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NGWA
The Groundwater Association

By:

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NATIONAL GROUNDWATER ASSOCIATION
Outstanding Groundwater Project Awards
Nomination for Groundwater Remediation Category

LAUNCH READY!

High-Resolution Site Characterization and the Expedited Remediation of a Multi-Acre Chlorinated Volatile Organic Compound Plume at

NASA's Launch Complex 39B

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NASA's Launch Complex 39B

Project Description

Client: National Aeronautics and Space Administration

Estimated Project Budget: $5,400,000

Introduction

Geosyntec teamed with the National Aeronautics and Space Administration (NASA) to restore groundwater resources and protect sensitive aquatic habitats at Launch Complex 39B (LC39B), a National Historic Site located within the John F. Kennedy Space Center (KSC) on the east coast of Florida **(Figure 1)**. The goal of this project was to remediate chlorinated volatile organic compound (CVOC) impacts in groundwater that had the potential to discharge to the sensitive habitat surrounding LC39B and to complete the remediation before NASA's Artemis Program's Space Launch System missions began. The Geosyntec NASA team met this goal by developing a robust Conceptual Site Model (CSM) using High Resolution Site Characterization (HRSC), using the CSM to design a multifaceted and highly specialized air sparge (AS) system to remediate the groundwater, and installing, operating, and optimizing the AS system to achieve the Corrective Action Objective (CAOs). The CAOs were achieved after only 2 years of AS system operation, which has significantly reduced the CVOC concentrations and mass present in the groundwater and mitigated the potential discharge of impacted groundwater to the surrounding sensitive aquatic habitat, all before the Artemis Program's launches at LC39B.

Background

LC39B encompasses approximately 170 acres and was developed in the mid-1960s to support NASA's manned lunar program, Project Apollo. LC39B was retrofitted in the mid-1970's to support the space shuttle program launches which continued through 2007. In 2010, the fixed service structure was removed to create a "clean pad" that is being reconfigured for future Artemis missions destined to return mankind to the moon and beyond. A unique feature of LC39B is that it is surrounded by environmentally sensitive surface waters and is inside the Merritt Island National Wildlife Refuge, which focuses on providing habitat and protection for endangered and threatened species and natural wildlife diversity.

Historic operations at LC39B impacted site groundwater and the constituents of concern (COCs) included trichloroethene (TCE), *cis*-1,2-dichloroethene (cDCE), and vinyl chloride (VC). NASA-KSC is regulated under the Resource Conservation and Recovery Act (RCRA), which is administered by the Florida Department of Environmental Protection (FDEP). The concentrations of COCs exceeded FDEP Groundwater Cleanup Target Levels (similar to the Environmental Protection Agency Maximum Contaminant Levels [MCLs]) and warranted active remediation. Since LC39B is surrounded by environmentally sensitive surface waters, there are strict groundwater to surface water discharge limitations which had to be considered as part of this project.

The groundwater impacts were identified during the RCRA Facility Investigation (RFI) in the early 2000's; however, a complete investigation and remedy could not be implemented near the operational launch pad. Accordingly, the Geosyntec NASA Team developed an interim remedy outside the active launch pad area to begin remediating groundwater and protecting the sensitive aquatic habitats surrounding LC39B. After the space shuttle program ended in 2011, the Geosyntec NASA Team initiated environmental remediation activities with the goal of completing active remediation before Artemis mission operations began and protecting the sensitive aquatic habitat surrounding LC39B. The plan to achieve this goal included developing an accurate CSM using existing RFI data coupled with HRSC, completing a remedial alternative evaluation (RAE), selecting and designing the remedy, and installing/operating/optimizing the remedy to complete remediation prior to NASA's return to launches.

High-Resolution Site Characterization and Conceptual Site Model Development

Development of an accurate CSM is critical to the successful implementation of a remedy. HRSC is a method to define COC distribution and subsurface characteristics with a high degree of certainty and is built on the use of solid groundwater principals. The HRSC performed at LC39B included direct-push technology (DPT) groundwater sampling to define COC distribution and the collection of soil cores to define the lithology. The unique DPT groundwater sampling strategy included collecting 5,298 DPT groundwater samples from 992 locations combined with mobile laboratory analysis of the samples. The use of a mobile laboratory allowed for rapid, data-driven decisions on sample locations and depth intervals and the near real-time mapping of the COC distribution, which contributed to the accuracy of the CSM.

