



Sulfate Enhanced In Situ Biodegradation of MTBE and TBA in Fractured Bedrock for Source Area Treatment and Downgradient Risk Mitigation

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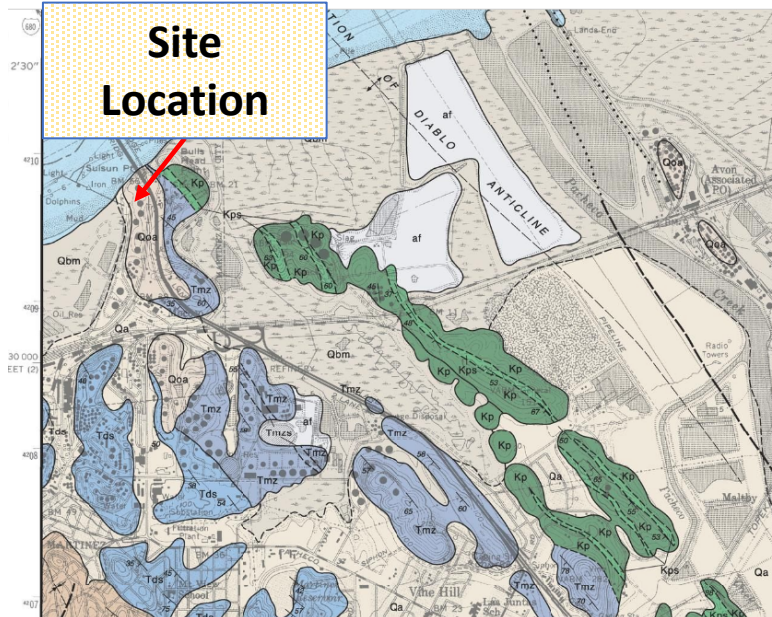
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Sustainable Environmental Technologies
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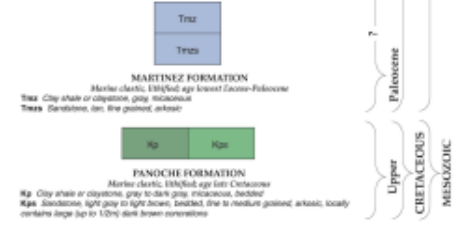


Complex site geology with interbedded bedrock layers

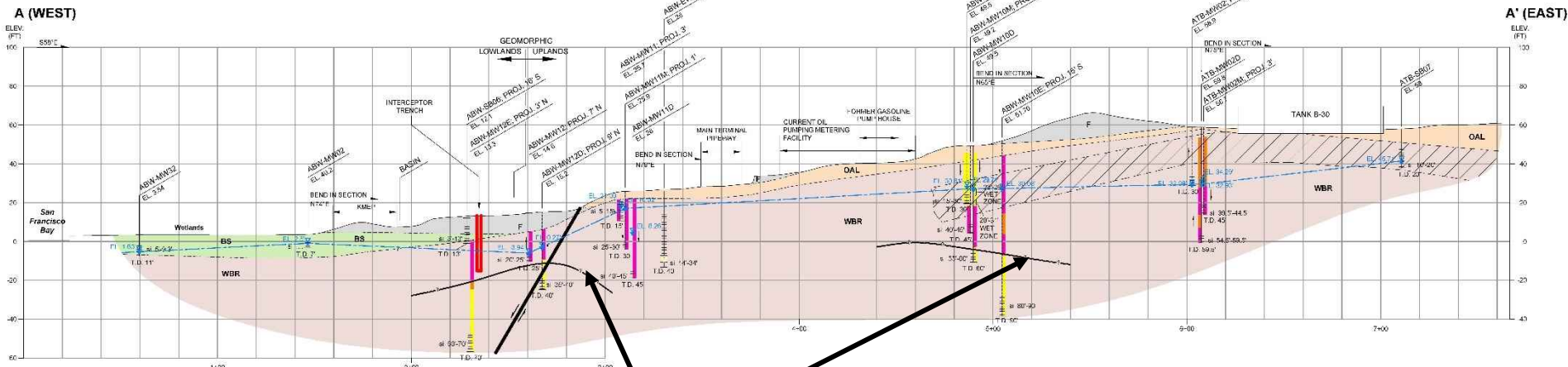
SULFATE ENHANCED IN SITU BIODEGRADATION OF MTBENT AND TBA IN FRACTURED BEDROCK FOR SOURCE AREA TREATMENT AND DOWNGRADE RISK MITIGATION



Weathered claystone



Weathered Interbedded siltstone and sandstone (redlines)

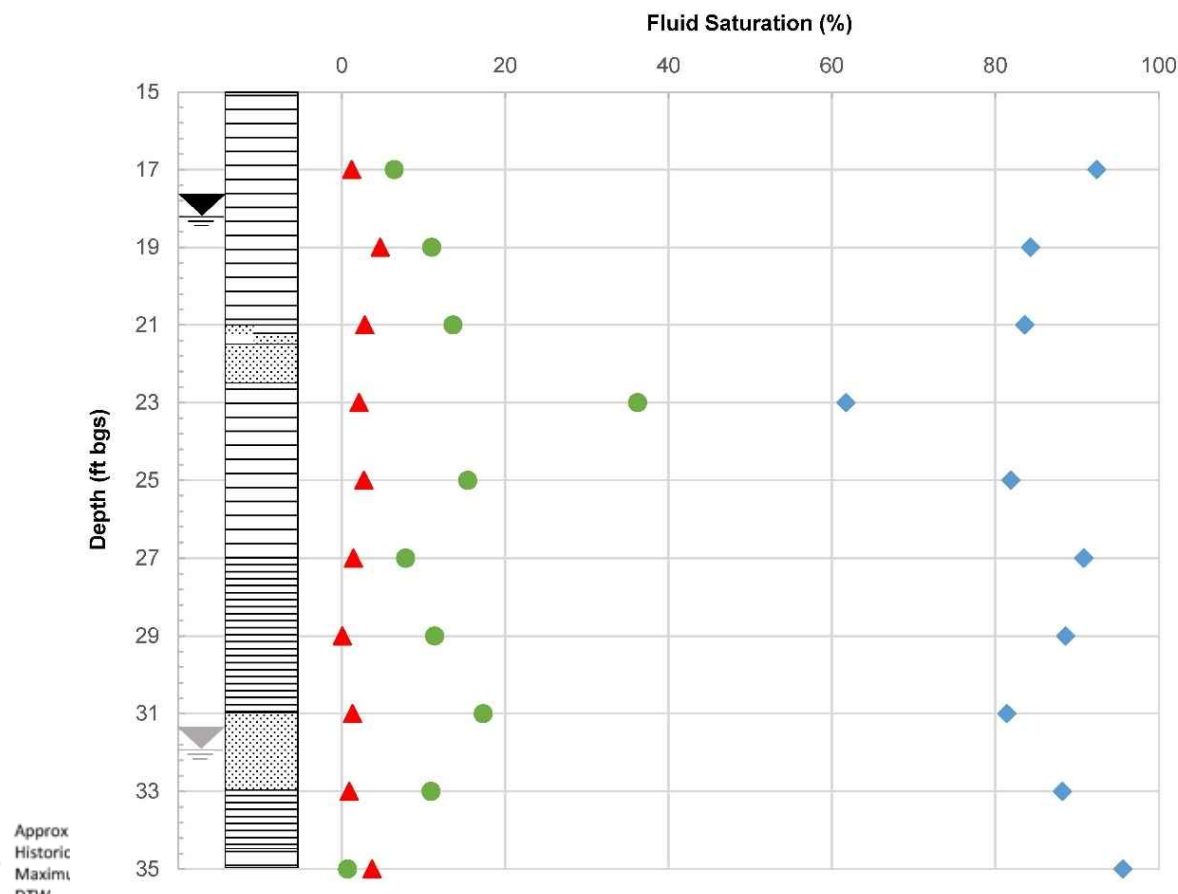
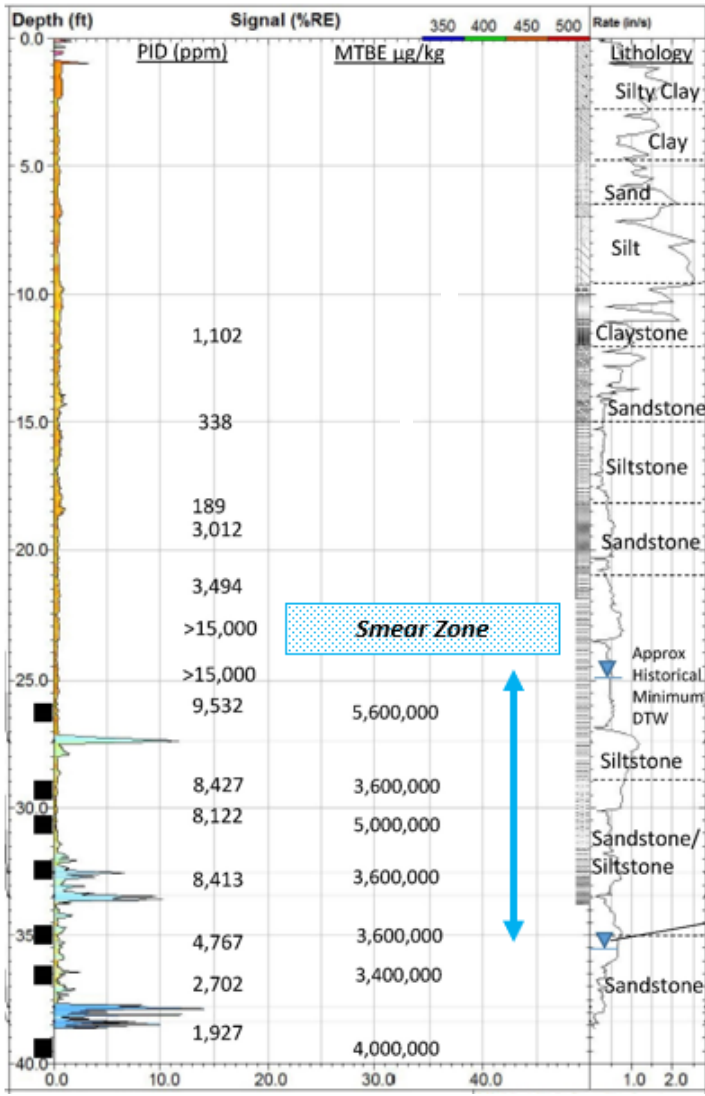


