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RACER LANSING PROPOSED LOWER 1,4-DIOXANE INTERIM MEASURE UPDATE

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August 30, 2018

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Agenda

- Conceptual Site Model
- Remedy Development & Bioremediation Refresher
- Pre-design Testing with Enhancements
- Pre-design Testing Results and Conclusions
- Corrective Action Objectives
- Full Scale Biosparge Components
  - Transects
  - Biosparge Points
  - Conveyance Piping
  - Process Equipment
- System Operation
- Performance and Stability Monitoring

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Conceptual Site Model

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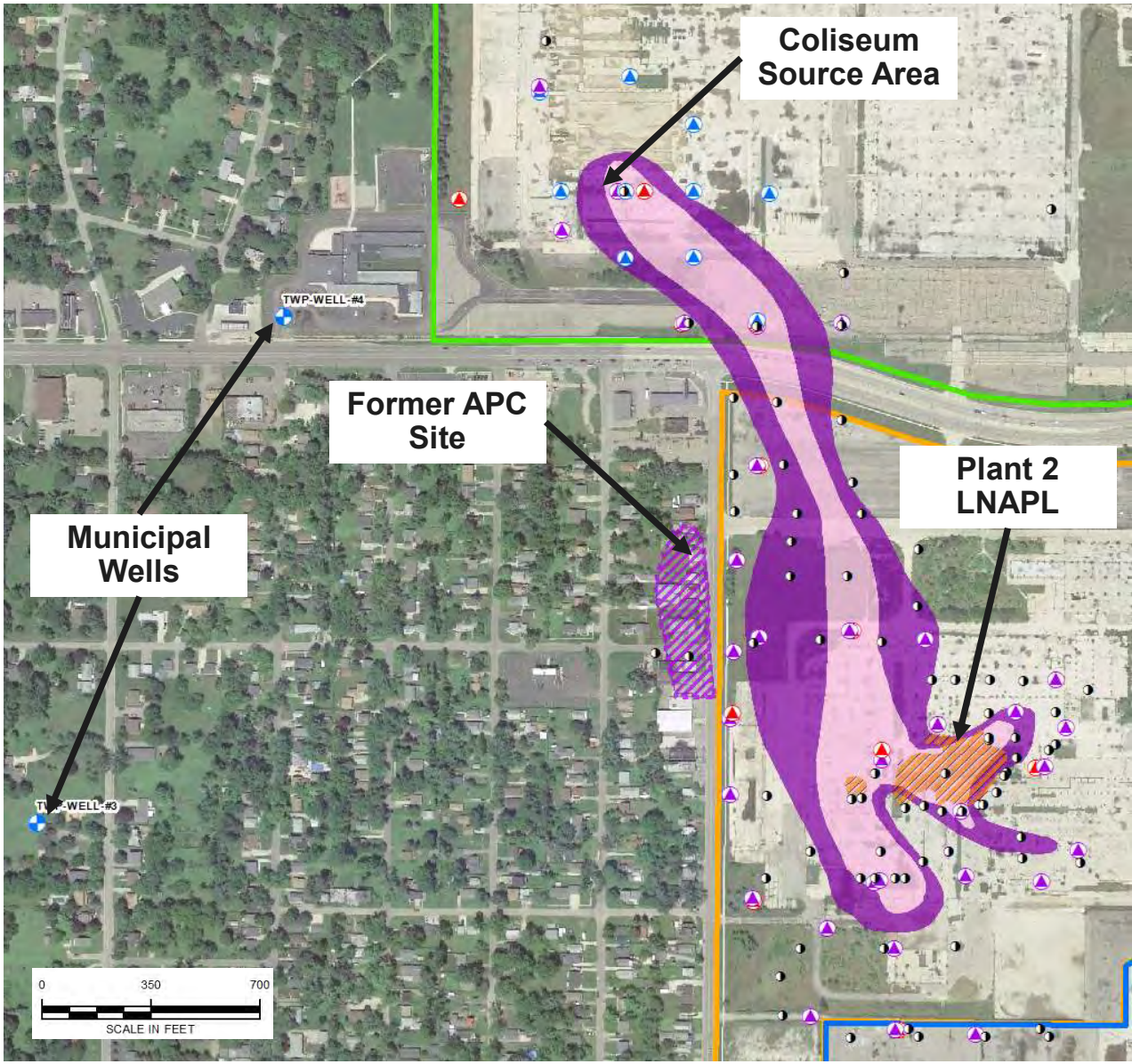
Lower 1,4-Dioxane Plume



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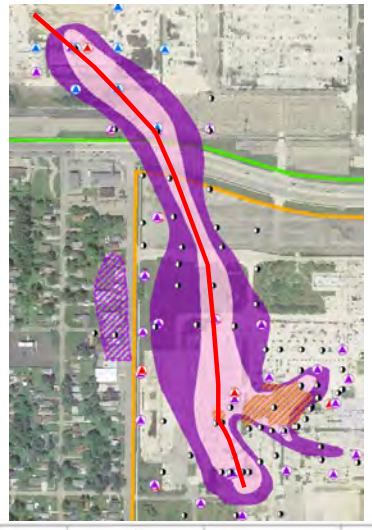
Cross-Section



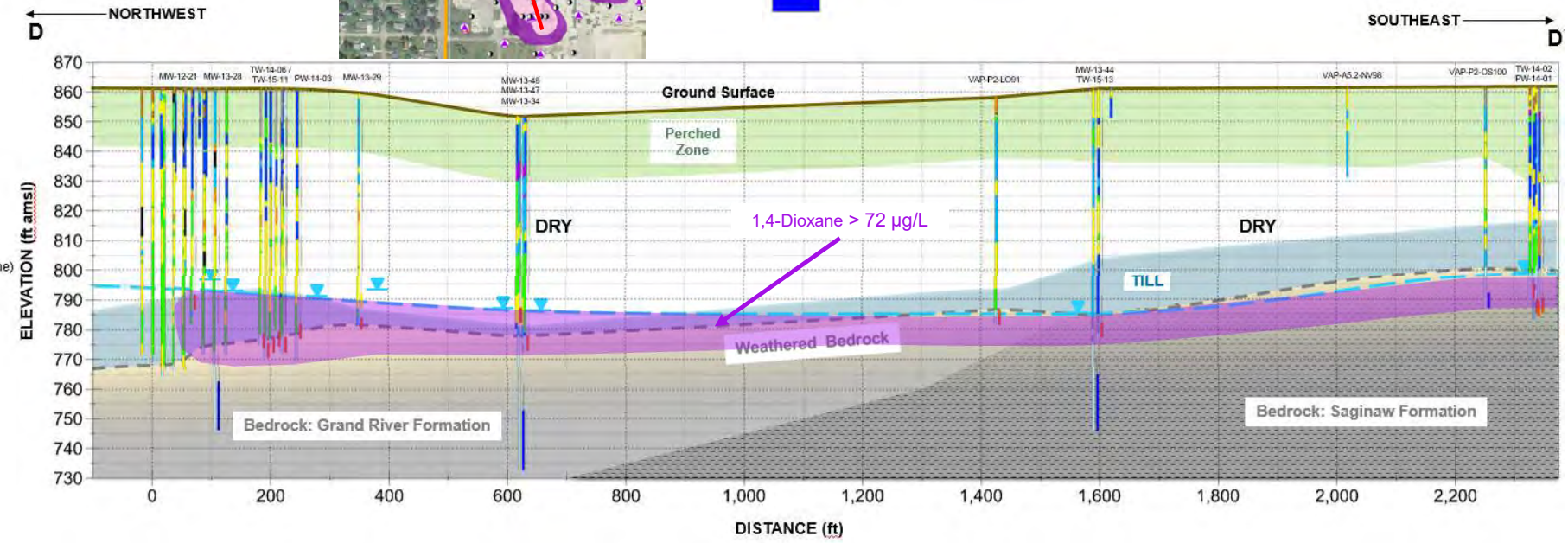
Monitoring Well/VAP

1,4-Dioxane

- > 72 ug/L
- 7.2 - 72 ug/L
- < 7.2 ug/L

Stratigraphy

- Topsoil/Concrete/Asphalt
- Fill
- Gravelly Sand
- Sand
- Sandy Silt/Silt
- Silty/Sandy/Gravelly Clay
- Clay
- Peat
- Bedrock (Primarily Sandstone)
- Bedrock (Primarily Shale)
- No Recovery



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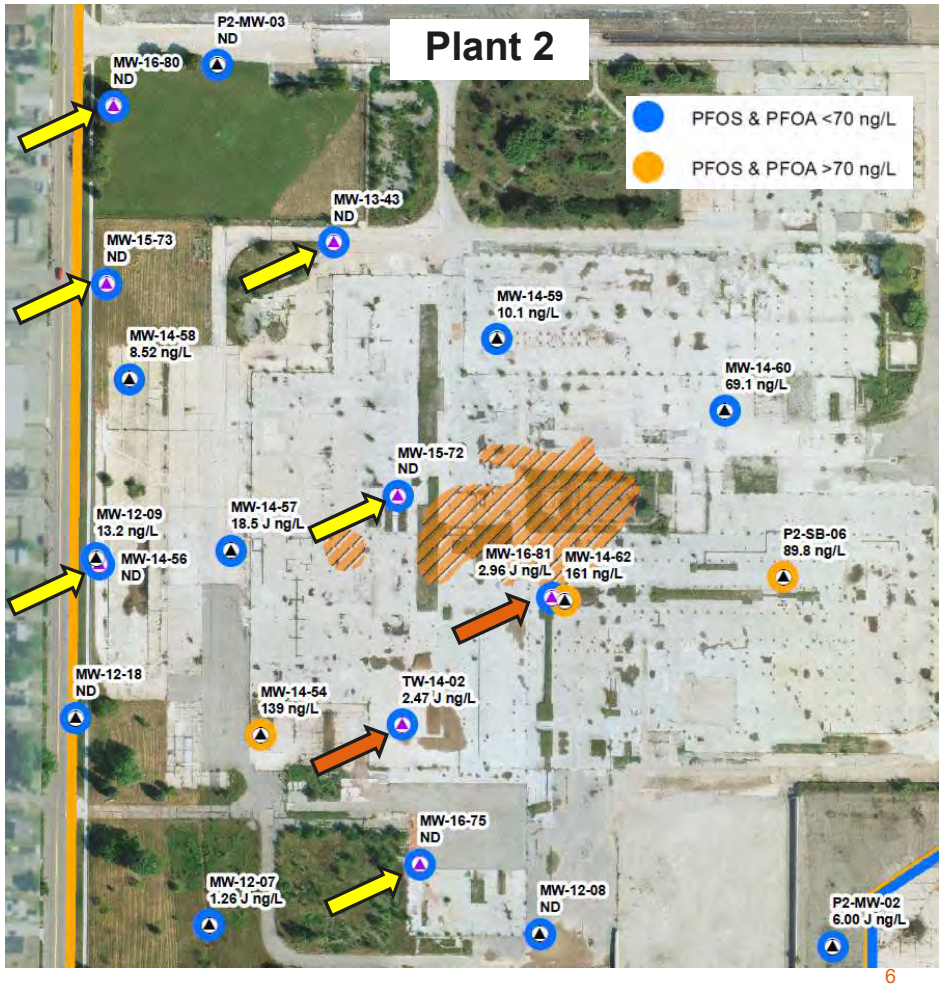
PFAS in Weathered Bedrock

Two of the weathered bedrock wells show trace concentrations of PFOS+PFOA

- Low-concentration of PFAS in perched zone
- Trace PFAS in weathered bedrock, will not effect 1,4-dioxane remedy