HRSC identified groundwater impacts that were divided into four areas: "Hot Spots" 1 and 2, a 9-acre High Concentration Plume, and a 27-acre Low Concentration Plume which are defined on **Figure 2**. Critical to the accuracy of the CSM was the identification of Hot Spots 1 and 2, which were the "source areas" contributing to the groundwater impacts; therefore, it was vital to address these areas in the remedy selection and design. To further enhance the CSM, the Geosyntec NASA Team developed a site-wide 3D Environmental Visualization System (EVS) model of the COC distribution **(Figure 3)** to visually comprehend the large data set, provide additional insights into plume characteristics, and to support the engineering design solution. The 3D EVS model provided NASA and FDEP a with a clear and concise visual of the CSM that allowed faster regulatory approval for the path forward.

The HRSC and existing RFI data were utilized to develop a robust CSM and a brief summary of the key CSM points are: (i) COCs were generally present in higher permeability sand/silty sand and underlain by lower permeability sandy clay; and (ii) groundwater flow at LC39B was radial from the center of the pad toward surface water with a northwest tendency.

Corrective Action Objectives

Once the CSM was established, the Geosyntec NASA Team developed a RAE to evaluate remedial alternatives to meet the CAOs **(Figure 2)**. The CAO developed and approved by FDEP was to rapidly reduce COC concentrations below the FDEP Natural Attenuation Default Concentrations (concentrations where transition to Monitored Natural Attenuation (MNA) was generally accepted). AS in the 9-acre High Concentration Plume (which included treatment of the Hot Spots) in combination with MNA of the Low Concertation Plume was selected as the remedy. The RAE estimated up to 5 years to achieve CAOs.

Air Sparge System Design and Installation

Following AS system design approval by FDEP, AS system construction began in January 2017 and was completed in July 2017 with zero safety incidents, a significant accomplishment considering the magnitude of drilling and remedial construction. The AS system layout is presented on **Figure 4**, and a brief discussion of the AS system components are provided below.

- 279 AS wells installed via Sonic drilling screened at various depth intervals (maximum depth of 59 ft BLS) which were uniquely laid out/spaced based on anticipated radius of influence (ROI), COC concentration, and area-specific groundwater flow velocity.
- 32 manifold enclosures housing air metering equipment for individual AS wells.
- 14,000 linear feet (2.7 miles) of trenching and 65,000 linear feet (12.3 miles) of high-density polyethylene air conveyance piping **(Photo 1)**.
- 100-horsepower air compressor housed in a trailer and a control panel to allow for on-site and remote adjustments to system operations.
- 37 performance monitoring wells in the treatment area to evaluate AS performance.

At the time of construction, this system was the largest known AS system operating in the eastern United States.

Air Sparge System Design/Installation Uniqueness and Creativity

For air sparging to be successful, it is important to have adequate air distribution within the subsurface to achieve the design ROI and maximize mass removal. The depth of the lower permeability unit identified during the HRSC varied; therefore, soil cores were collected from the bottom 5 to 10 feet of each AS well location to visually identify the depth of the lower permeability unit. AS well screen intervals were adjusted to assure they were placed within the higher permeability unit.

The manifolds **(Photo 2)** were uniquely engineered to easily optimize air flow to individual AS wells and to be reused by NASA. The manifolds were constructed with weatherproof NEMA enclosures that housed metering equipment (pressure gauges, flow meters, and valves connected with quick-connects). The manifold design allowed for efficient data collection, ease of adjusting air flows to individual wells, simplified equipment replacement (if necessary), and an air bypass loop to protect the metering equipment from continued air flow-related fouling.

The AS trailer system **(Photo 3)** was designed for flexibility and reuse by NASA. The AS trailer was designed with a 17-leg manifold with 13 legs plumbed with metering equipment (solenoid valves, air flow adjustment valves, flow meters and pressure gauges) for use at LC39B. The inclusion of 4 extra legs allowed for flexibility for use at another site and also allowed for potential expansion of the AS system at LC39B. The AS trailer manifold system also allowed flexibility in the operation of the AS system by allowing modifications to the air flow and operational time of each leg.

Air Sparge System Operation and Optimization

The AS system operation began in July 2017. The AS system was configured with 4 operational zones that operated 6 hours per day each that allowed pulsed air delivery to the zones to minimize preferential pathway development and to reduce the size of the air compressor required. Performance monitoring included monthly operation and maintenance (O&M) and quarterly performance monitoring well sampling (including the collection of geochemical parameters to evaluate the distribution of oxygen in the subsurface). The AS system was shut down a minimum of 72 hours prior to performance monitoring to enable collection of groundwater samples that were representative of static conditions.

One challenge in operating a large air sparge system, is the collection, management, and evaluation of the O&M data. The Geosyntec NASA Team developed site and system-specific electronic O&M forms uniquely designed to make data collection and management more efficient. Field personnel could easily record operational parameters on electronic forms using a tablet, and data were uploaded remotely, allowing for rapid data processing and review to enable optimization in real time.

