PARSONS

21th International Petroleum Environmental Conference

Full-Scale Implementation of In-Situ Chemical Oxidation Persulfate Injection

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Authors and Presenter

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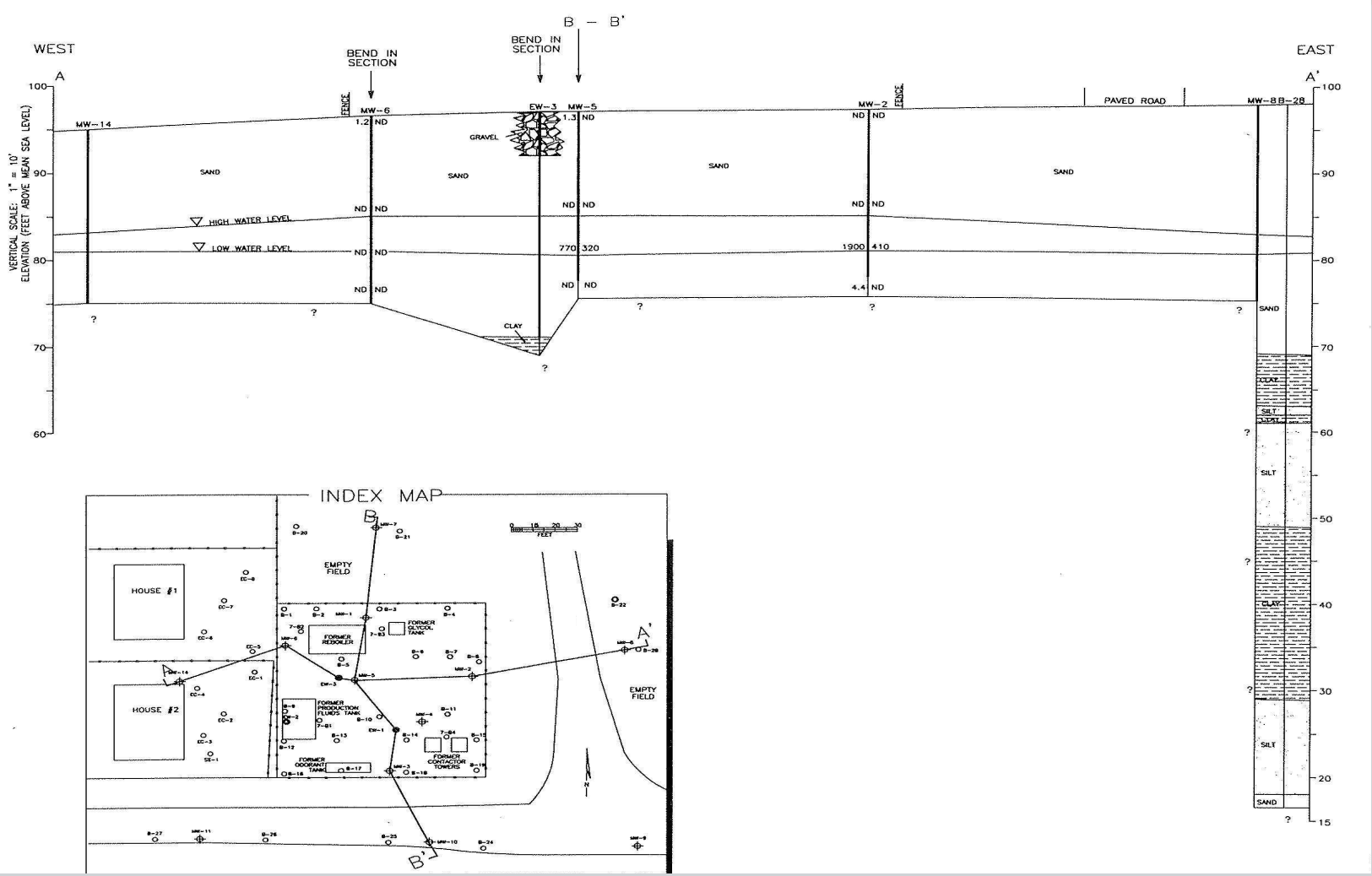
Presentation Overview

- Site Background
- Bench Test
- Groundwater Modeling
  - Capture Zone Analysis (MODFLOOW)
  - By-products Impacts Evaluation (MT3D)
- Full Scale Implementation
  - Induced Resonance Well Rehabilitation
  - Injection and Monitoring Program
  - Geotechnical Monitoring
  - GWETS

Site Background - Site Specific Information

- Former natural gas processing station (1960 - 1980s)
- Interbedded layers of sand and silty sand (0 - 30 ft bgs)
- Three hydrostratigraphic layers:
  - **Shallow unconfined zone (15 - 30 ft bgs)**
  - Confining layer (30 – 70 ft bgs)
  - Deep zone (70 – 90 ft bgs)
- Shallow unconfined zone
  - Groundwater velocity: 0.4 ft/day
  - Flow direction: southeast and northeast

Site Background - Cross Section



Site Background – Nature and Extent of Impacts

- Chemicals of Concern identified in **saturated zone:**
  - Gasoline Range Organics (GRO)
  - Diesel Range Organics (DRO)
  - Motor Oil Range Organics (ORO)

Matrix	GRO	DRO	ORO
Groundwater (µg/L)	3,500	3,700	440
Clean-up Levels (µg/L)	100	100	100

Bench Test

- Oxidants
  - Persulfate
  - Stabilized Peroxide
  - Persulfate and Stabilized Peroxide

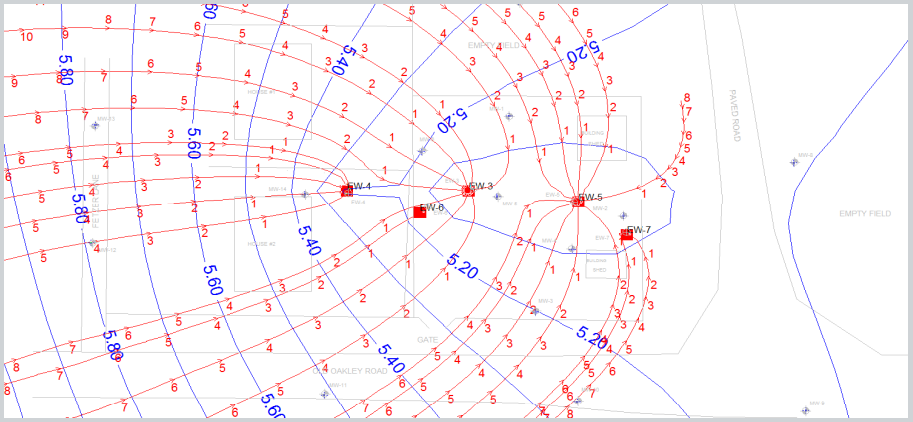
Bench Test – Results/Conclusions

- COC Removal
  - Three oxidants reduced DRO in groundwater
- Byproduct Effects
  - Persulfate – TDS, sulfate, and pH
  - Stabilized peroxide – acetone
- Soil Buffering
  - Mild buffering capacity
  - More remaining alkalinity from persulfate
- Longevity Test – Stabilized Peroxide
  - Insignificant temperature change
  - Off-gas generated

