



Bioaugmentation Design for Treatment of High-Level Source Area Contaminated With Explosives

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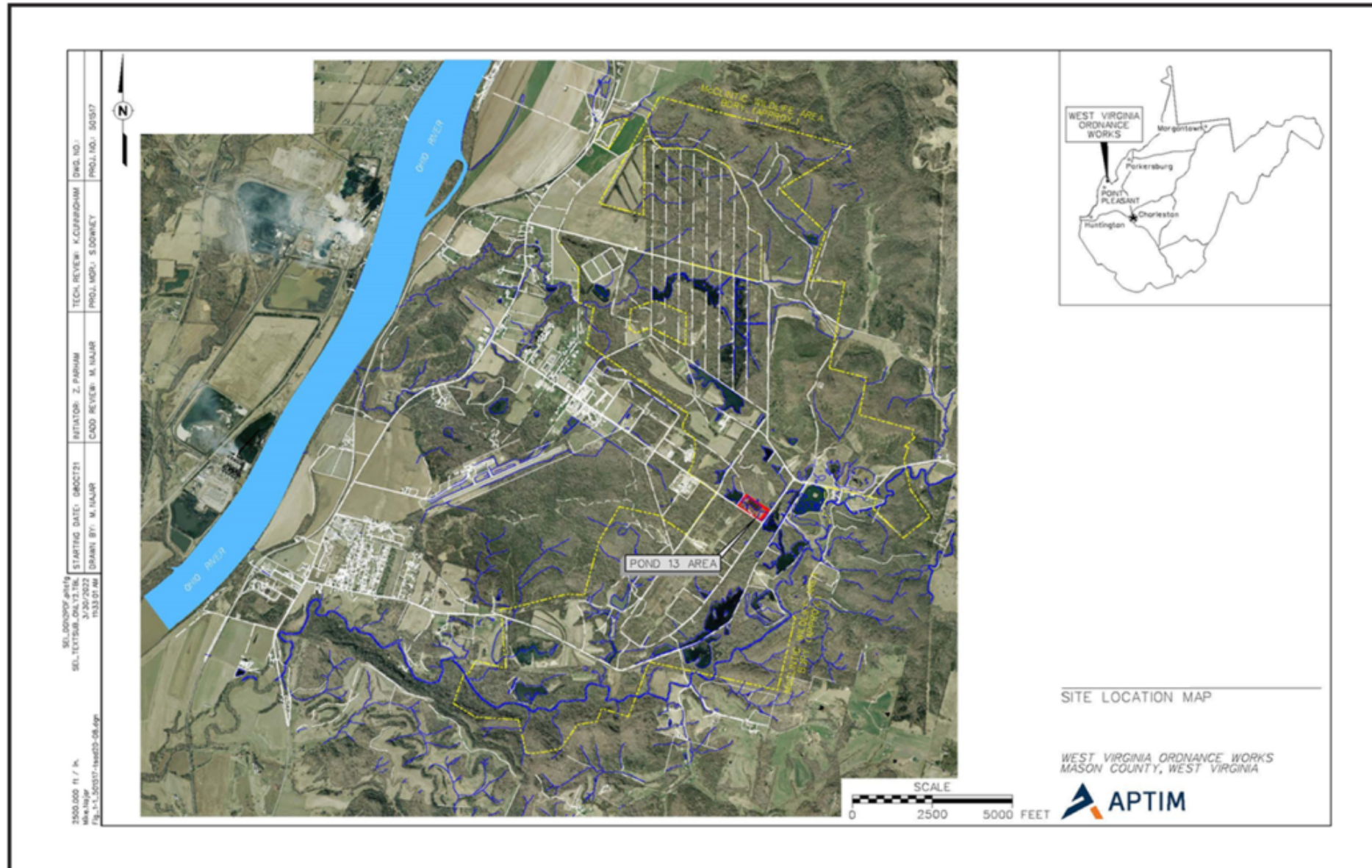
Zach Parham

BACKGROUND

- Former West Virginia Ordnance Works was used by the US Army to manufacture 2,4,6-trinitrotoluene (TNT) during the early 1940s
- Located on the east bank of the Ohio River, six miles north of Point Pleasant, WV
- Added to the NPL in 1983 due to remaining contamination of surface water, soil, and groundwater
- Currently managed as part of the McClintic Wildlife Management Area
- OU-2 ROD, signed in 1988, selected pump and treat as the remedy for OU-2; including the Pond 13 Wet Well Area
- ESD signed in 2019 updated RGs and recommended optimization of the OU-2 Groundwater remedy via biostimulation

