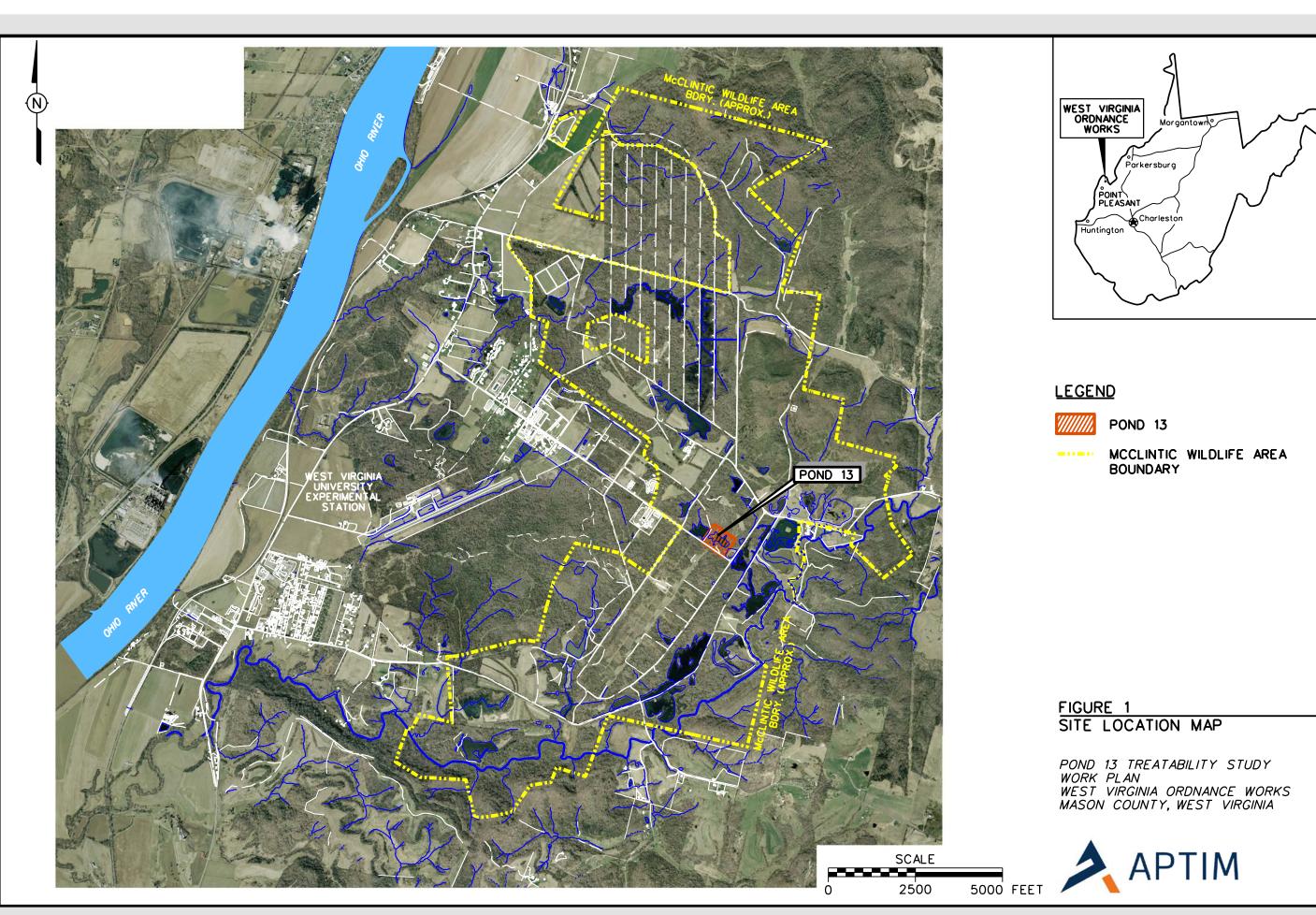
FIELD SCALE TREATABILITY STUDY TO EVALUATE IN SITU BIOREMEDIATION VIA SOIL MIXING OF EVO AND ZVI TO REDUCE MUNITIONS CONSTITUENTS STEVEN DOWNEY (Steven.Downey@APTIM.com) and ROBERT MAYER (APTIM Federal Services, Knoxville, Tennessee, USA) RICHARD MEADOWS (US Army Corps of Engineers, Huntington, West Virginia, USA)