Air Sparge System Performance Monitoring Results

The O&M data collected indicated the air sparge system operated as designed based on the following: (i) each AS well received the design air flow; (ii) system was operational >90%; and (iii) a 30+ foot ROI (exceeding the design ROI) was achieved at the target treatment depths based on geochemical conditions (dissolved oxygen and oxidation reduction potential).

A unique challenge to evaluating air sparge system performance monitoring results, is evaluating the potential for rebound once the system is shut down. The July 2018 performance monitoring results indicated that COC concentrations were below the CAO in two of the four operational zones. Therefore, with FDEP's approval, these two zones were turned off, select wells were sampled in these zones to monitor for rebound, and the operational periods were extended for the remaining two zones. The performance monitoring results nine months post air sparge system shut down in the two zones indicated that COC concentrations did not rebound and remained below CAOs.

Performance monitoring results from approximately 2 years post-start-up (August 2019) indicated that the: (i) CAOs were achieved at all 37 performance monitoring wells **(Figure 5)**; and (ii) mass removal was >98% in the Hot Spots and the High Concentration Plume.

Summary

The goal of this project was to remediate COC impacts in groundwater that had the potential to discharge to the sensitive habitat surrounding LC39B and to complete the remediation before Artemis mission launches began at LC39B. The CAOs were achieved within 2 years post-air sparge system startup, and > 98% of the mass from the High Concentration Plume was removed, which mitigated the potential discharge of impacted groundwater to the surrounding sensitive aquatic habitat. The Geosyntec NASA team achieved this goal by using innovative HRSC techniques to develop an accurate CSM, and developing unique and creative site-specific solutions such as: (i) collecting soil cores from each AS well location to assure placement of well screens in a higher permeability layer allowing for effective distribution of air in the subsurface to maximize mass removal; (ii) designing manifolds to increase the efficiency of data collection, allow for flexibility in the operation of the AS system, and for reuse; and (iii) designing the AS trailer for operational flexibility and reuse. Based on the initial evaluation of rebound, it is unlikely that rebound will occur after the AS system is shut down. Since the Artemis missions are not scheduled, NASA has elected to continue to operate the AS system to continue to further reduce COC concentrations.