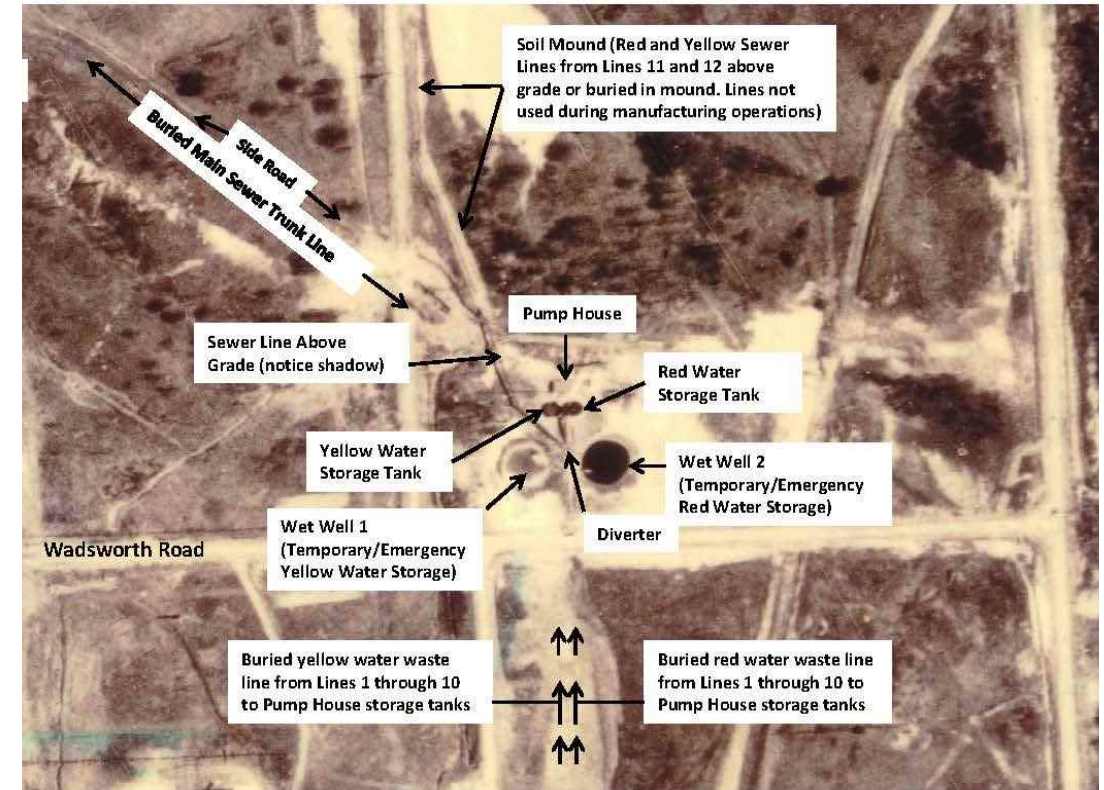


POND 13 AREA



