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23th International Petroleum Environmental Conference

Upgradient Persulfate Injection and Downgradient Ozone Sparging to Accelerate Closure of a Petroleum Hydrocarbon-Impacted Site

November 9, 2016

Authors and Presenter

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Presentation Overview

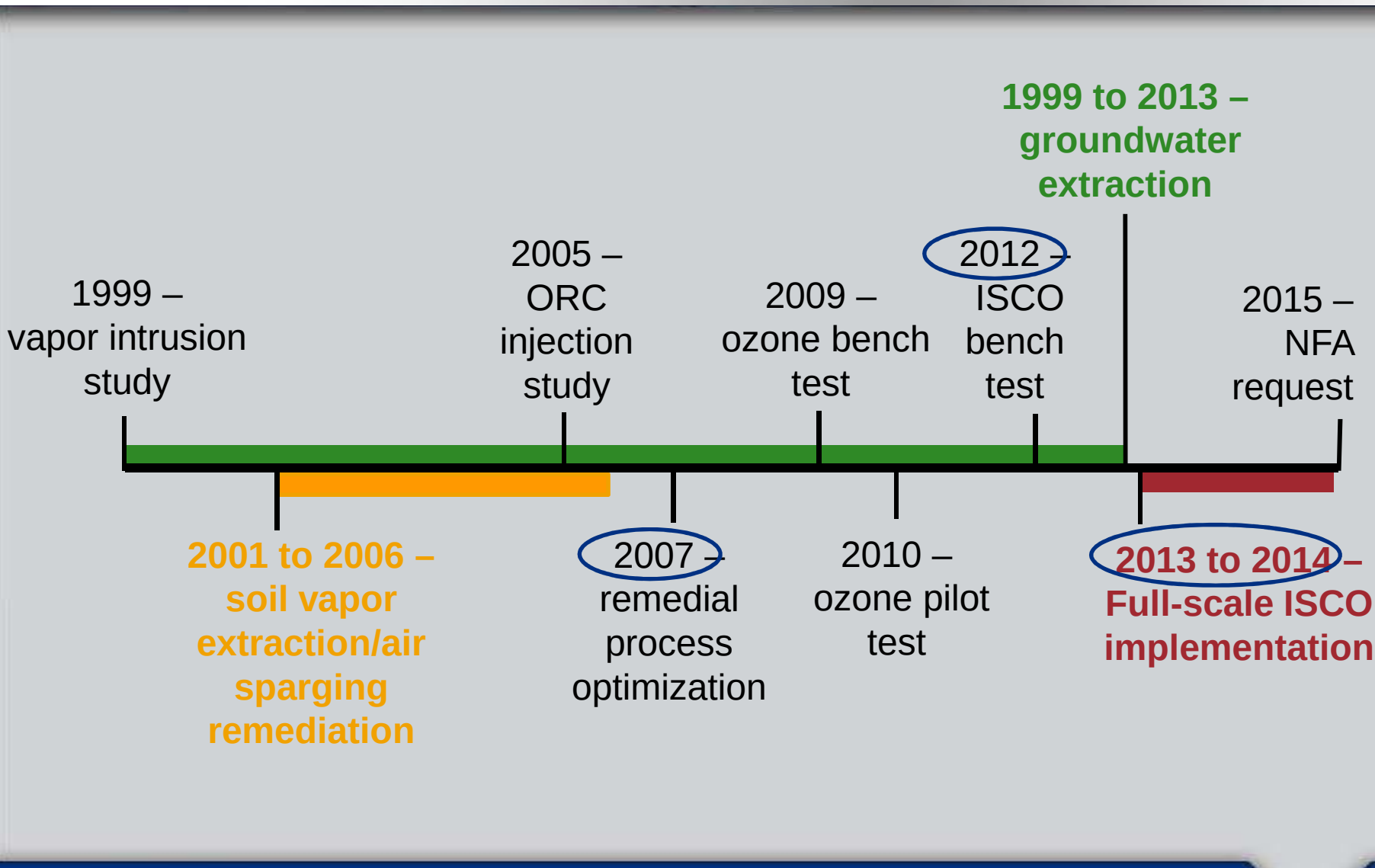
- Site Background
- Groundwater Modeling
  - Capture Zone Analysis (MODFLOOW)
  - By-products Impacts Evaluation (MT3D)
- Upgradient Persulfate Injection
  - Injection and Monitoring Program
  - Geotechnical Monitoring
- Downgradient Ozone Sparging
  - Pilot Test
  - Interaction with Persulfate

TPH Site Background

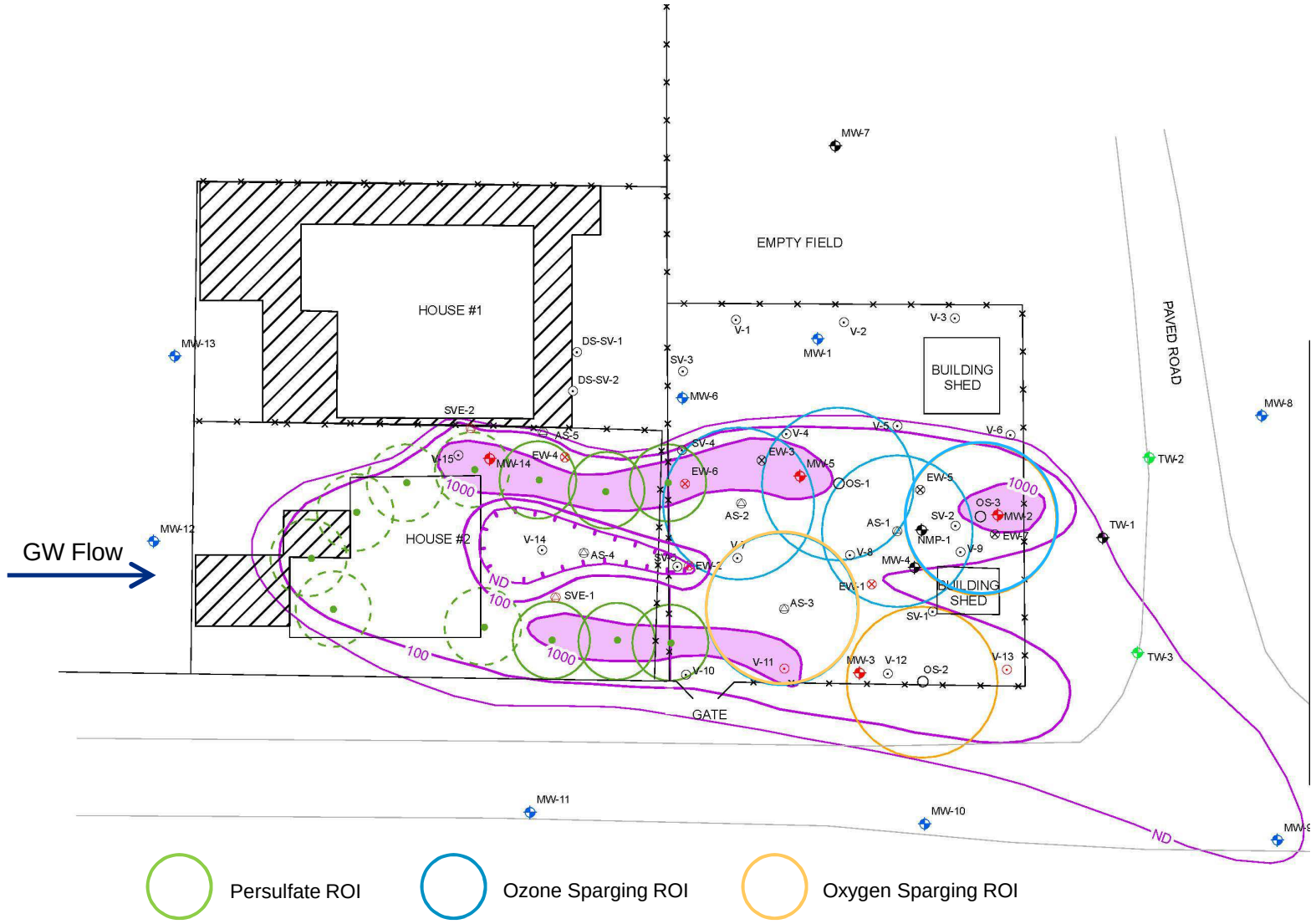
- Former natural gas processing station (1960 to 1980s)
- Interbedded layers of sand and silty sand (0 to 30 ft bgs)
- Shallow unconfined zone (15 to 30 ft bgs)
- Chemicals of concern

