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Biosparge Pilot Testing for Aerobic Degradation of Sulfolane

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Agenda

Introduction

Background

Pilot Test Design

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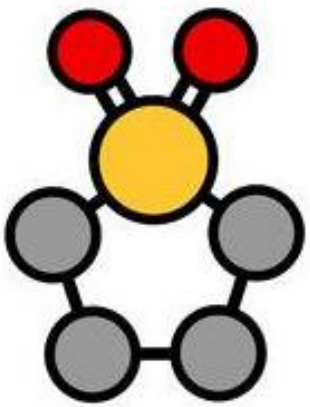
Ongoing Efforts

Conclusions

Background

Sulfolane Use Onsite



- $C_4H_8SO_2$
- Industrial solvent used as a sweetening agent in sour gas processes
- Historically used onsite from the 1960s to the 1980s
- Biodegradation Pathways:

1) $C_4H_8O_2S + 6.5O_2 \rightarrow 4CO_2 + 3H_2O + 2H^+ + SO_4^{2-}$ (Greene et al., 2000)

2) $5C_4H_8O_2S + 18NO_3^- \rightarrow 20HCO_3^- + 9N_2 + 5HS^- + 7H^+ + 4H_2O$ (Greene et al.,1998)

3) $C_4H_8O_2S + 9MnO_2 + 5HCO_3^- \rightarrow 9MnCO_3 + 4H_2O + HS^- + 4OH^-$ (Greene, 1998)

4) $C_4H_8O_2S + 10H_2O + 18Fe^{3+} \rightarrow S^{2-} + 18Fe^{2+} + 4HCO_3^- + 24H^+$ (Greene, 1999)

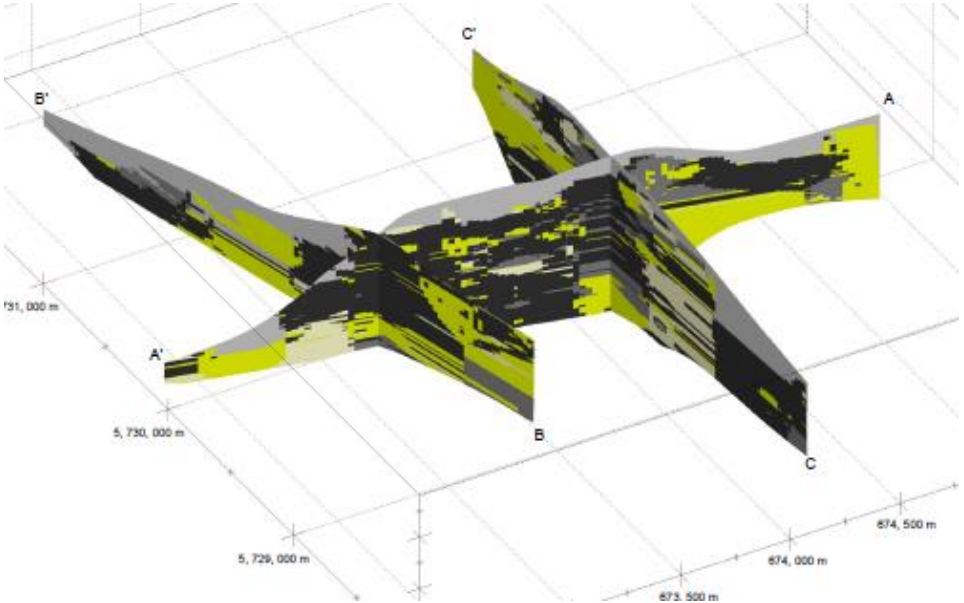
5) $4C_4H_8O_2S + 4H_2O + 9SO_4^{2-} \rightarrow 13HS^- + 16HCO_3^- + 11H^+$ (Greene, 1999)

6) $C_4H_8O_2S + 1.5H_2O \rightarrow 1.75CO_2 + 2.25CH_4 + H_2S$ (Greene et al.,1998)

Complex Fracture Bedrock

Lithology

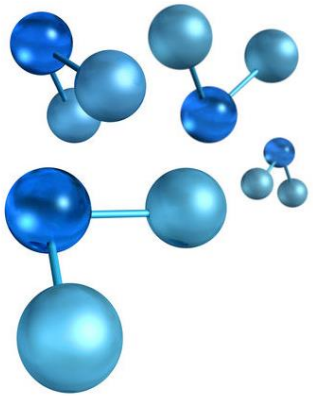
- Overburden
- Siltstone
- Mudstone
- Interbedded sandstone, mudstone and siltstone
- Sandstone