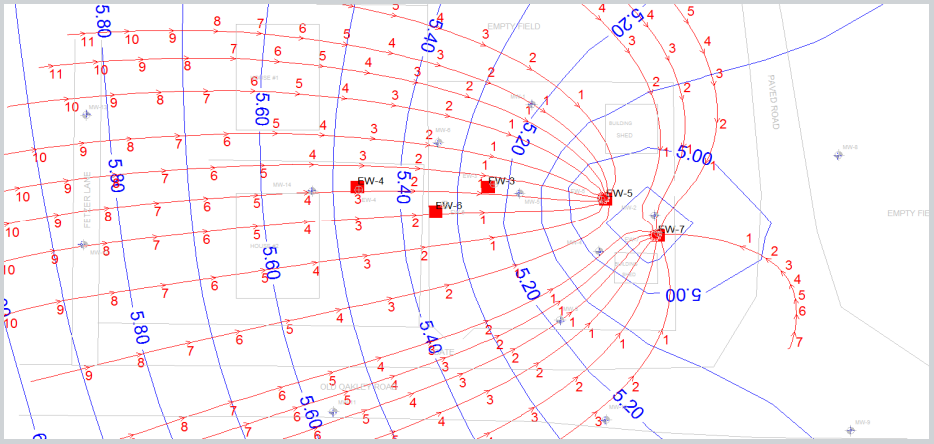
Bench Scale Test - Recommendations

- Persulfate Selected:
  - Equivalent COC removal in GW
  - Byproduct effects (no acetone)
  - Persistent
- Persulfate Dose:
  - 33 g/L from SOD & theoretical COCs requirements
  - Higher than dosages used in COC removal