Boundary between Weathered Rock and more Competent Bedrock



Smear zone remains near saturation primarily in siltstone and claystone and serves as long-term MTBE source to groundwater

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- Legend**
- Siltstone
 - Siltstone/Sandstone (very fine sand)
 - Sandstone (very fine sand)
 - Siltstone/Claystone
 - No return
 - Historical Minimum DTW (ft bgs)
 - Historical Maximum DTW (ft bgs)
 - Total Porosity
 - LNAPL
 - Gas
 - Water

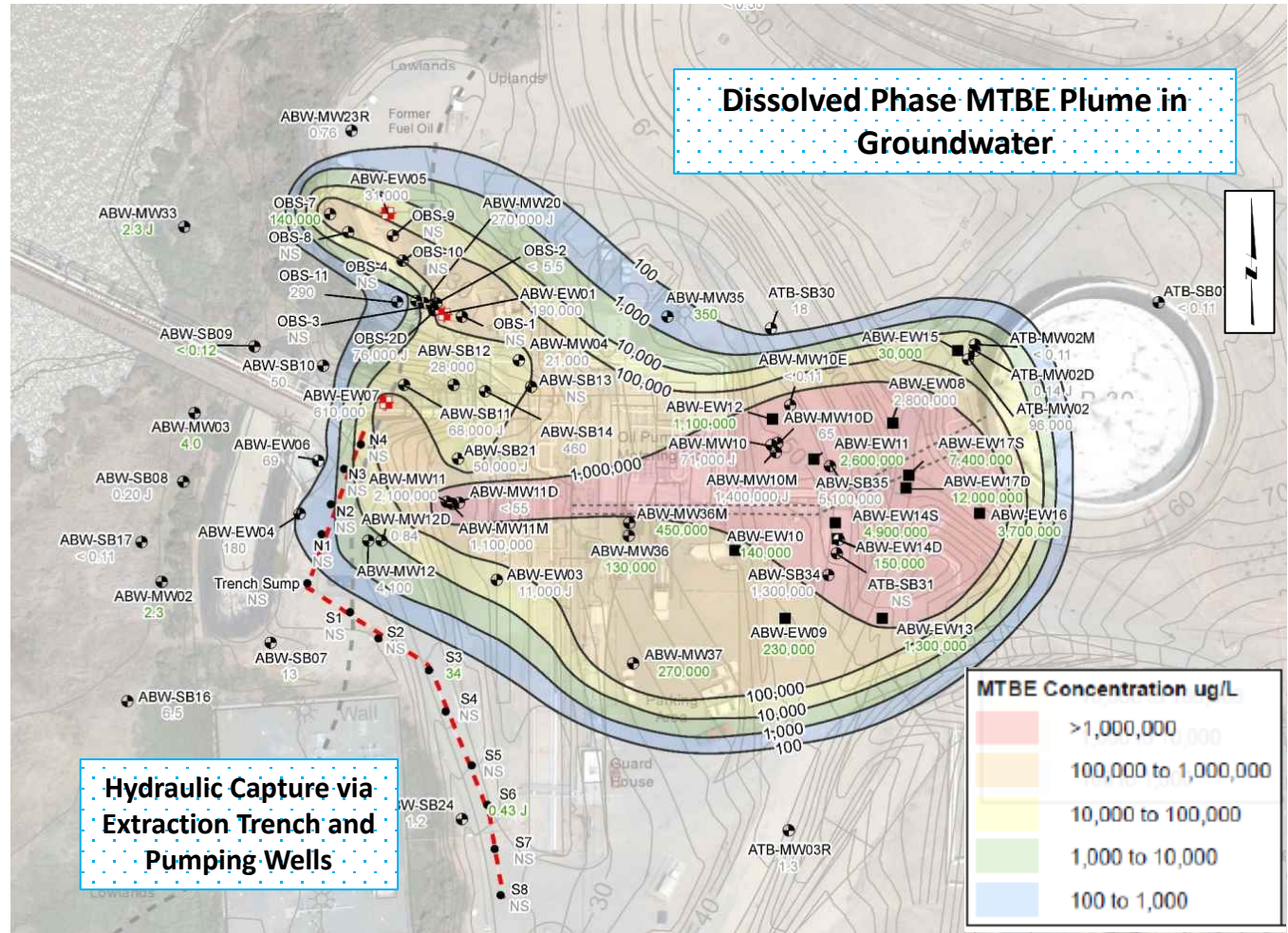
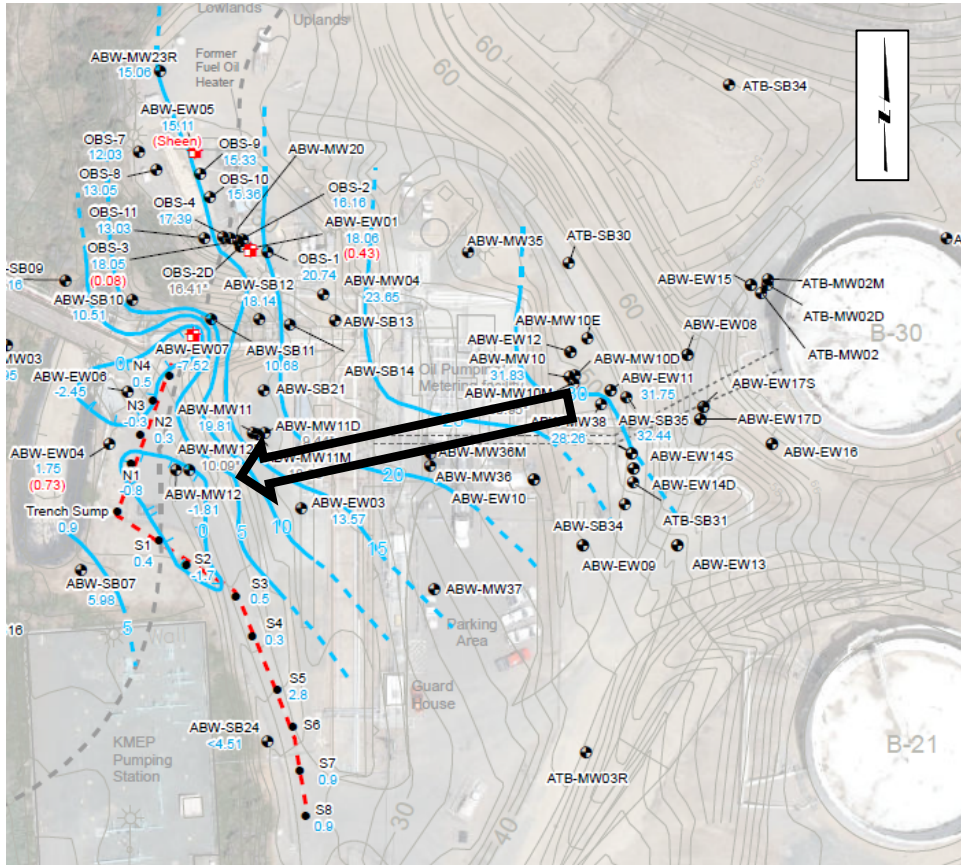
SG-02

UVOST-04



Initial CSM: transport in the saturated zone behaves primarily like flow in a porous media and follows interpreted hydraulic gradient