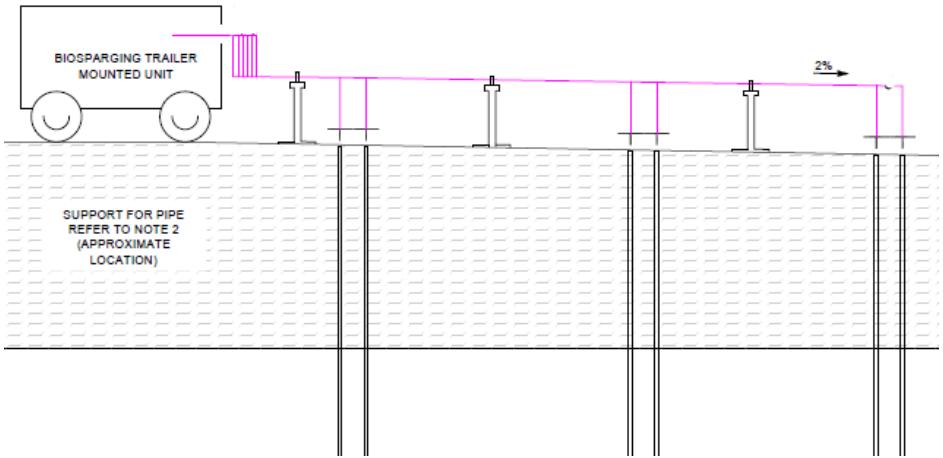
Pilot Test Design

Objectives

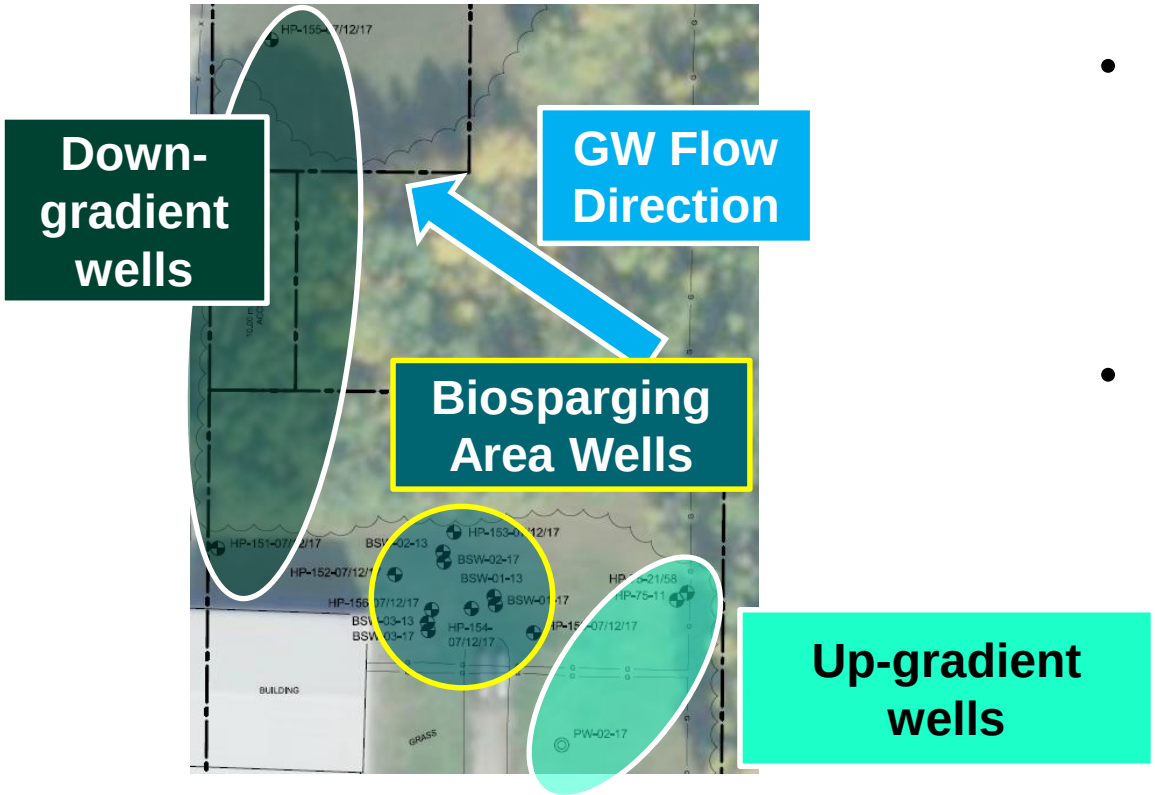
- What is the goal?
- How do we measure the success of the pilot?
  1. Increase dissolved oxygen concentrations
  2. Decrease dissolved plume sulfolane concentrations
  3. Provide evidence to support *in situ* biodegradation is the dominant mechanism of decreased sulfolane concentrations