MODFLOW - Capture Zone

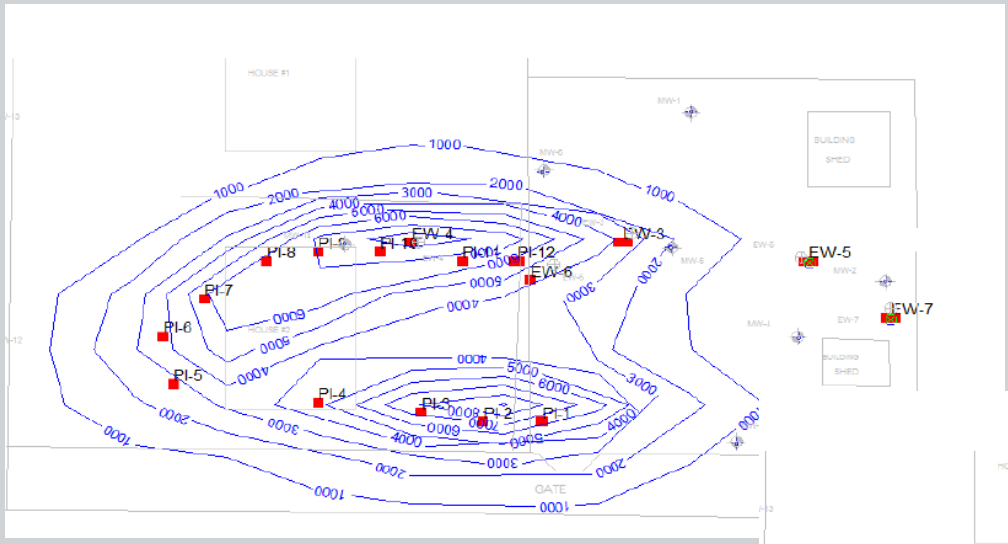


Existing 5 EWs at 3 gpm

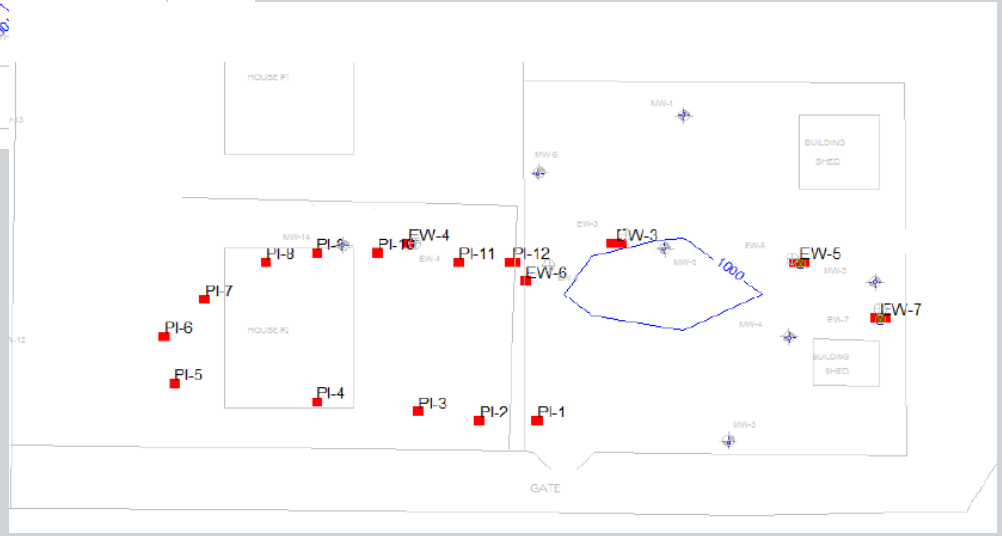


Proposed EWs at 3 gpm

MT3D - TDS Impact Distribution

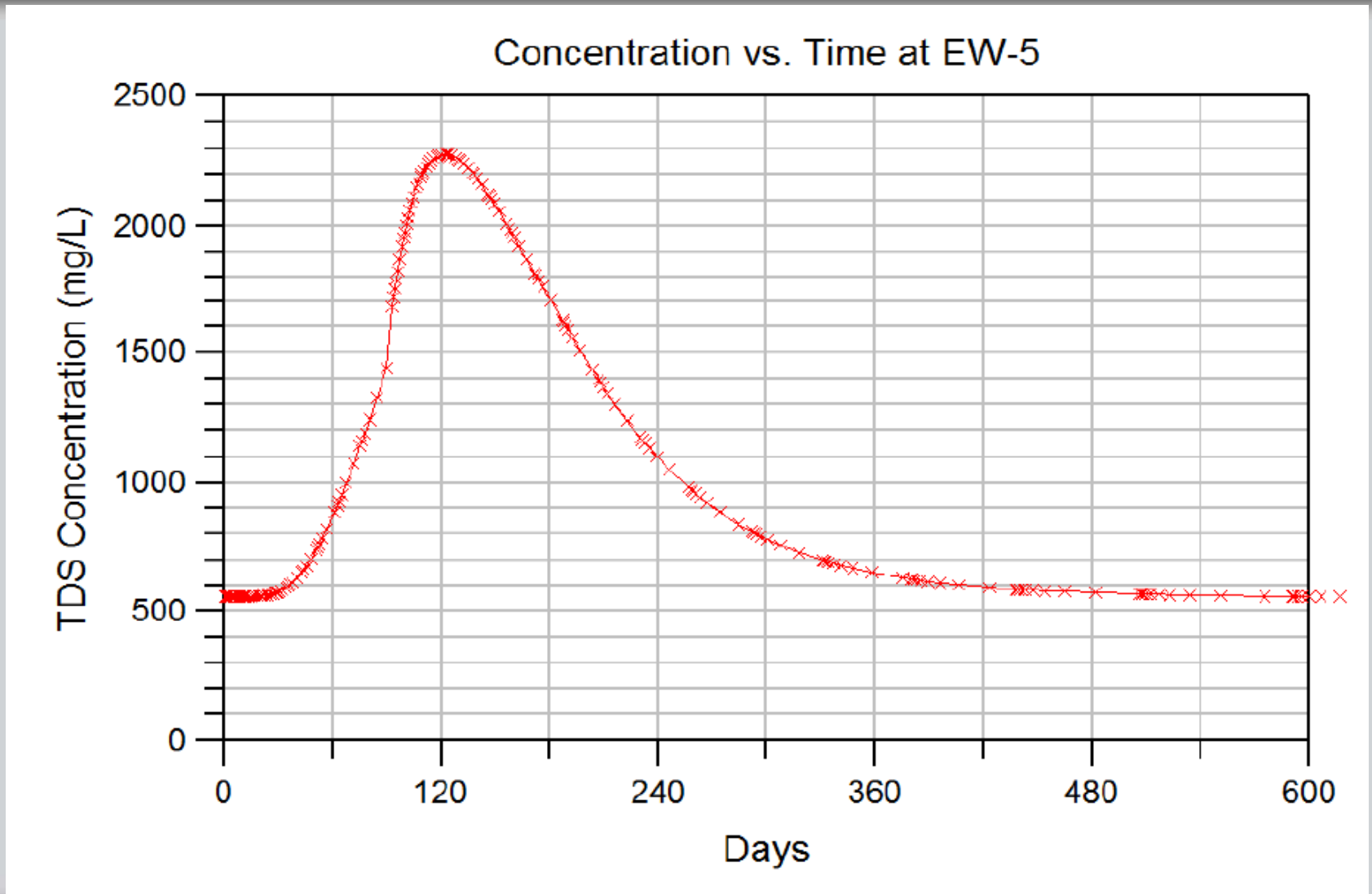


ONE MONTH AFTER



NINE MONTHS AFTER

MT3D - TDS Concentration at EW-5



Groundwater Modeling – Summary and Conclusion

- Existing EWs capture byproduct impacts
- Proposed EW-5 and EW-7 @ 3 gpm will capture byproduct impacts
- TDS at EW-5
  - Maximum concentration in 4 months
  - Back to baseline concentration in 12 months
- GWETS will be initiated in 3 months

Full Scale Persulfate Injection

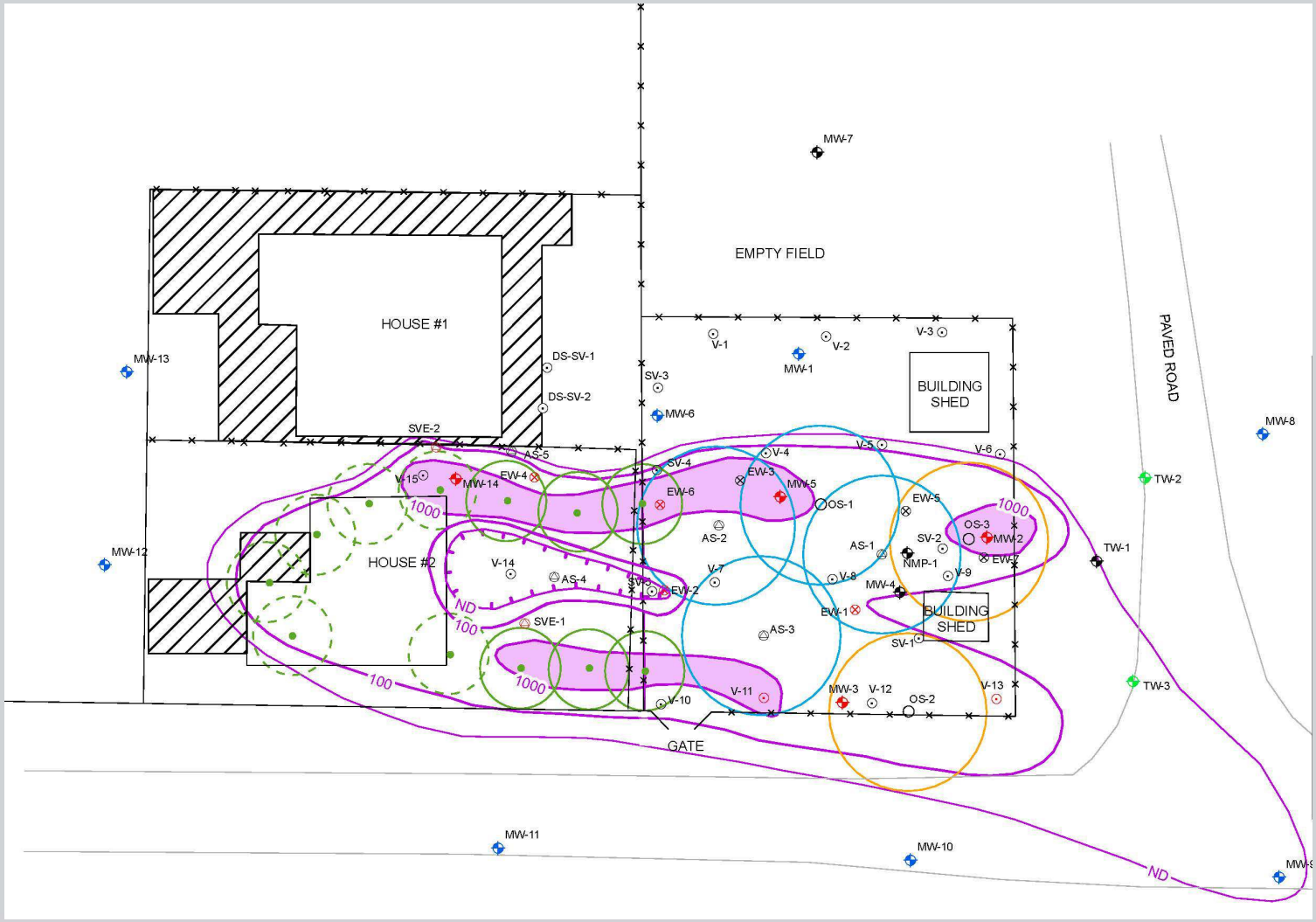
Induced Resonance Well Rehabilitation

- Nitrogen gas pulsing
  - Pressure : 300 psi
  - Pulse rate : 1 - 2 seconds
- Groundwater pumping
  - Turbidity: < 50 NTU
- Cycle: 2 – 4
- Specific capacity increase
  - EW-5 : 150%
  - EW-7 : 150%