Weathered Bedrock Well
Non-detect

Weathered Bedrock Well
J-flag detection



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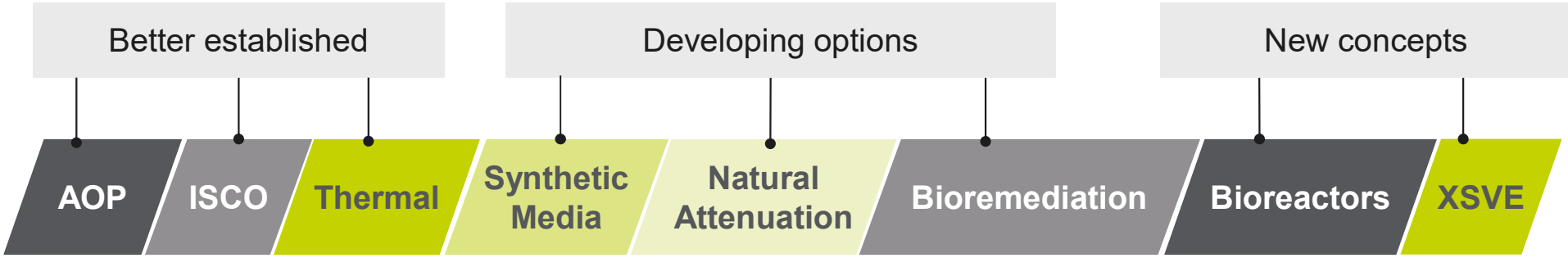
Remedy Development

1,4-Dioxane Treatment Technologies



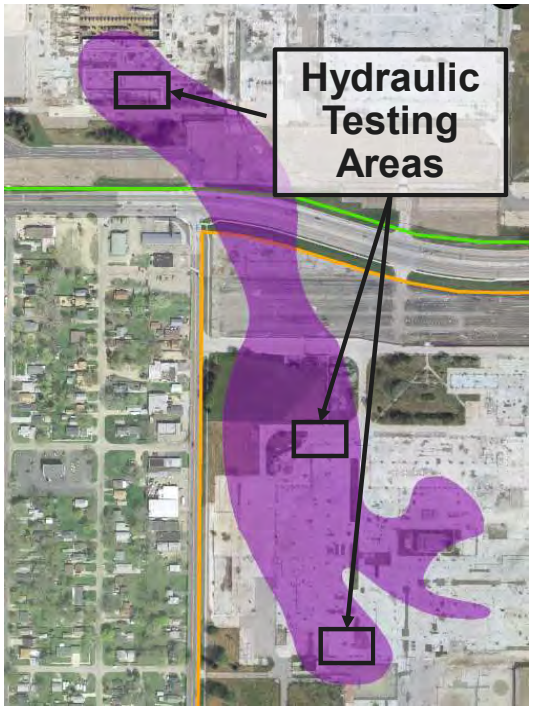
Pump and Treat with AOP

Advanced Oxidation Process Bench Testing

- Treated 1,4-D < 1 part per billion
- No by-product concerns

Field Hydraulic Testing

- Low extraction flow rates, difficult to maintain
- Relatively easier to inject



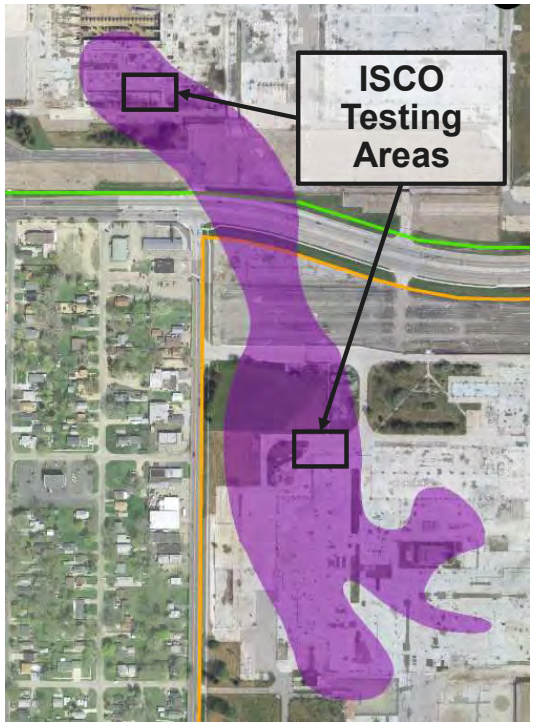
In-Situ Chemical Oxidation (ISCO)

Bench Testing

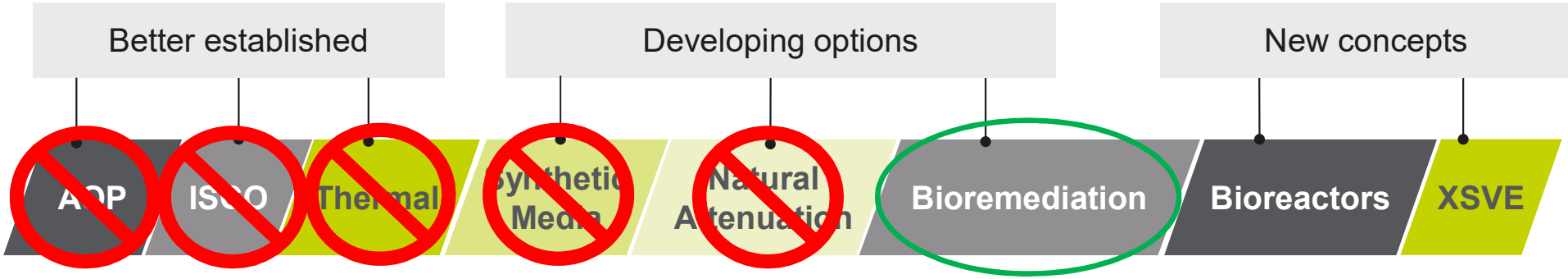
- Successful oxidation using persulfate without engineered activation

Field Oxidant Injection

- Treatment limited to injection ROI. No drift of working strength oxidant and subsequent rebound. Not practical to implement full scale.



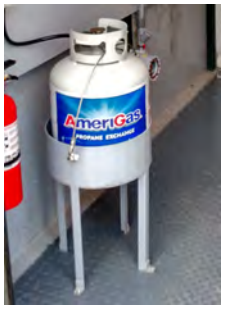
1,4-Dioxane Treatment Technologies



Bioremediation Basics - Refresher

- Research and field testing showed the potential to co-metabolically biodegrade 1,4-dioxane

- Important components of co-metabolic biodegradation for 1,4-dioxane:
  - Propane
  - Microbes with genes that express enzymes that can co-metabolize 1,4-D
  - Aerobic conditions (DO)
  - Nutrients



ENV 425

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Biosparge Pilot Testing

Spargability of weathered bedrock → Proof of concept for biodegradation lab studies → Proof of concept for biodegradation field study → Pre-design testing with enhancements

Air Sparge Only Test

Determine spargability and optimal well placement field testing

Lab Proof of Concept

Understand processes and response to changing conditions in a controlled environment

Propane Biosparge Test

Determine if biosparge is capable of biodegrading 1,4-D at the site

Pre-Design Test

Incorporate field/lab findings. Vet conceptual design assumptions and assess realistic treatment expectations

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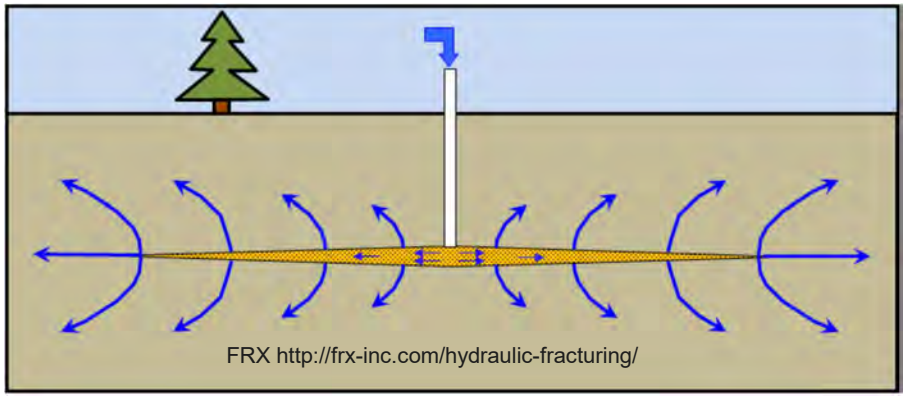
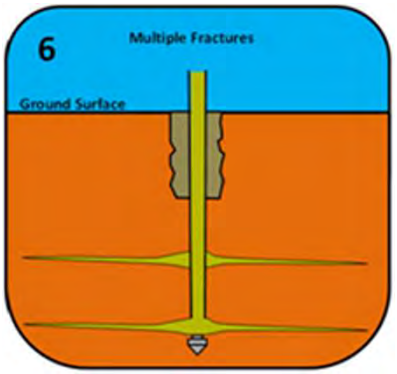
Pre-Design Testing with Sand Lens Enhancements

Pre-Design Test Objectives

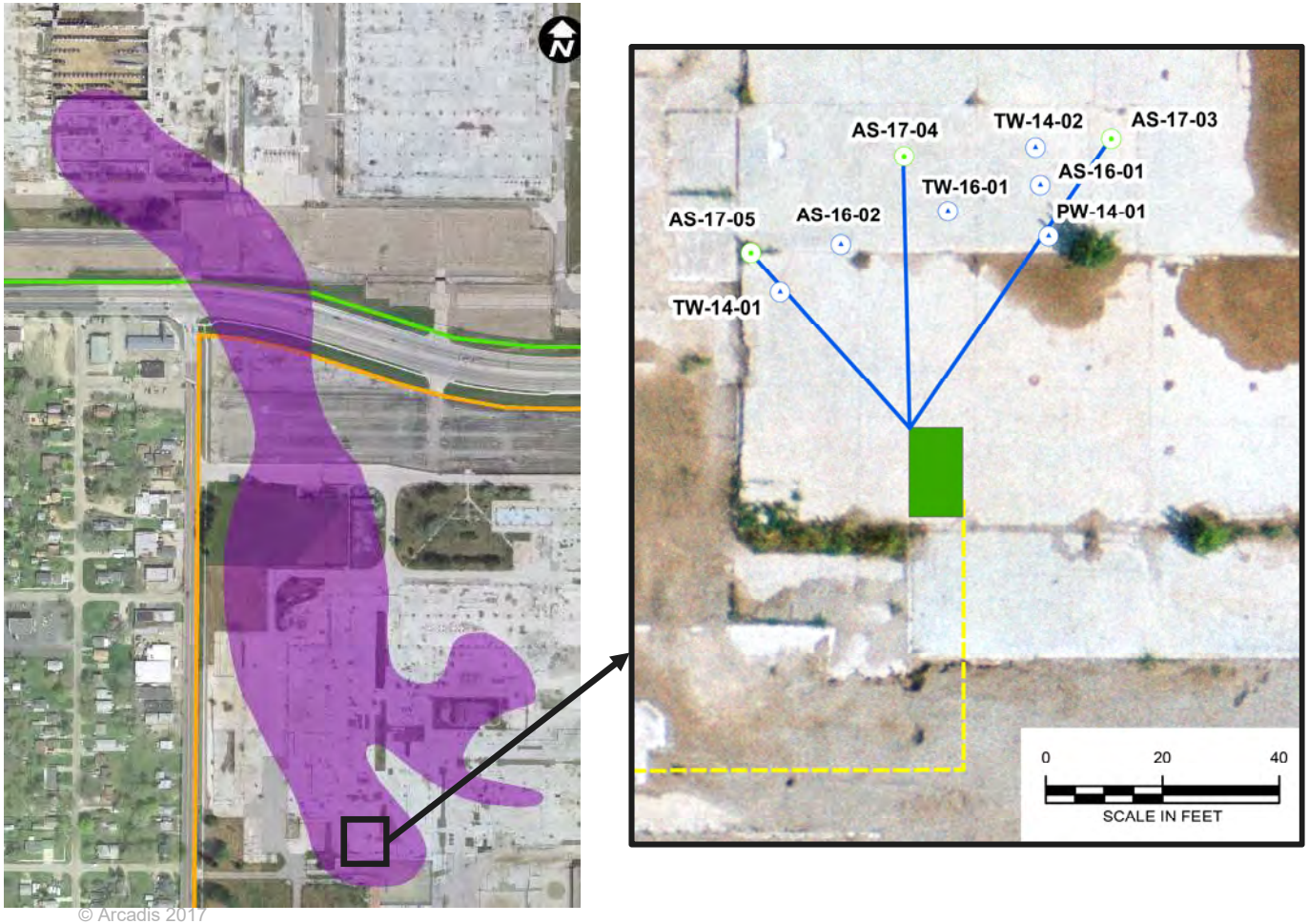
1. Determine if gas distribution can be optimized in the weathered bedrock through sand lens enhancements
2. Define the ROI of the active treatment zone and verify spacing of biosparge points for full-scale implementation
3. Optimize operational parameters such as: flow rates, propane dosage, DO, bioaugmentation applications, and nutrient injections to maximize treatment and minimize cost