Biosparge System Design



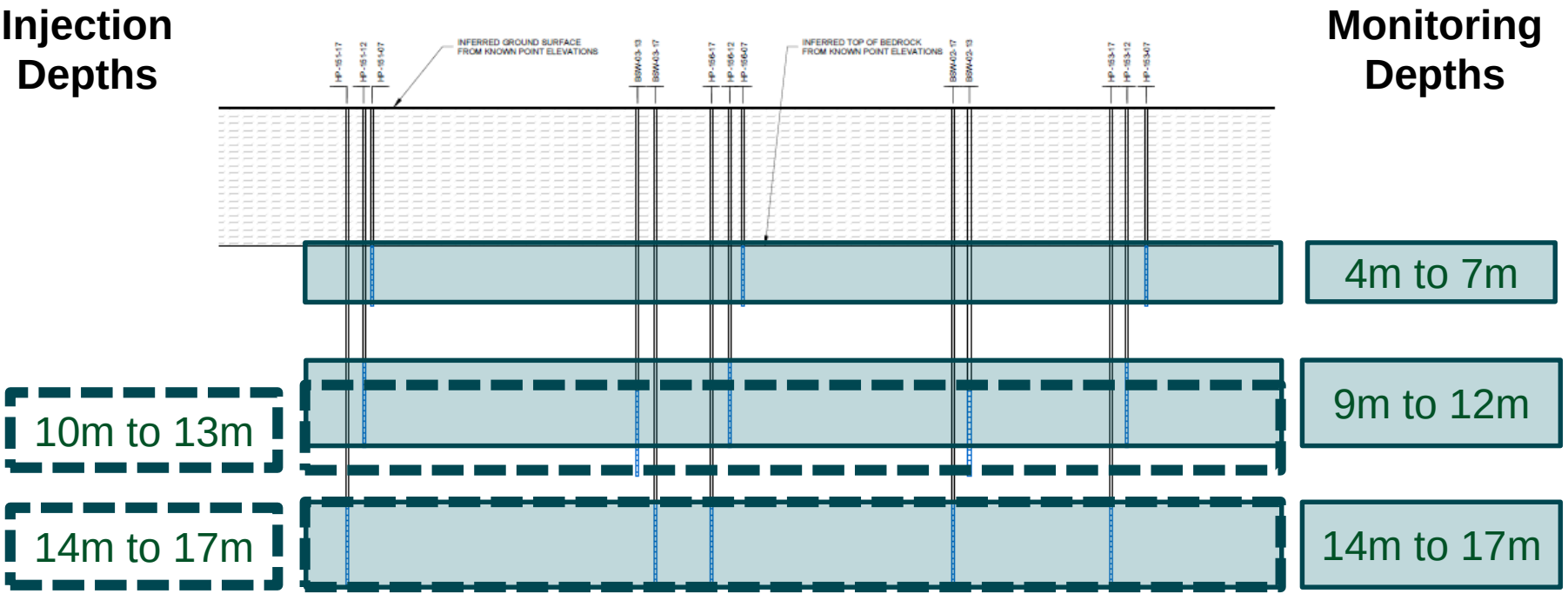
Biosparging and Monitoring Well Network



- Biosparging Wells
  - 12m Interval - 3 wells
  - 17m Interval – 3 wells
- Monitoring Network
  - 7m Interval – 8 wells
  - 12m Interval – 14 wells
  - 17m Interval – 14 wells