Figure 1

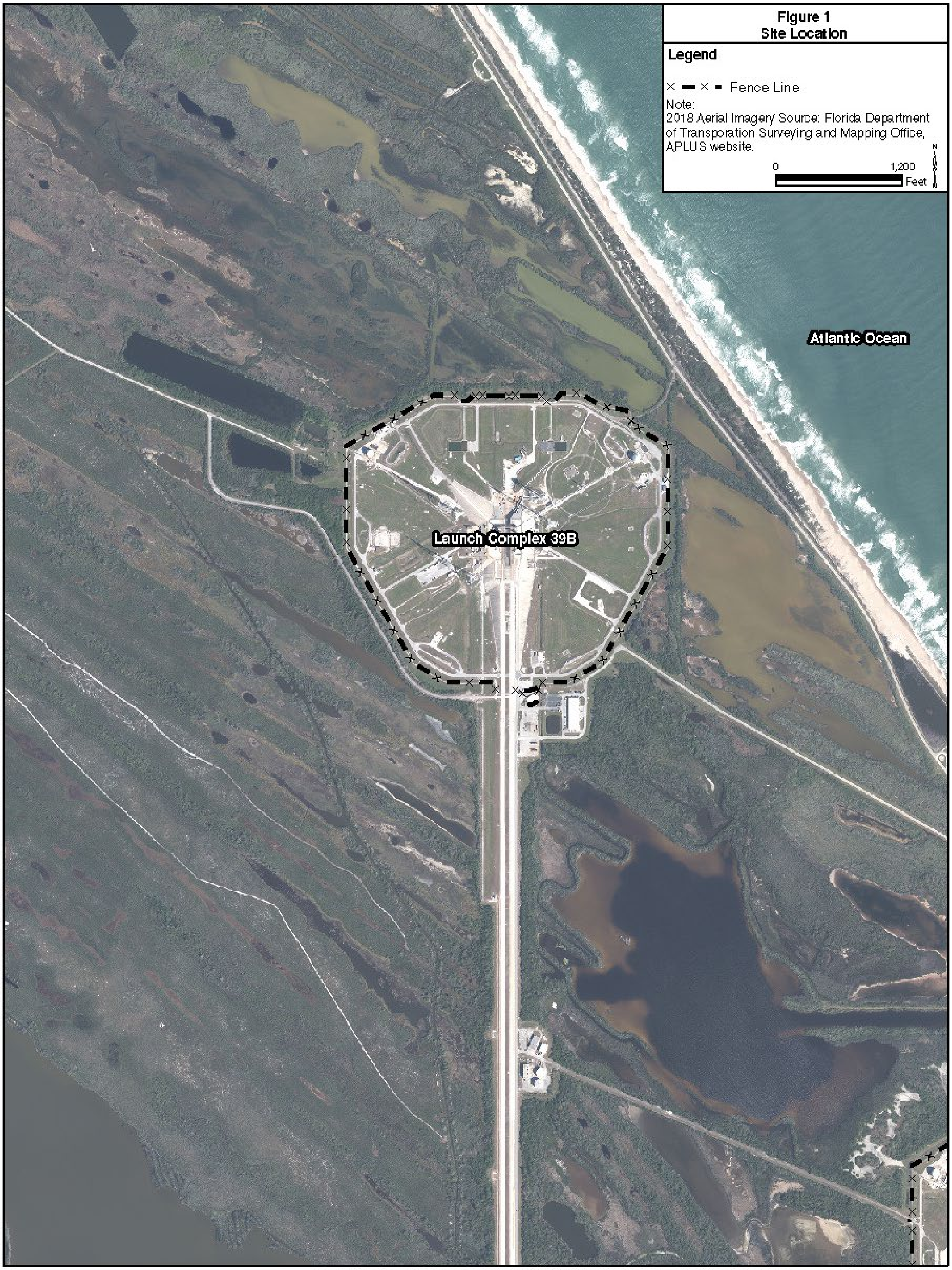


Figure 1
Site Location
Legend
Fence Line
Note:
2018 Aerial Imagery Source: Florida Department of Transporation Surveying and Mapping Office, APLUS website.
0