FRX http://frx-inc.com/hydraulic-fracturing/



Pre-Design Testing Layout



- Three new sparge wells:
  - Oriented to maximize existing well infrastructure
  - Similar location as previous pilot to allow for direct comparison of performance
  - Aligns with potential full scale implementation locations

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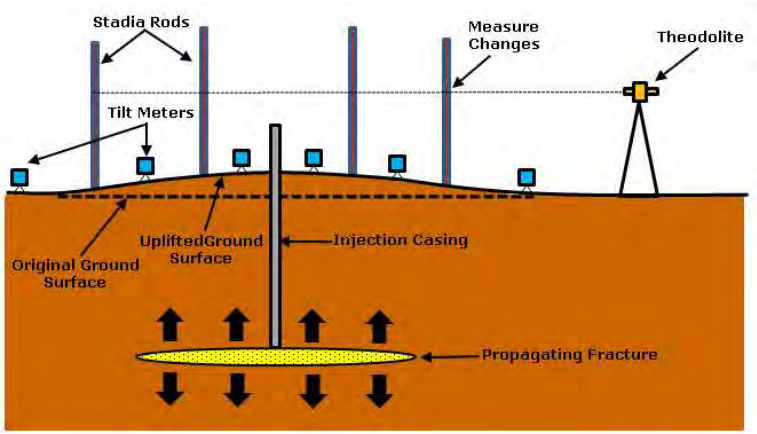
Sand Lens ROI Monitoring

- Anticipated sand lens ROI of 15 feet
- Installed highly sensitive tilt meters to detect surface deformation as fracture propagates, estimate shape and attitude of fractures
- Calculated injected sand mixture volume
- Water level monitoring in nearby MWs to detect hydraulic response
- TOC samples collected after each sand lens installation to verify extent of guar gum in near by MWs

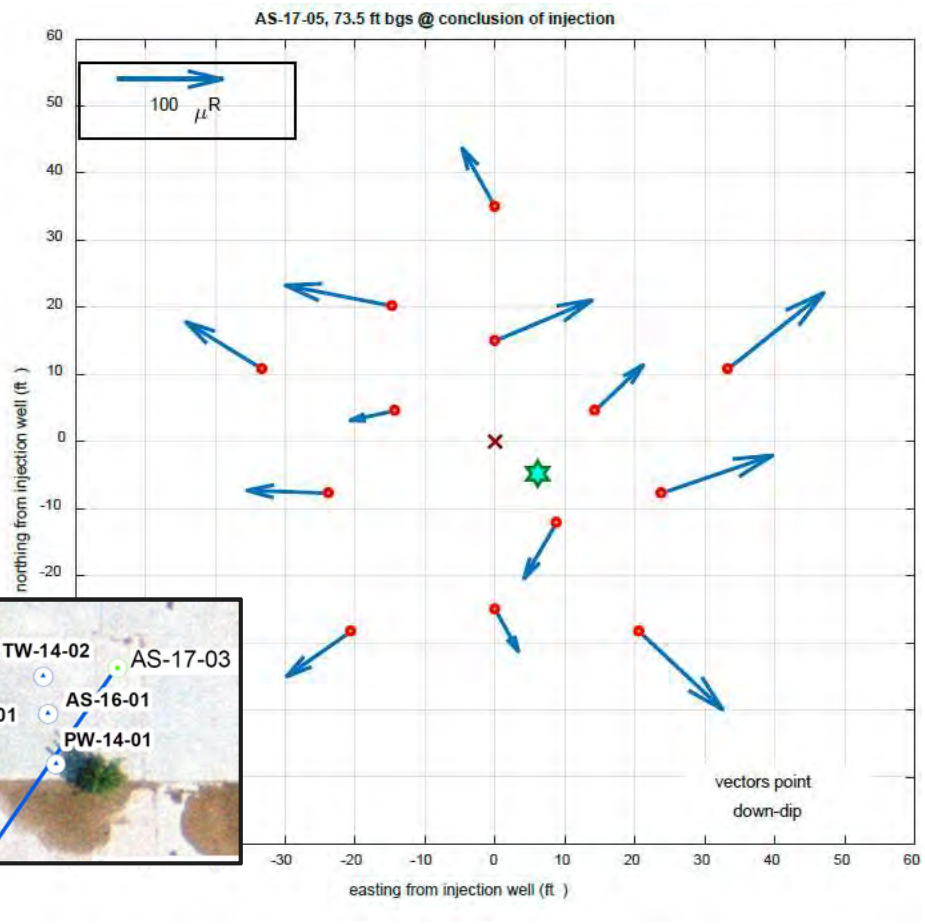


FRX http://frx-inc.com/hydraulic-fracturing/

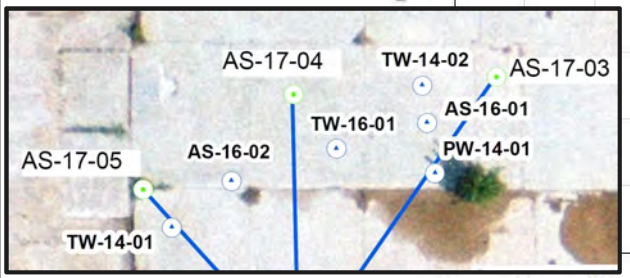
Sand Lens ROI Results

- Tilt meters detected surface deformation 20-35 ft
- Injected sand mixture volume indicated minimum of 15ft ROI assuming a 0.5 cm thick sand lens
- Hydraulic response in MWs 10 to 25 ft away
- Increase in TOC up to 15 ft
- DO response in MWs greater than 15 ft

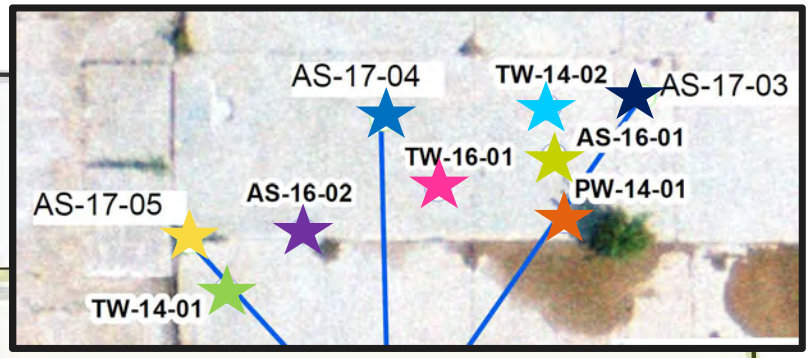
Tilt Meter



AS-16-02		
Date	Sparge Well Installed (Sand Lens)	Result (mg/L)
8/31/2017 (Baseline)	None	7.7
11/29/2017	AS-17-03 (1)	8.8
11/29/2017	AS-17-03 (2)	9.1
11/30/2017	AS-17-05 (2)	272
12/6/2017	All	330



Biosparge Point Installation



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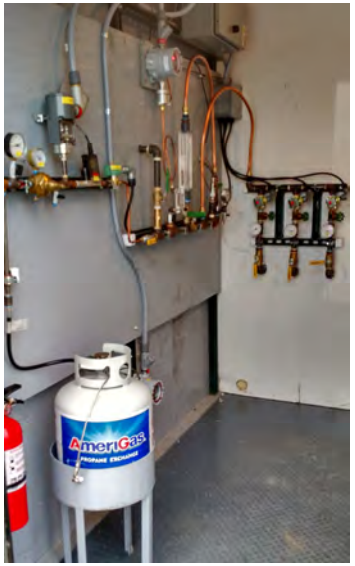
System Operation

- 4 month test sparging 3 sparge wells
- 6 hours of air flow per point per day, 1 hour intervals,
- 2 hours of propane flow per day, 1/2 hour intervals @ 15% LEL
- Bioaugmentation (ENV 425) and nutrient addition (DAP)
- Greater than 97% up time during testing



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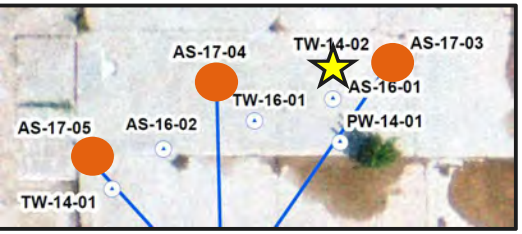
Results and Conclusions



1,4-Dioxane

Propane

Dissolved Oxygen

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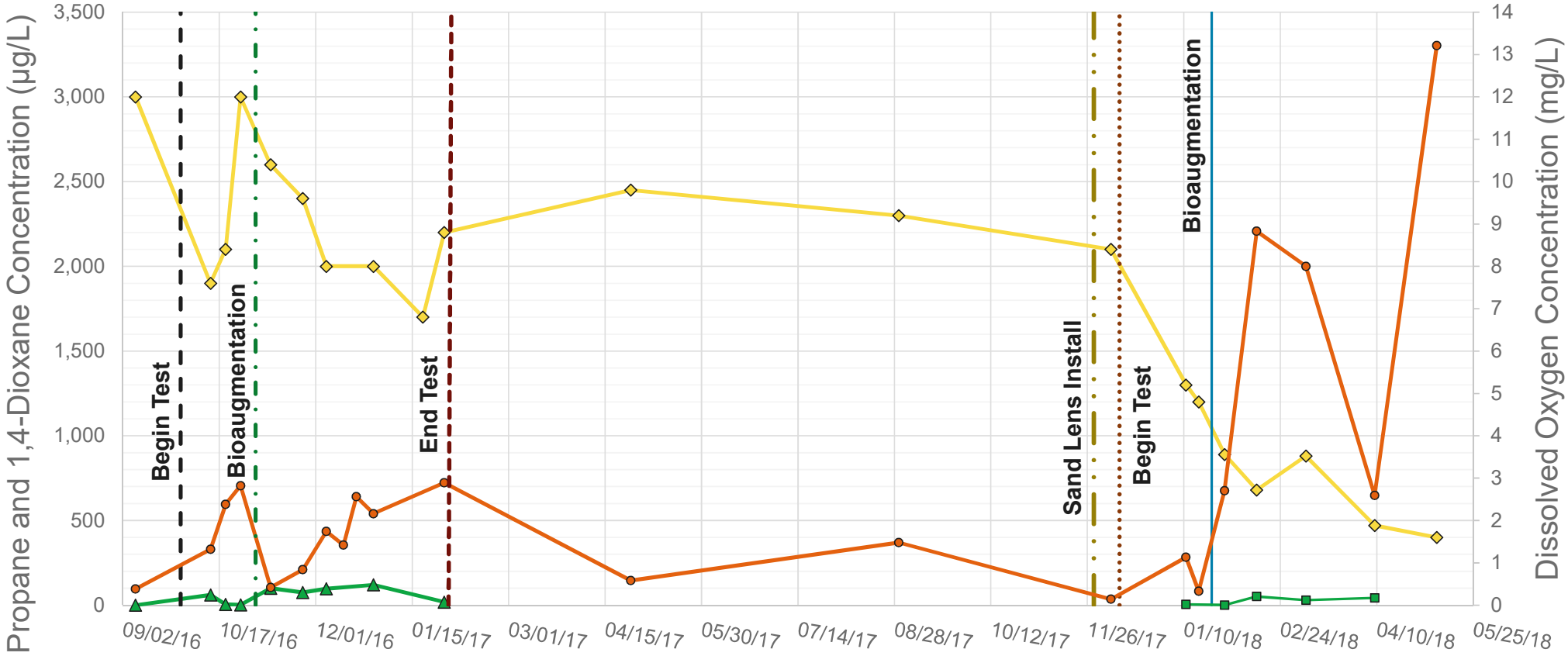
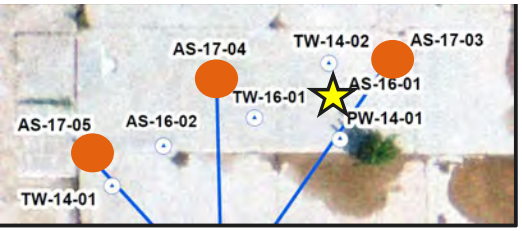
TW-14-02





