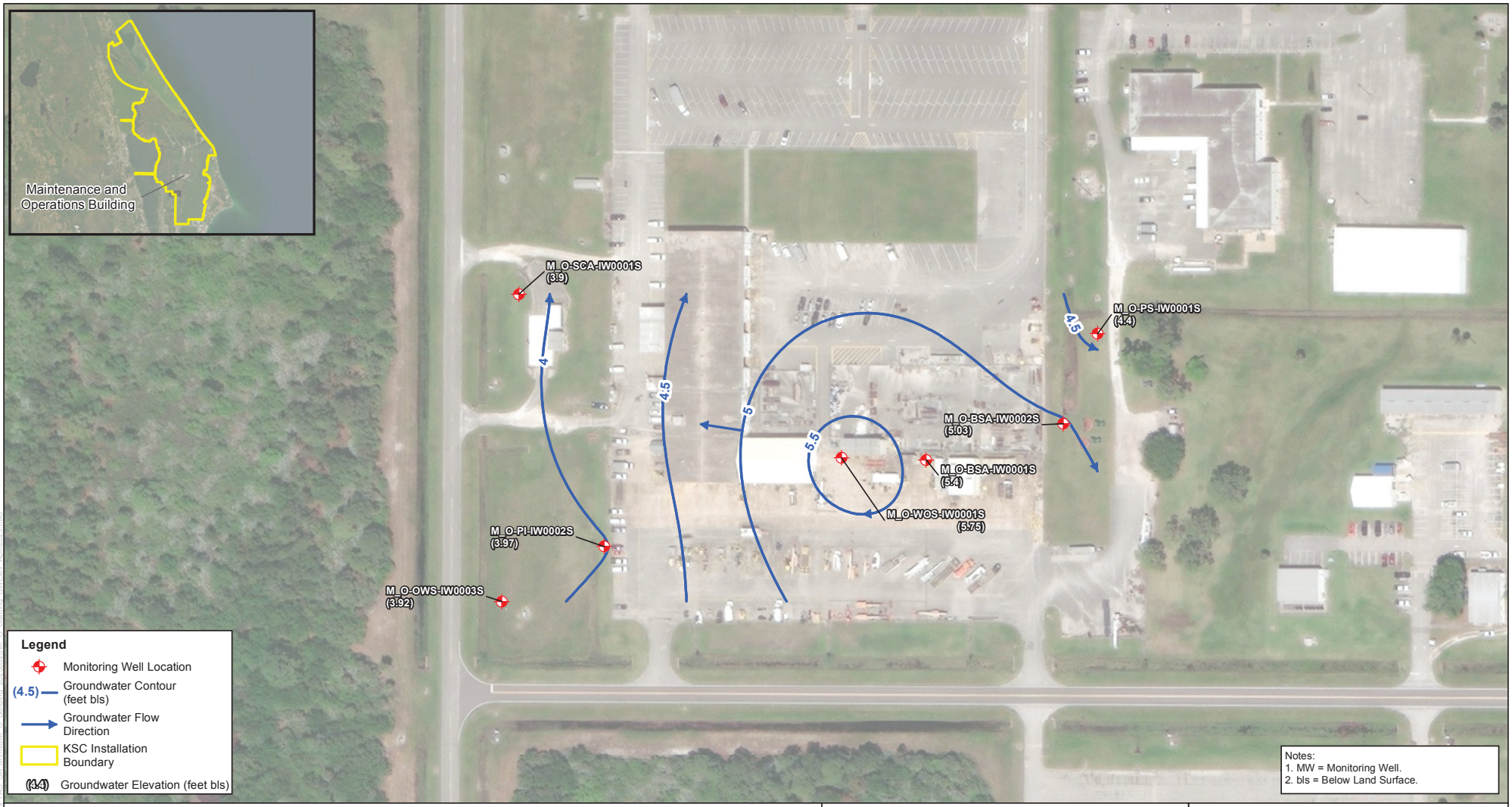

MAPPING NOTES:
-Basemap Source
Orthoimagery from Brevard County, 2018.
-Projection
Coordinate System: NAD 1983 StatePlane Florida East FIPS 0901
-Scale
1 Inch = 125 Feet