1,200
Feet
N
Atlantic Ocean
Launch Complex 39B

Figure 2

Figure 2
Groundwater Chlorinated Volatile Organic Compounds Impacts

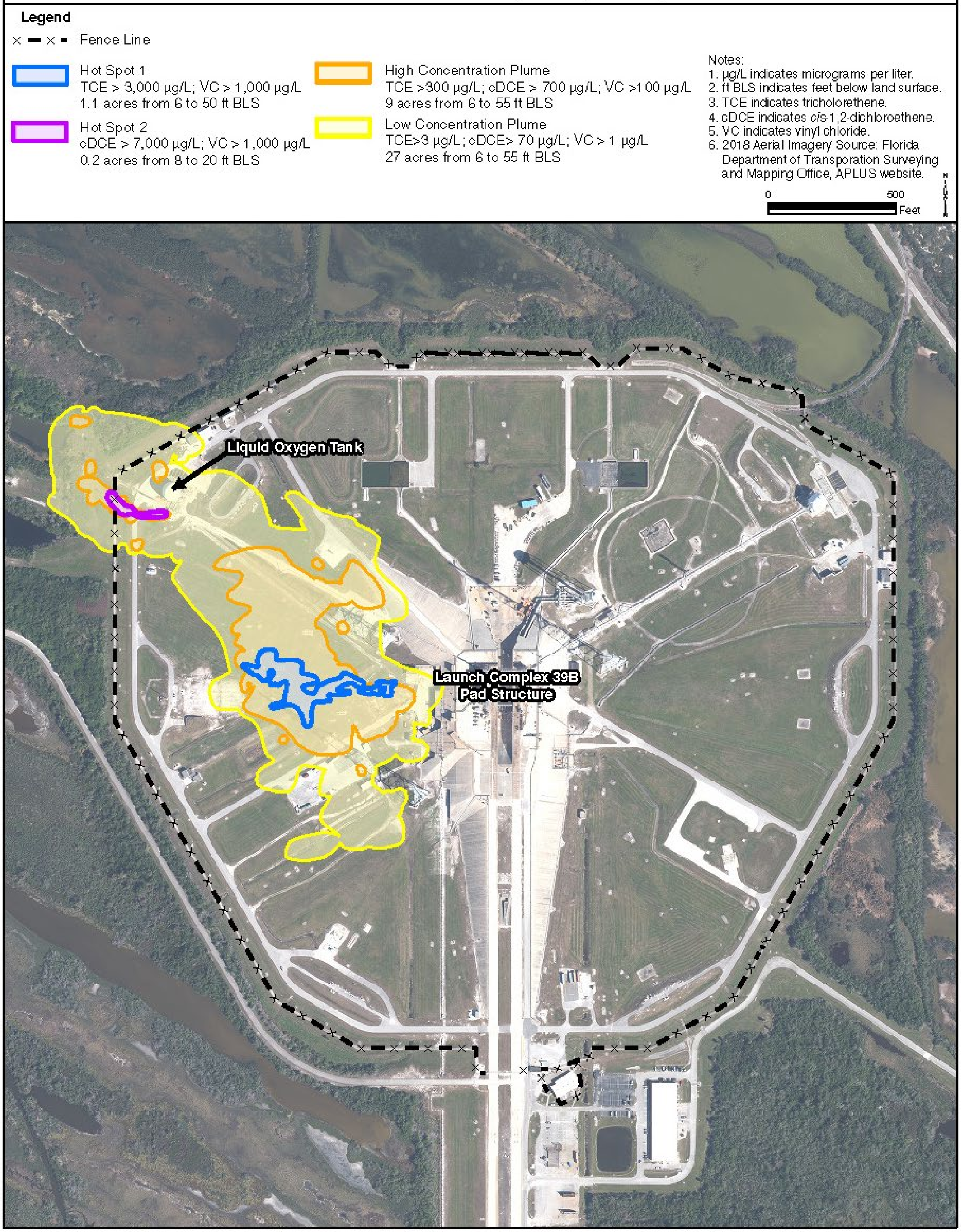
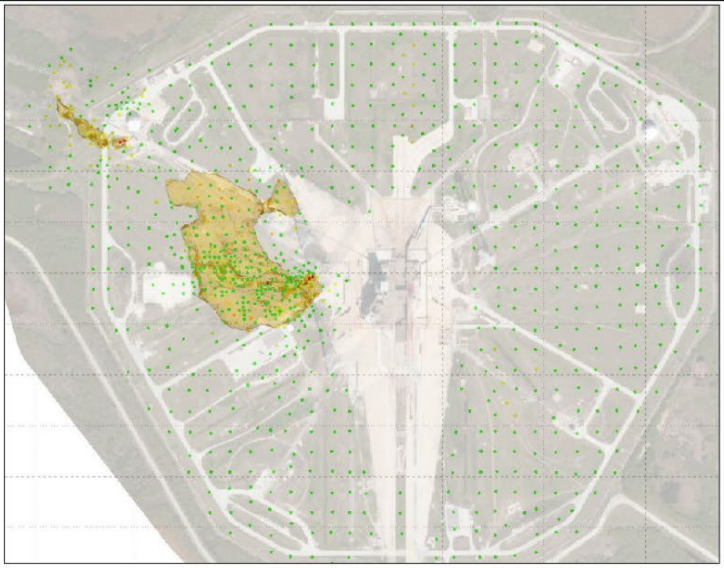