Matrix	GRO	DRO	ORO
Upgradient GW (µg/L)	3,500	3,700	440
Downgradient GW (µg/L)	3,500	5,600	520
Clean-up Levels (µg/L)	100	100	100

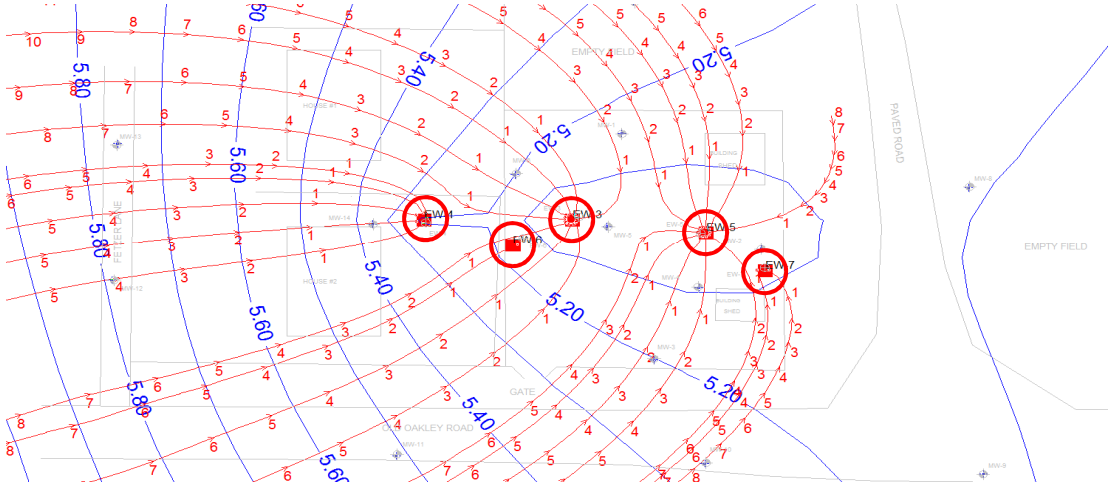
Chronology of Key TPH Site Events



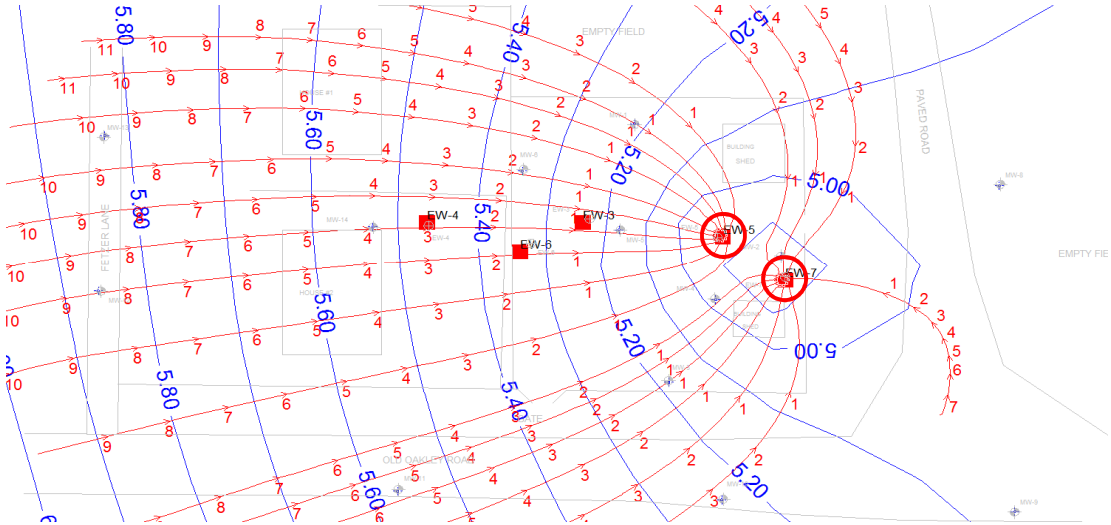
Persulfate Injection and Ozone Sparging



MODFLOW – Capture Zone

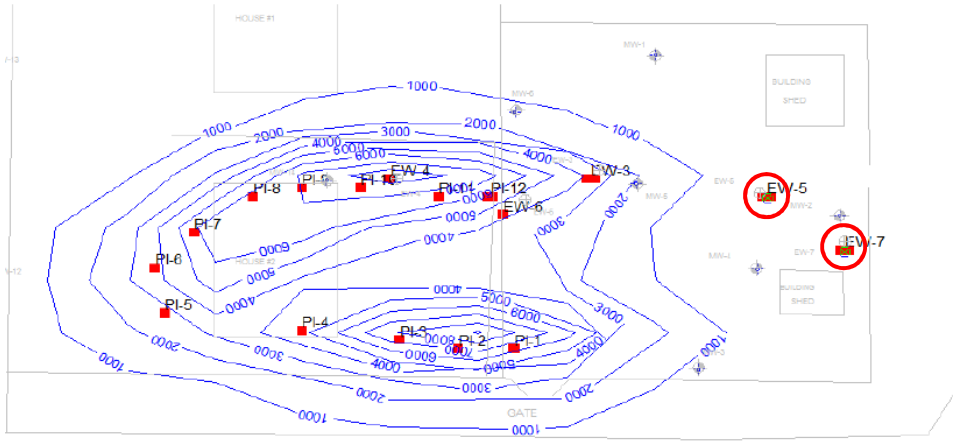


Existing 5 EWs at 3 gpm

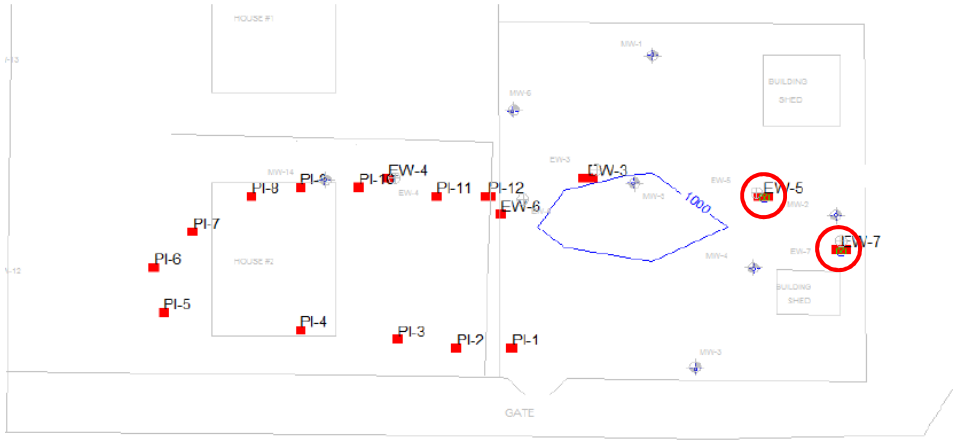


Proposed 2 EWs at 3 gpm

MT3D – Predicted TDS Impact Distribution

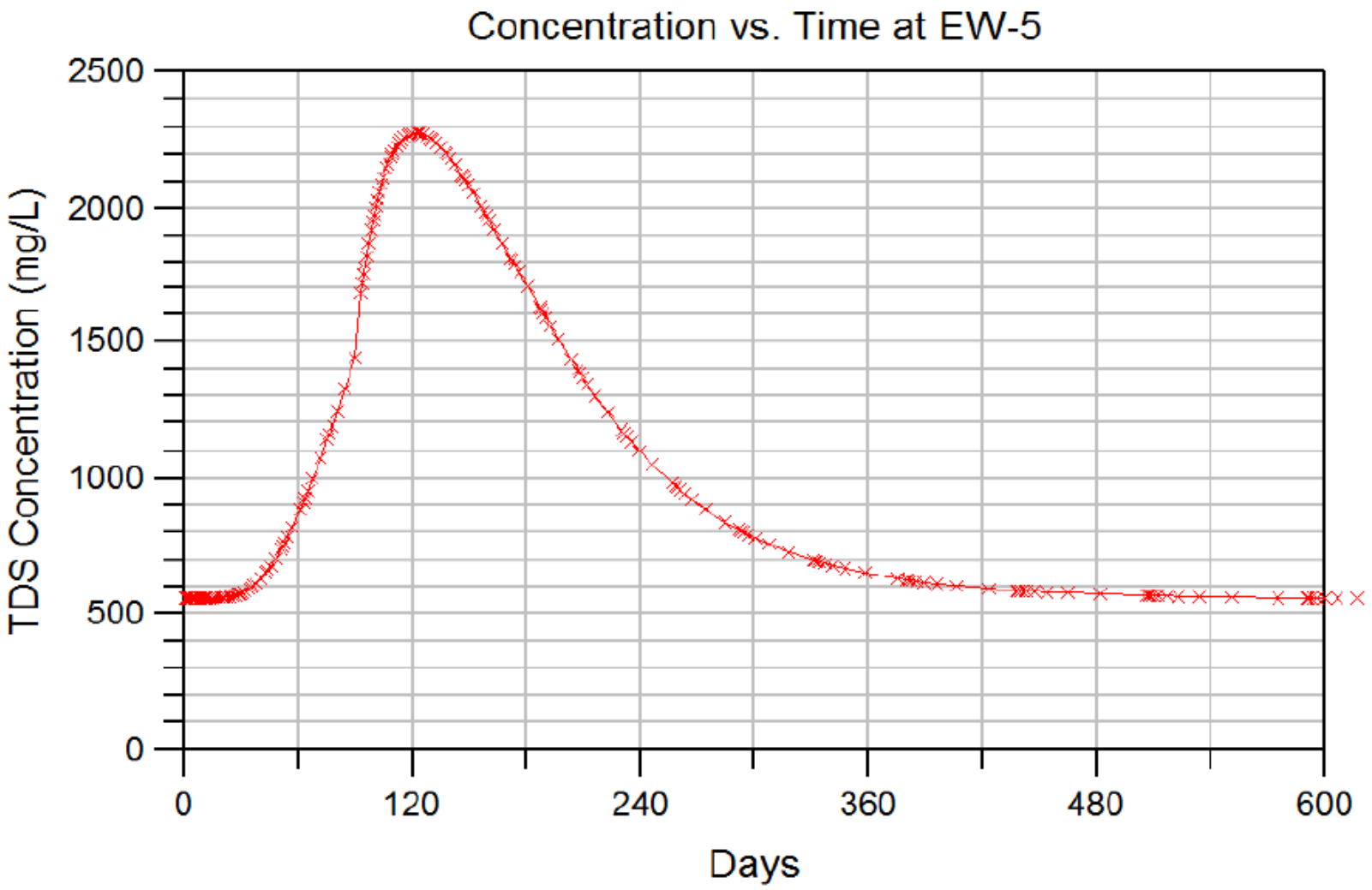


One month after



Nine months after

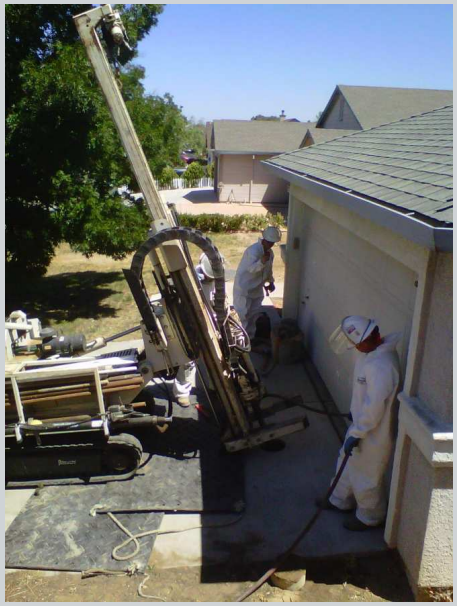