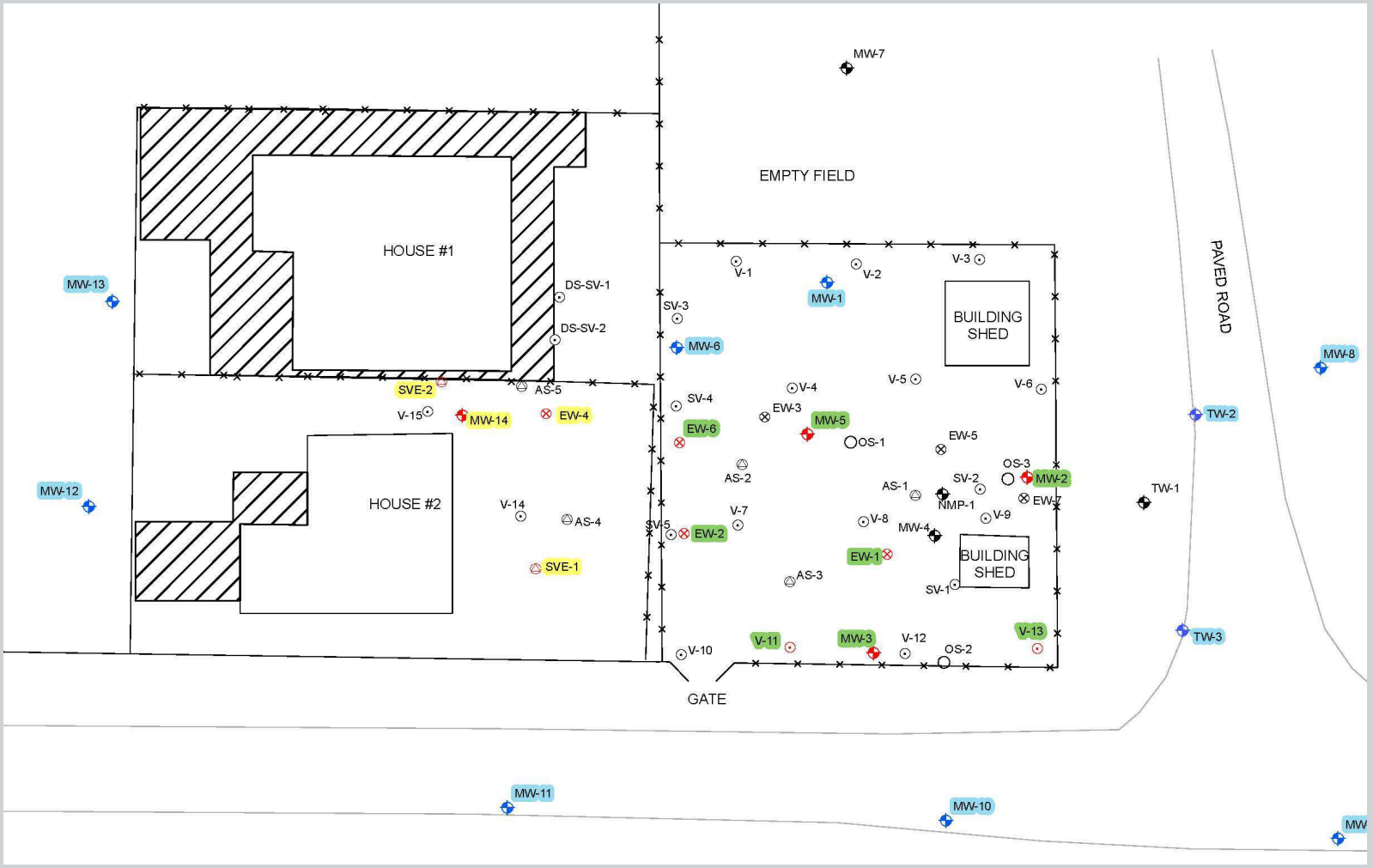
Persulfate Injection and Monitoring Summary

- Persulfate Injection
  - Solution: 10% sodium persulfate
  - Volume: 1,400 gal/well
  - Points: 12
  - Pressure: 5 - 65 psi
  - Rate: 0.5 - 5 gpm
  - Duration: 1.5 weeks
- Groundwater Monitoring
  - Performance well: 4 (COCs)
  - Compliance well: 8 (COCs, Byproducts)
  - Transition well: 2 (COCs, Byproducts)

Persulfate Injection Plan (DRO Concentration Contour)



Groundwater Monitoring Well Locations JLin5



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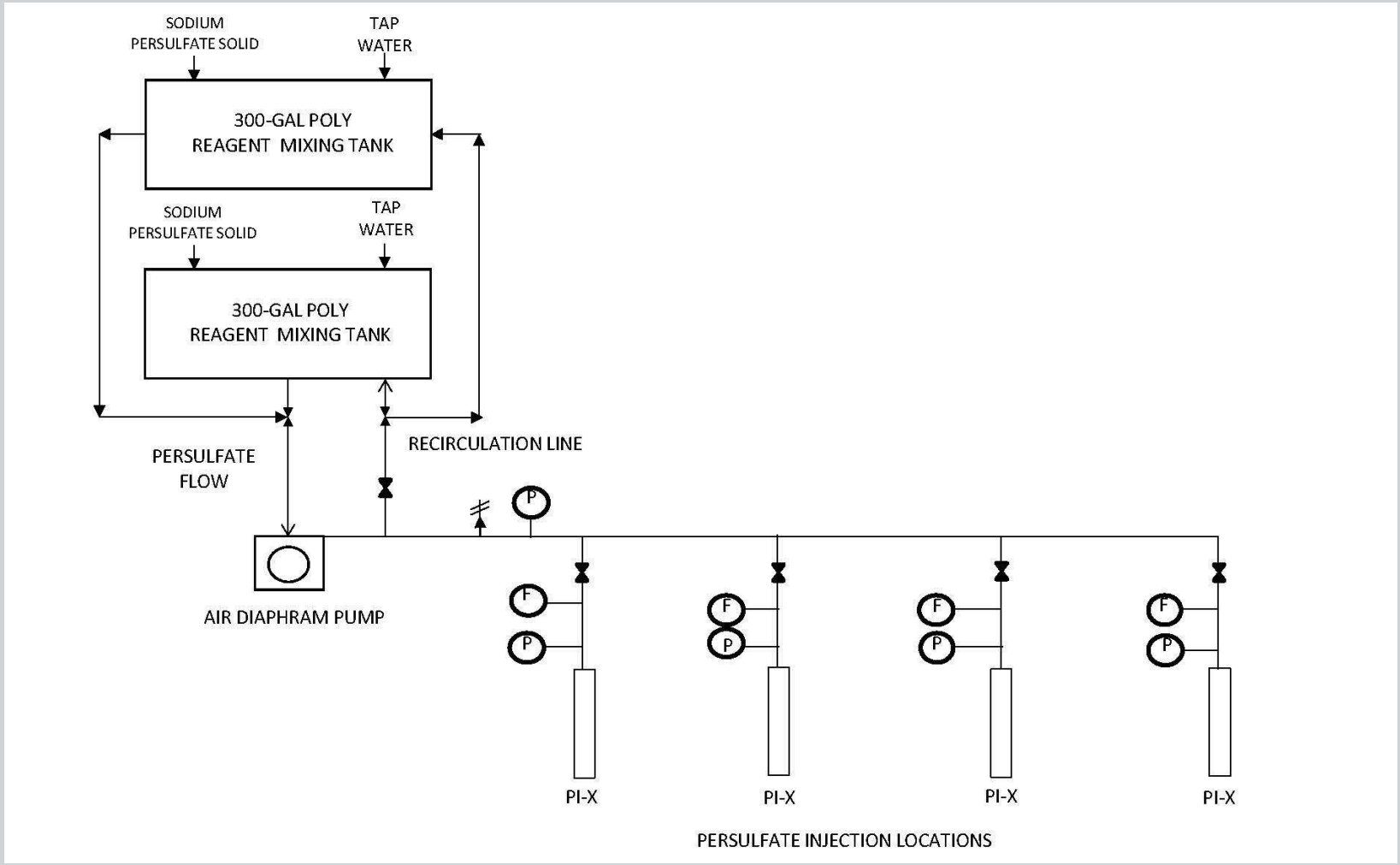
JLin5 Need to remove the street names.
Joann Lin, 9/25/2014