Figure 3

Figure 3
Environmental Visualization System (EVS) Vinyl Chloride Model



Plan View of the EVS Model – VC Plume Extent

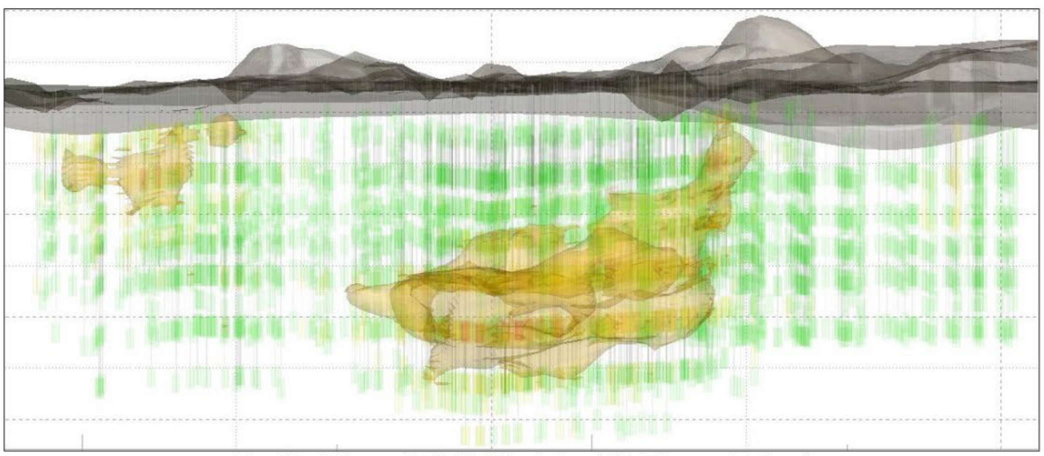
Legend

- DPT Sampling Location
- 100 µg/L VC Plume

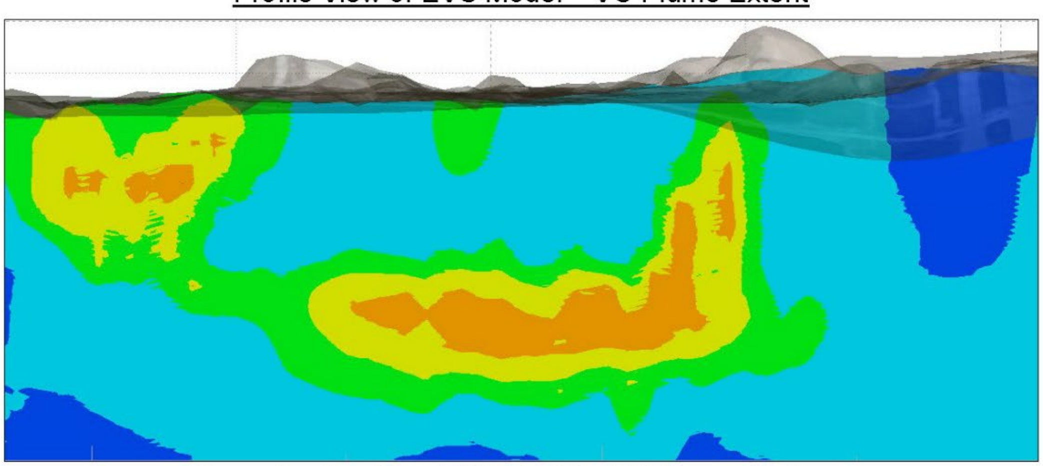
Vinyl Chloride Concentrations

- <1 µg/L
- 1 to 100 µg/L
- 100 to 1,000 µg/L
- > 1,000 µg/L

Notes:
1. DPT indicates direct push technology.
2. VC indicates vinyl chloride.
3. µg/L indicates micrograms per liter.