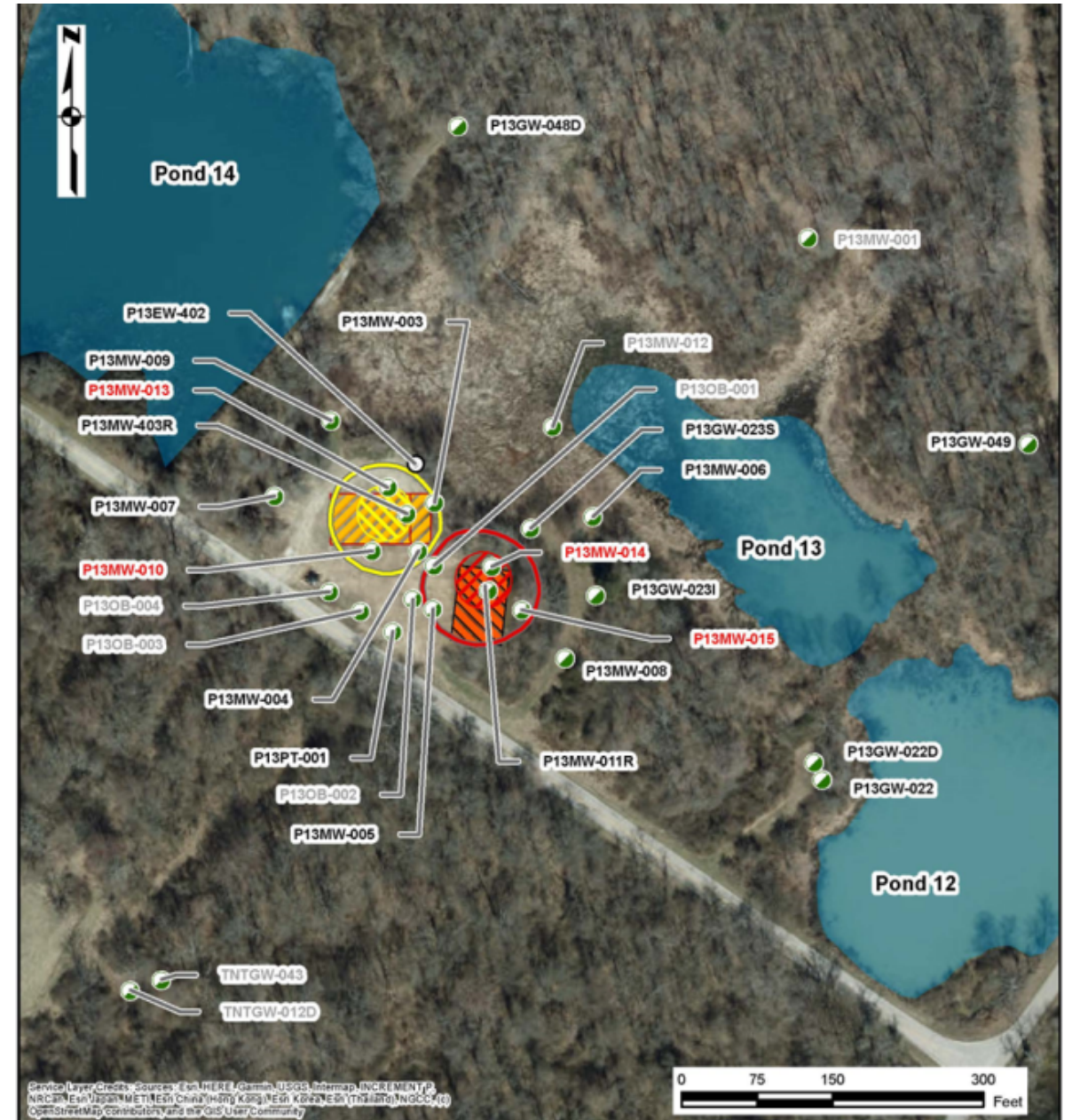
BACKGROUND (CONT.)