Persulfate Injection P&ID



Persulfate Injection Equipment

REAGENT MIXING TANK

INJECTION MANIFOLD

INJECTION TOOL

Vertical Drilling and Injection

Drilling/Injection Specifics

- Open Field
- Points: 6
- Depth: 15 - 23 ft vertical

Angle Drilling and Injection

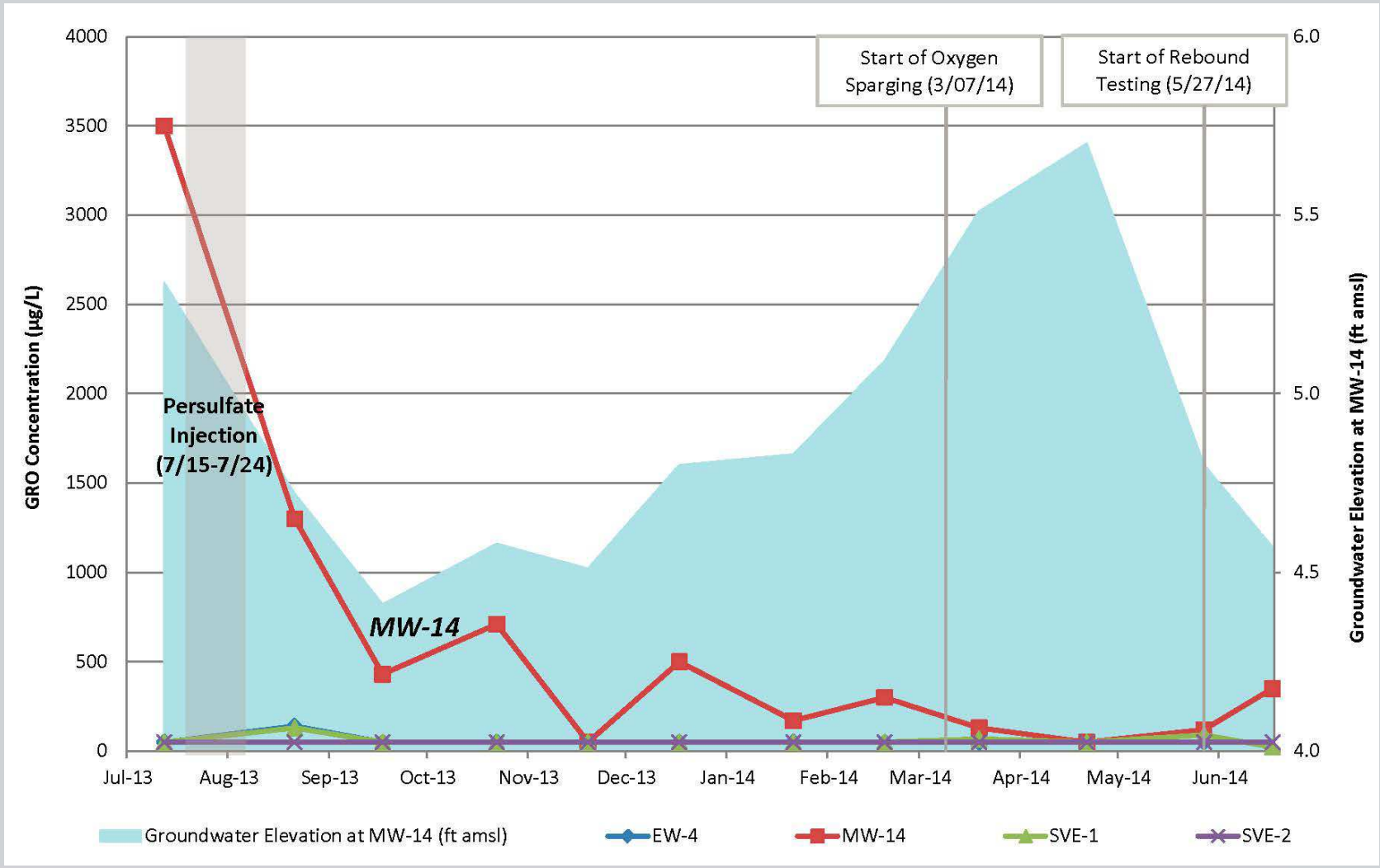
Drilling/Injection Specifics

- Below the Building
- Points: 6
- Angles: 10 - 20 degrees
- Depth: 14 - 21 ft vertical