INTRODUCTION

- West Virginia Ordnance Works (WVOW) site is located on the east bank of the Ohio River in Mason County, West Virginia (Figure 1)
- ► WVOW was a 2,4,6-Trinitrotoluene (TNT) manufacturing facility from 1942-1945
- WVOW included 12 TNT production lines (only 10 were actually used for production)
- TNT production resulted in soil and groundwater contamination
- Primary chemicals of concern (COC) include: TNT, 2,4-Dinitrotoluene (2,4-DNT), 2,6-DNT, 2-Amino-4,6-DNT (2-A-4,6-DNT), and 4-A-2,6-DNT
- Complete decontamination was not achieved by the army, so the site was listed on the National Priority List (NPL) in
- Portions were transferred to the state of West Virginia for use as a wildlife management reserve
- The site is now the McClintic Wildlife Management Area



The treatability study area formerly consisted of a wastewater handling system (which included a pumping station, two small tanks, and two large earthen constructed wet wells) that was used to handle red and yellow wastewaters during the TNT manufacturing process (Figure 2)



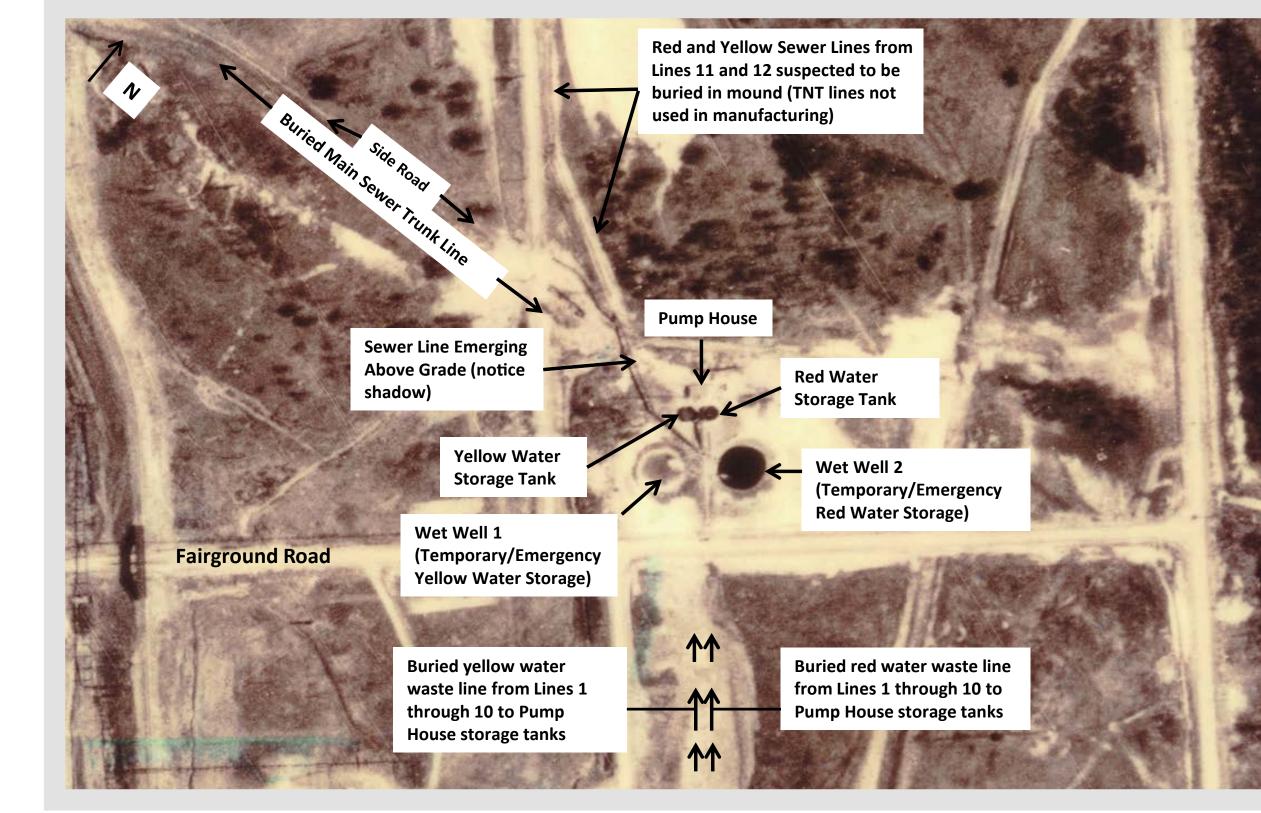


Figure 2 Pond 13/Wet Well Area, circa 1945 Former West Virginia Ordnance Works, Mason County, West Virginia