MT3D – Predicted TDS Concentration at EW-5



Vertical/Angle Drilling and Injection

Vertical Drilling/Injection

- Open field
- Points: 6
- Depth: 15 to 23 feet vertical



Angle Drilling/Injection

- Below the building
- Points: 6
- Angles: 10 to 20 degrees
- Depth: 14 to 21 feet vertical

Geotechnical Monitoring Results

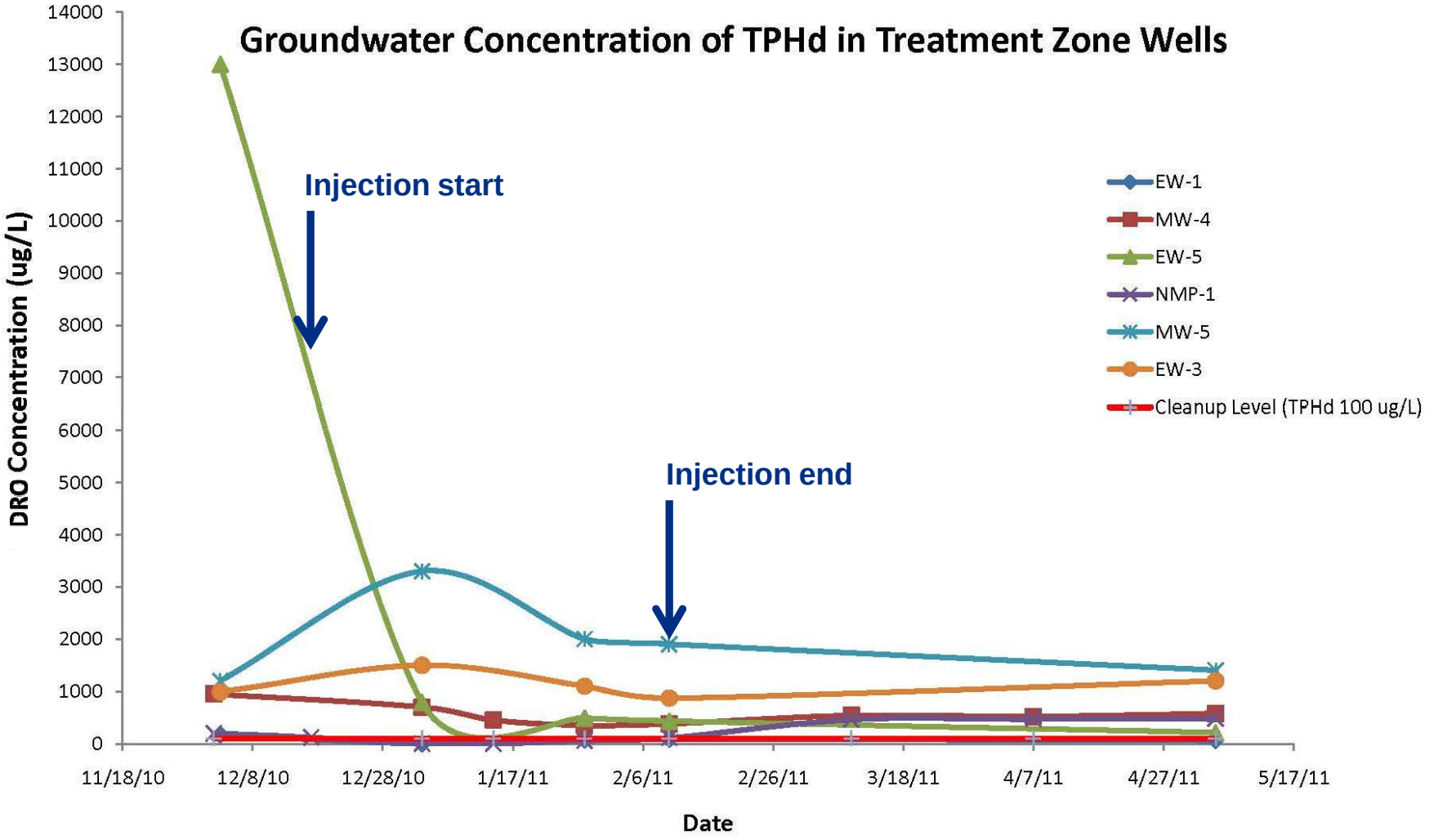
- Visual inspection: No observable changes
- Crack monitoring
  - No expansion or extension of existing cracks
- Settlement monitoring
  - Differential settlement less than 1%
  - Total settlement less than 0.5 inches