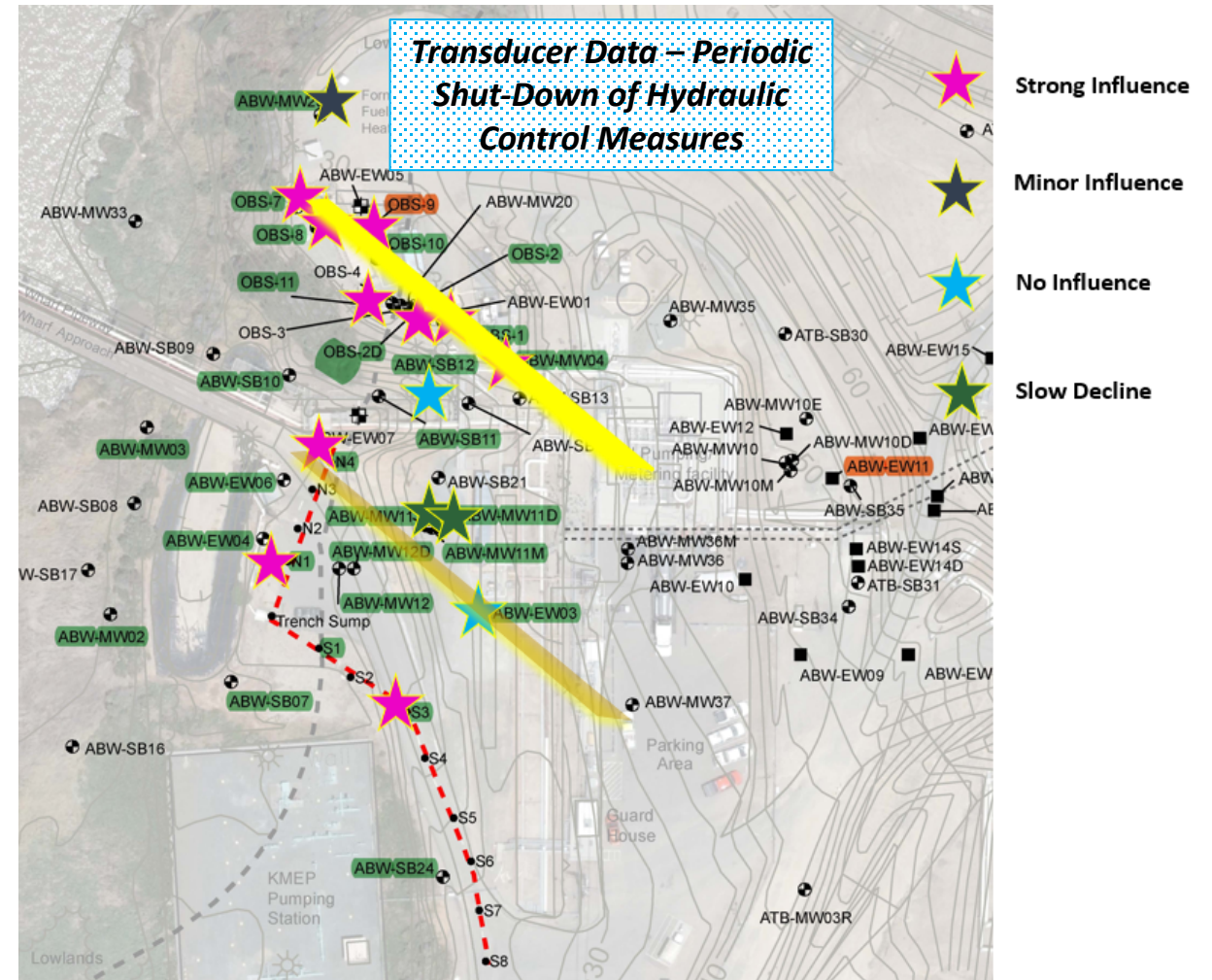
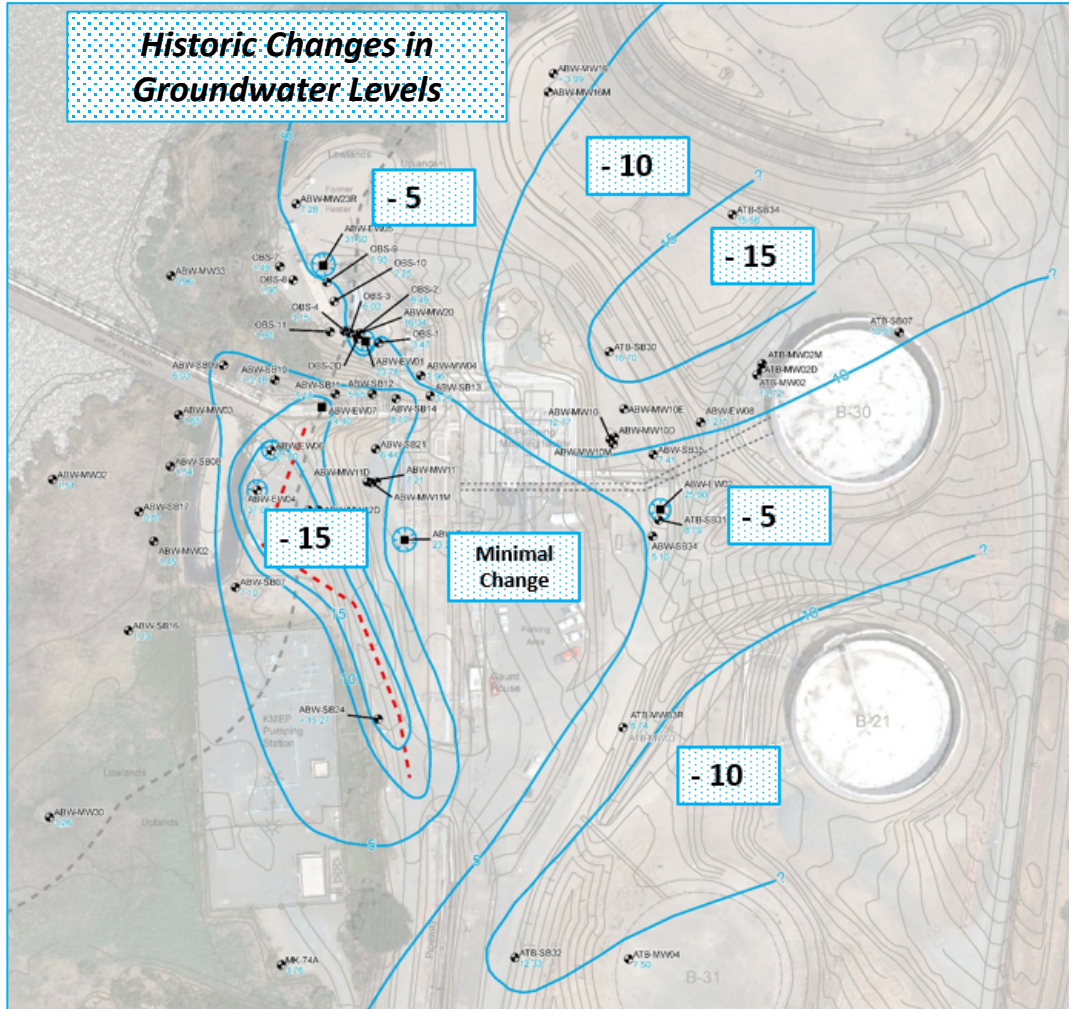
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Differential water table responses to seasonal changes and pumping conditions