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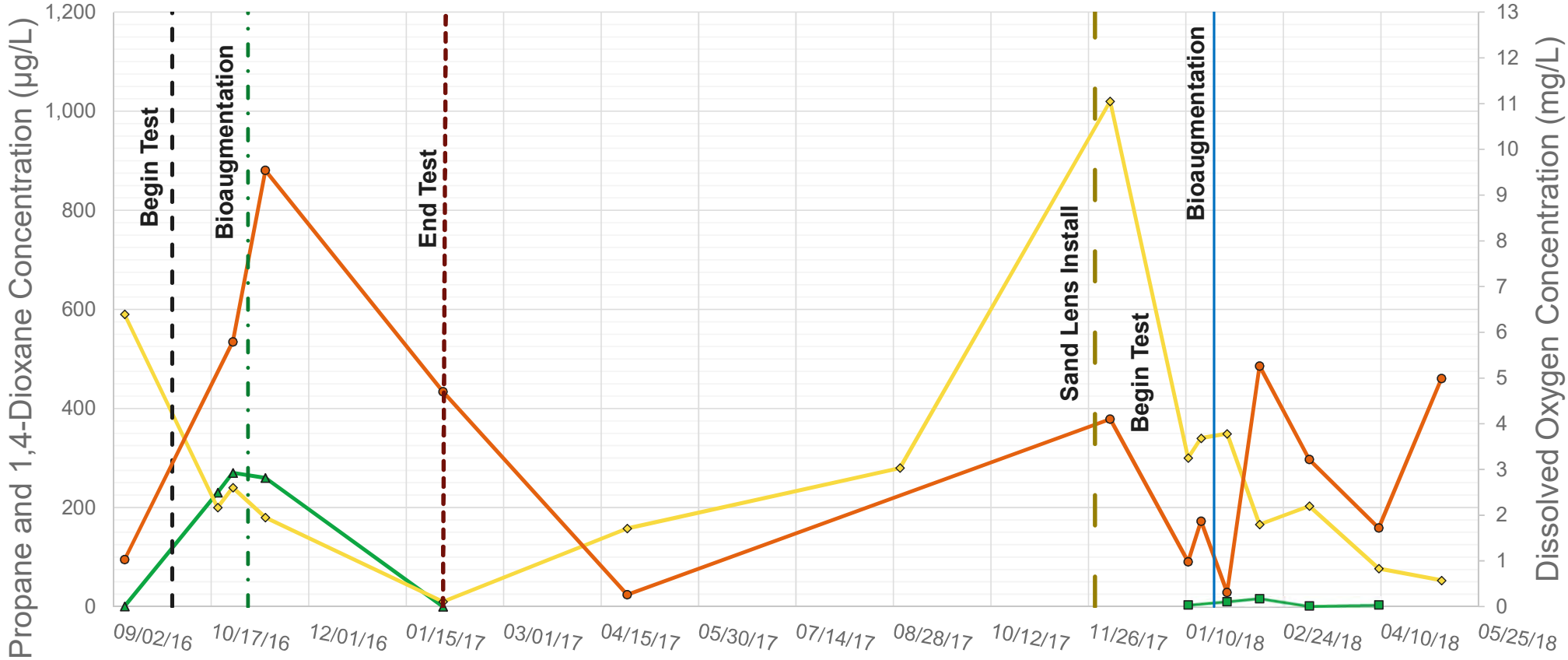
AS-16-01



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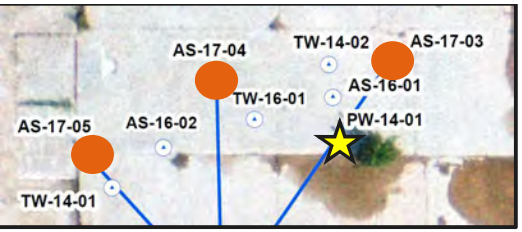

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PW-14-01

1,4-Dioxane
Propane
Dissolved Oxygen

Propane and 1,4-Dioxane Concentration (µg/L)

Dissolved Oxygen Concentration (mg/L)

Begin Test
Bioaugmentation
End Test
Sand Lens Install
Begin Test
Bioaugmentation

09/02/16 10/17/16 12/01/16 01/15/17 03/01/17 04/15/17 05/30/17 07/14/17 08/28/17 10/12/17 11/26/17 01/10/18 02/24/18 04/10/18 05/25/18

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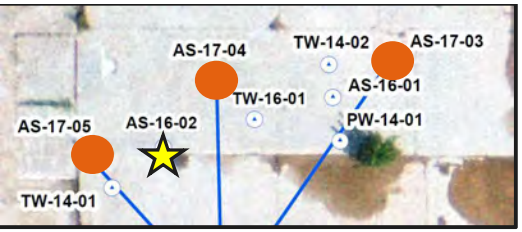

1,4-Dioxane
Propane
Dissolved Oxygen

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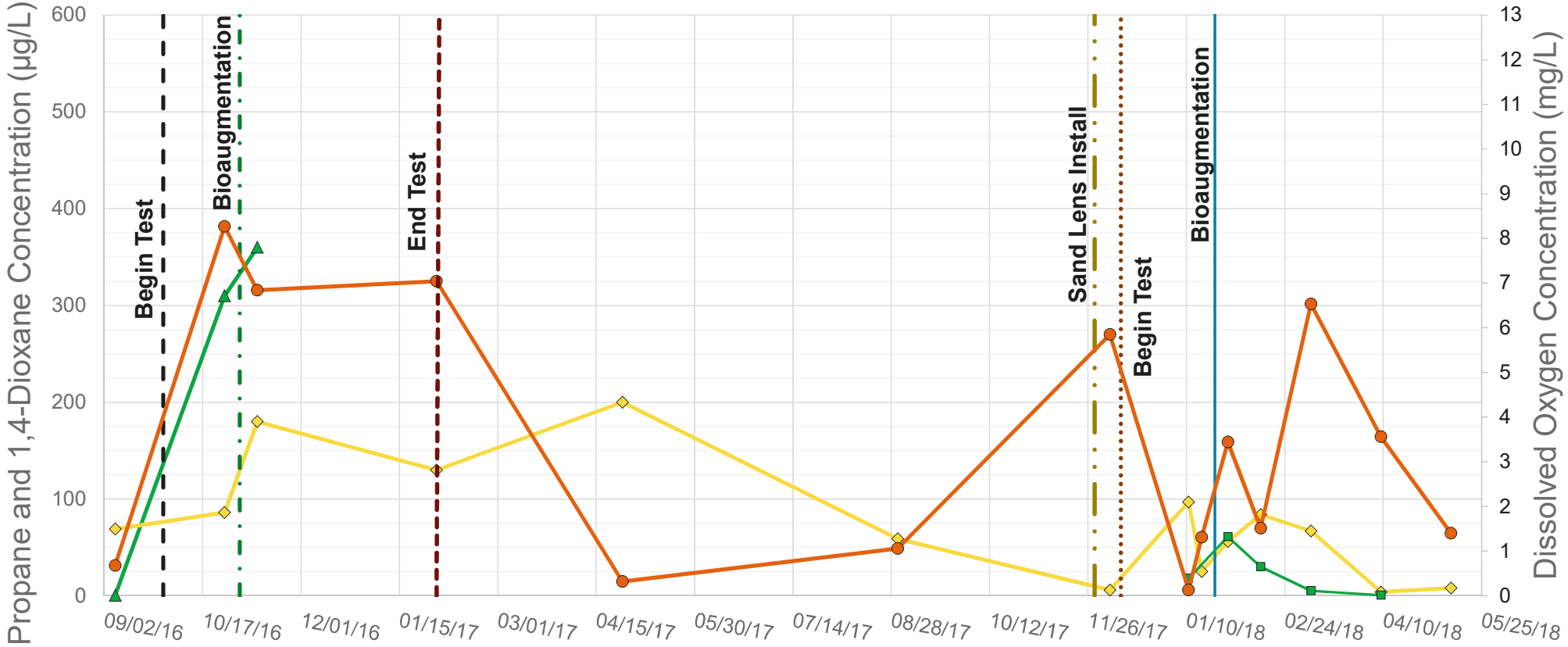
AS-16-02



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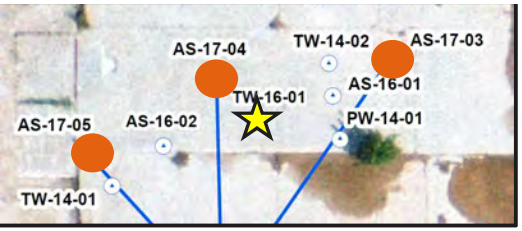

1,4-Dioxane

Propane

Dissolved Oxygen

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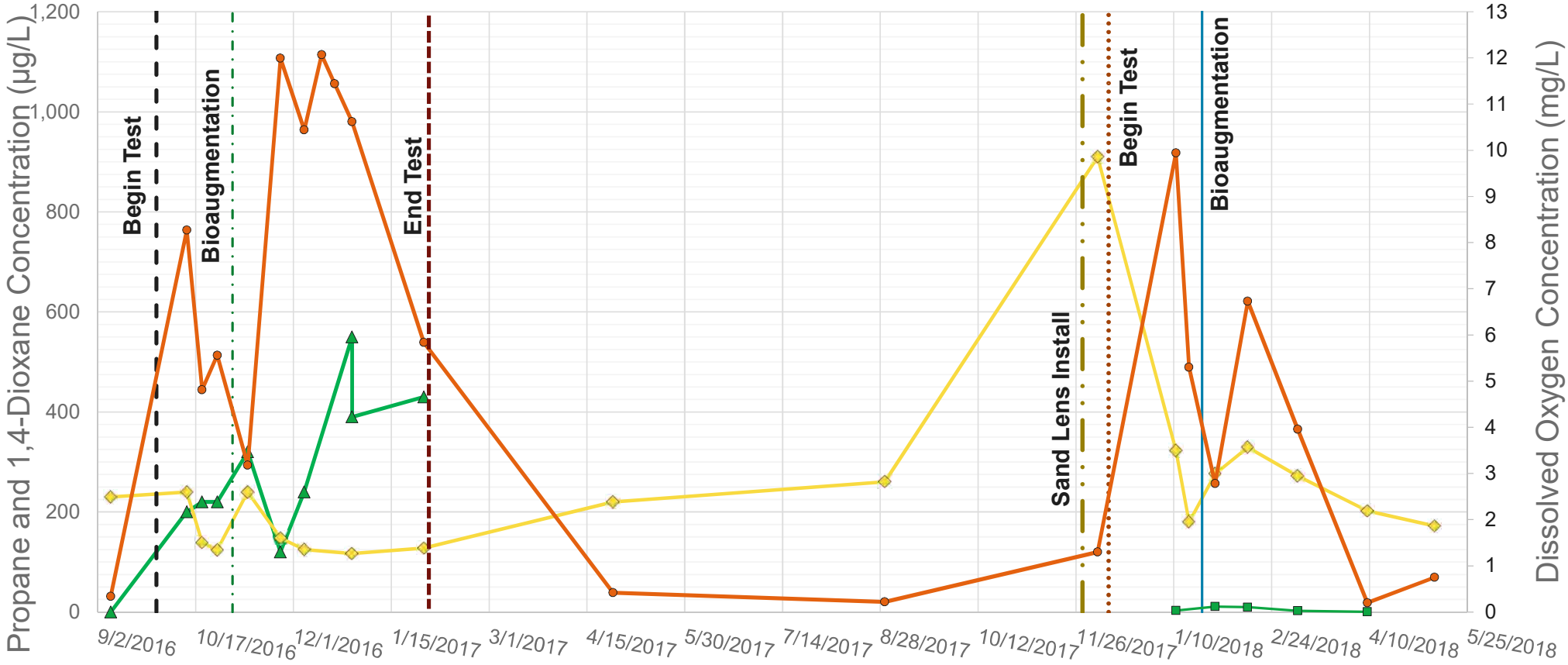