Ozone Sparging Pilot Test

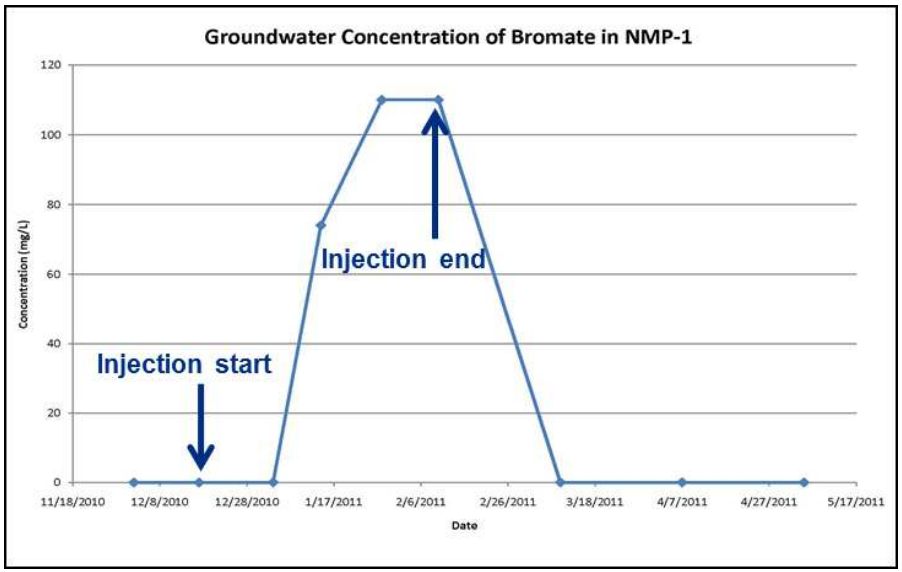
Pilot Test Injection Specifications

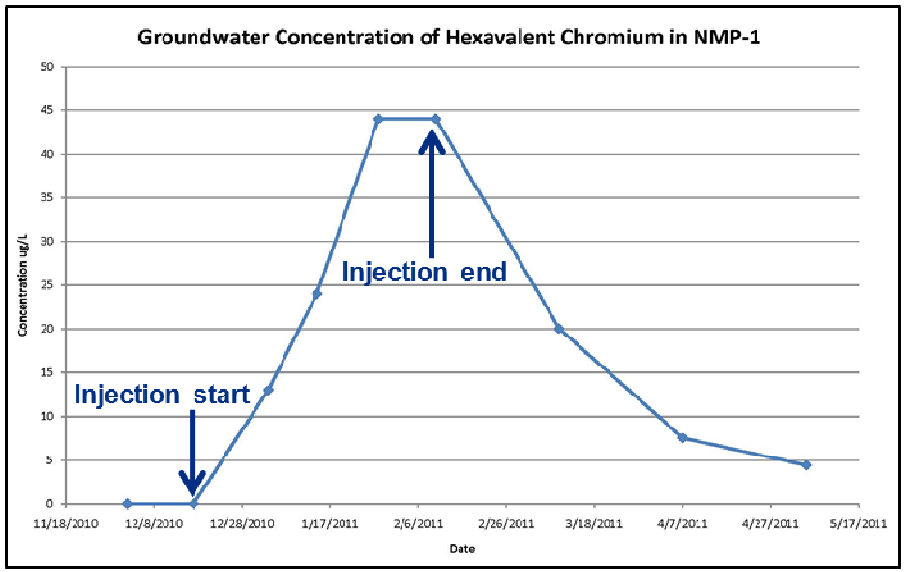
- Injection well: 2
- Pressure: 5.5 to 6.0 psi
- Flow rate: 3.5 cfm per well
- Equivalent to ~ 2 lb O_3/day
- ROI ~ 20 feet
- Injection time: 60 minutes

Pilot Test Results – DRO Concentration



Pilot Test Results – Secondary Impacts (Bromate and Hexavalent Chromium)



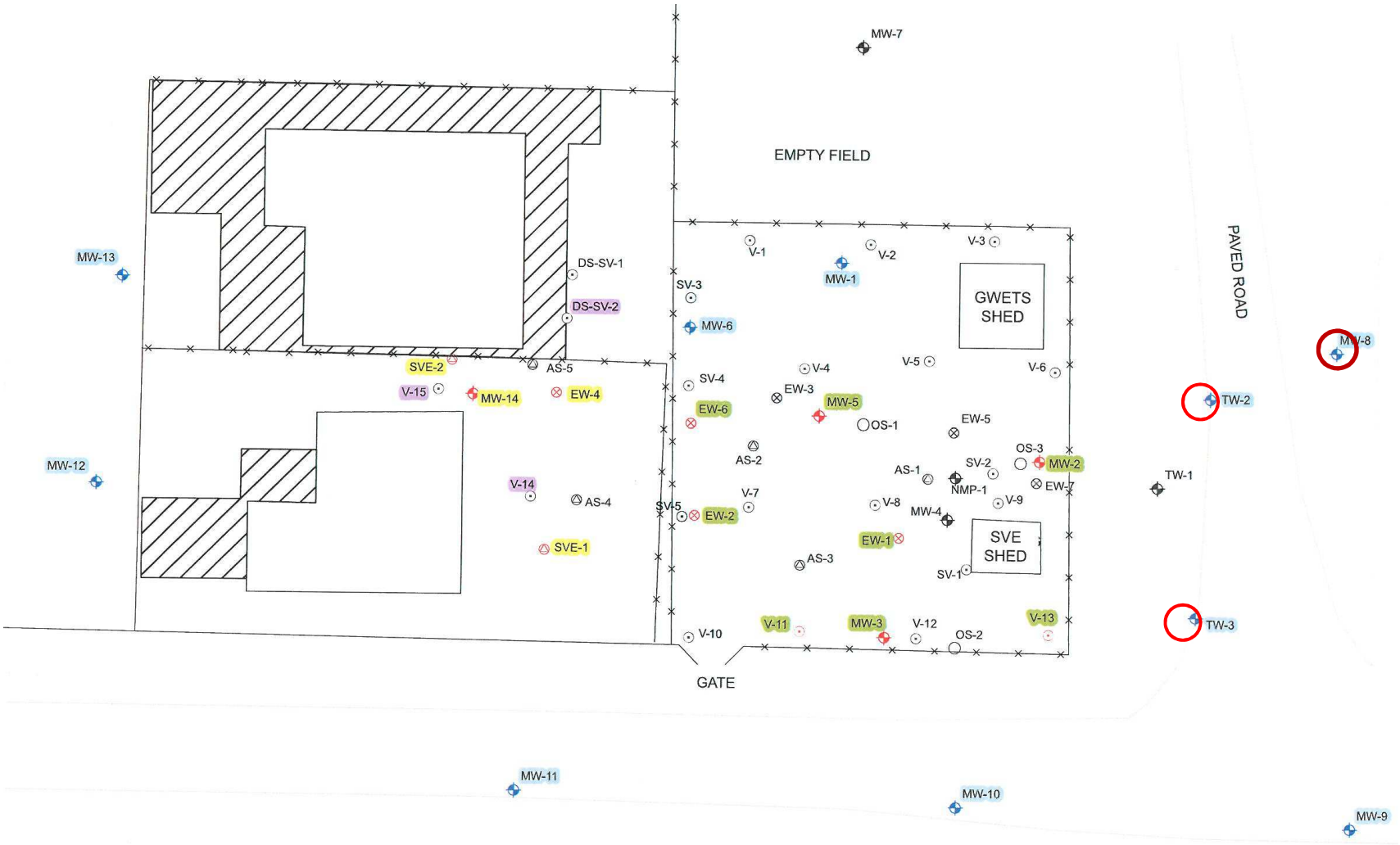


Full-scale Ozone Sparging Implementation

Full-scale Ozone Injection Implementation

- Injection wells: 6
  - Ozone sparging wells: 4
  - Oxygen sparging wells: 2
- Injection pressure: 12 to 25 psi
- Sparge flow rate: 6.8 cfm per well
- Ozone capacity: 27 ppd
- ROI: 20 feet based on DO and ORP measurements
- Treatment monitoring wells: 8
- Transition and compliance wells: 10