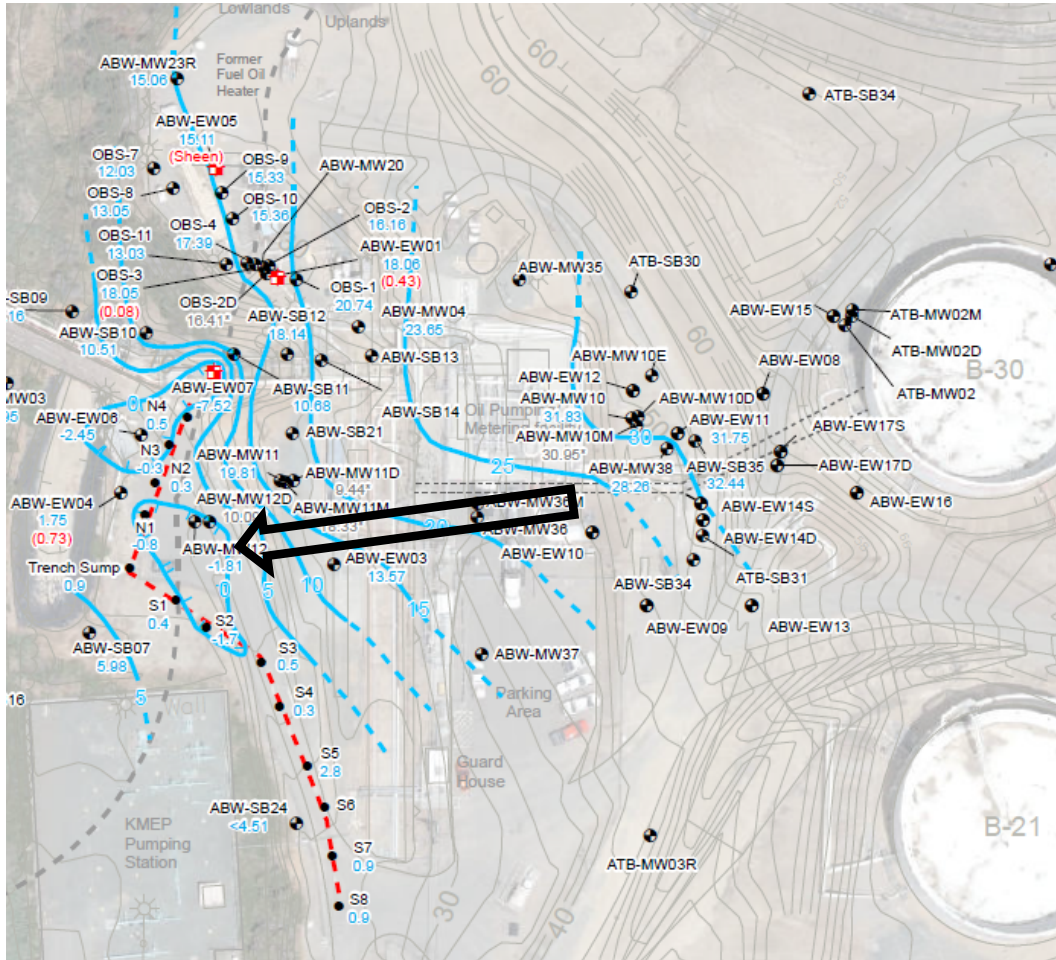
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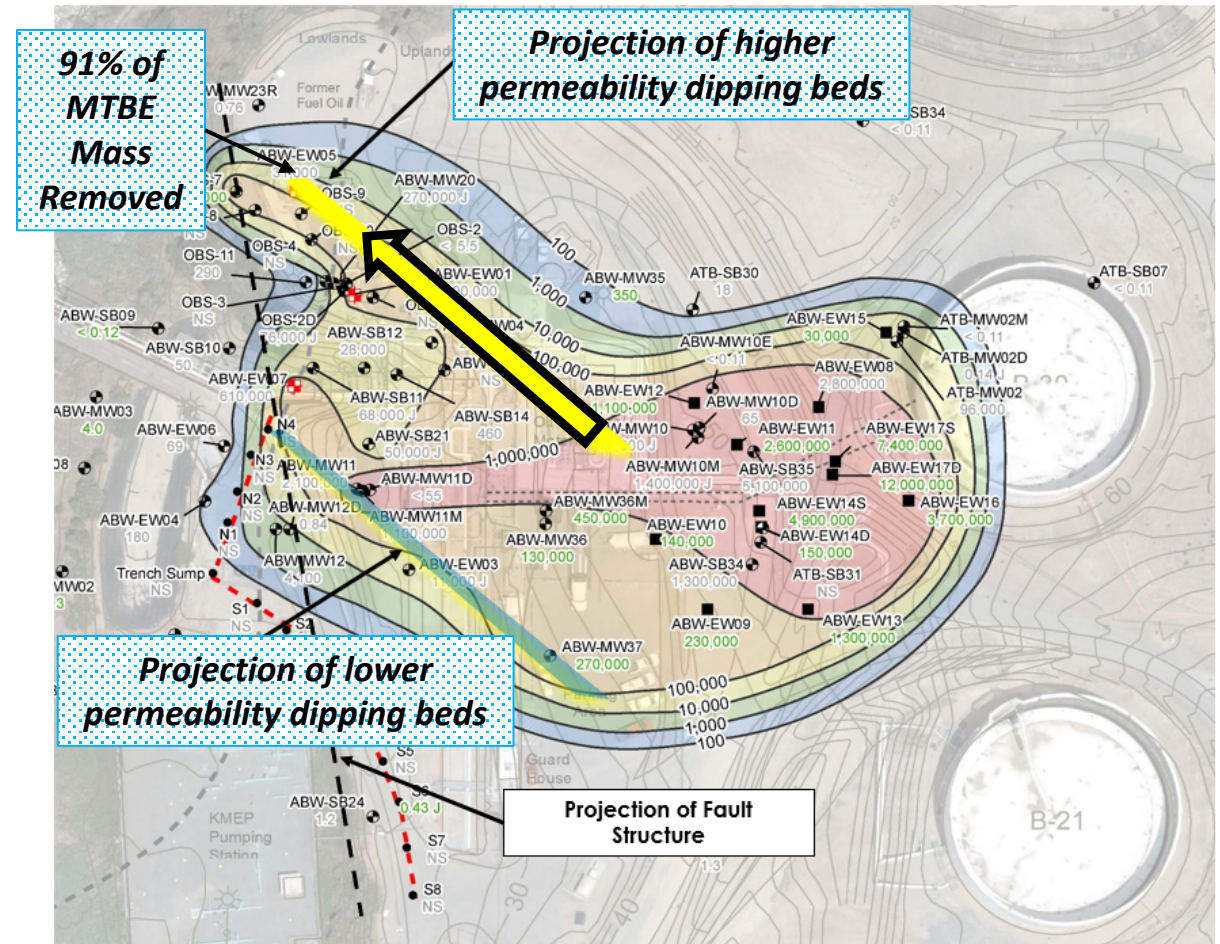


Revised CSM: dissolved phase transport is controlled by strike of bedrock layers

Initial CSM



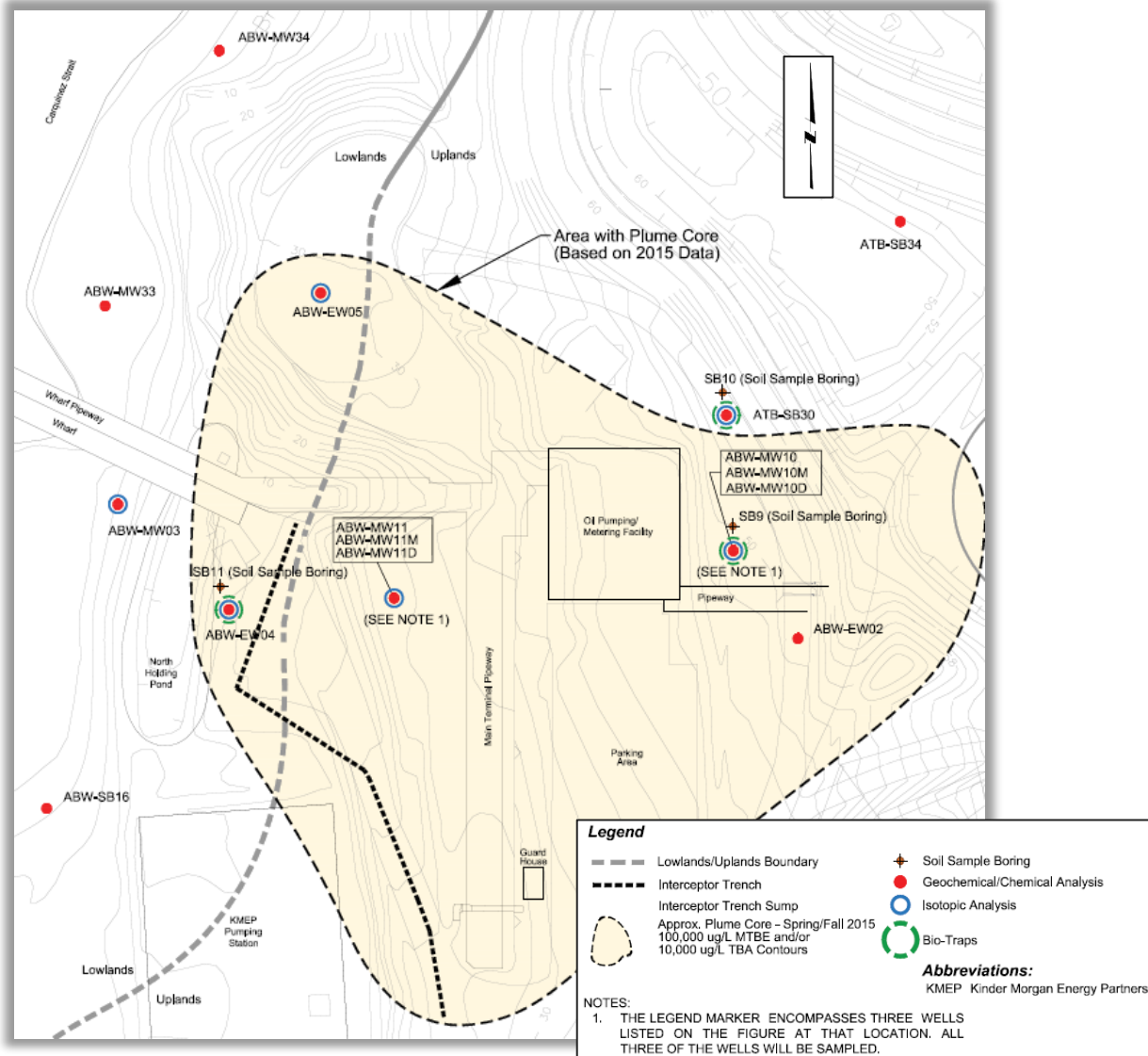
Revised CSM



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Studies demonstrate intrinsic MTBE biodegradation via sulfate reduction



Multiple lines of evidence:

1) Chemical and Geochemical Analysis

2) Ratios of MTBE to TBA

3) Equilibrium Partitioning

4) Microbiological Tools:

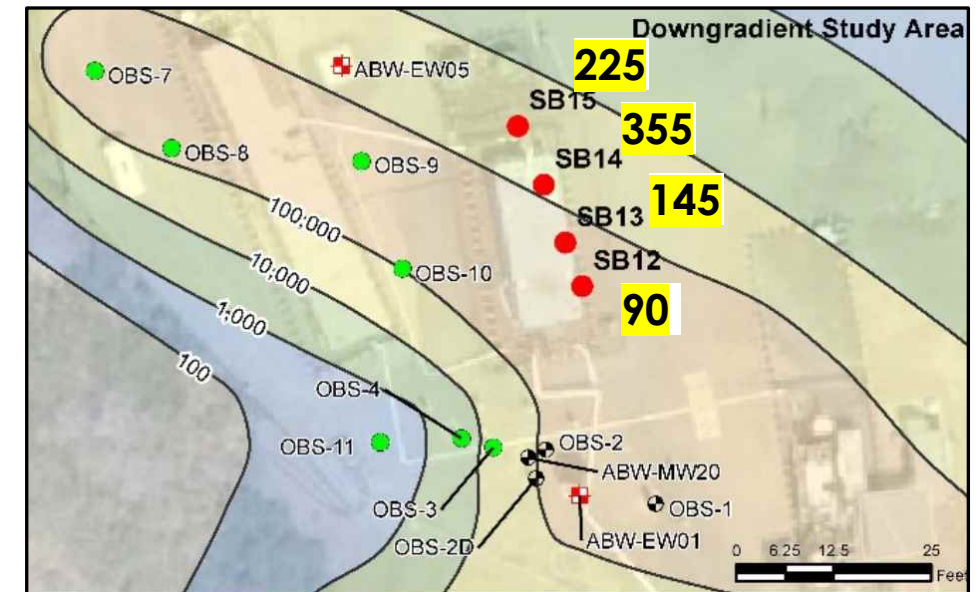
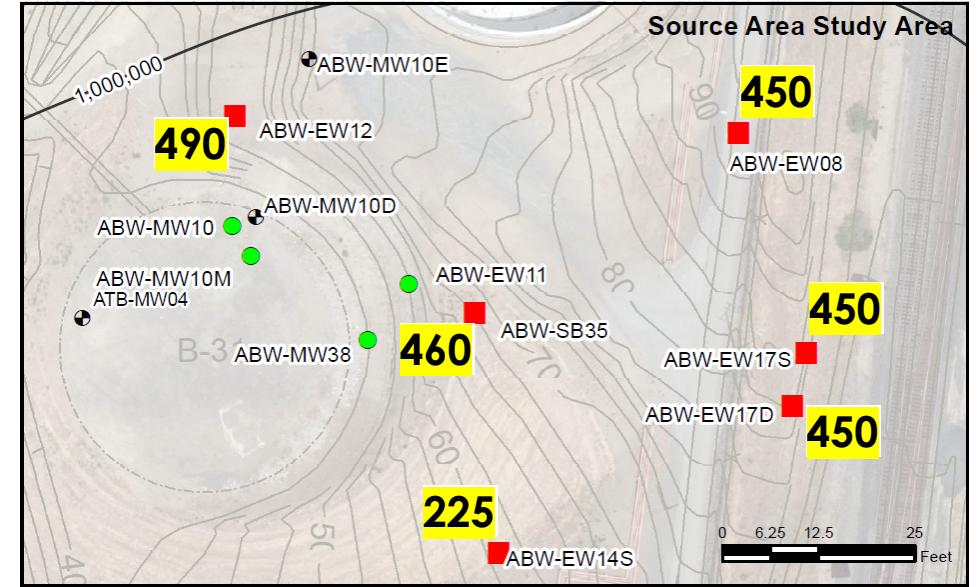
- PLFA
- qPCR
- In situ microcosms w/ SIP

4) Compound Specific Isotope Analysis



Gravity-fed injections into source and downgradient areas

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450 Total Salt Solution Injection Volume (gal)

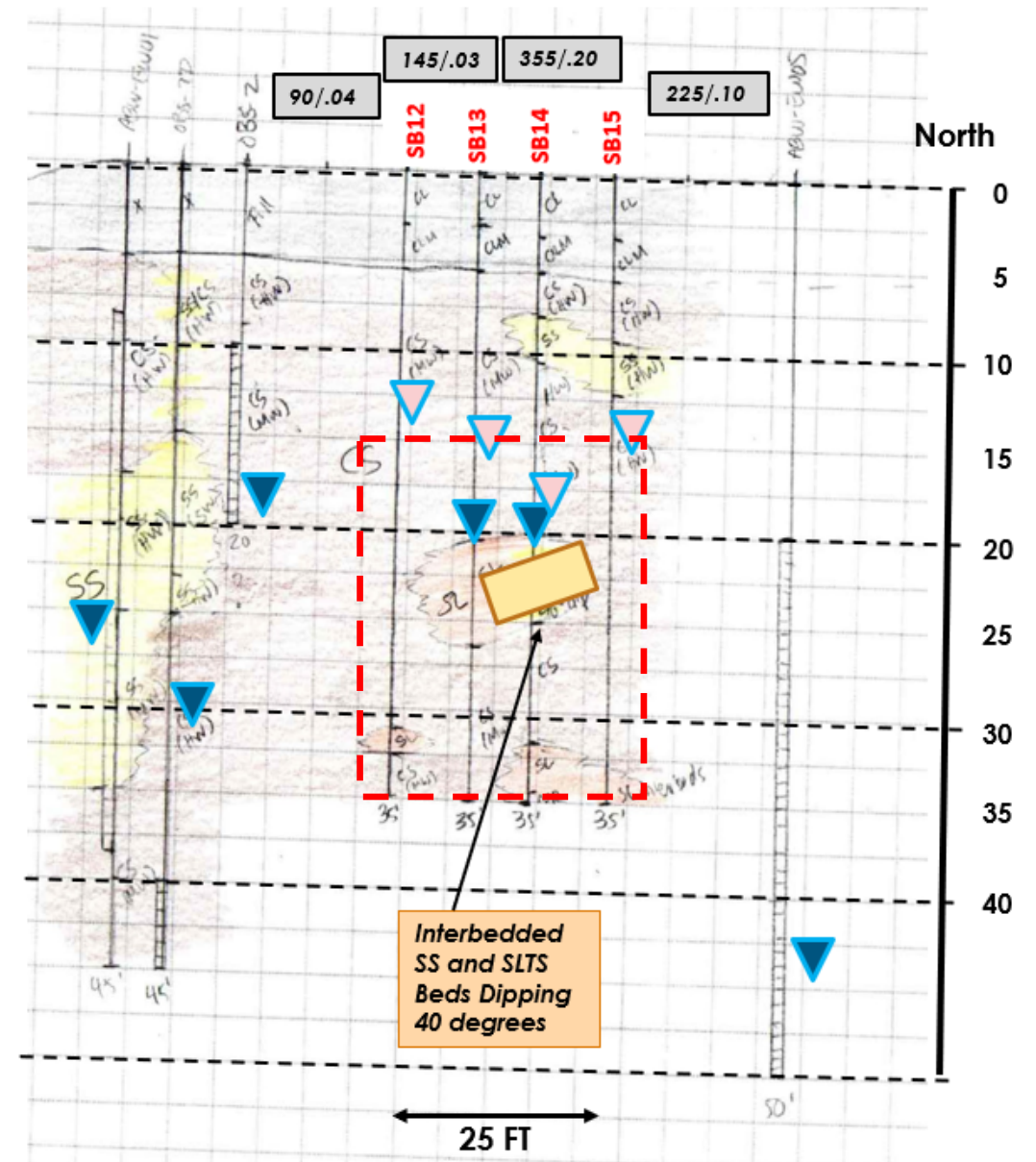
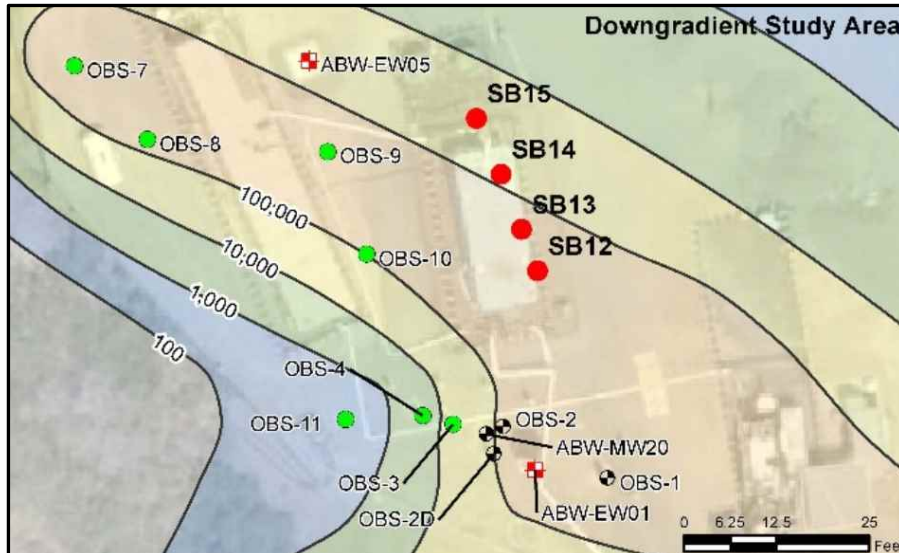


Higher injection volumes in wells intercepting sandstone beds

SULFATE ENHANCED IN SITU BIODEGRADATION OF MTBE AND TBA IN FRACTURED BEDROCK FOR SOURCE AREA TREATMENT AND DOWNGRAIDENT RISK MITIGATION