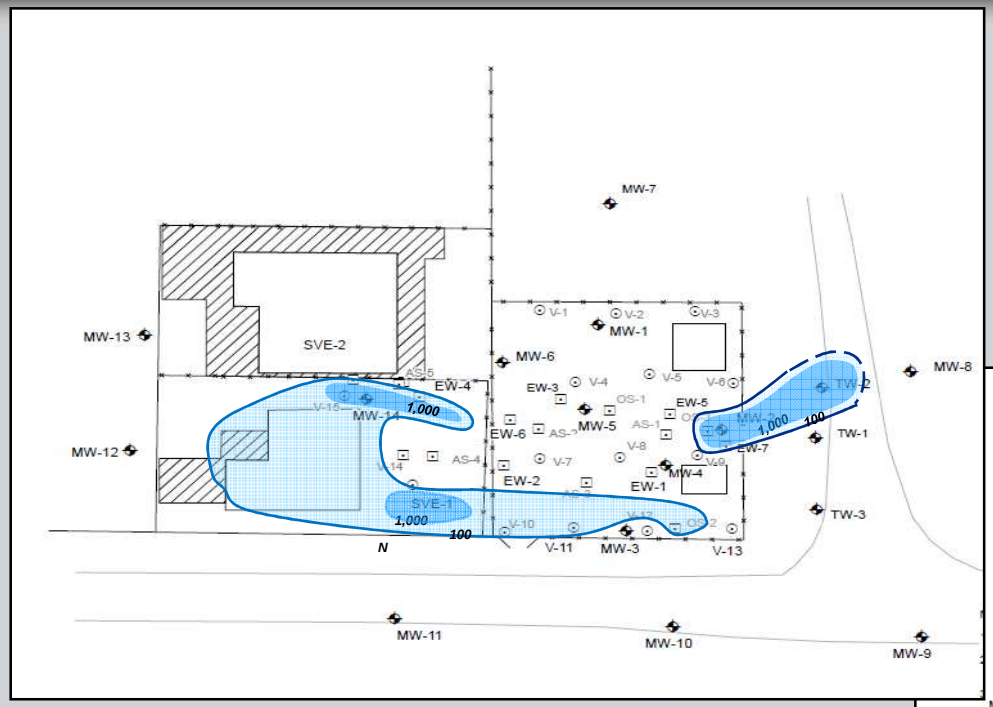
Geotechnical Monitoring Results

- Visual inspection: No observable changes
- Crack monitoring:
  - No new cracks induced
- Settlement monitoring:
  - Differential settlement less than 1%
  - Total settlement less than 0.5 inches