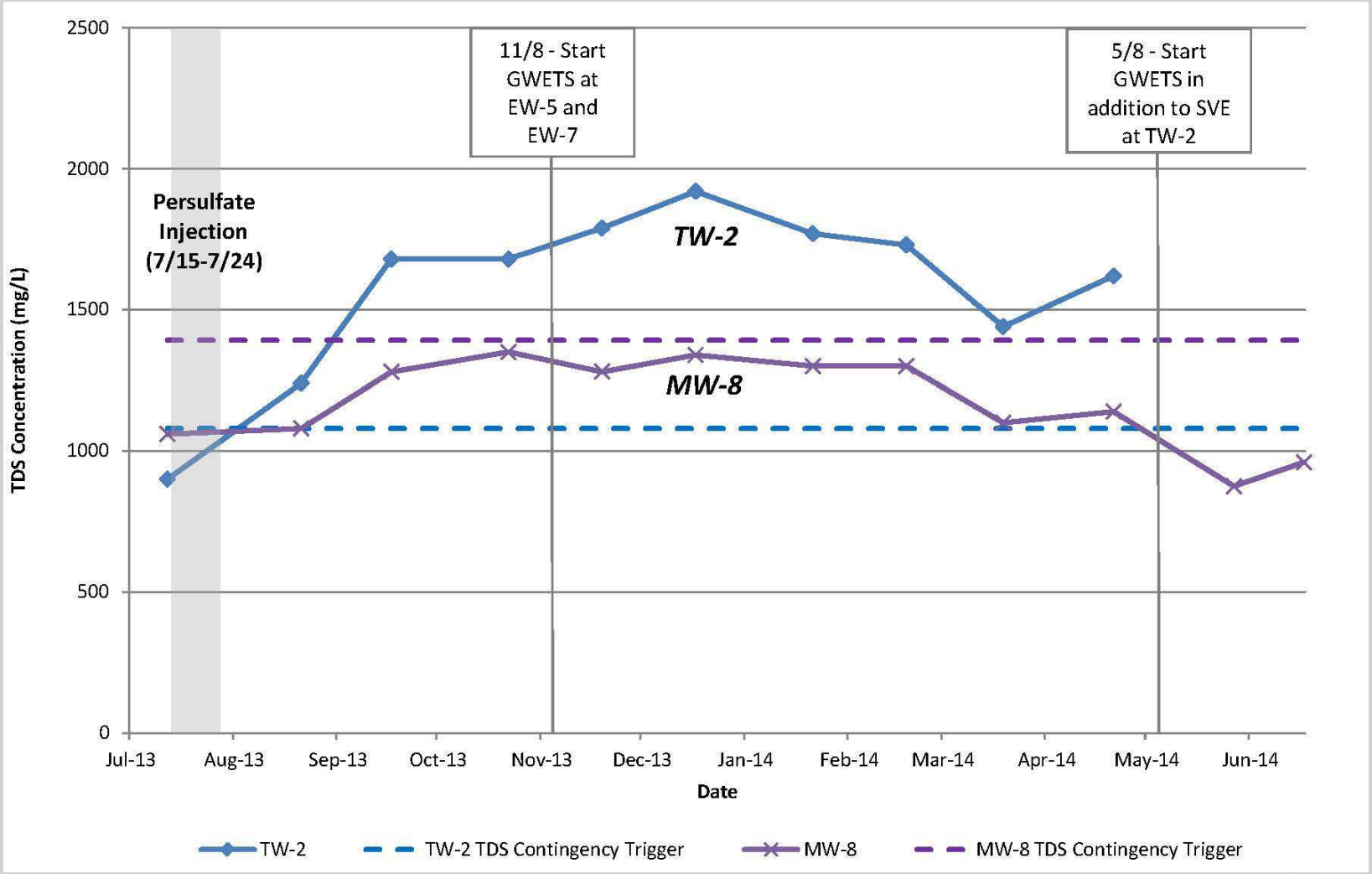
Groundwater Monitoring Well Locations



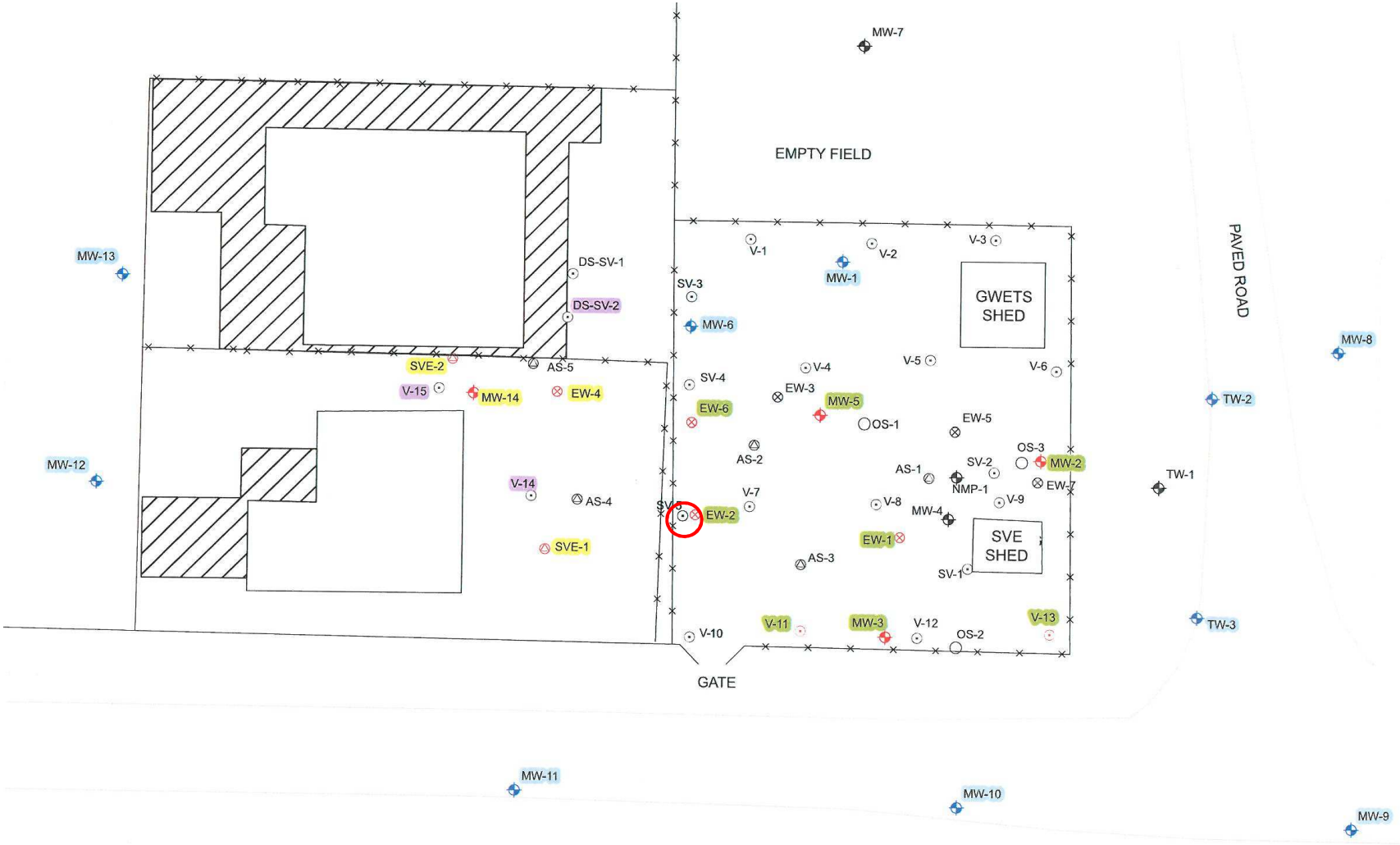
Persulfate Injection Contingency Plan

- Trigger: TDS concentrations at transition wells (TW-2, TW-3) exceed 20% of baseline concentration continuously for 3 times
- Response: Initiate GWETS at extraction wells