TIMELINE OF SITE INVESTIGATION/TREATMENT

- ▶ 1997 A groundwater treatment system (GTS) was constructed and operations began; however, the system was shut down within 6 months due to discharge violations
- 2000 GTS was restarted and continued to operate until 2017
- 2004 Excavation and treatment of approximately 1,000 cubic yards of contaminated soil
- 2005 Installation of new extraction wells in a more highly contaminated area; however, despite better plume capture, contamination levels have remained relatively constant
- 2008-2010 An in situ enhanced bioremediation treatability study was conducted. Treatment was very effective in reducing nitroaromatic concentrations; however, concentrations rebounded once the carbon source was exhausted, indicating a contaminant source may still be present
- 2014 Soil and groundwater samples were collected to delineate contamination in the vicinity of Pond 13
- 2016 Additional soil and groundwater samples were collected in the Pond 13 area to further define contaminant distribution; these samples focused on multiple depth intervals to provide vertical delineation of contamination
- 2017 Initiated treatability study using soil mixing to distribute EVO and ZVI



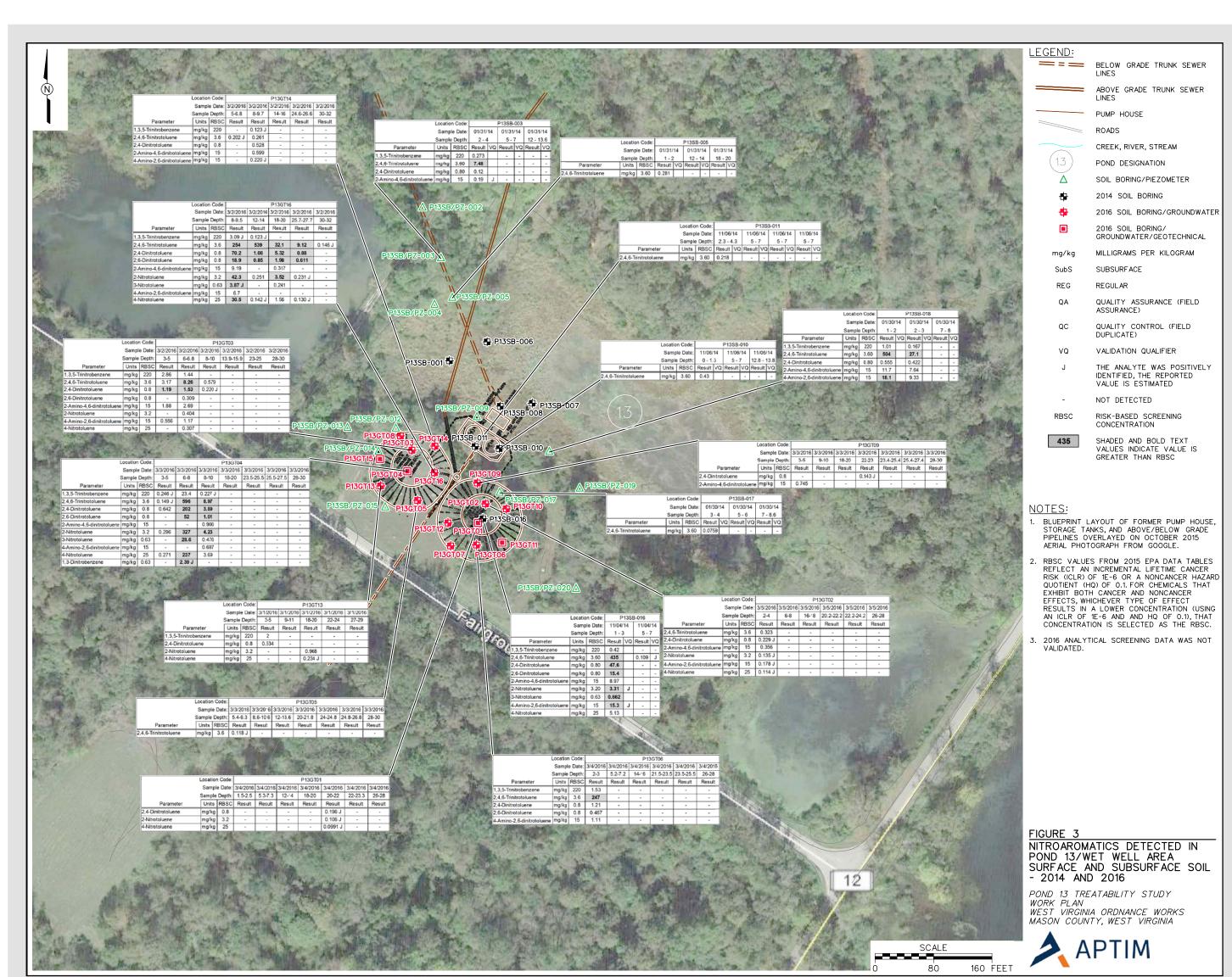
RECENT INVESTIGATION ACTIVITY

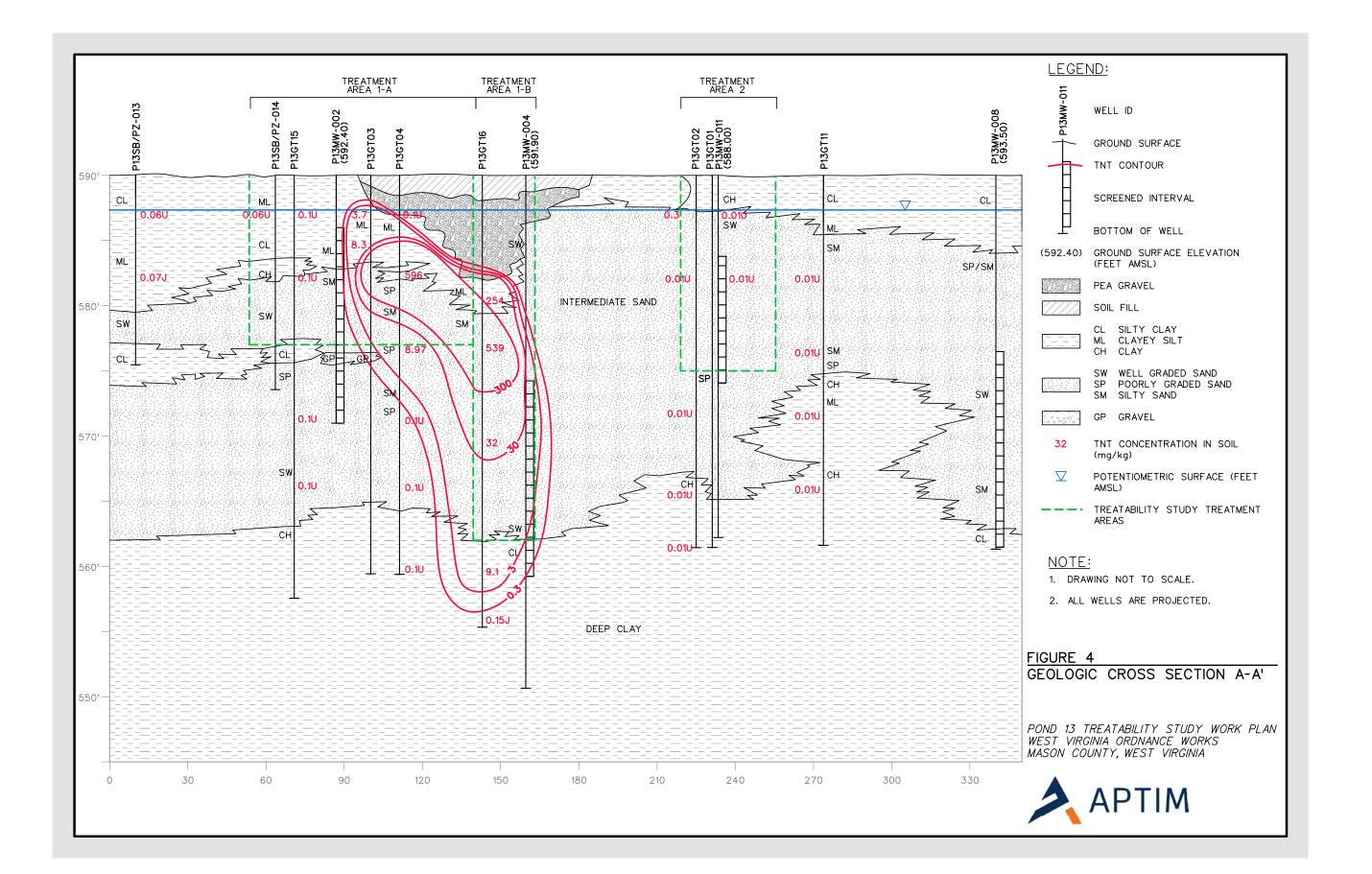
2014 Sampling Activities:

- Soil samples were collected from 20 soil borings using direct-push techniques (Figure 3 and 4)
- 15 temporary piezometers were installed and groundwater samples were collected
- Series a permanent groundwater wells were installed and sampled along with 18 existing wells

2016 Sampling Activities:

- Soil samples were collected from 16 boring locations at 7 different depth intervals
- A groundwater sample was collected from each boring location. Soil samples were collected from 4 additional borings for
- geotechnical analysis, including:
 - Atterberg Limits
 - > Water Content
 - Size Distribution
 - Total Density
 - > Unconfined Compression
 - Coefficient of Permeability





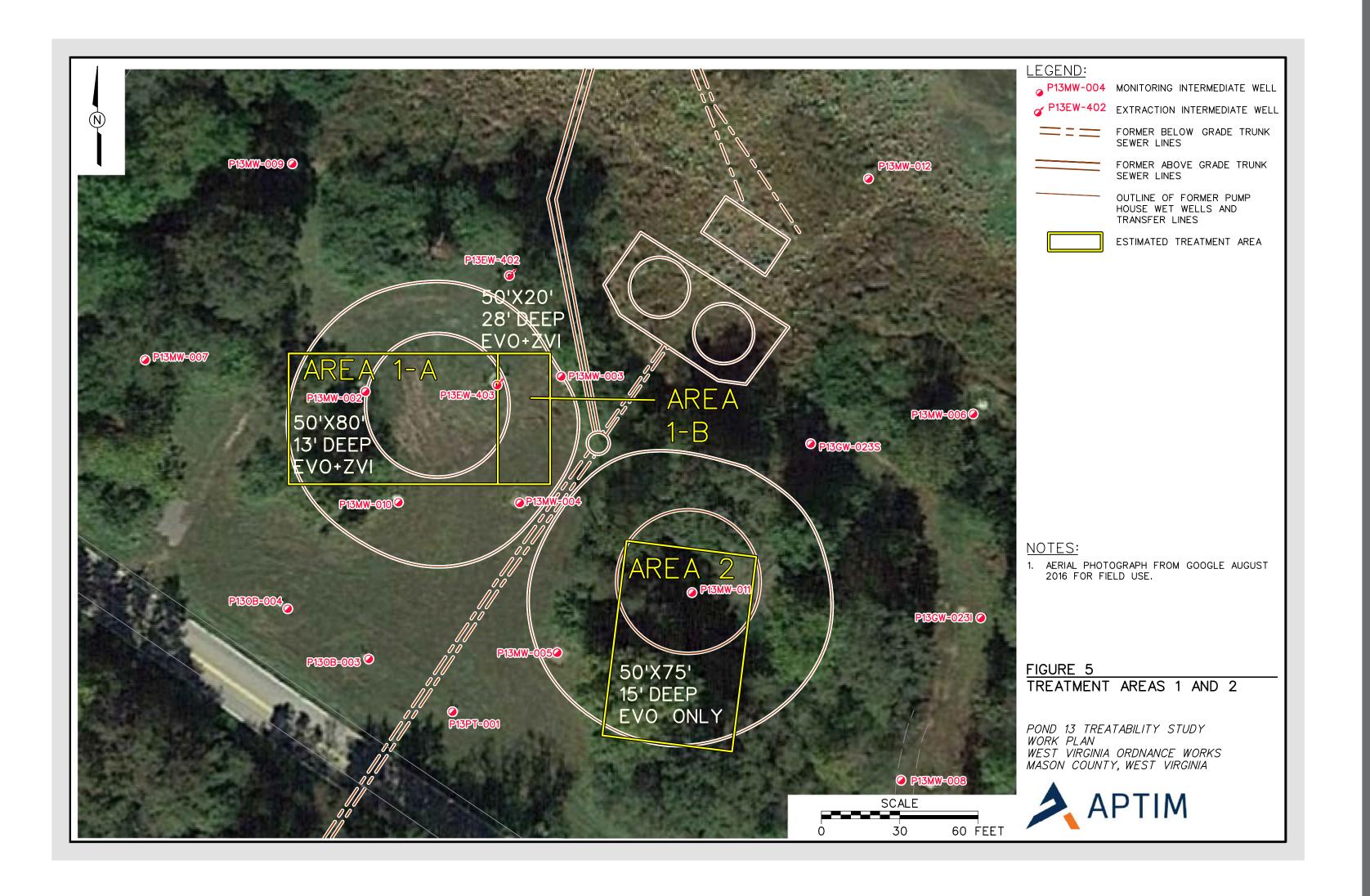
TREATABILITY STUDY

Objectives

- Evaluate effectiveness of soil mixing to distribute treatment amendments in both the saturated zone and vadose zone
- Determine the time required to achieve remedial objectives using soil mixing Evaluate cost vs. benefit of adding ZVI to the amendment used
- Determine design characteristics for potential future large scale remediation using these technologies at this site or other sites with similar contaminants and geology

Design

- lateral and vertical delineation of contaminants (Figure 4)
- Two areas of contamination coincide with the location of the former wet wells The area and depth of treatment in each area was designed based on the
- Area 1 was treated with both EVO and ZVI (this area is slightly more contaminated) (Figure 5)
- Area 2 was treated with EVO only (Figure 5) Soil mixing was used to provide for a better distribution of amendments into the saturated and vadose zones
- 3 wells were abandoned (within the mixing zones) and 5 new wells were installed to monitor the study
- Area will be monitored quarterly for 18 months to evaluate the study