GRO Concentration Trends in Treatment Zone Wells

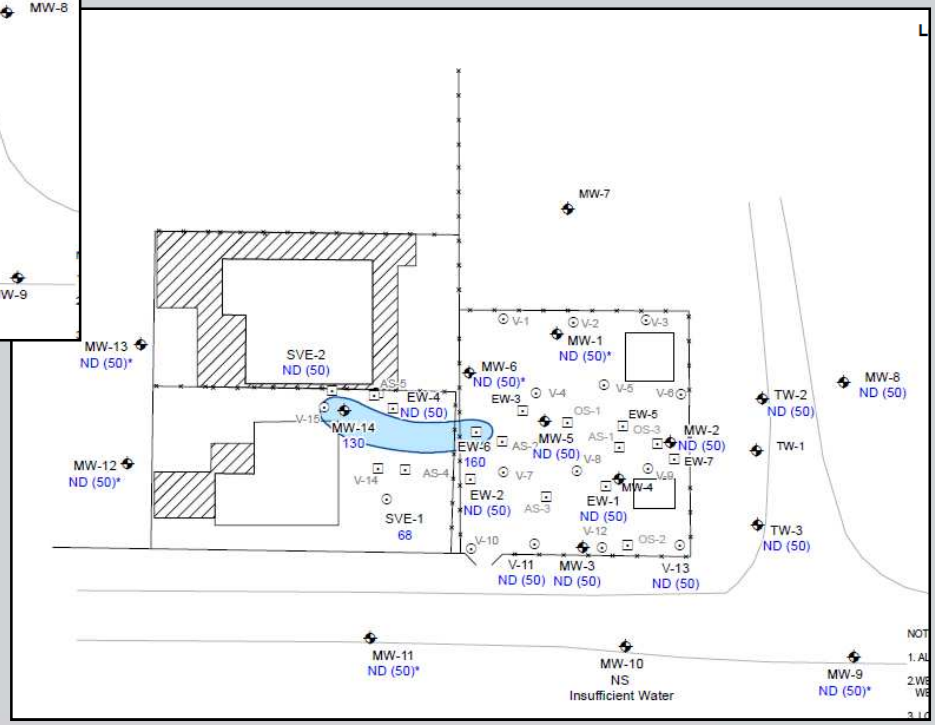


GRO Concentration Contour

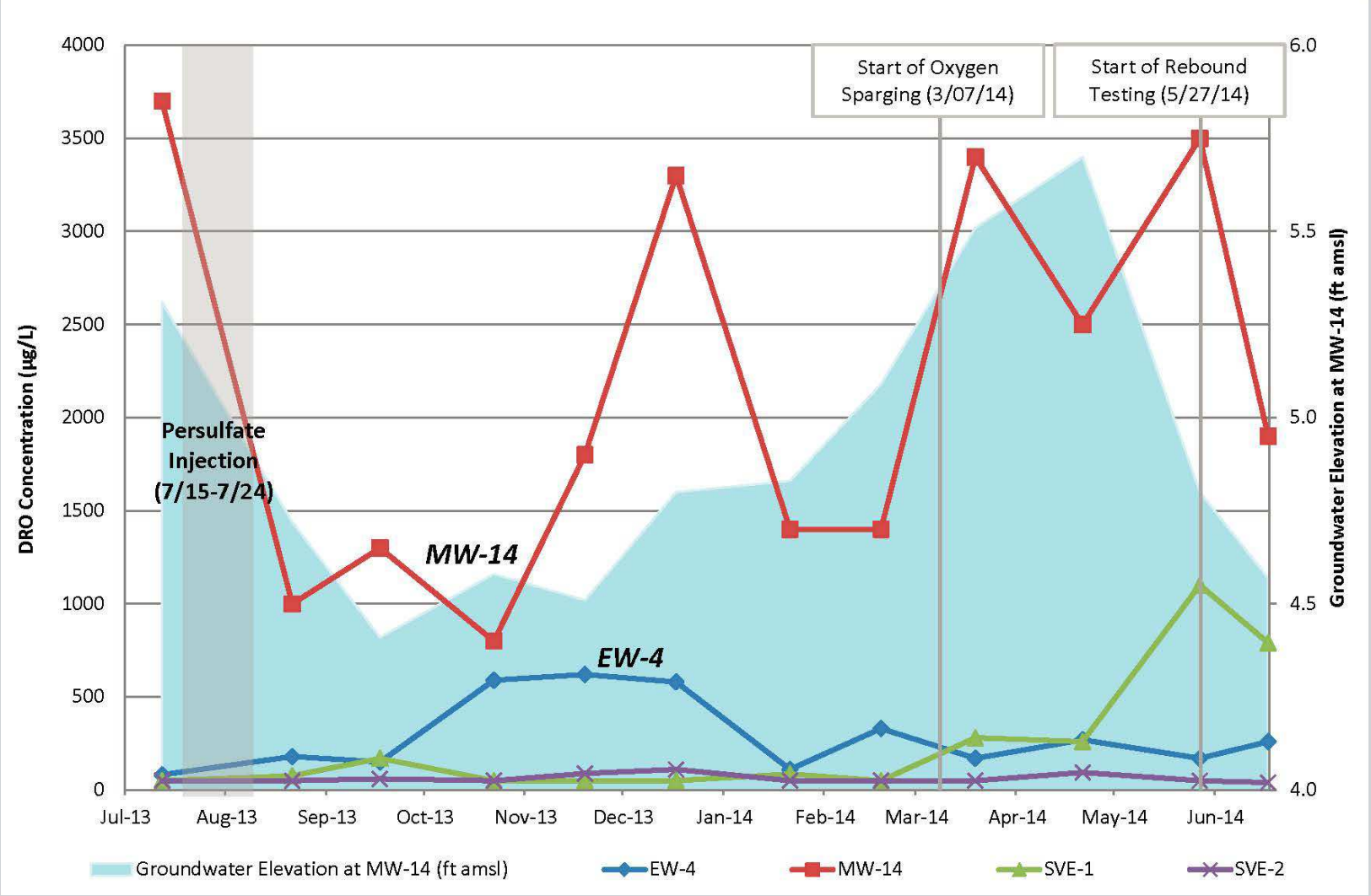


BEFORE

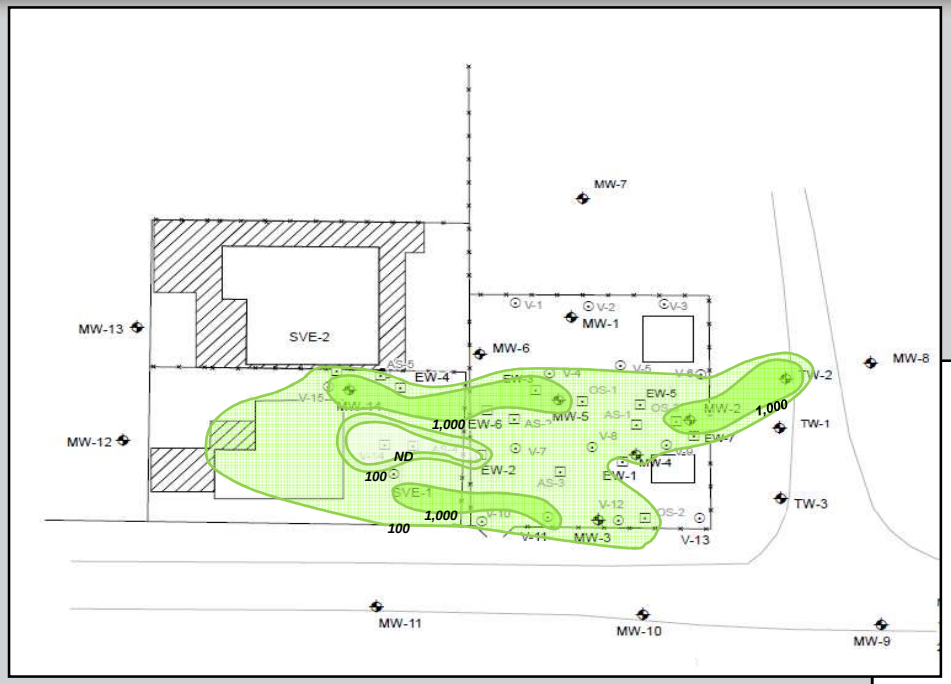
AFTER



DRO Concentration Trends in Treatment Zone Wells



DRO Concentration Contour



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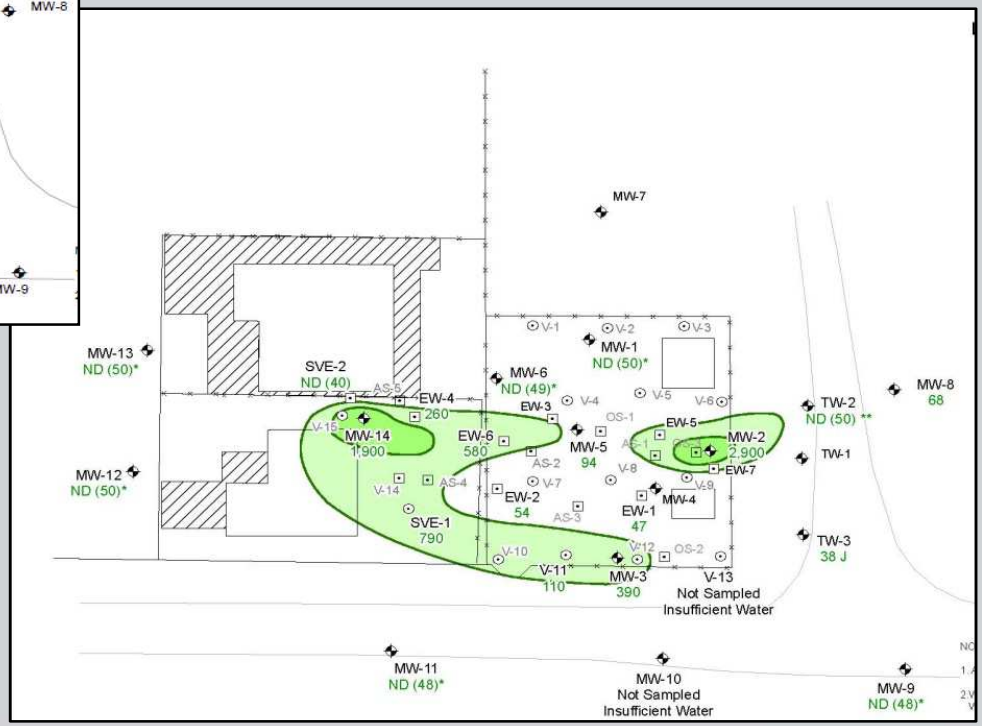
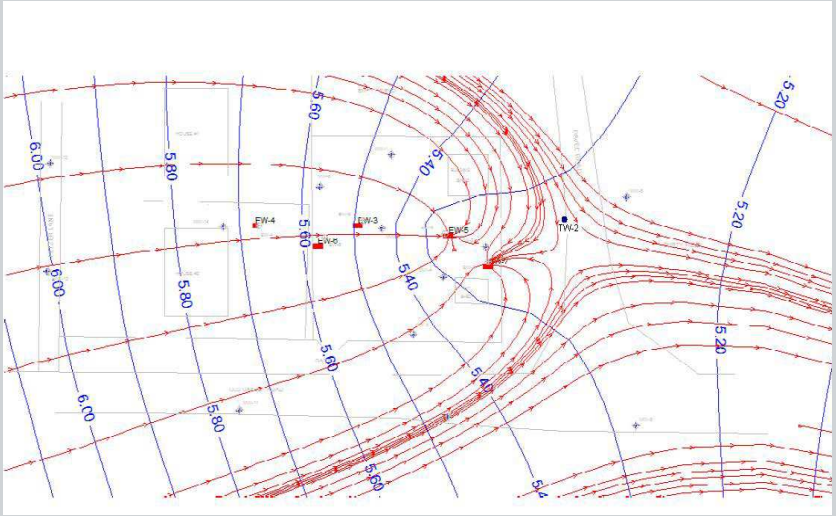