-  DTW Observed During Drilling
-  DTW – Post Injection (16 hours after)

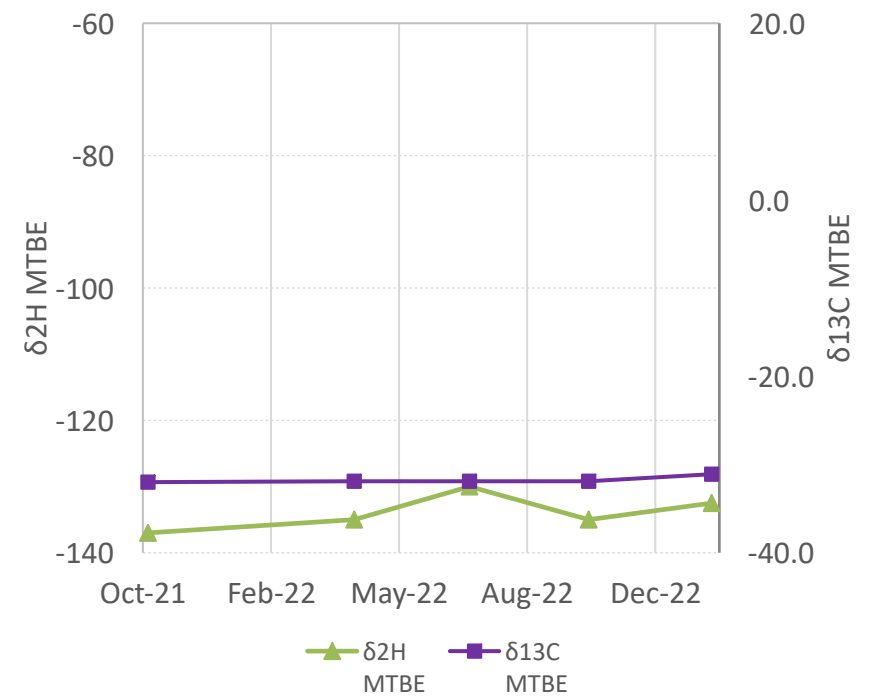
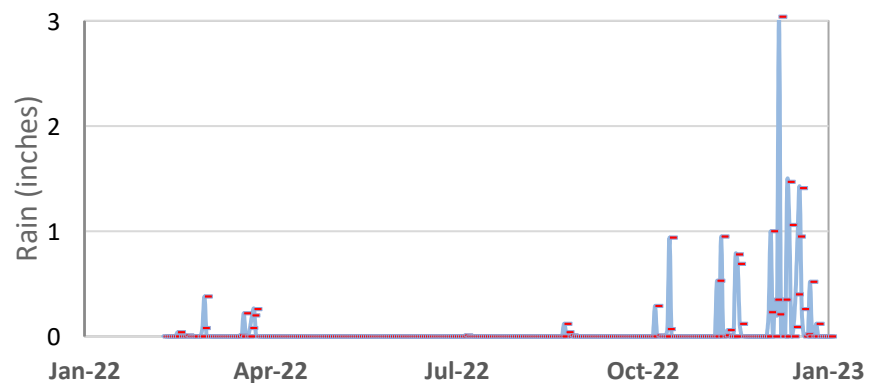
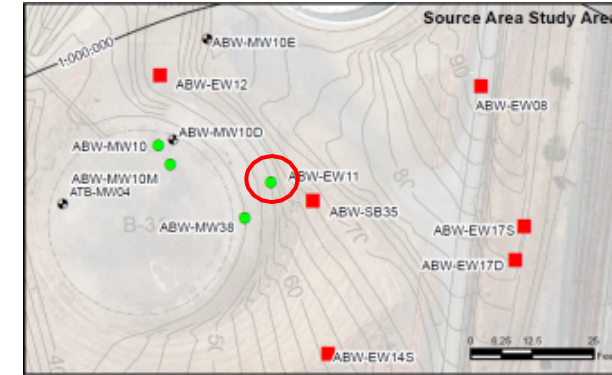
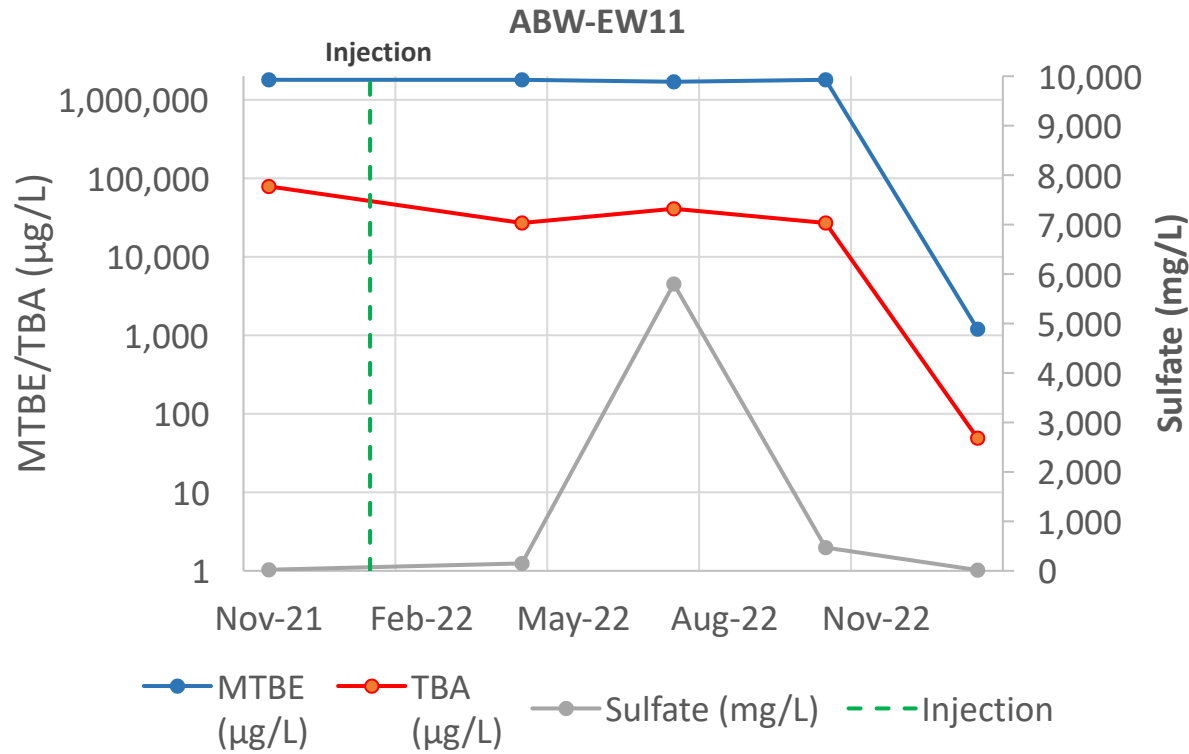
 Total Salt Solution Injection Volume (ga) and Ending Injection Rate (gpm)





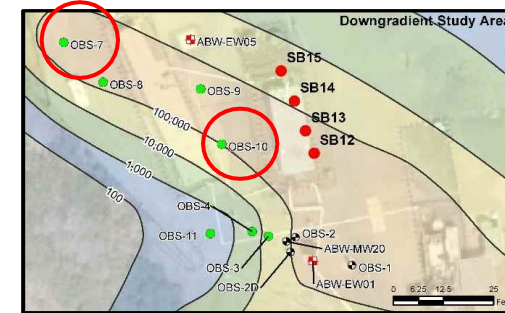
Source Area - amendment arrival in nearest downgradient well after 6 months but limited evidence of biodegradation

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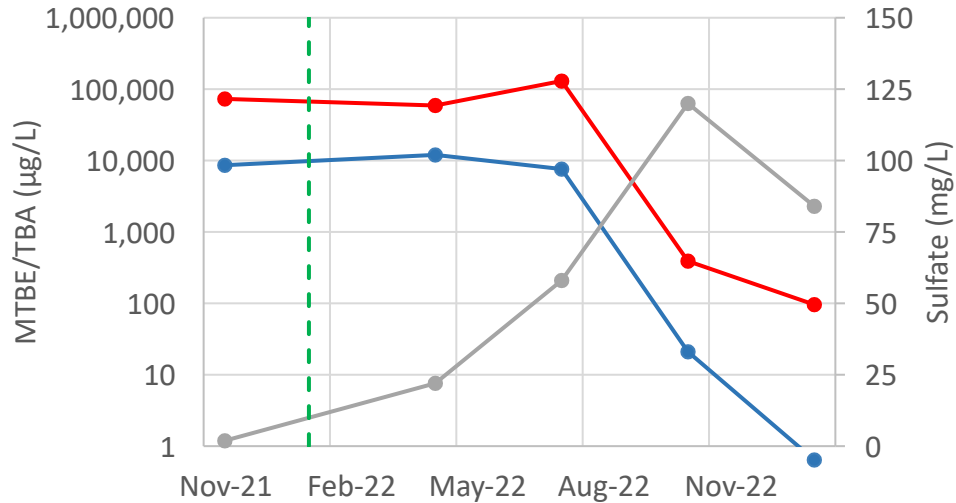