Biosparging and Monitoring Well Network

Injection Depths



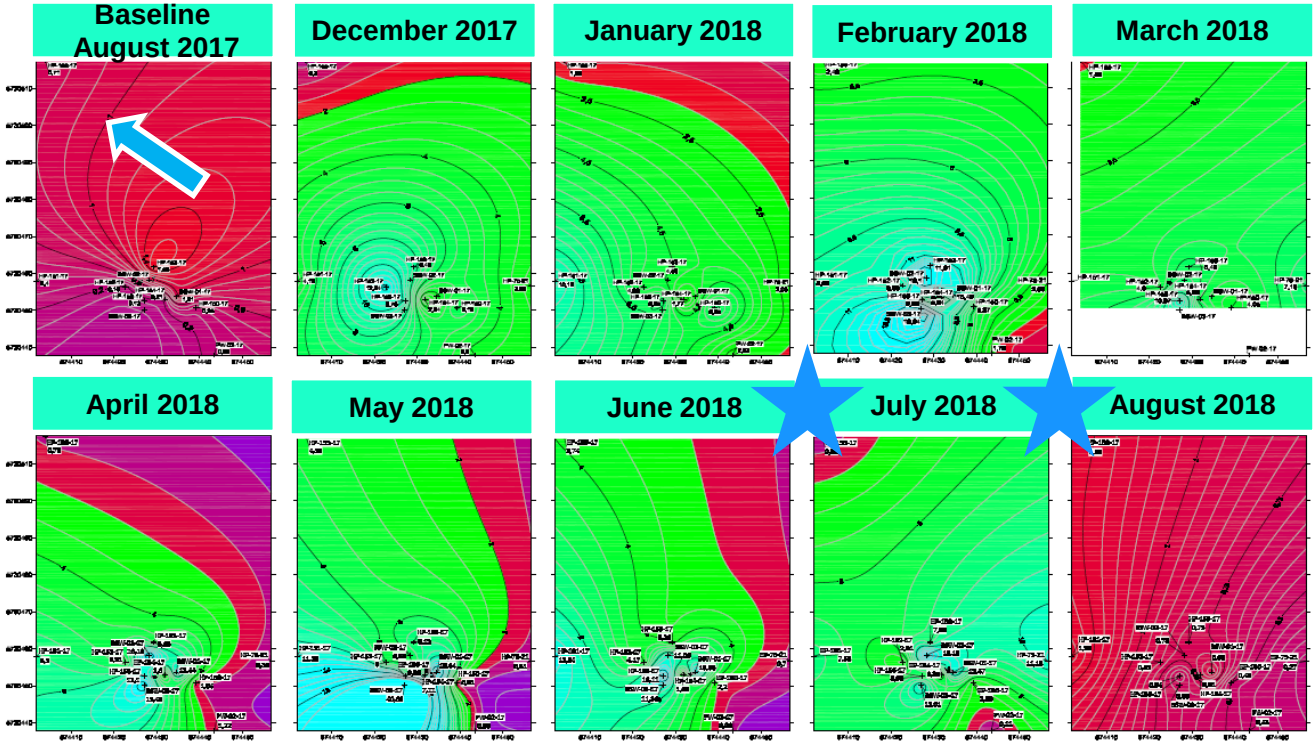
Monitoring Depths

Groundwater Monitoring Program

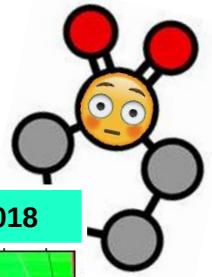
- Sulfolane and Dissolved Oxygen
- Traditional Geochemistry
- Microbial Testing