Persulfate Injection Contingency Plan

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

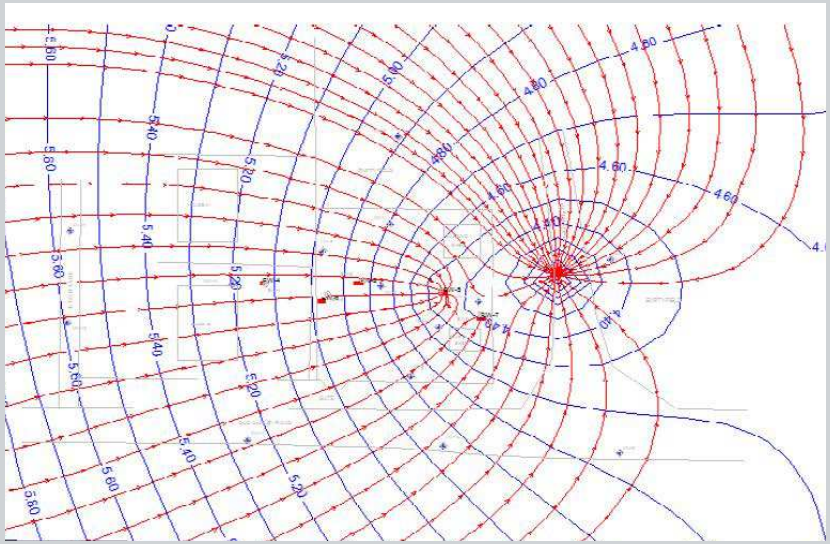
MODFLOW - Capture Zone for TDS Impacts

JLin8



3 Months Later
2 EWs at 2 gpm

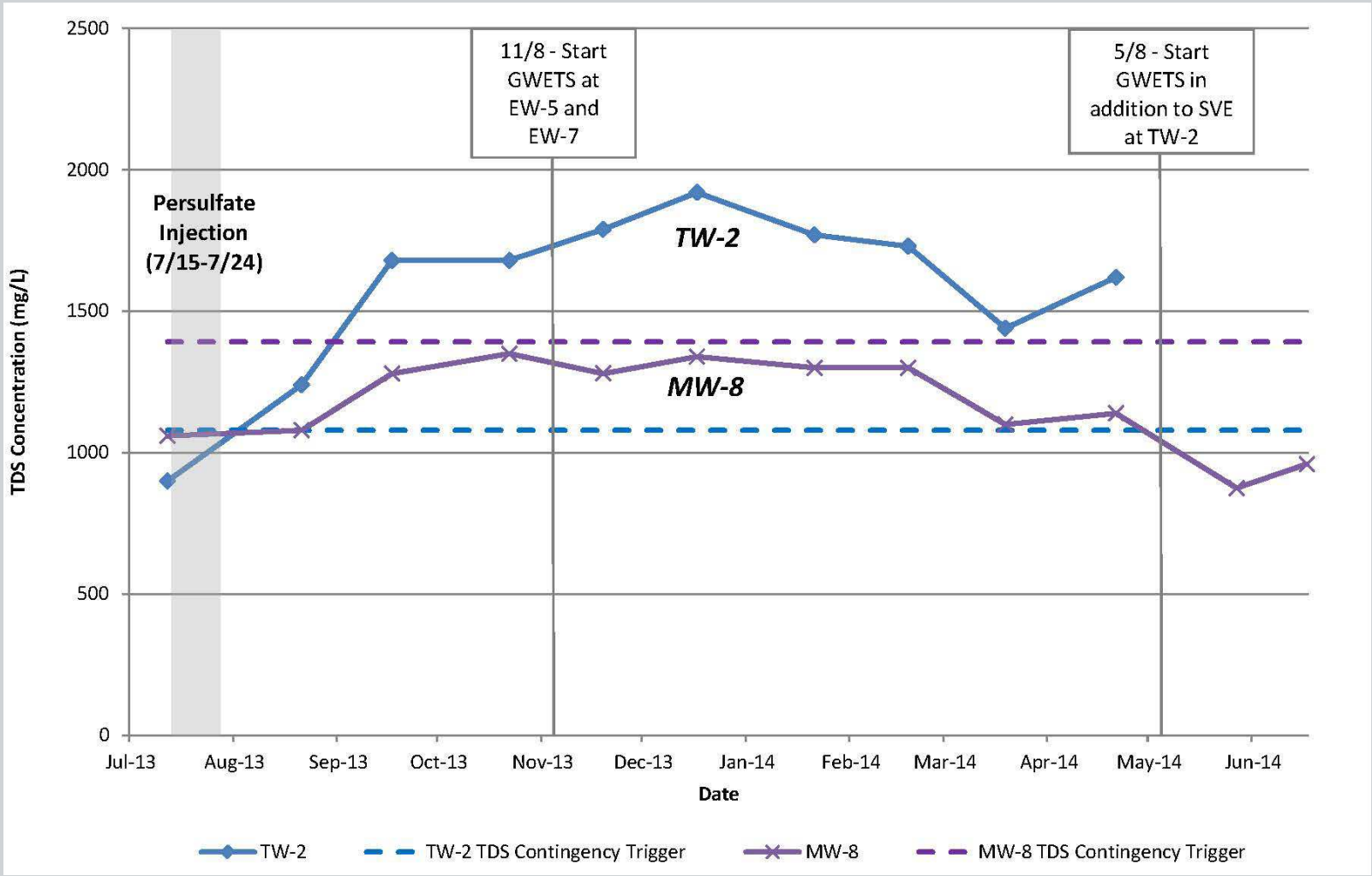
9 Months Later
3 EWs at 5.5 gpm



Slide 29

JLin8 It's hard to see the Site and hard to identify the extraction wells and transition wells.
Joann Lin, 9/25/2014

TDS Concentration Trends in Downgradient Groundwater Wells



Persulfate Injection Results

- GWETS initiated to capture TDS and sulfate after 3 months
- GRO decreased without rebound, DRO decreased but rebounded
- Metals increased insignificantly
- Monitoring Parameters
  - ORP - increased
  - Conductivity – increased
  - Sulfate – increased
  - pH - decreased
  - Temperature – no change

Persulfate Injection Conclusions

- Successfully destroys COCs in saturated zone
- Byproduct impacts
  - Injected chemicals captured
  - Oxidized chemicals contained
- Sustained persulfate concentration
- Induced resonance increased well yield
- Angle injection caused minimal geotechnical impacts
- Hydrogen sulfide not generated

Acknowledgements

- Special thanks to OTG EnviroEngineering Solutions, PRIMA and VIRONEX for their outstanding implementation