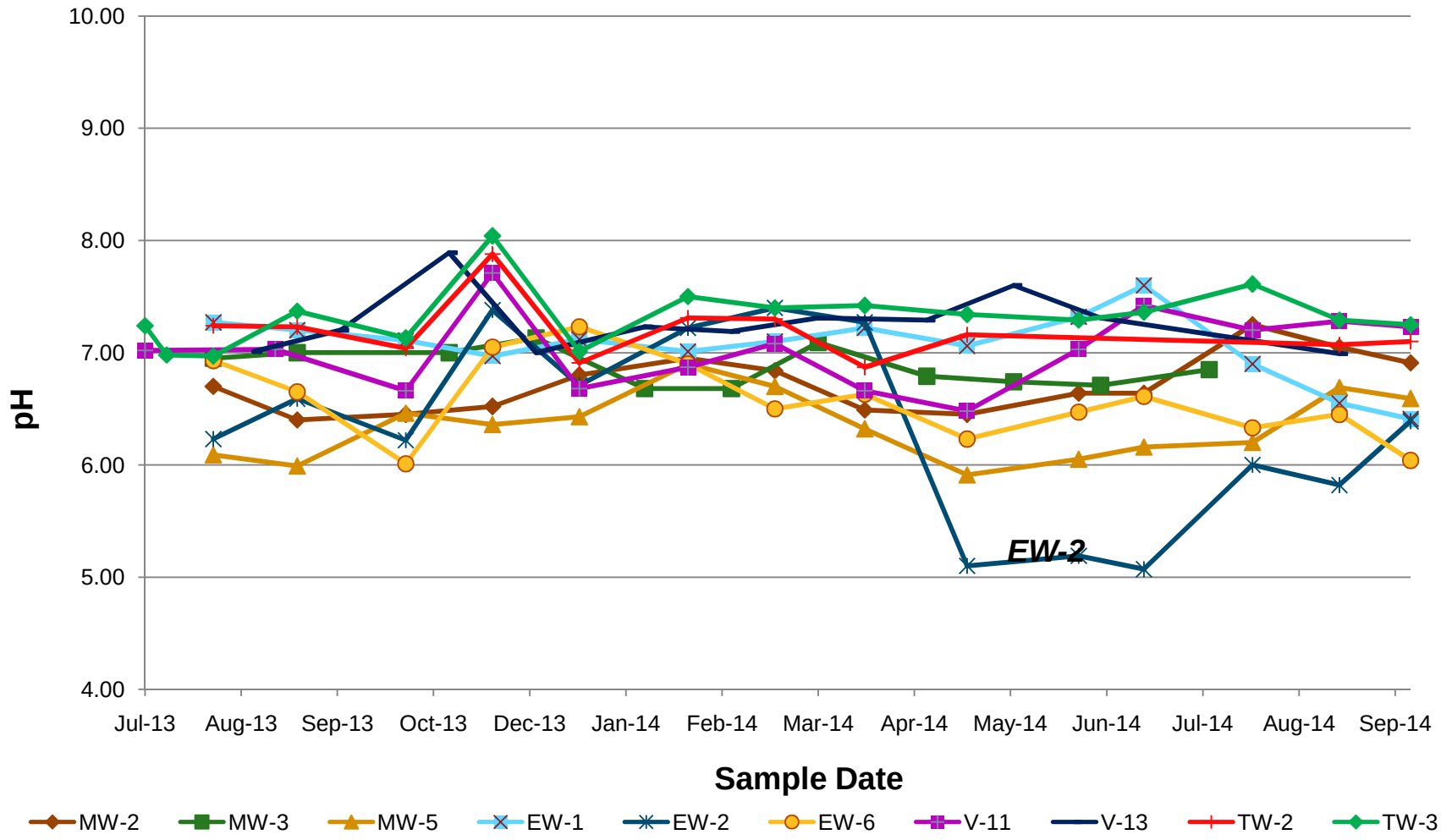
TDS Concentration Trends in Downgradient Groundwater Wells