- Pond 13 Area contained two wet wells (Yellow Water and Red Water) to contain wastewater from the TNT manufacturing process
- Pump & Treat system was operated nearly continuously from 1997 to 2017
- In 2008 a treatability study was conducted to evaluate the effectiveness of direct injection of a carbon source (EVO)
- 2017 to 2019 a field-scale treatability study was conducted utilizing soil blending to distribute amendments
 - A mixture of EVO and ZVI was blended in the former Yellow Water Wet Well Area
 - EVO alone was blended into the former Red Water Wet Well Area



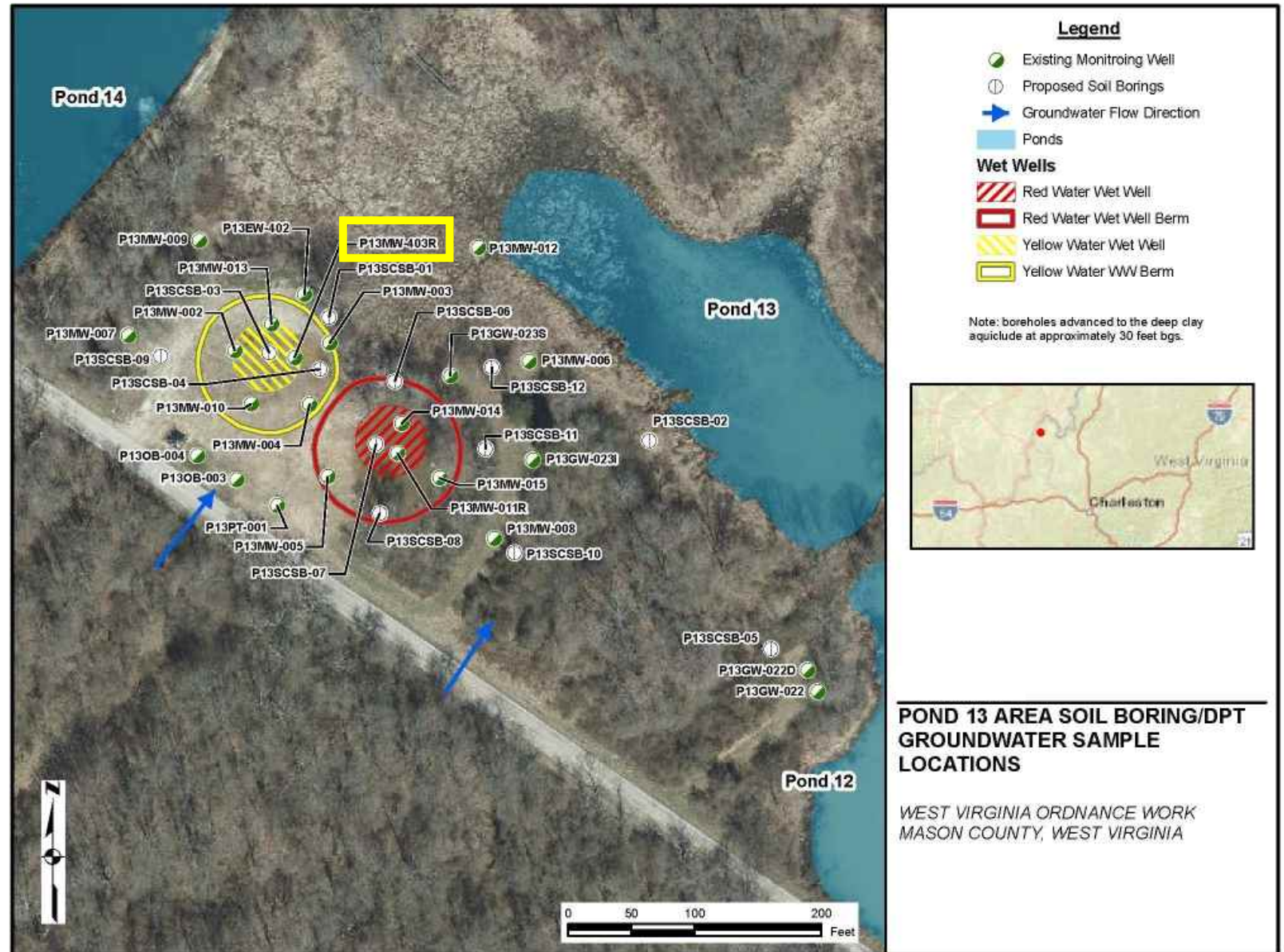
OBJECTIVES

- Accelerate reduction of nitroaromatic contaminants in groundwater at the Pond 13 Area to below OU-2 ROD levels.
- Perform additional site characterization to eliminate data gaps and provide additional design parameters
- Final deliverable is a detailed design using biostimulation to accelerate cleanup
- Deliverable will also include a “bid-quality” estimate for implementation of the design
- Buy-in from all stakeholders
- Ultimate goal is to discontinue operation of the pump & treat system



APPROACH

- Review historical soil and groundwater concentrations
- Known “hot spot” is P13MW-403R in the former yellow water wet well area
- P13MW-403R exhibited 2,4,6-TNT concentrations as high as 31,800 µg/L
- Utilize HRSC and DPT to collect additional soil and groundwater data
- Design a remedial augmentation treatment to accelerate cleanup
- Design started with a brainstorming session with all stakeholders