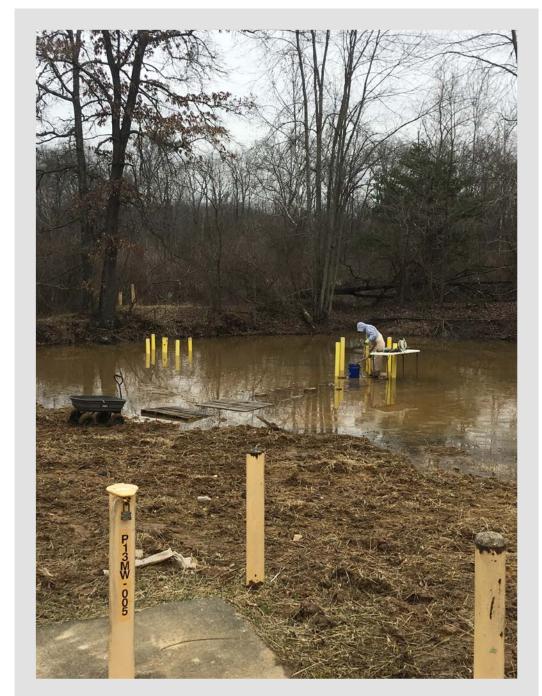
Benching Area 1



Unexpected Drain Pipe Encountered



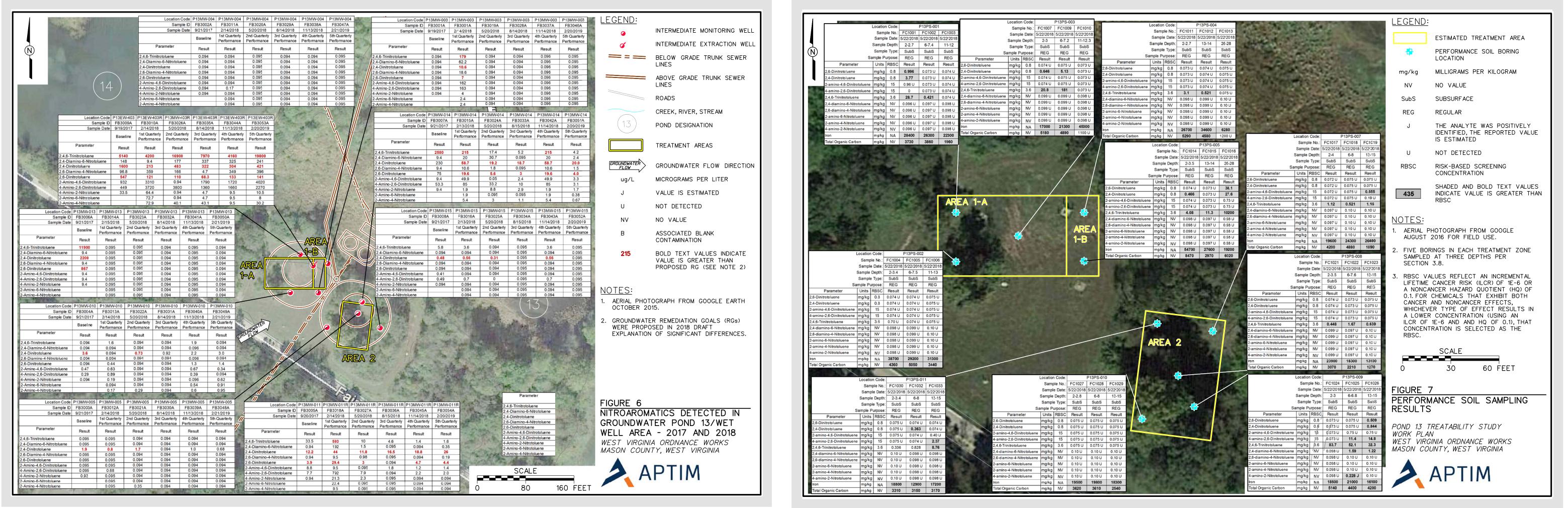
Adding Amendments



Sampling Challenges

RESULTS TO DATE

Figure 6: Groundwater analytical results from the baseline sampling in September 2017 and the first five quarterly performance samplings



Area 1

- P13MW-013 (down gradient north), 2,4,6-TNT reduced from 11,900 µg/L to non-detect after 3 months and remains at non-detect
- P13MW-003 (side gradient east), 2,4,6-TNT reduced from 179 µg/L to non-detect after 3 months and remains at non-detect
- P13EW-403R (which replaced extraction well P13EW-403) > 2,4,6-TNT has cycled with lows of 4,200 μ g/L and 4,160 μ g/L and highs of 16,900 μ g/L and 19,800 μ g/L (most recent sample)
- 2- Amino-4,6-dinitrotoluene remains high at 4,020 µg/L and 4-Amino-2,6-dinitrotoluene at 2,270 µg/L which indicates biological reduction is still taking place
- Soil samples (May 2018) revealed a hot spot near the SW corner of Area 1 with 2,4,6-TNT at 10,200 mg/kg in the 26-28' depth interval
- Soil sample near the NE corner was non-detect for all nitroaromatics at all depths except for minor detections of 2,4,6-TNT