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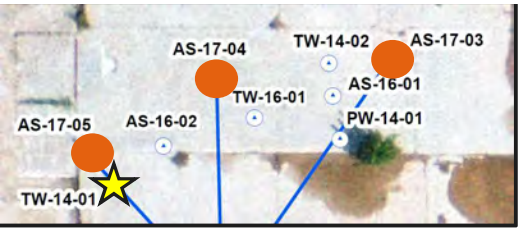

1,4-Dioxane
Propane
Dissolved Oxygen

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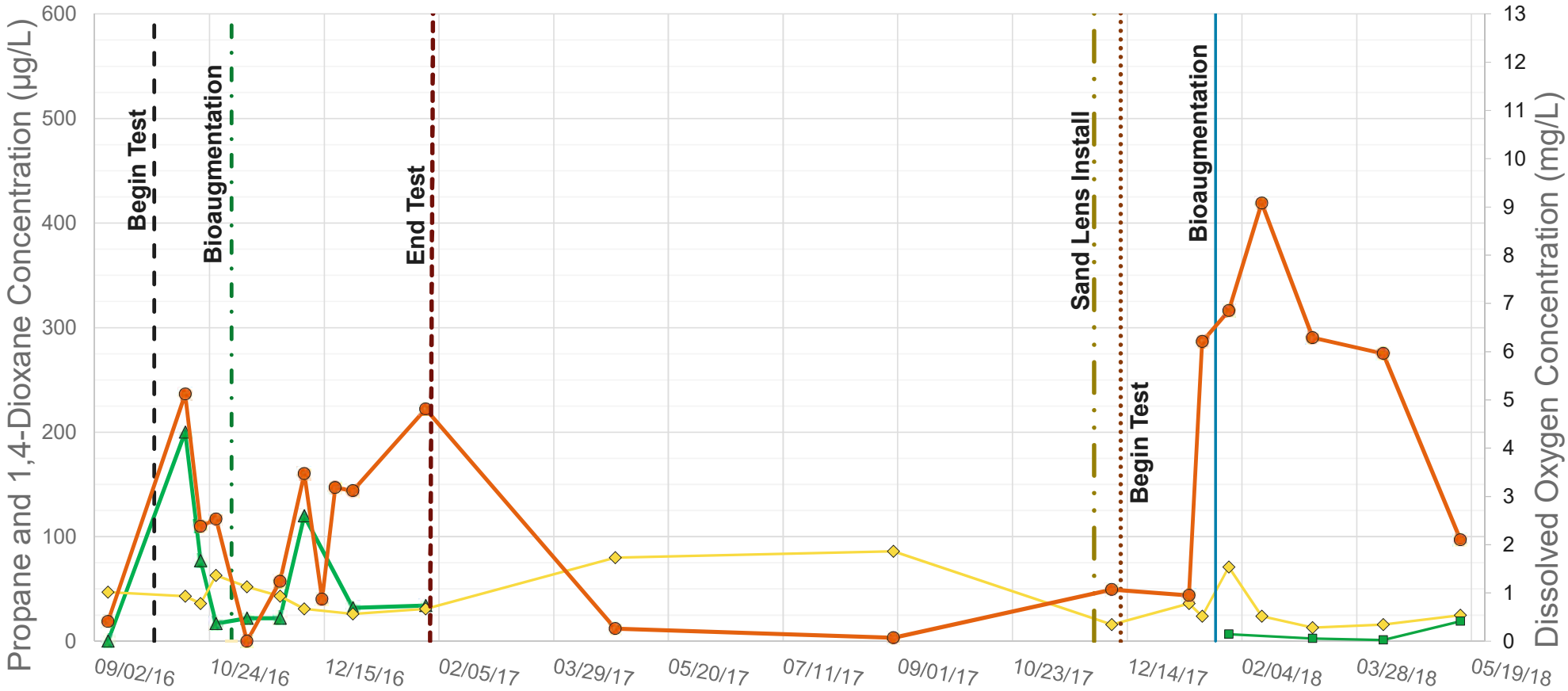

Conclusions

1. Sand lens enhancements allow for more consistent and controlled injection of gases in the weathered bedrock
2. All lines of evidence during sand lens installation support a minimum of 15 foot ROI. Treatment effectiveness confirmed 15 foot spacing will result in robust treatment.
3. Optimize operational parameters:
   - With sand lens enhancements, able to sparge:
     - At higher flow rates (5 cfm vs. 2 cfm)
     - At lower pressure (<10psi vs. 20-30 psi) and
     - Less frequently (6hrs/day/well vs. 12 hrs/day/well)
   - Utilizing significantly less propane (205 lbs vs 59 lbs) resulted in better performance
   - Maintaining DO is critical, adaptive operation will be required
   - Bioaugmentation applications not required, reductions observed via native communities
   - Nutrient application frequency may be every 6-12 months initially

Corrective Action Objective

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Biosparge CAO

- Short-term objective: Install biosparge system to reduce the concentration of 1,4-dioxane along the core of the lower 1,4-dioxane weathered bedrock plume
- Long-term objective: Continued protection of the municipal drinking water supply by preventing Site related 1,4-dioxane impacted groundwater from migrating off-site at concentrations greater than 7.2 µg/L (Part 201 Drinking Water Cleanup Criteria)
- Current information does not indicate that Site related 1,4-dioxane has, or ever will, reach the municipal wells at a concentration greater than 7.2 µg/L.
  - Reduction of on-site 1,4-dioxane concentrations is proposed to further reduce the likelihood of impacts migrating to the municipal water supply
- Biosparge system performance will be evaluated on an annual basis to optimize performance
  - Performance will be evaluated using a flux-based monitoring program, including trend analysis for wells located within the treatment zone and around the boundary of the plume

Biosparge CAO

- There is the potential for comingling with the APC 1,4-dioxane impacts along the western Plant 2 property boundary. The APC site is located on Rosemary Street adjacent to the RACER Plant 2 western boundary. The goal of the biosparge system is to address RACER's portion of the 1,4-dioxane impacts
- The biosparge system (or portions of the system) will be operated until:
  - Further reduction in groundwater concentrations require extraordinary effort (i.e. diminishing returns)
  - Concentrations along the core of the lower 1,4-dioxane plume, and at the property boundary show stable to decreasing concentrations using statistical evaluation, or
  - The short and long term objectives have been met

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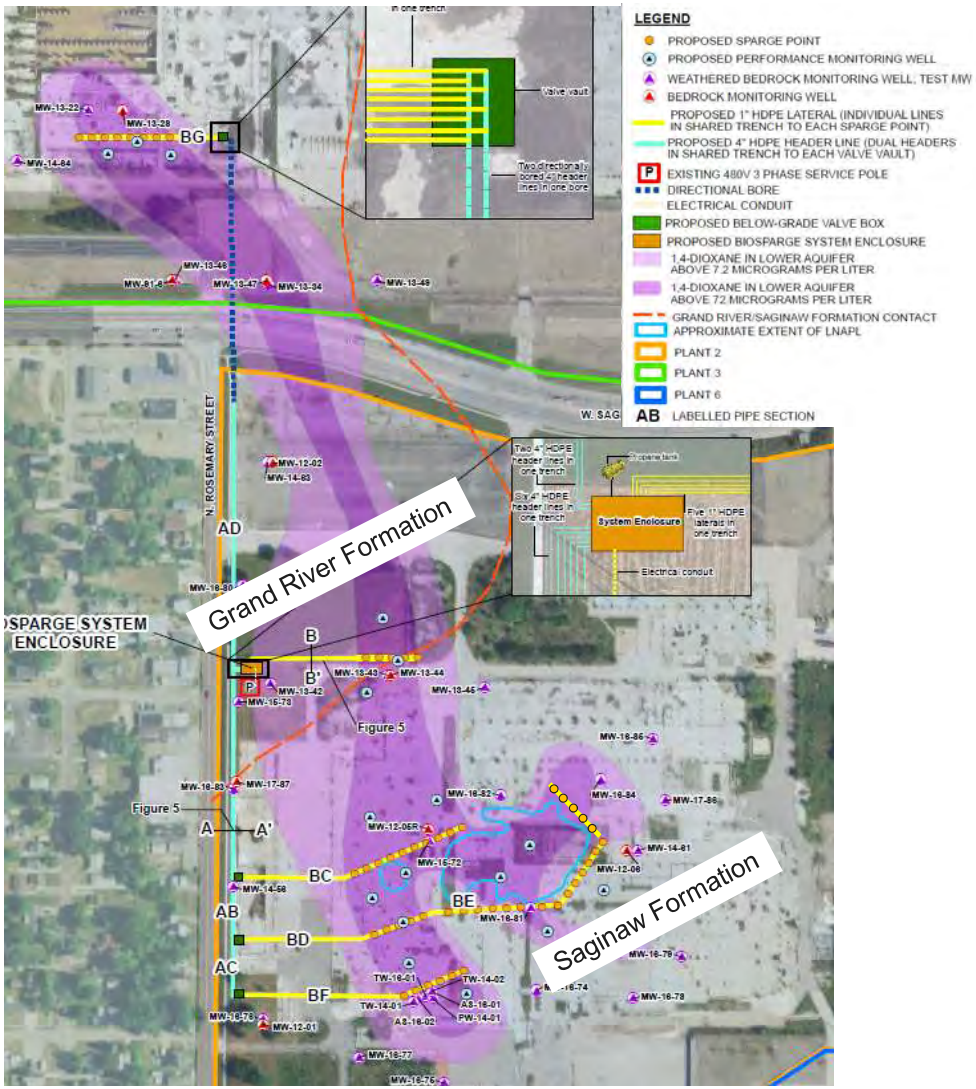
Biosparge System Components