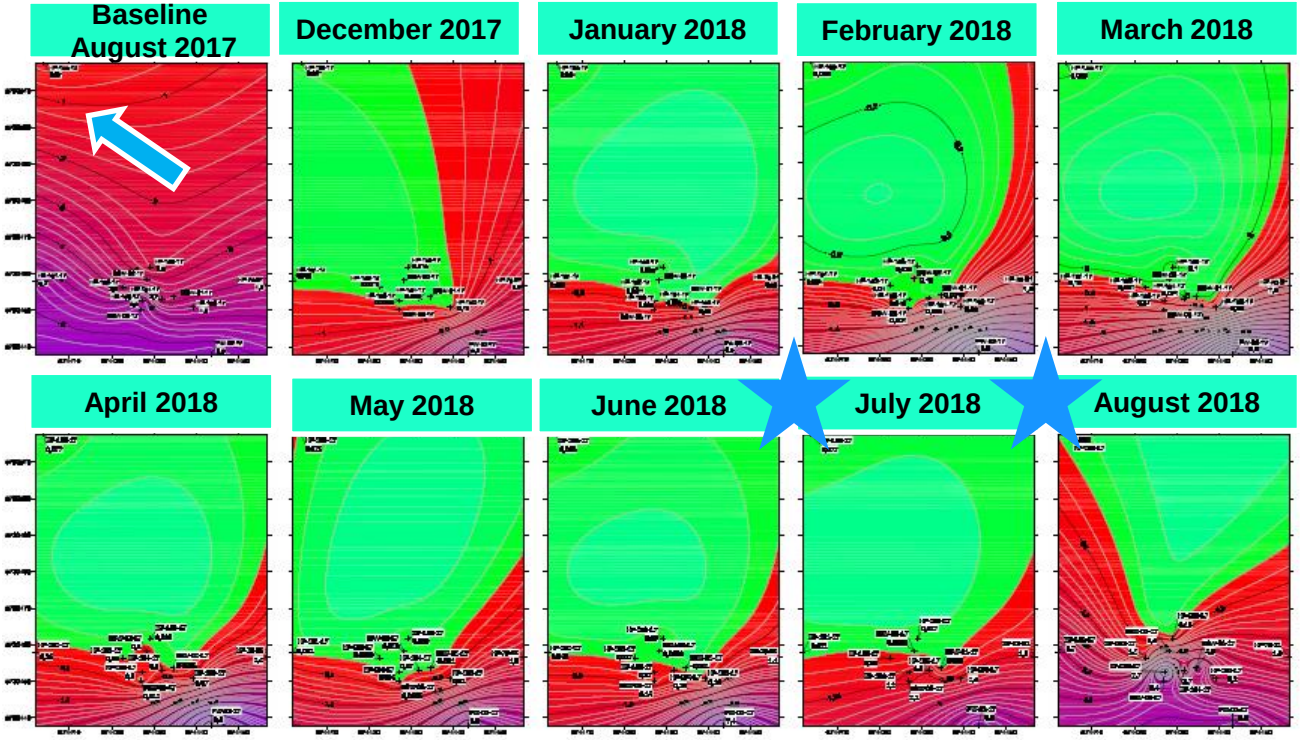
Field Results

Dissolved Oxygen Concentrations – 17m Interval