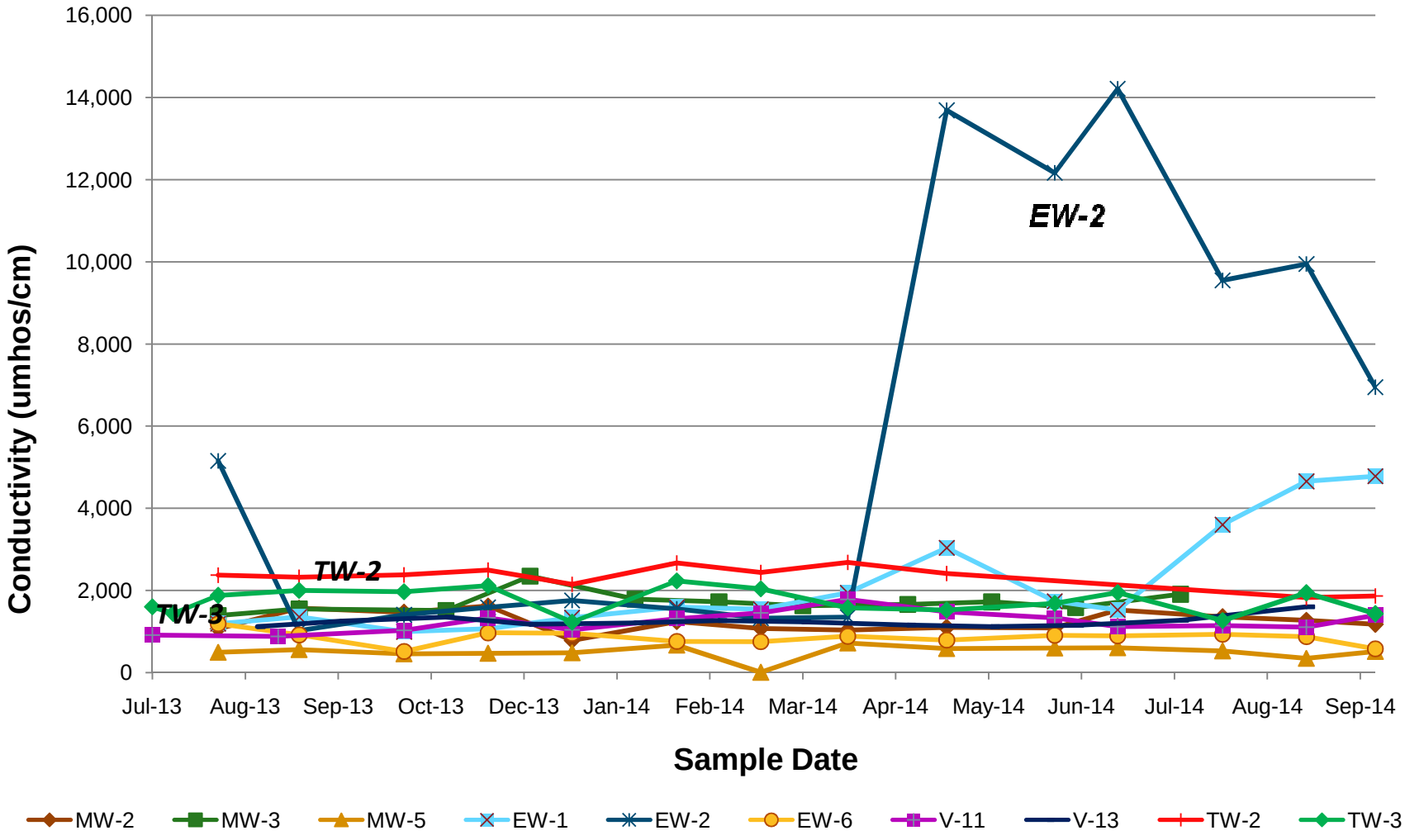
Groundwater Monitoring Well Locations



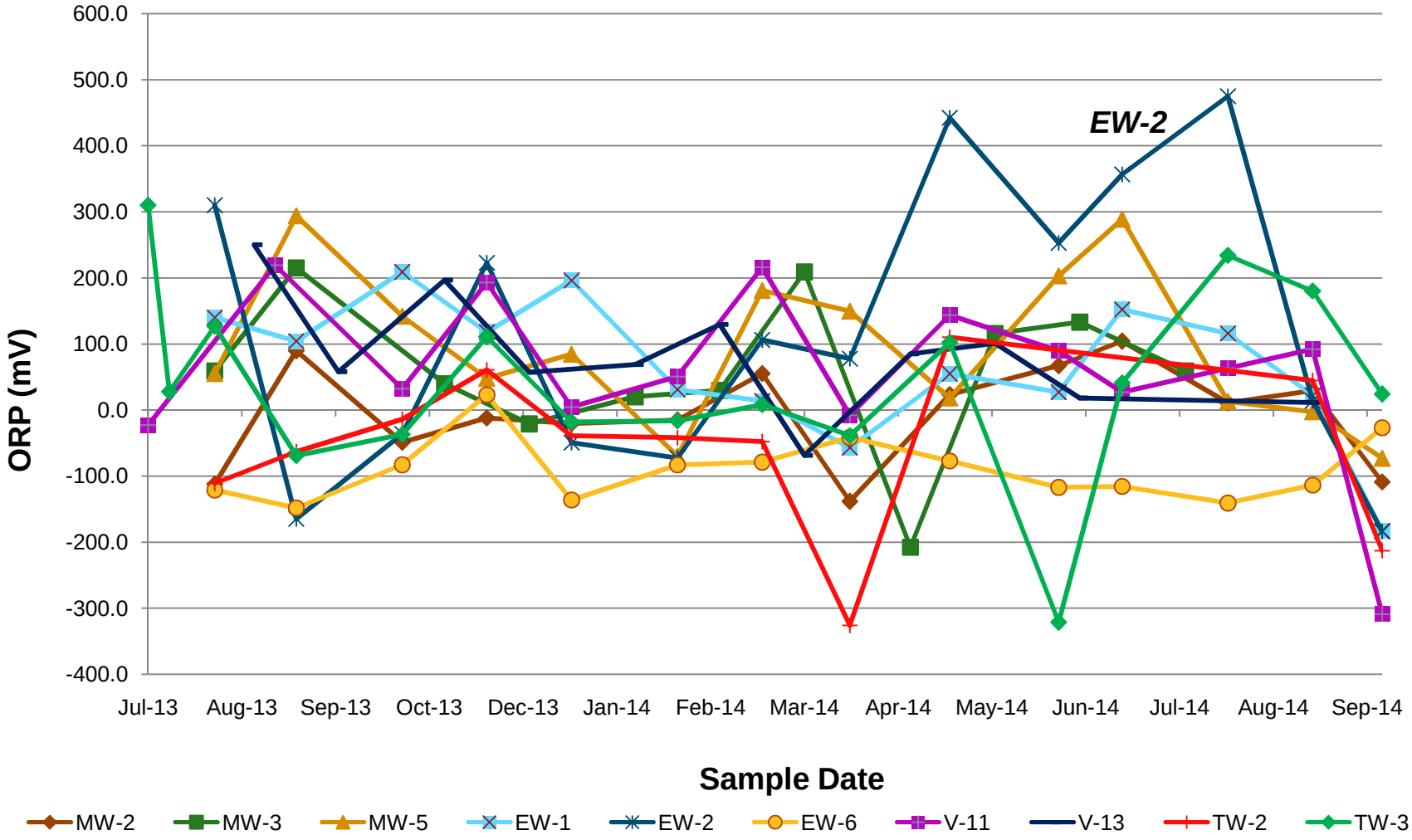
Ozone Treatment Wells – pH



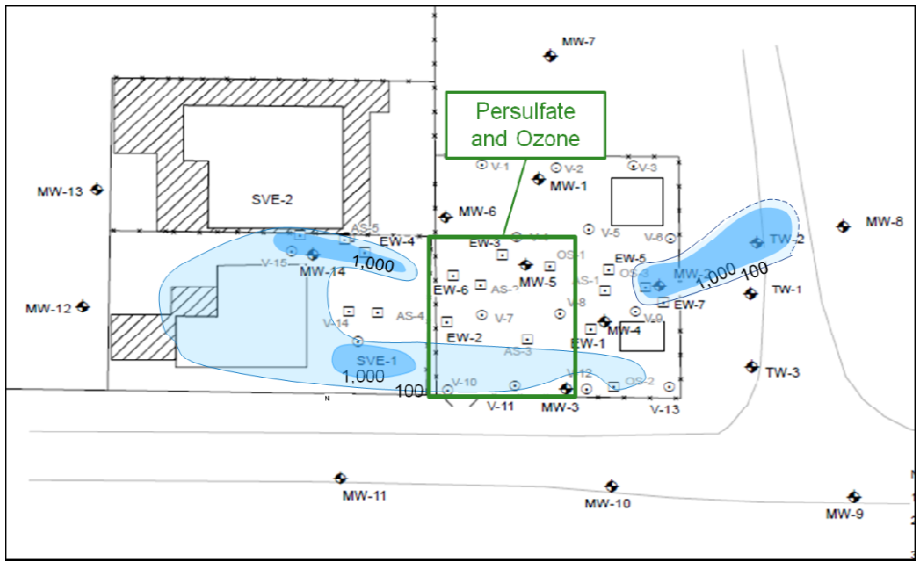
Ozone Treatment Wells – Conductivity



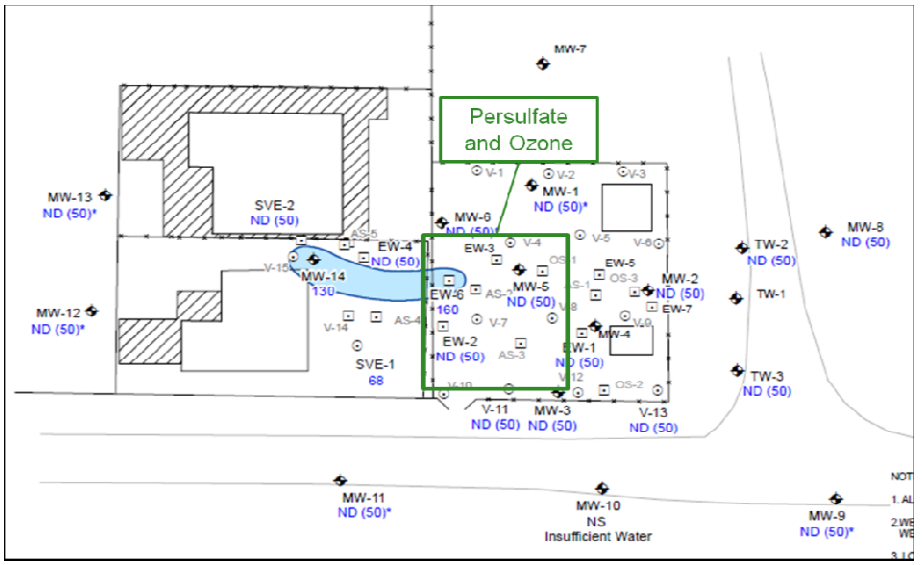
Ozone Treatment Wells – ORP



GRO Results

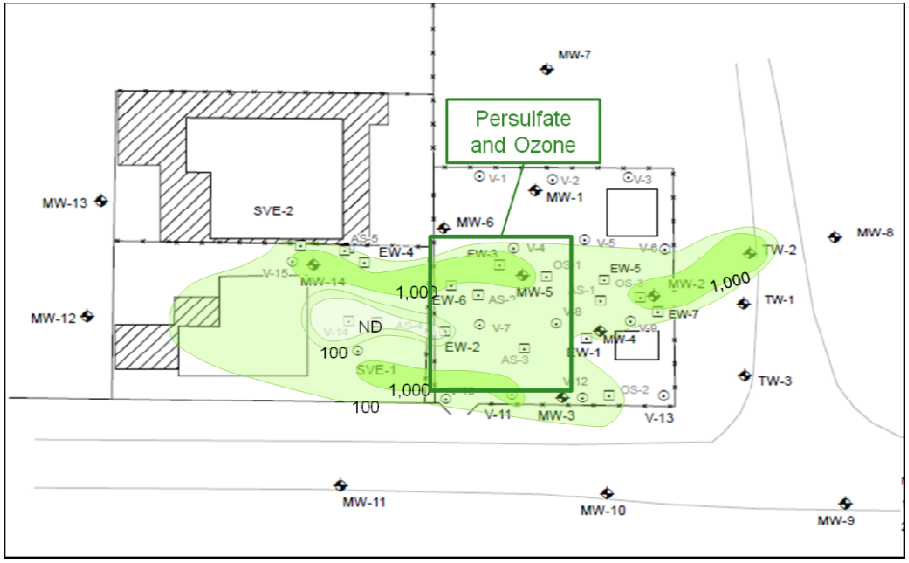


Prior to remediation

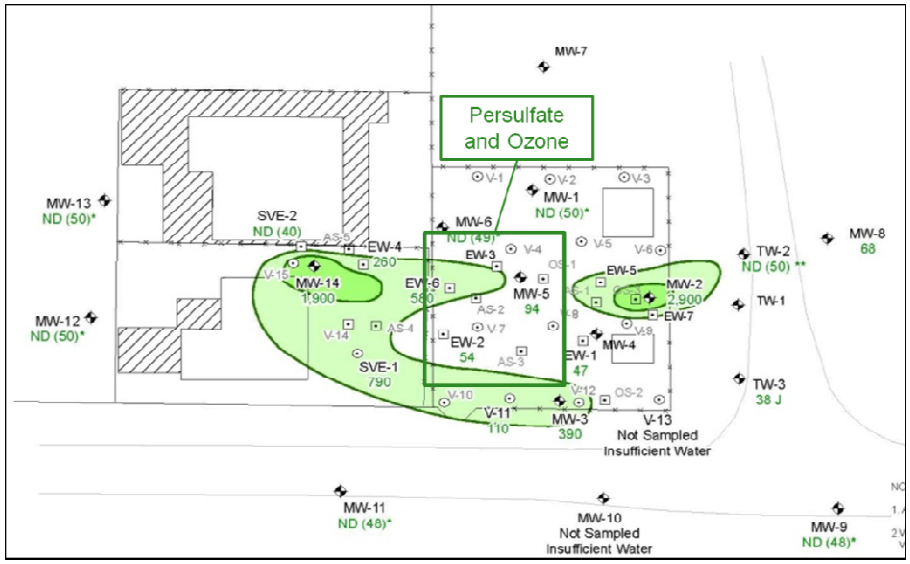


One year after remediation
95% removal after rebound

DRO Results

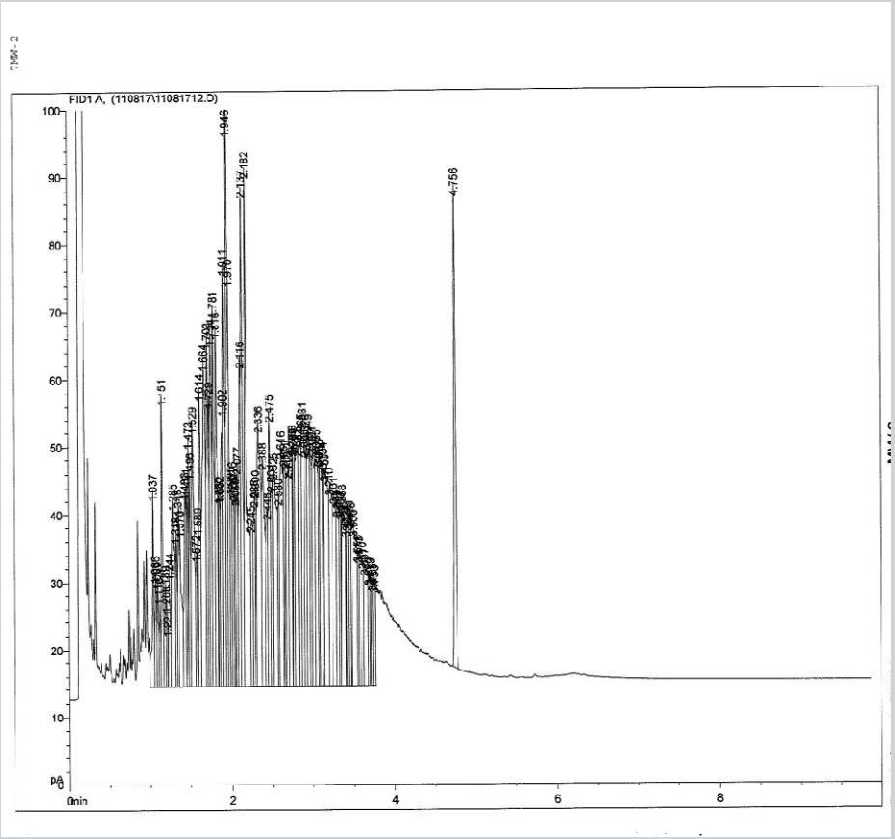


Prior to remediation

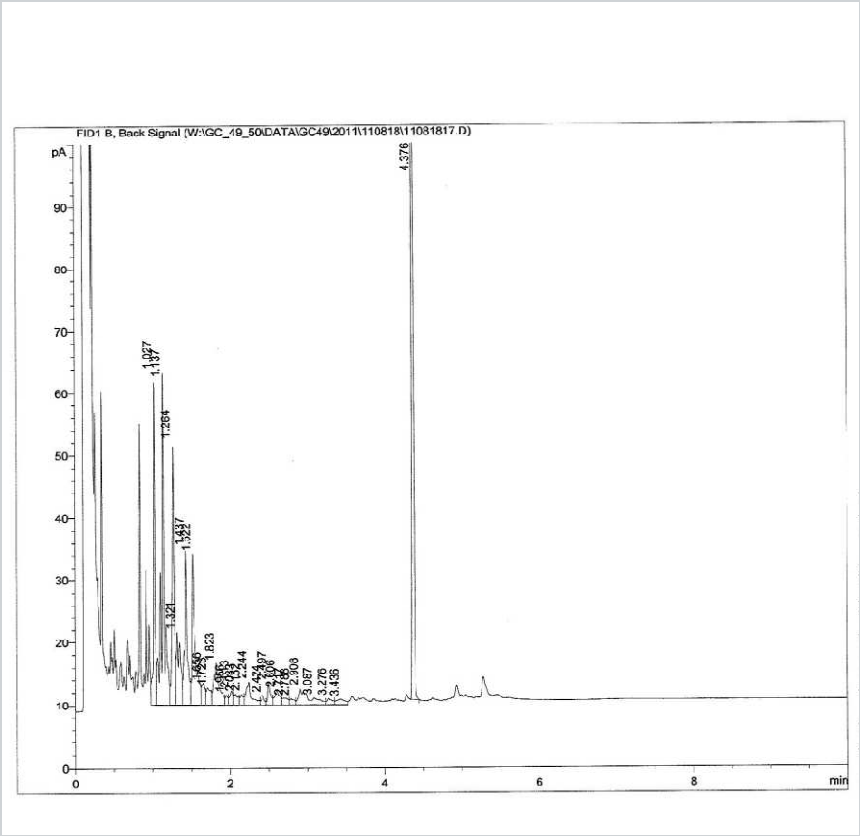


One year after remediation
65% removal after rebound