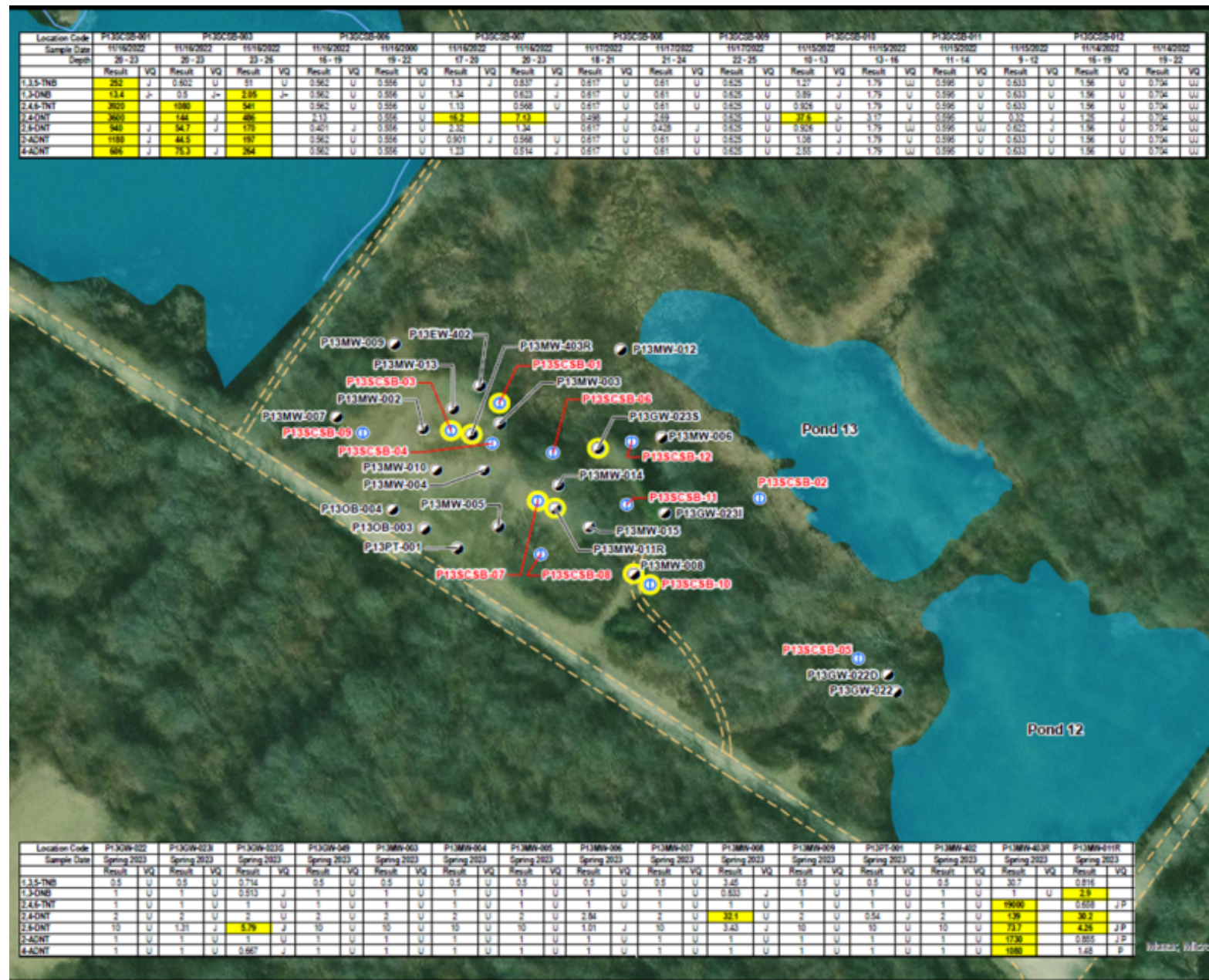
GROUNDWATER REMEDIATION GOALS

1,3,5-Trinitrobenzene (1,3,5-TNB)	118 µg/L
1,3-Dinitrobenzene (1,3-DNB)	2.0 µg/L
2,4,6-Trinitrotoluene (2,4,6-TNT)	4.0 µg/L
2,4-Dinitrotoluene (2,4-DNT)	7.0 µg/L
2,6-Dinitrotoluene (2,6-DNT)	4.0 µg/L
2-Amino-4,6-Dinitrotoluene (2A-DNT)	4.0 µg/L
4-Amino-2,6-Dinitrotoluene (4A-DNT)	4.0 µg/L