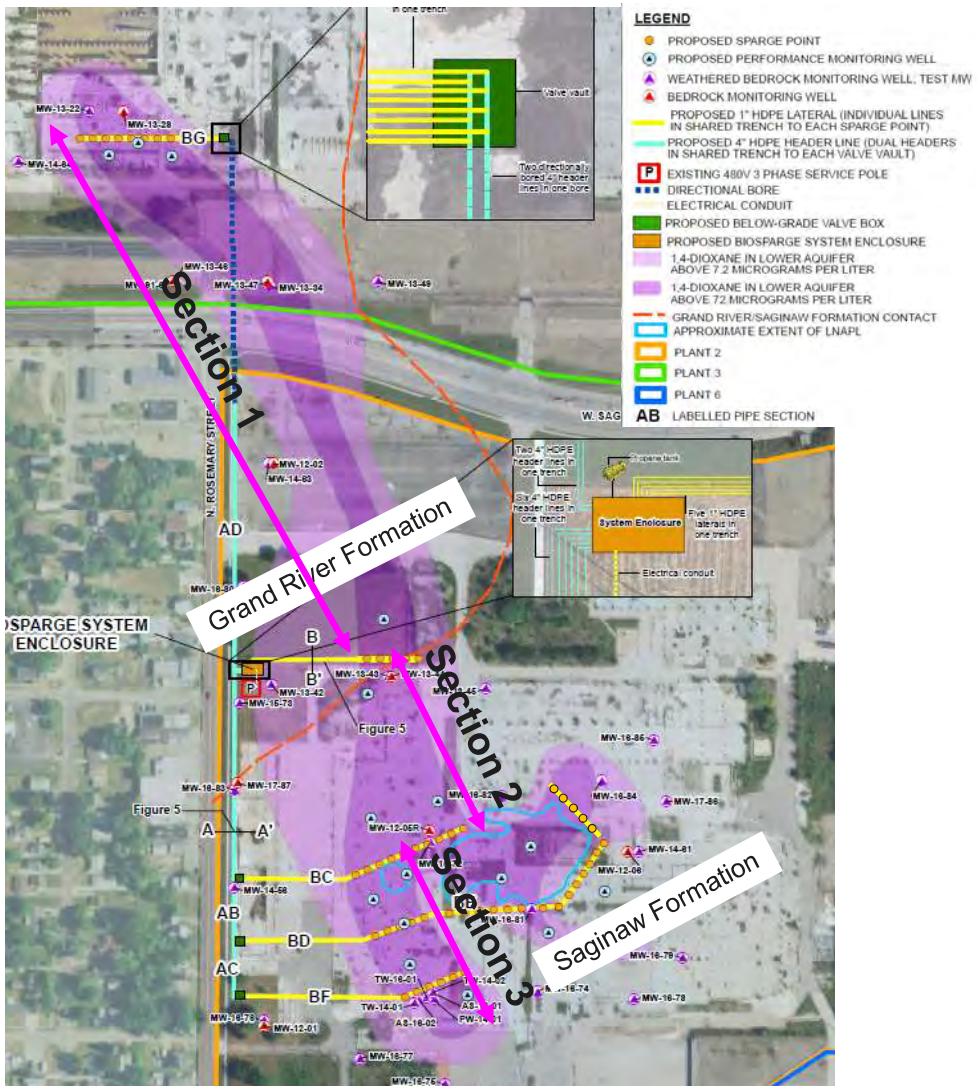
Biosparge Components

- Treatment transects perpendicular to groundwater flow to promote clean water flushing downgradient
- Biosparge points with high-permeability sand lenses screened in weathered bedrock
- Underground conveyance network to carry compressed gases to biosparge points
- Above-grade injection equipment (compressor, piping, valves)
- Performance monitoring well network



Biosparge System Transects

- Transect approach where groundwater will be treated within each biosparge transect; once treated clean water will flush between the transects to reduce groundwater concentrations downgradient
- Pilot/pre-design testing indicates biosparge treatment transects can reduce concentrations of 1,4-dioxane within the transect to <10 μg/L
- Section 1
  - Grand River Formation
  - GW Velocity 275 - 500 ft/yr
  - 1,4-dioxane concentration trends in weathered bedrock upgradient of transect show 1,4-D will reach target in ~6 years



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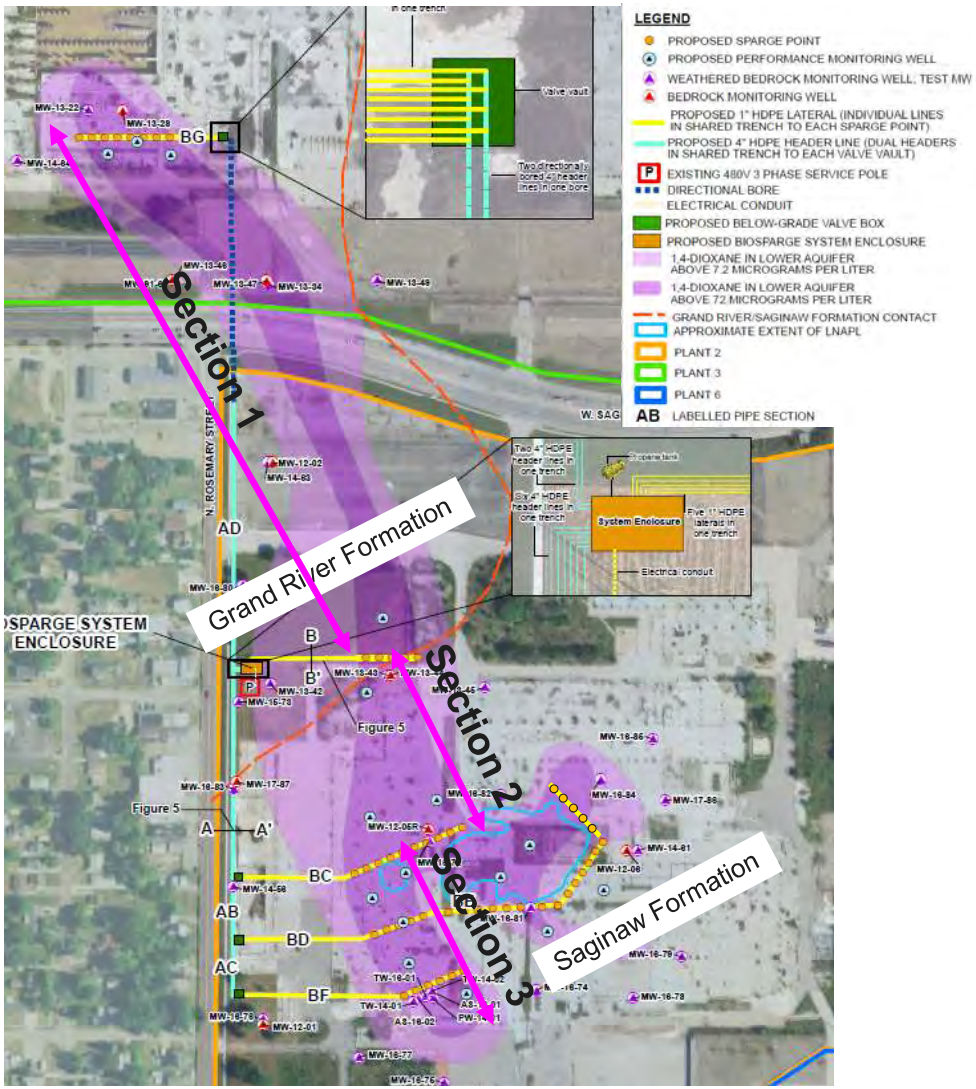
Biosparge System Transects

- Section 2
  - Transitional area between Grand River and Saginaw Formation
  - GW Velocity 85 - 265 ft/yr
- Section 3
  - Saginaw Formation
  - GW Velocity 25 - 50 ft/yr
  - Includes transect to address impacts beneath the NAPL
  - Three pre-design biosparge wells will be incorporated into the southern most transect



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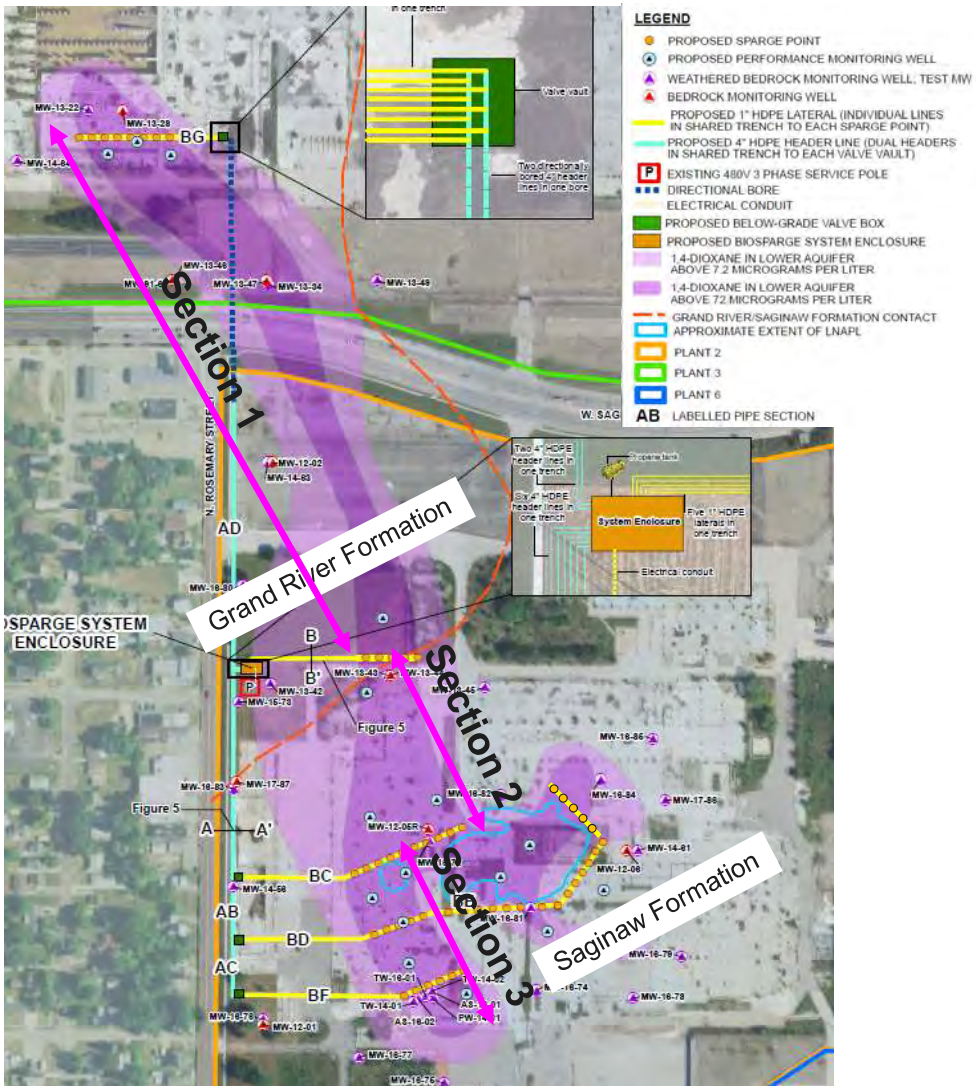
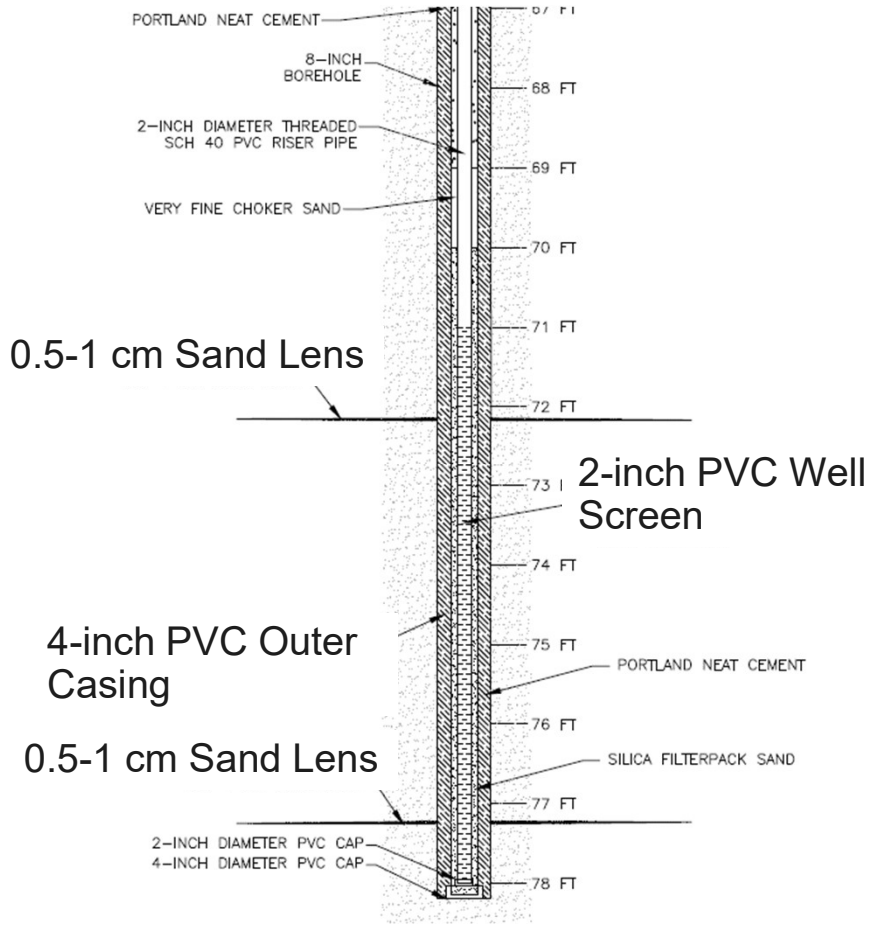
Biosparge System Transects