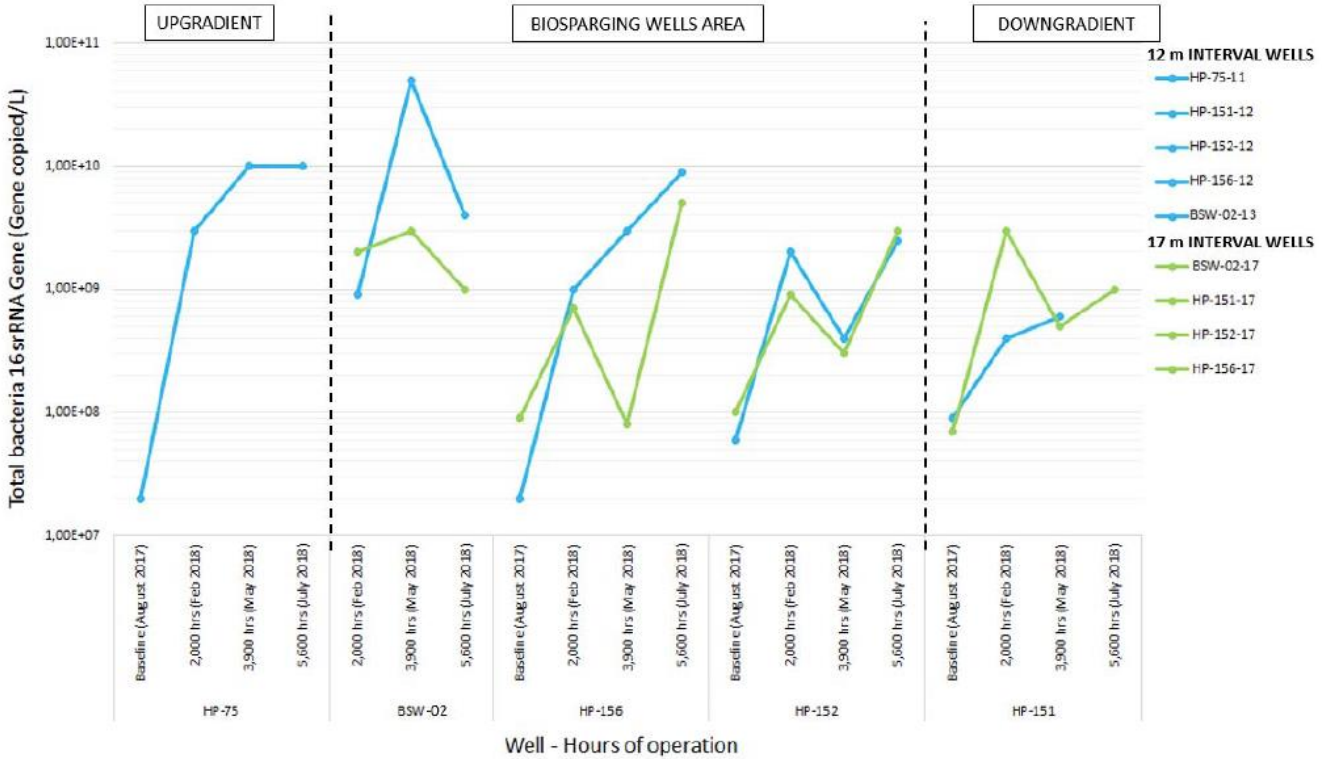


Sulfolane Concentrations – 17m Interval

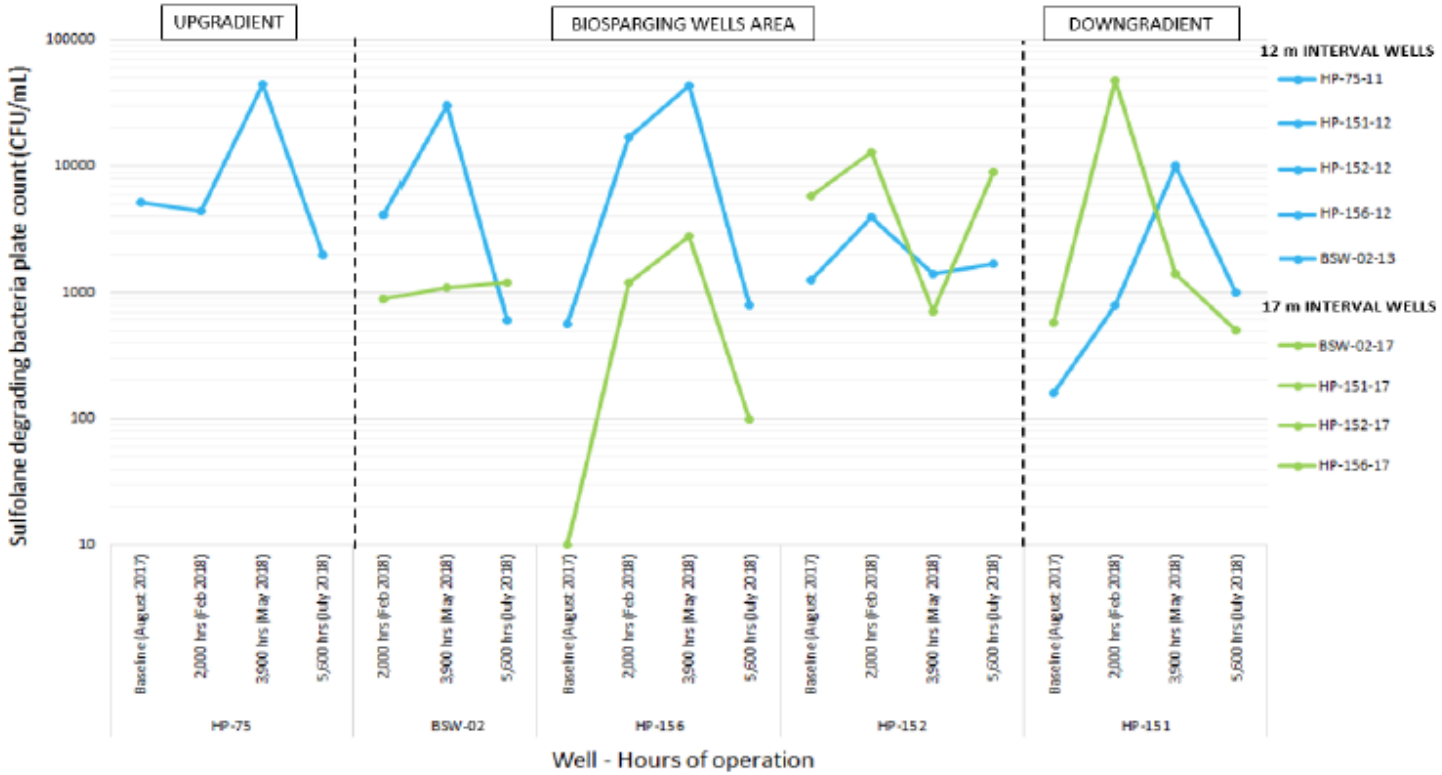