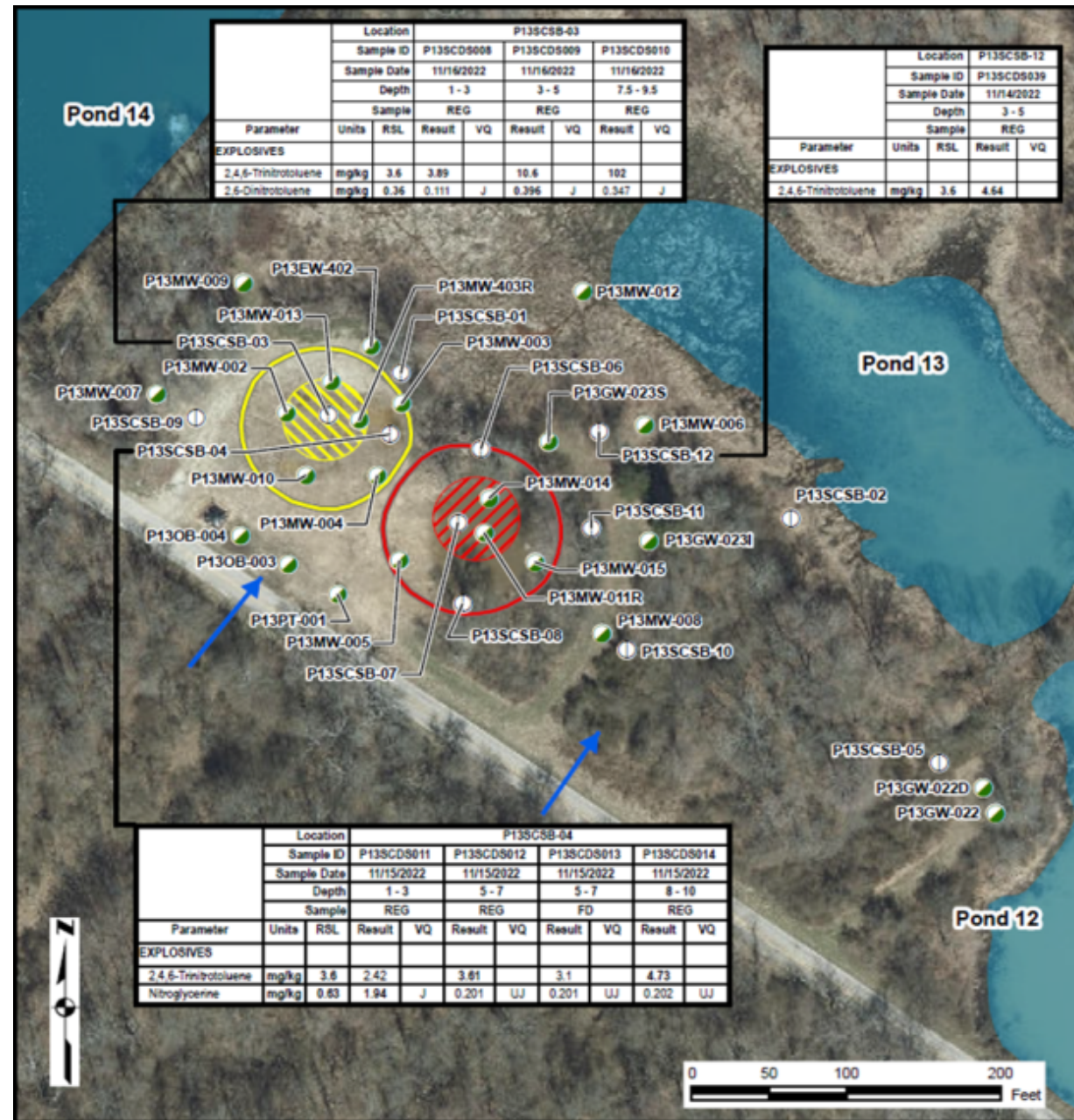
GROUNDWATER RESULTS

- Yellow halo: Exceeded remediation goal
- Black: existing wells
- Red: DPT samples
- P13MW-403R having 19,000µg/L of 2,4,6-TNT was most contaminated area
- P13SCSB-001 and P13SCSB-003 helped delineate this hot spot
- RW wet well area also exceeded RGs for 1,3-DNB; 2,4-DNT and 2,6-DNT
- Additional exceedances were observed at P13GW-023S for 2,6-DNT and at P13MW-008 and P13SCSB-10 for 2,4-DNT



SOIL RESULTS

- Nitroaromatics detected above RSL at 3 locations:
- P13SCSB-003 exceeded RSL
 - 2,4,6-TNT at depths of 1-3, 3-5 and 7.5-9.5 feet BGS and
 - 2,6-DNT at 3-5 feet BGS
- P13SCSB-004 exceeded RSL
 - 2,4,6-TNT at depths of 1-3, 5-7 and 8-10 feet BGS
- P13SCSB-012 exceeded RSL
 - 2,4,6-TNT at depth of 3-5 feet BGS



TREATMENT SYSTEM AUGMENTATION DESIGN

Amendment Selection

- Previous treatability studies demonstrated that EVO and a mixture of EVO and ZVI were effective in reducing nitroaromatics in groundwater
- A benefit of the EVO/ZVI mixture is the added longevity as compared to EVO alone
- To treat the elevated levels of nitroaromatics, colloidal activated carbon (CAC) has been selected to aid in pulling contaminants from the groundwater and adhering them to a solid phase carbon to be biologically degraded
- Sulfidated micro Zero Valent Iron (S-mZVI) is the ZVI product selected
 - Delivered as a colloidal suspension 40% ZVI by weight in glycerol
 - Particle size of less than 5 microns.
 - The sulfidation process coats the ZVI which increases activation and extends performance longevity
 - S-mZVI destroys contaminants abiotically and creates reducing conditions that can aid in stimulating the bioremediation processes