- Slower groundwater velocity in Sections 2 and 3 results in denser transect spacing
- The system layout was designed to be as efficient and sustainable as possible by minimizing subgrade infrastructure and the operational timeframe
- Sparge points spaced 30 feet apart based on 15-foot ROI
  - Pre-design study sand lens installation confirmed 15 foot is consistently achievable
  - Evaluating if a larger ROI can be implemented full scale, but maybe difficult to decipher with existing well network

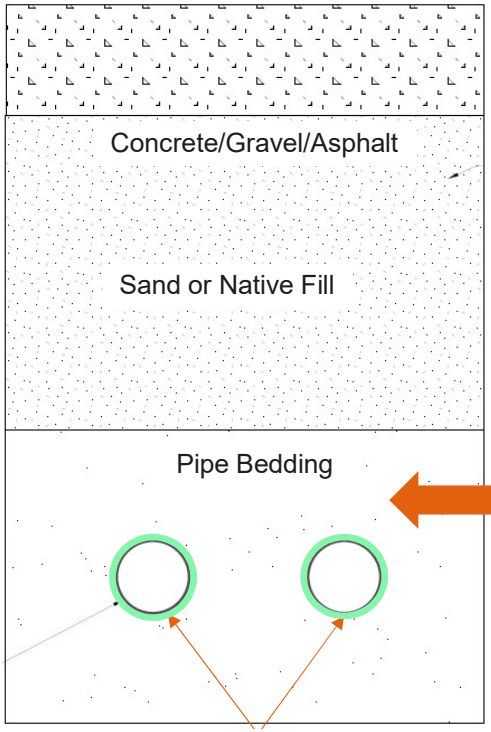


Biosparge Points

- Borehole installed using roto-sonic drilling method
  - 4” blank PVC casing installed to depth
  - Neat cement around casing, allowed to cure for ~1 week
- Sand lens installation
  - Two lenses per sparge point
  - Blank casing and formation are pre-notched with water jet
  - Injection rig used to inject a guar gum, quarts silica sand, borax, and LEB-H – endo-1,4-R-mannase mixture. Approximately 1,000 lbs of sand and 200 gallons carrier fluid injected per lens
- Each point fitted with an air sparge well screen

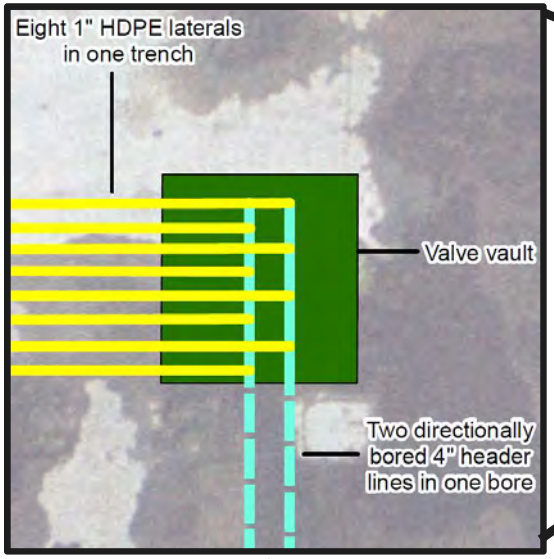


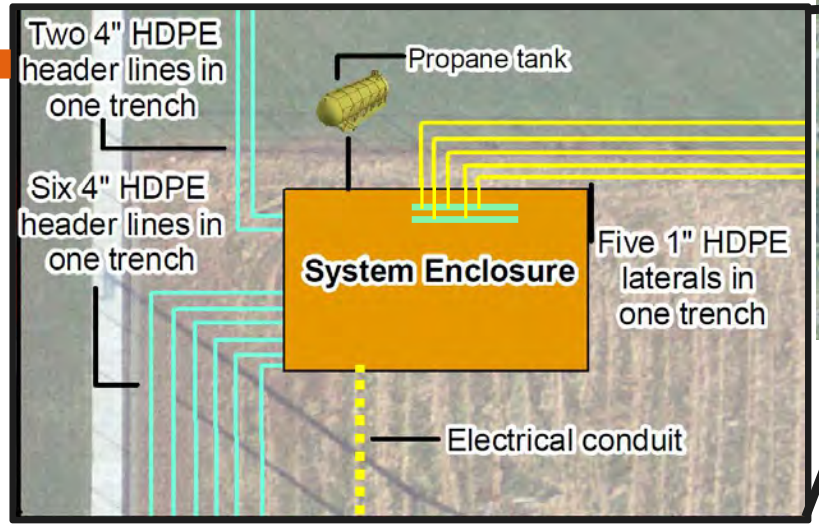
Conveyance Piping

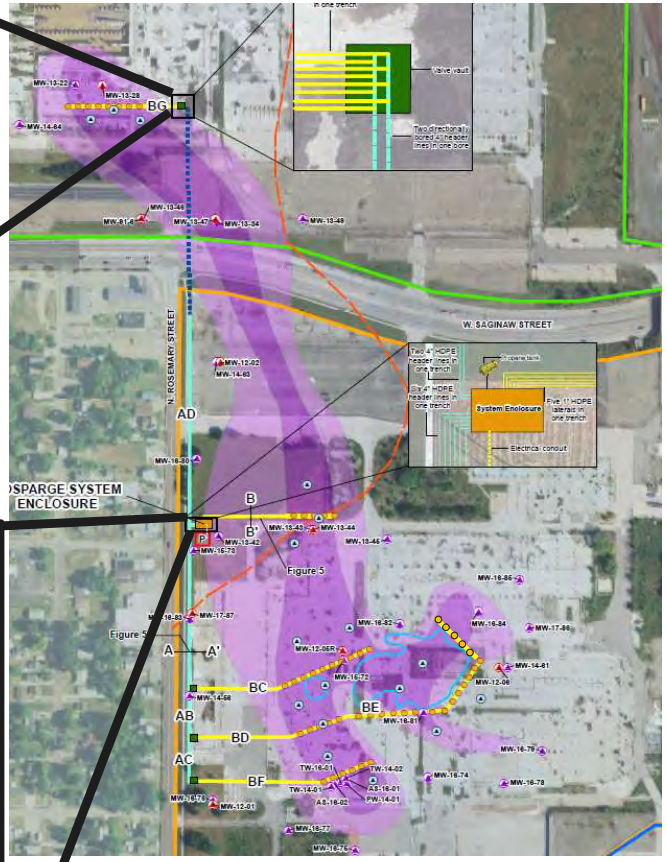


4" HDPE Header Lines to Valve Vaults

Depth of piping 24" – 42" below ground surface







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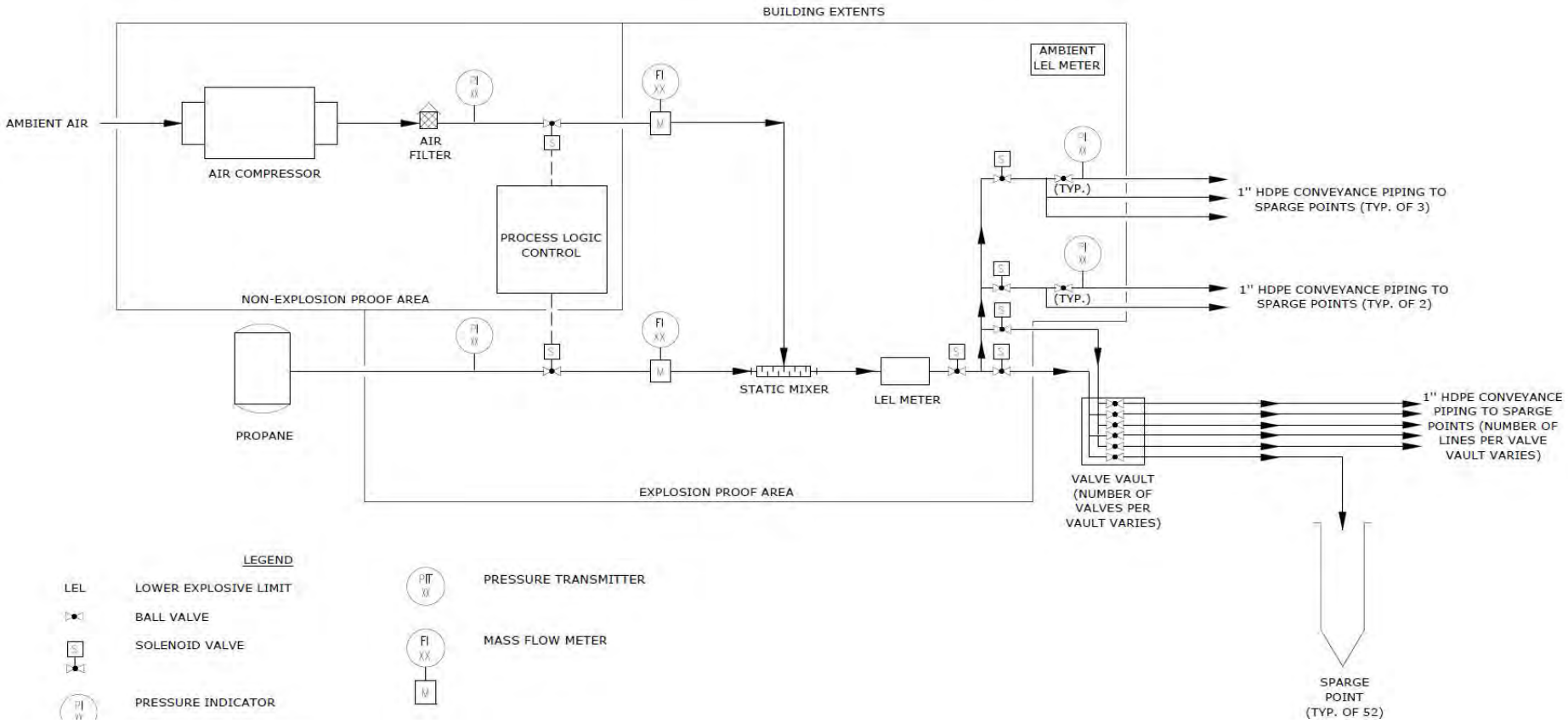
Process Equipment



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System Operation

Operation

- Start-up period to determine air/propane flow rates/cycles for optimal dissolved phase propane and oxygen distribution
- Bioaugmentation - injections of propanotrophic cultures and/or nutrients as-needed
  - Both pilot tests have shown initial decreases of 1,4-D prior to bioaugmentation
- Operating Strategy
  - Up to 10 SCFM air flow per biosparge point (currently operating at 5 scfm)
  - Adaptive system design allows biosparge points to be turned on and off to optimize performance
  - Propane dose 15 – 35% of LEL, cycled (currently operating 15% LEL, 6, 30 min cycles/day)
- Operations and Maintenance
  - Routine: DO/flow/pressure monitoring, equipment maintenance, well head LEL monitoring
  - Non-Routine: Troubleshooting, sparge point rehabilitation, maintenance bioaugmentation and/or nutrient injections

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Performance and Stability Monitoring