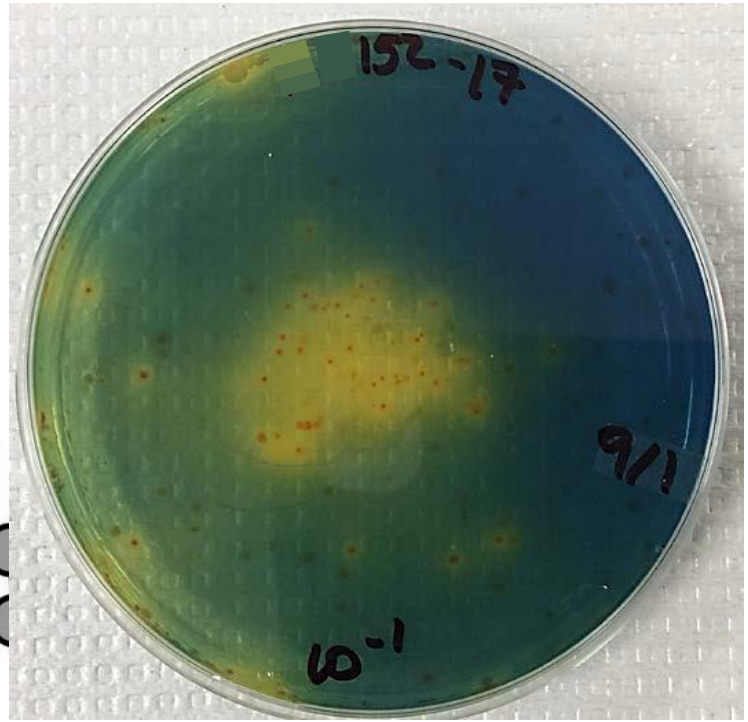
Biodegradation – Total Bacteria via qPCR (16S rRNA)