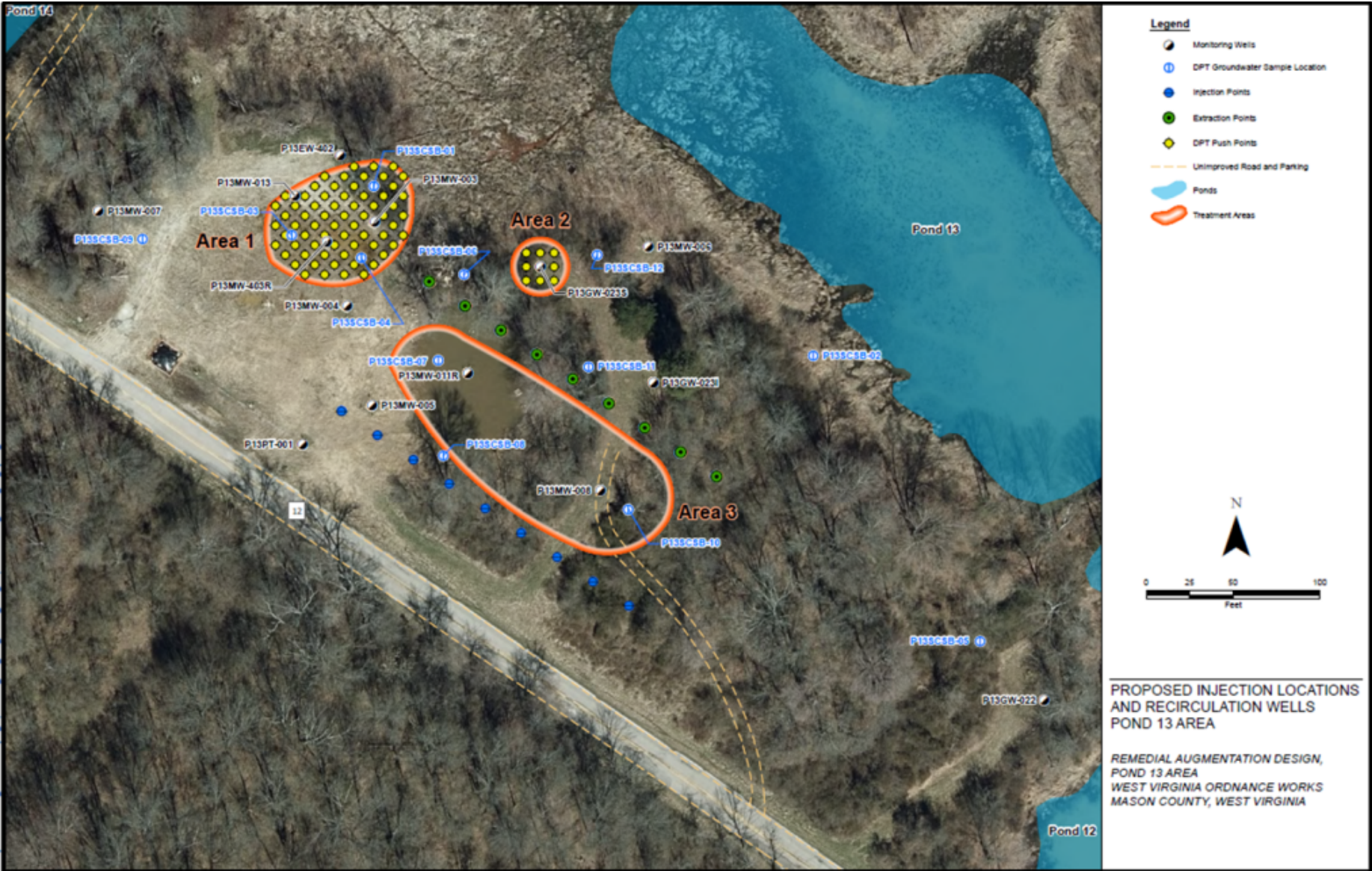
TREATMENT SYSTEM AUGMENTATION DESIGN

Amendment Selection cont.

- AquaFix™ is an electron donor that is both fast-acting and long-lasting
 - Slow releasing to drive anerobic biodegradation of contaminants
 - This product can also be co-injected with PlumeStop while EVO products are not compatible because the oil content can bind to the CAC and pacify the adsorption sites
 - Includes a solid phase source of fatty acids and beneficial nutrients to support anaerobic degradation
 - The slow-release will decrease the frequency of re-application
- Sodium Lactate is a soluble carbon source
 - Well suited for use in a recirculation treatment system
 - Amount required to treat the aquifer is determined by the treatment zone dimensions and stoichiometry to provide 500 mg/L of carbon
 - Sodium Lactate provides carbon for an estimated six months to a year and therefore additional applications are expected