Area 2

- P13MW-014 (down gradient north), 2,4,6-TNT reduced from 2,580 µg/L to 5.2 μ g/L, rebounded to 215 μ g/L, then reduced to 4.2 μ g/L (most recent sample)
- \blacktriangleright P13MW-015 (side gradient east), reduced from 5.8 µg/L to non-detect, rebounded to 3.6 µg/L, then reduced to non-detect (most recent sample)
- P13MW-011R (replaced P13MW-011 within mixing zone), 2,4,6-Trinitrotoluene increased from 33.5 µg/L to 593 µg/L, then decreased to 1.6 µg/L over subsequent sampling event
- Soil samples (May 2018) revealed minor detections of 2,4,6-TNT near the NW and NE corners and in the center; highest concentration was observed near the SE corner (83.7 mg/kg 2,4,6-TNT)

Remaining Sampling Event

- One final groundwater sampling event will be conducted in May 2019
- In addition to groundwater samples, additional soil borings will be conducted
- Boring locations will be adjusted to better define extent of hot spot near SE corner of Area 1





Mixing Equipment

EVO - Emulsified Vegetable Oil

Group 1





Soil Mixing



Red Water after Mixing



Surface Stabilization

Expect the Extraordinary.

Figure 7: Soil analytical results from sampling in May 2018