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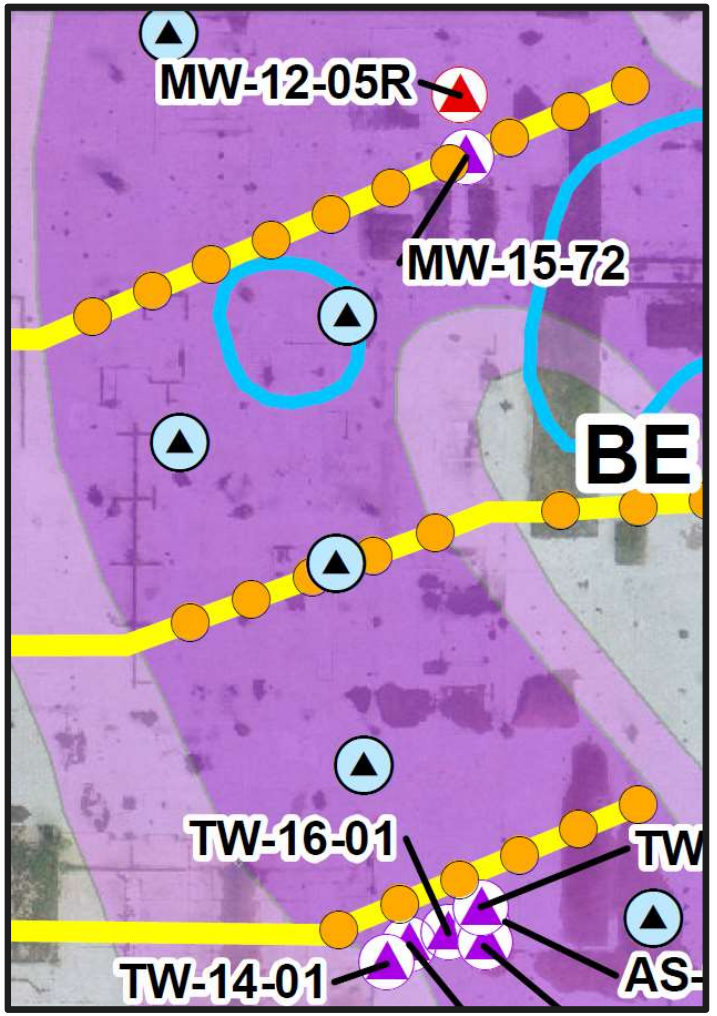
Performance Monitoring Wells

- Network of approximately 12 existing and approximately 16 new monitoring wells
- Mass flux-based performance monitoring utilizing only wells screened in the weathered bedrock and bedrock
- Each biosparge transect will have monitoring wells up-gradient, within ROI, and downgradient, with approximately 1 well per 200 feet

PROPOSED SPARGE POINT
PROPOSED PERFORMANCE MONITORING WELL
WEATHERED BEDROCK MONITORING WELL; TEST MW
BEDROCK MONITORING WELL
PROPOSED 1" HDPE LATERAL (INDIVIDUAL LINES IN SHARED TRENCH TO EACH SPARGE POINT)



Stability Monitoring - 1,4-Dioxane

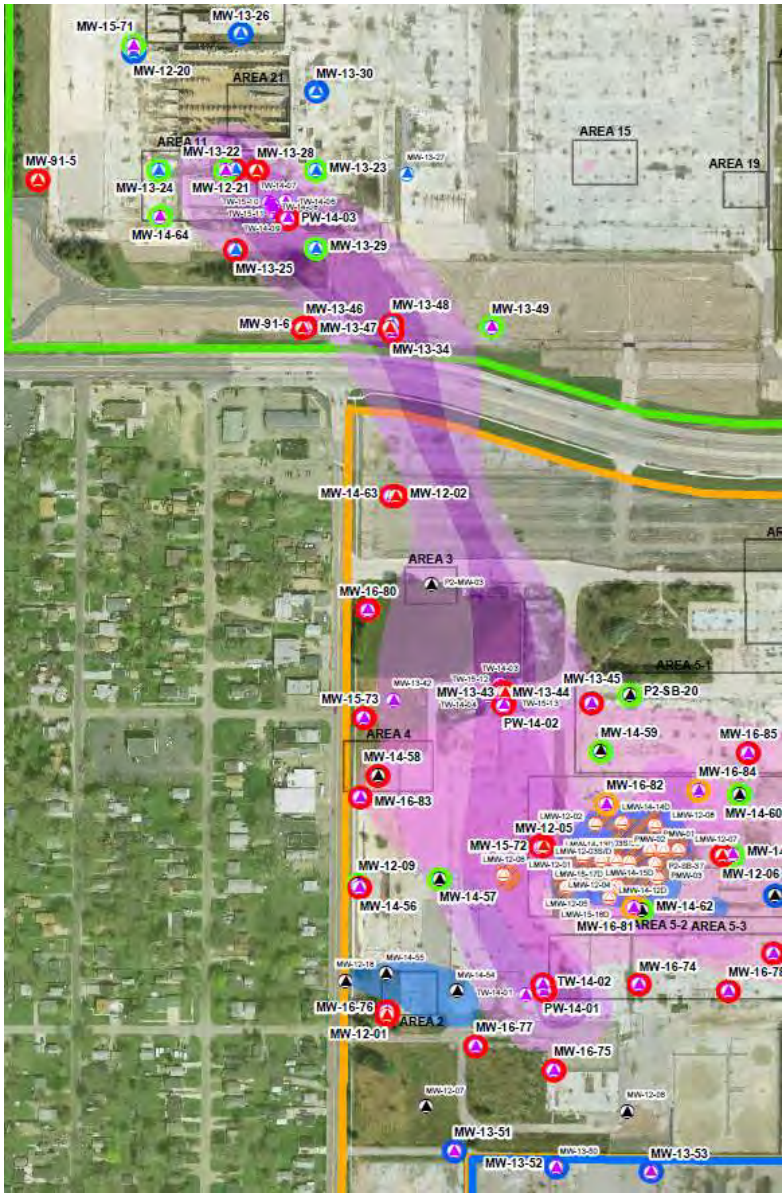
Semi-annual reporting.
Annual stability analysis.

Sampling:

- Completed quarterly in new wells until trends are established, then
- Semi-annual if increasing trend noted, or at sentinel perimeter wells
- Annually where ND or stable/no trend
- Biennial upgradient/ far downgradient

LEGEND

- LNAPL MONITORING WELL
- PERCHED ZONE MONITORING WELL
- DEEP OVERBURDEN MONITORING WELL
- WEATHERED BEDROCK MONITORING WELL
- BEDROCK MONITORING WELL
- QUARTERLY FREQUENCY
- SEMI-ANNUAL FREQUENCY
- ANNUAL FREQUENCY
- BIENNIAL FREQUENCY
- APPROXIMATE EXTENT OF LNAPL
- APPROXIMATE EXTENT OF VOCs IN PERCHED GW > DW CRITERIA
- PERCHED 1,4-DIOXANE IMPACTS > PROPOSED DW CRITERIA (8.5 µg/L)
- LOWER 1,4-DIOXANE IMPACTS > DW CRITERIA (85 µg/L, NOT DEFINED)
- LOWER 1,4-DIOXANE IMPACTS > PROPOSED DW CRITERIA (7.2 µg/L, NOT DEFINED)
- PLANT 2
- PLANT 3
- PLANT 6



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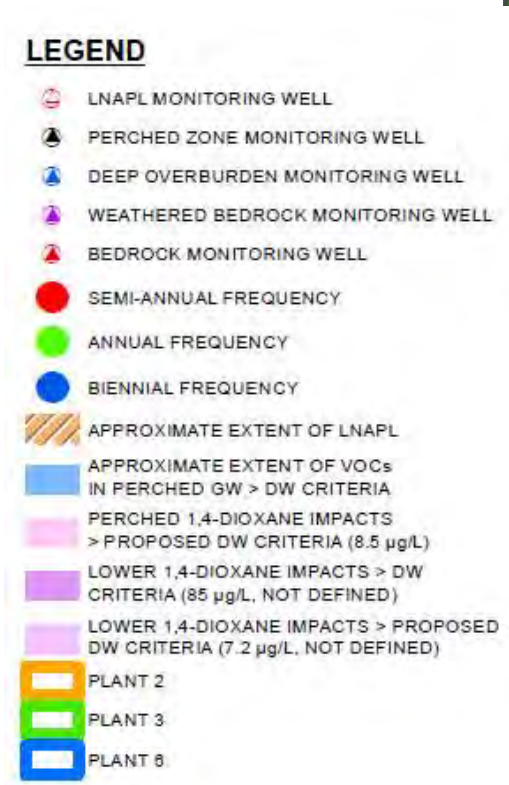
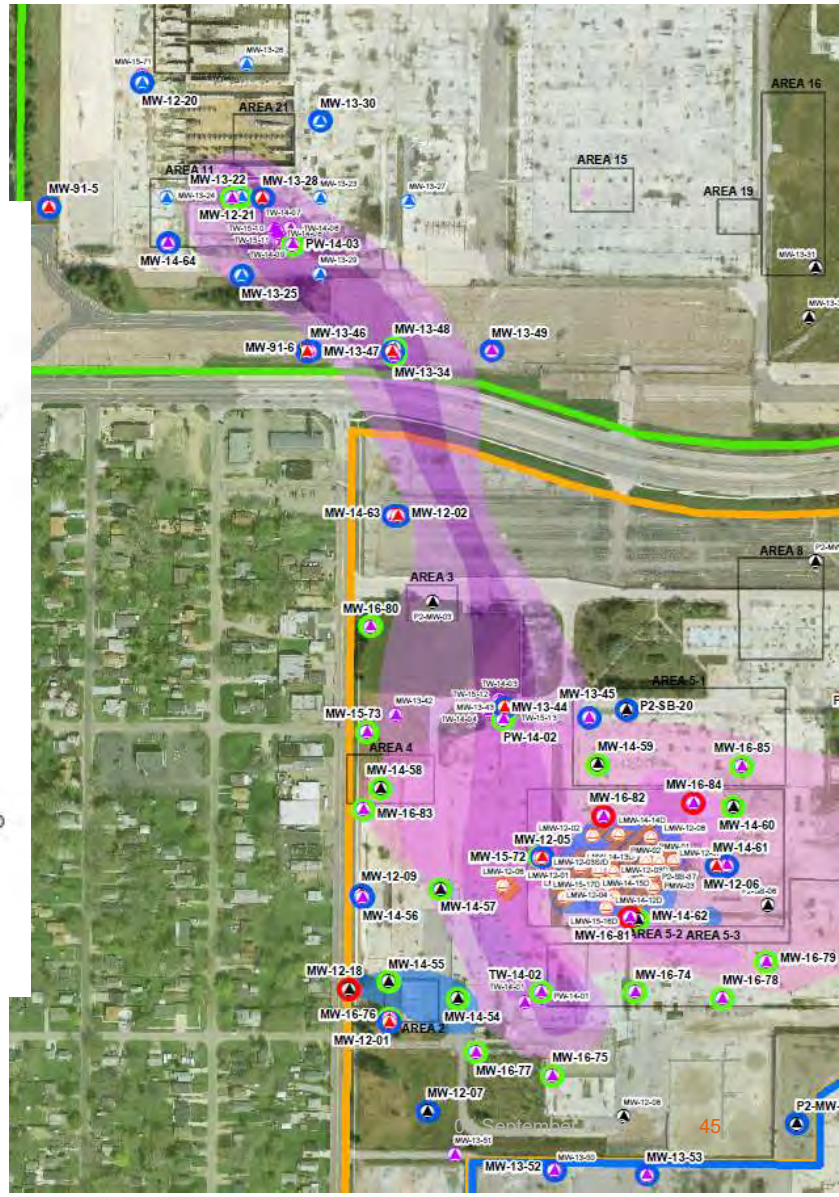
Stability Monitoring - VOCs

VOCs not noted in deep overburden or weathered bedrock wells

Sampling:

- Annual in performance monitoring wells and sentinel wells
- Biennial, upgradient/side gradient





Next Steps

- Finalize and Submit Biosparge Interim Measures Work Plan – October 2018
- Review and approval of IM Work Plan
- Design of Full Scale System – approximately 4 - 5 months from approval
- Contractor Bid and Selection (Drilling, Sub-grade, Electrical, Equipment) – approximately 1 - 2 months following design
- Pre-Construction Planning, Coordination, and Equipment Procurement – approximately 3 – 4 months after contractor selection
- System Construction – approximately 4 – 6 months