Profile View of EVS Model – VC Plume Extent



Cross Section from EVS Model – VC Concentrations

internal info: path, date revised, author

Figure 4

Figure 4
Air Sparge System Layout and Groundwater Monitoring Network

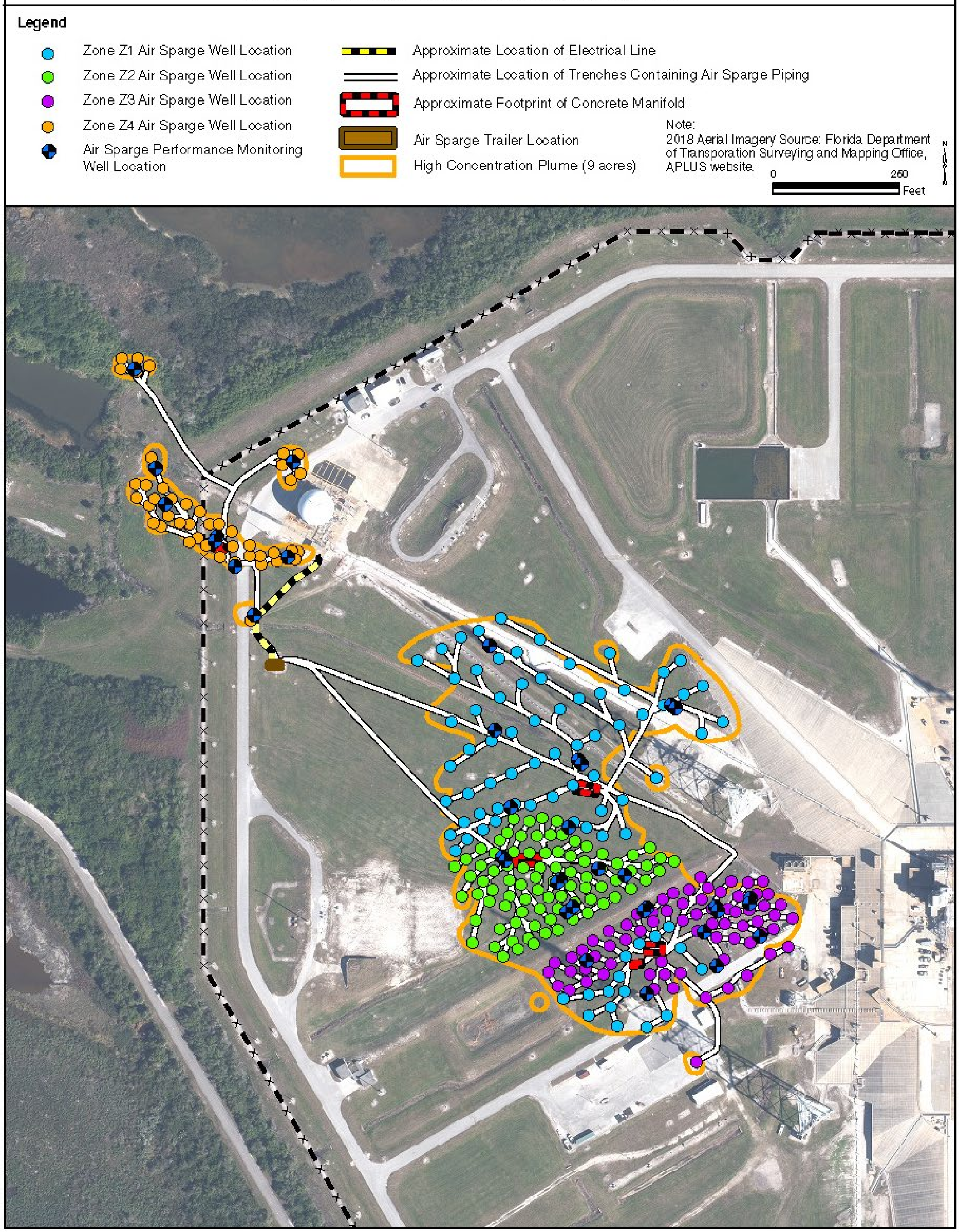
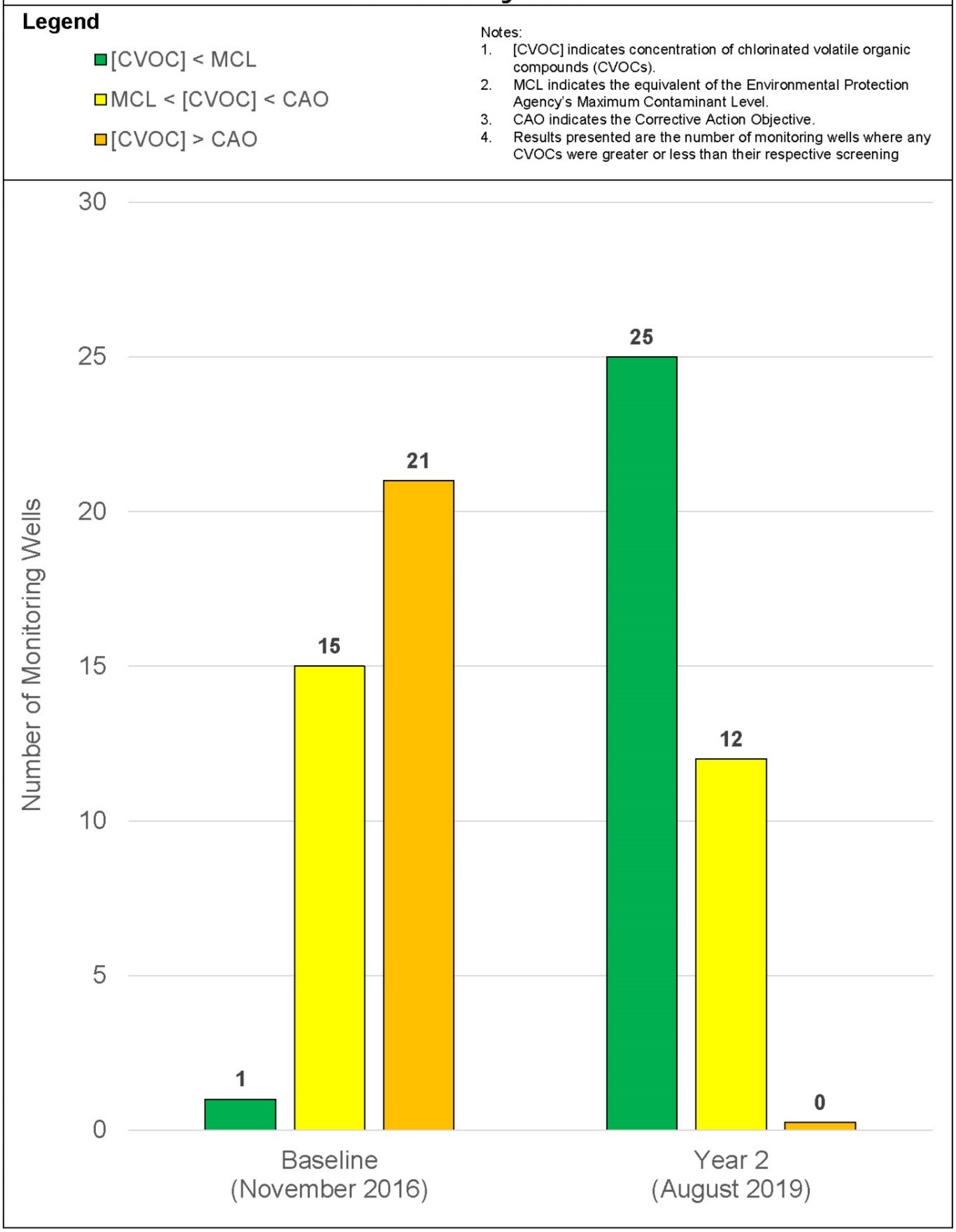