Downgradient Area – enhanced anaerobic degradation following amendment arrival

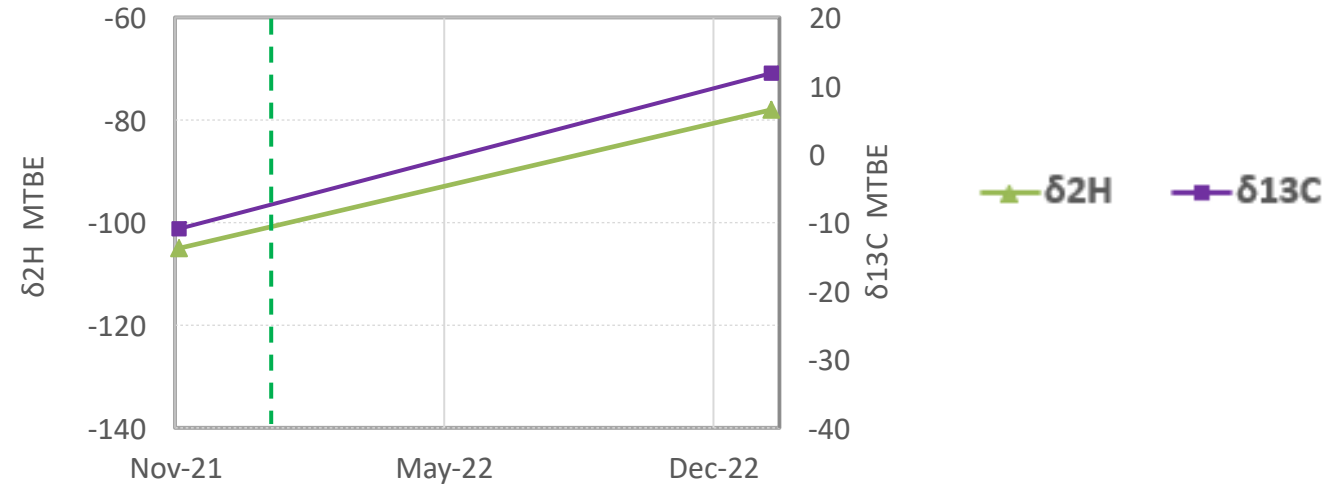
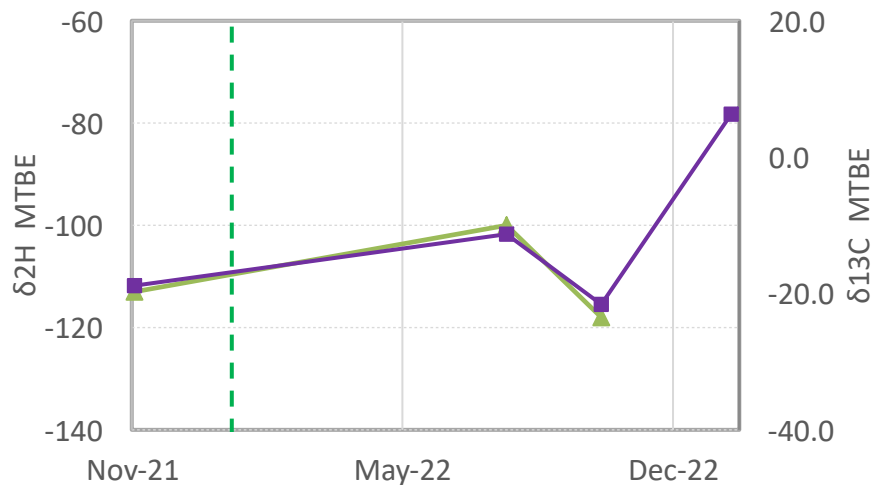
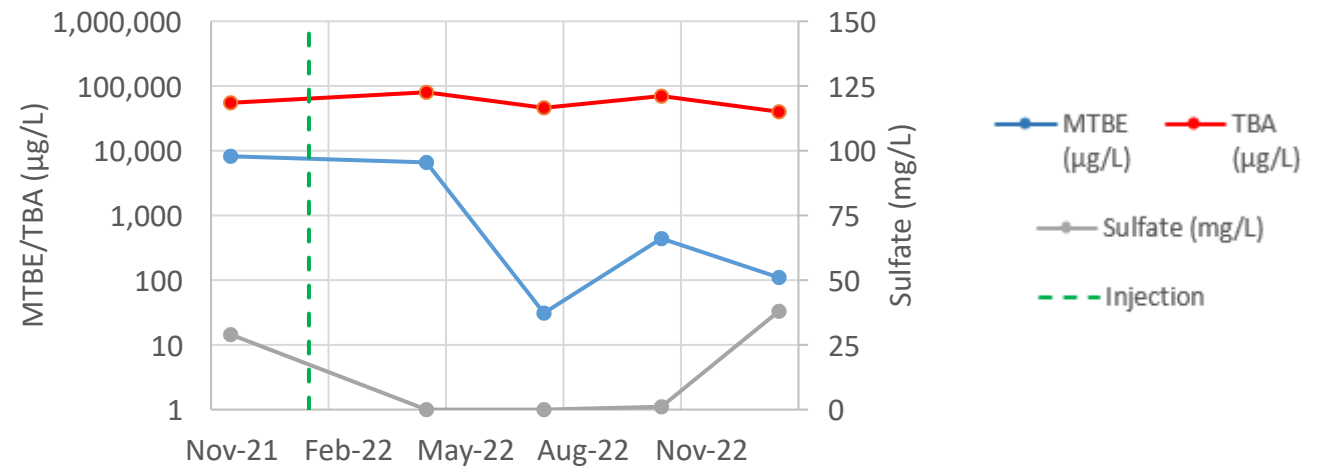


SULFATE ENHANCED IN SITU BIODEGRADATION OF MTBE AND TBA IN FRACTURED BEDROCK FOR SOURCE AREA TREATMENT AND DOWNGRADIENT RISK MITIGATION

OBS-10



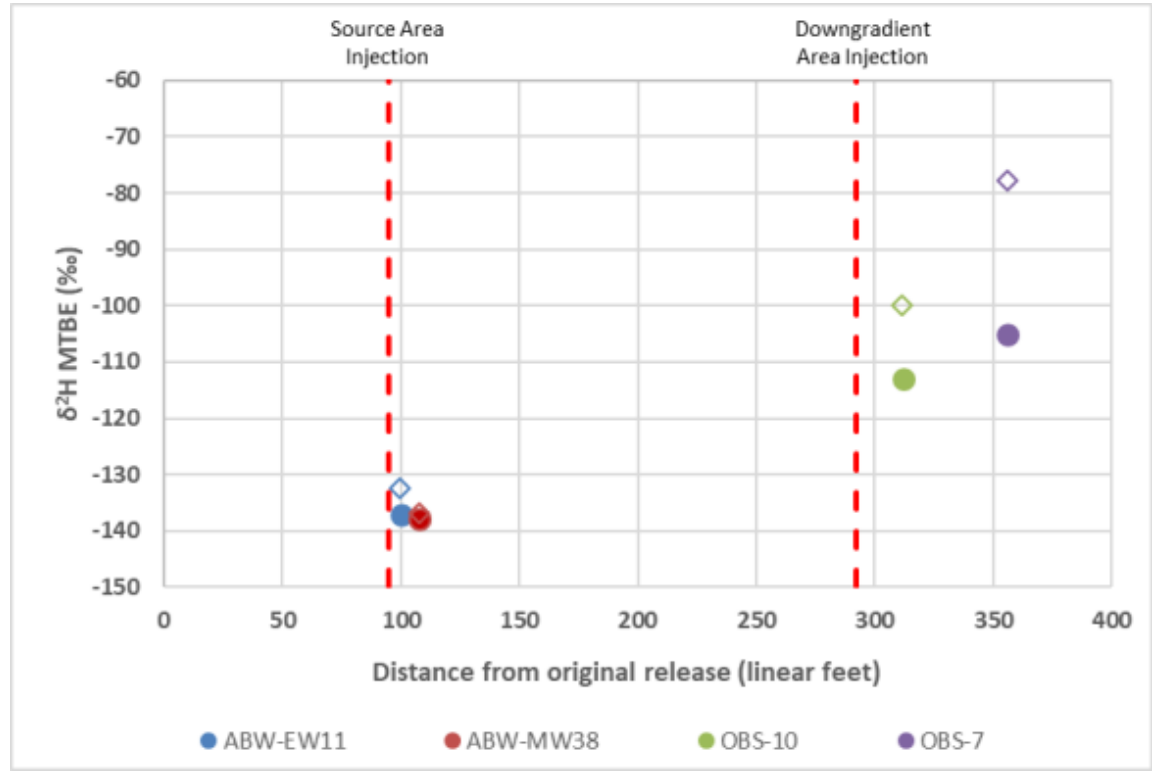
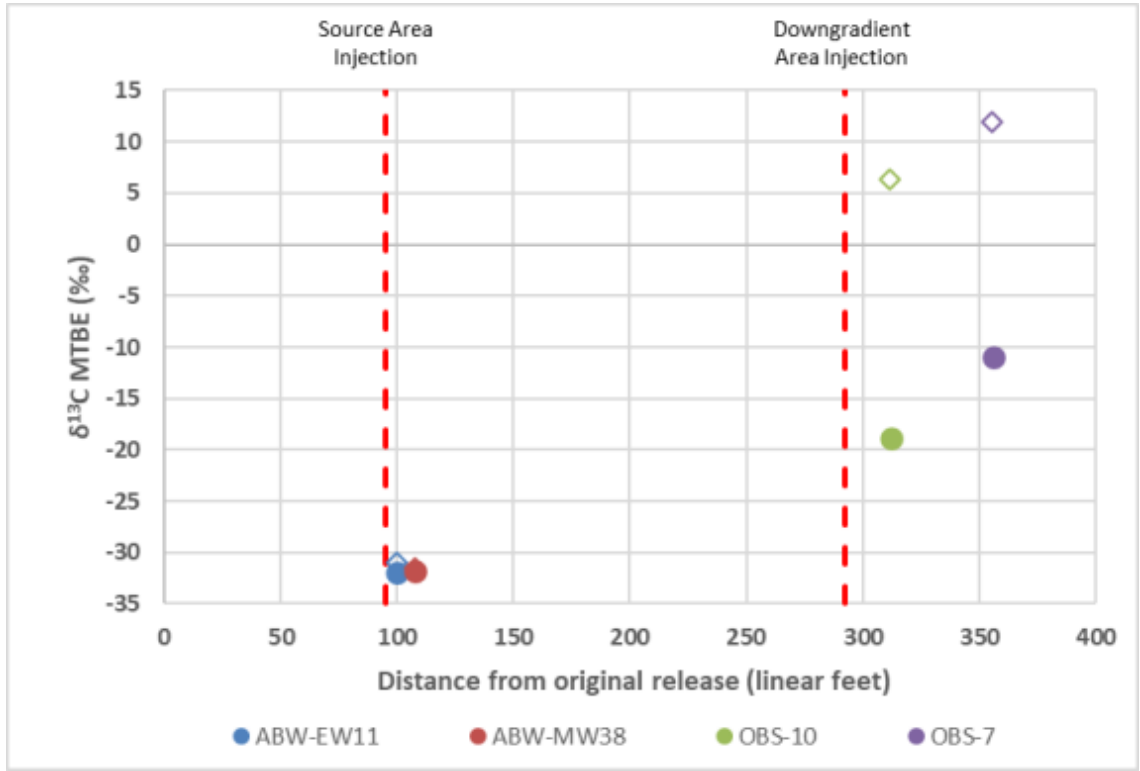
OBS-7