0 62.5 125 250 Feet

N

AECOM

JOHN F. KENNEDY
SPACE CENTER
MERRITT ISLAND, FLORIDA

Drawn By: SD | Date Saved: 8/28/2023

GROUNDWATER FLOW CONTOURS
APRIL 2023
BASE SUPPORT BUILDING

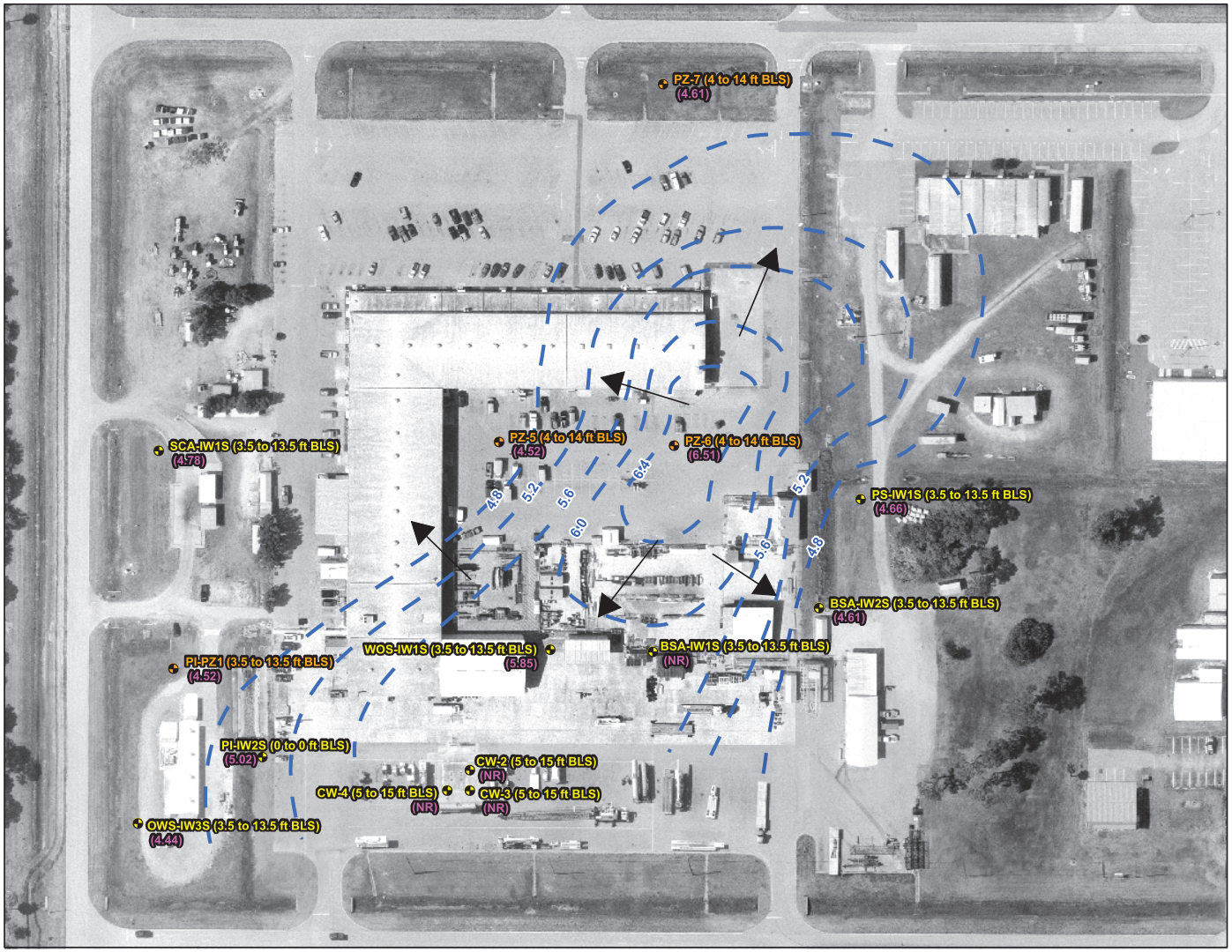

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Figure 2-3
Shallow Groundwater Elevations
September 17, 2002
M&O Building