Figure 5

Figure 5
Performance Monitoring Results Compared to Screening Criteria:
Baseline to August 2019



internal info: path, date revised, author

Photo 1

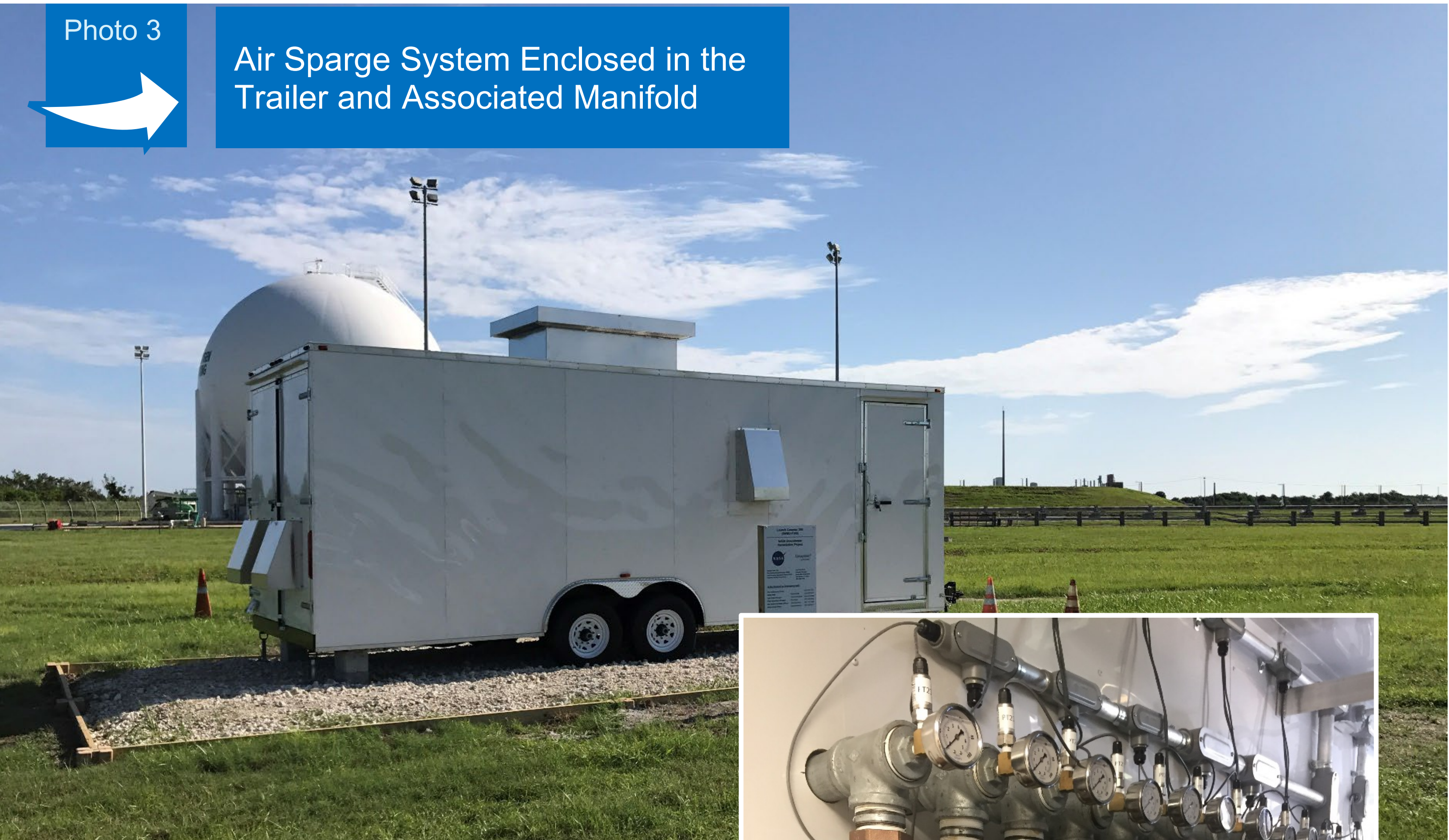
Air Sparge System Trenching and Piping Installation

Photo 2

Manifold for Air Sparge Wells

Photo 3

Air Sparge System Enclosed in the Trailer and Associated Manifold



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