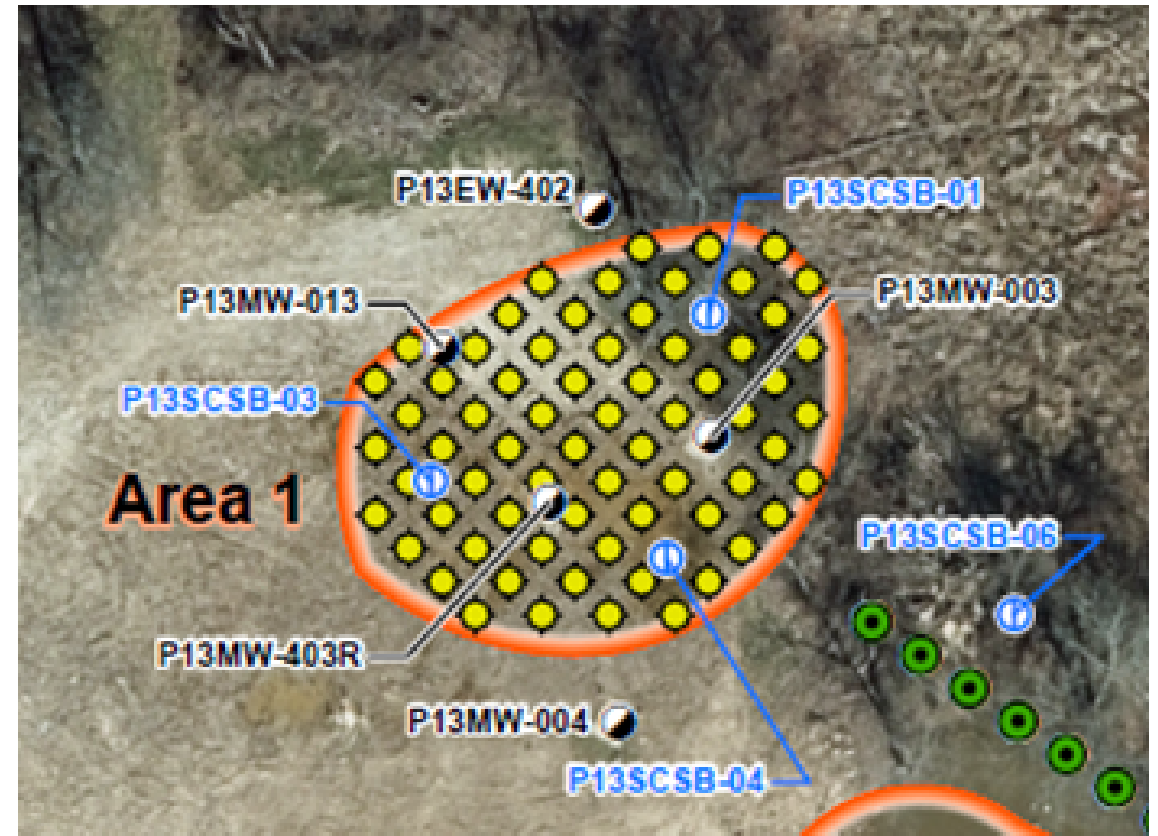


TREATMENT SYSTEM AUGMENTATION DESIGN



AREA 1 DESIGN

- Total COC concentrations over 1,000 µg/L, with 2,4,6-TNT in P13MW-403R at 19,000 µg/L in 2023
- Significant exceedances in groundwater at P13SCSB-01 and P13SCSB-03 in addition to P13MW-403R
- Although P13SCSB-04 did not exhibit groundwater exceedances, soil contamination exceeded RSLs
- CAC (PlumeStop) has been selected for use in this area to adsorb COCs along with treatment using carbon and ZVI
- AquaFix was selected as the carbon source along with S-mZVI
- Amendments will be deployed using direct injection via DPT into a grid pattern into eighty-one (81) points targeting 15-28 ft bgs



AREA 2 DESIGN

- Isolated area with RG exceedance for 2,6-DNT
- To treat this small area with 5.79 $\mu\text{g/L}$ 2,6-DNT, a combination of AquaFix and S-mZVI has been selected
- Amendments will be deployed using direct injection via DPT into a grid pattern into eight (8) points targeting 15-28 ft bgs



AREA 3 DESIGN

- Total COC concentrations under 1,000 µg/L, with 1,3-DNB; 2,4-DNT and 2,6-DNT exceedances at the former RW wet well area
- P13MW-008 and P13SCSB-10 exhibited exceedances of 2,4-DNT
- Due to the size of Area 3, a recirculation system will be used
- A soluble carbon source, sodium lactate, will be used as it is able to migrate with the groundwater flow that is induced by injection and extraction wells
- S-mZVI will be co-injected to aid in abiotically reducing the site COCs
- The amendments will be injected into nine (9) upgradient injection wells and be pulled across using nine (9) downgradient extraction wells



TREATMENT SYSTEM AUGMENTATION DESIGN

Pre-Injection Testing

- Clear potable water will be used.
- Water will be injected within a borehole approximately 4 feet from a monitoring well
 - Injection will start at the bottom of the target injection zone and continue in small increments up to the top of the injection zone
 - Flow rates, pressure and total volume will be monitored and recorded.
 - Groundwater depth, dissolved oxygen, oxidation-reduction potential, conductivity, pH, and temperature changes will be recorded near the end
 - Head rise, along with pressure and flow rate measurements, will provide an indication of how well the aquifer will accept the proposed volumes
- These data will be utilized to adjust injection rates and pressures to ensure adequate amendment distribution



TREATMENT SYSTEM PERFORMANCE MONITORING

- Performance monitoring will be performed to evaluate progress toward RAOs
- Nine (9) existing Pond 13 Area monitoring wells will be used to monitor the effectiveness and any potential need for reapplication at both the gridded injection areas
- Wells will be sampled quarterly for one year, semiannually the following year, then annually until final cleanup goals are achieved
- After three years of groundwater performance monitoring, COC concentration trends and groundwater geochemistry will be evaluated to determine if reinjections into specific areas are warranted



An aerial photograph showing a wide sandy beach with waves breaking on the shore. In the foreground, a row of houses with swimming pools is visible, separated from the beach by a line of trees. The word "QUESTIONS?" is overlaid in large white letters across the middle of the image.

QUESTIONS?