MW-2 Chromatography – Polar Compounds

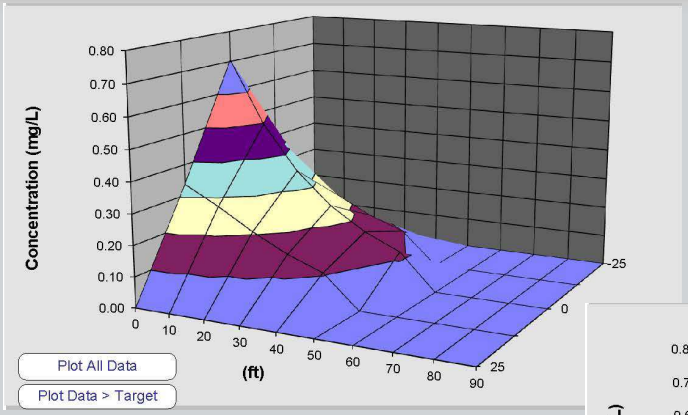


DRO

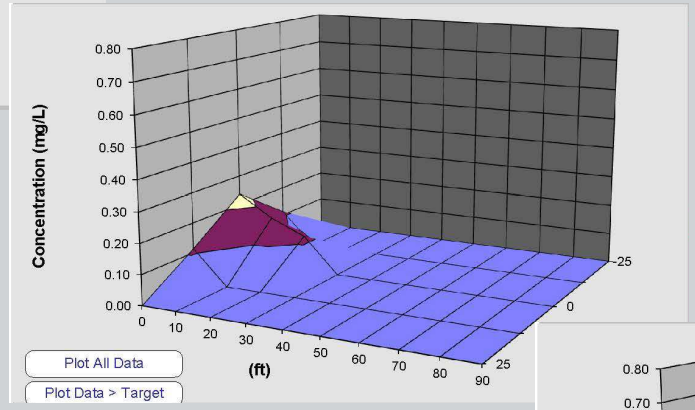


DRO with Silica Gel Cleanup

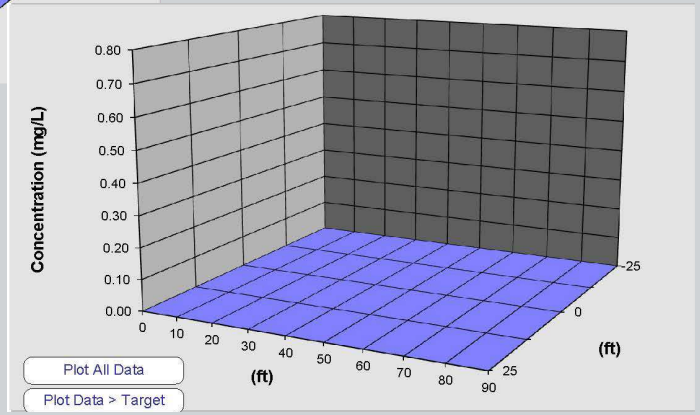
BIOSCREEN – Polar Compounds Biodegradation in MW-2



5 years



10 years



20 years

Conclusions

- Successfully destroys COCs in saturated zone
- Byproduct impacts
  - Injected chemicals (TDS, sulfate) captured
  - Oxidized chemicals (Cr(VI), BrO_3^-) contained
- Interaction monitoring parameters
  - pH – decreased
  - Conductivity – increased
  - ORP – increased

Questions

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