CSIA shows “enhanced” biodegradation in downgradient study area

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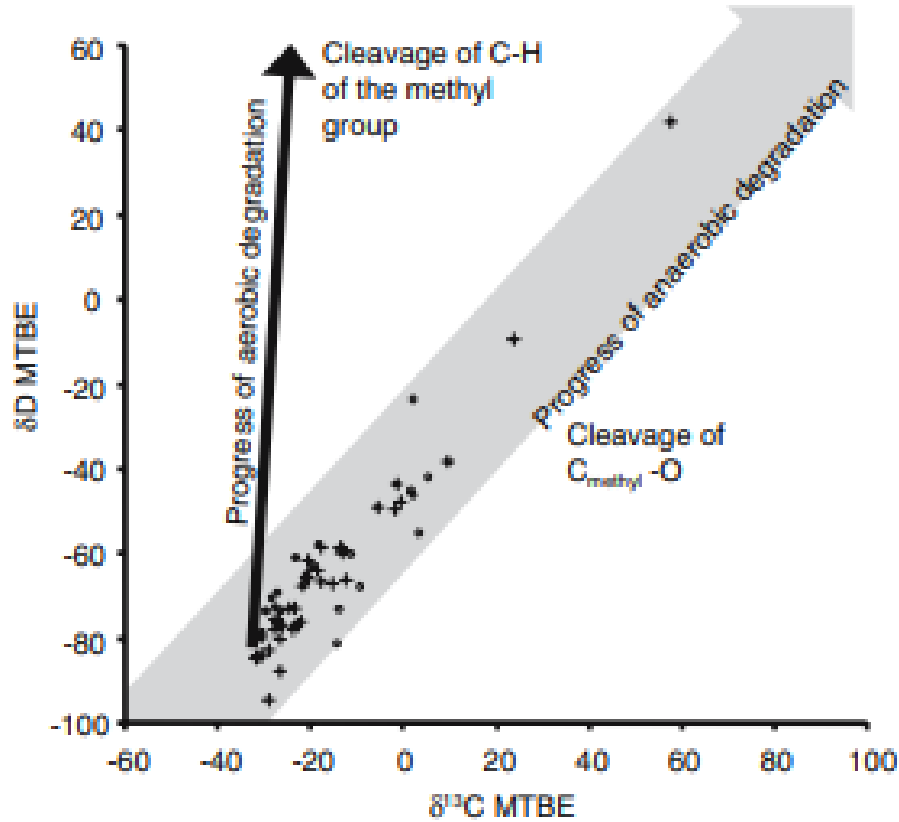


Solid icons: Baseline
Hollow icons: 1 year after injection

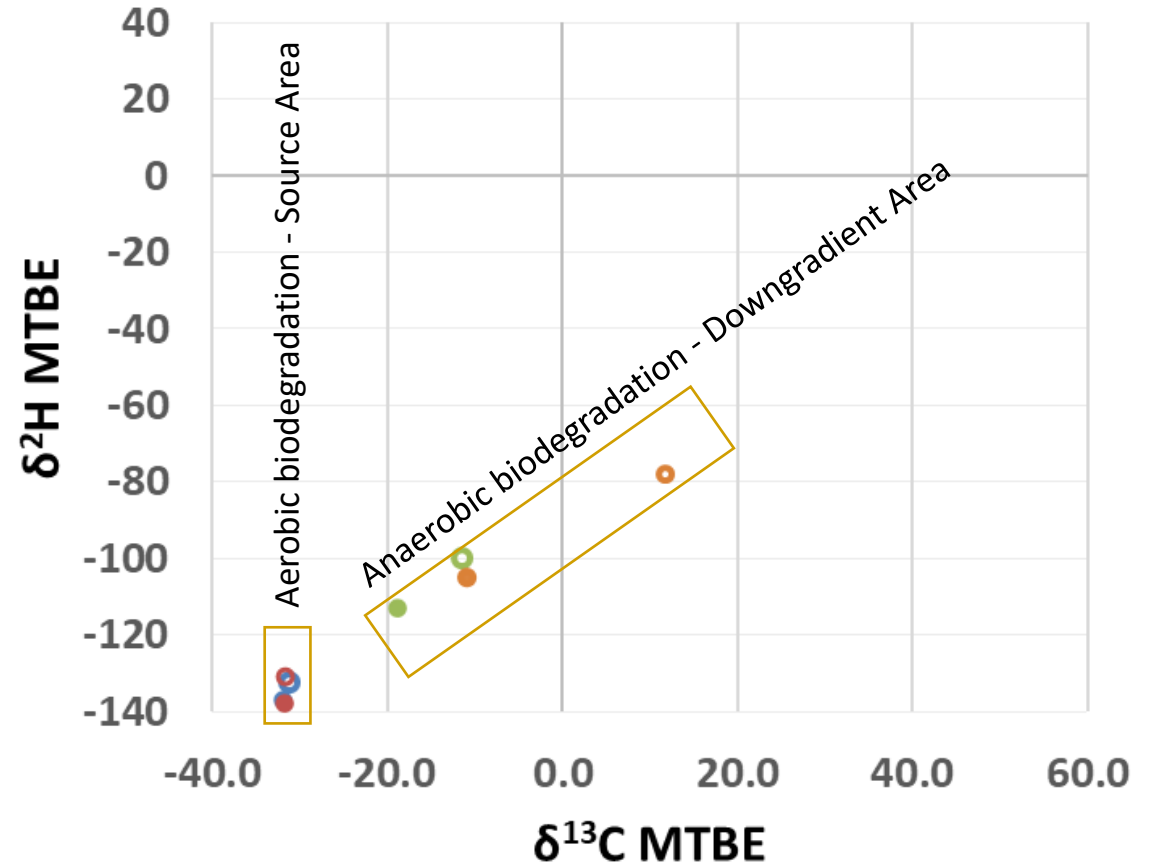


2-D CSIA suggests anaerobic biodegradation dominant pathway in the downgradient area

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Source: Kuder, T. et al., Environmental Science and Technology, 39: 213-220, 2005



- ABW-EW11 ● ABW-MW38 ● OBS-10 ● OBS-10
- Solid icons: Baseline
- Hollow icons: 1 year after injection



Takeaways

- Lower permeability layers in the smear zone remain saturated with high concentration MTBE and serve as long-term source to groundwater
- Groundwater flow and contaminant transport are controlled by the strike of bedrock features
- Wells and boreholes intercepting sandstone beds, where mass flux is highest, accepted majority of injected amendment
- CSIA data indicate that anaerobic degradation is the dominant pathway in the downgradient area
- High concentration sulfate injection reduced MTBE concentrations and addressed dissolved phase risk in downgradient area