Biodegradation – Sulfolane Degrading Bacteria Plate Counts



Biodegradation of Sulfolane – Colony Identification

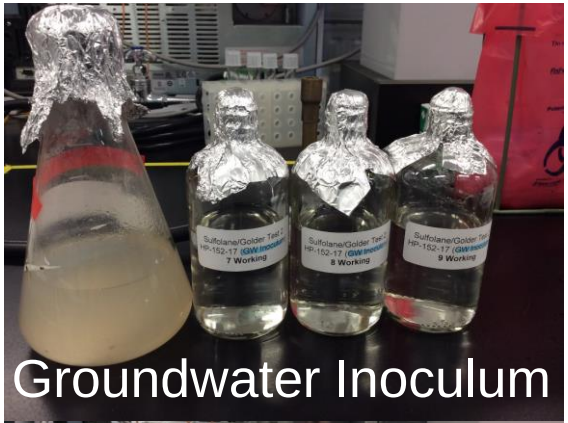


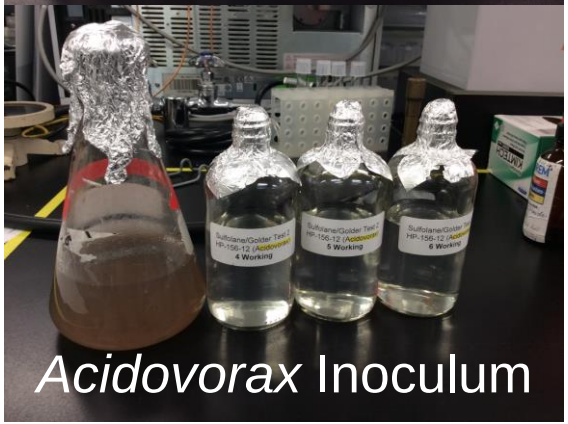
Ongoing Efforts

Sulfolane Treatability Study #2

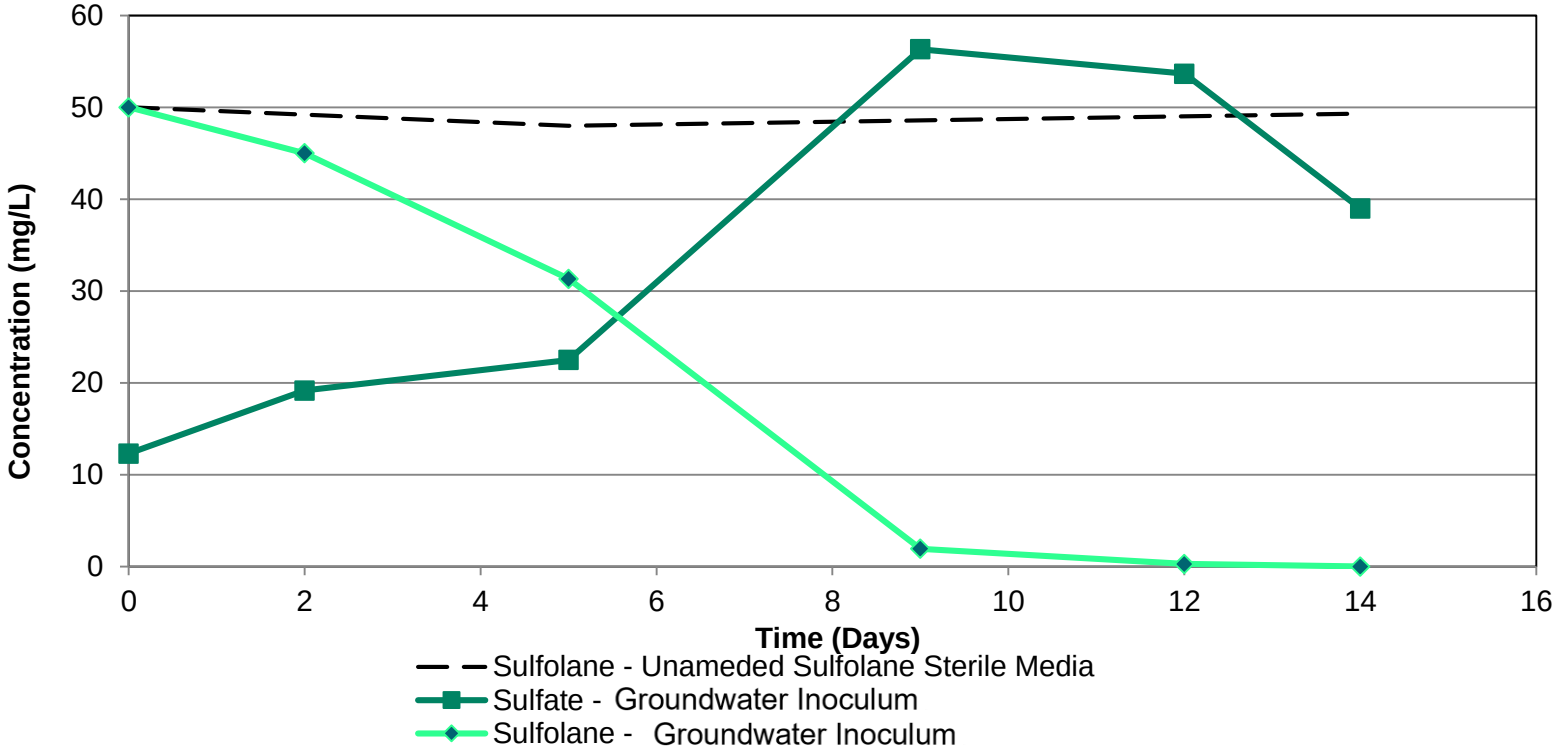
- Three treatments – groundwater inoculated, *Acidovorax* isolate inoculated, uninoculated killed controls (negative controls)
- 6 time steps per treatment
- Incubated at room temperature at 100 rpm
- Sterile foam stoppers used to allow gas headspace exchange and avoid oxygen limitation
- Samples analyzed for sulfate as a proxy for sulfolane degradation (analytical cost)

$$C_4H_8O_2S + 6.5O_2 \rightarrow 4CO_2 + 3H_2O + 2H^+ + SO_4^{2-}$$ (Greene et al., 2000)


Groundwater Inoculum


Acidovorax Inoculum

Aerobic Treatability Study – Groundwater Inoculum

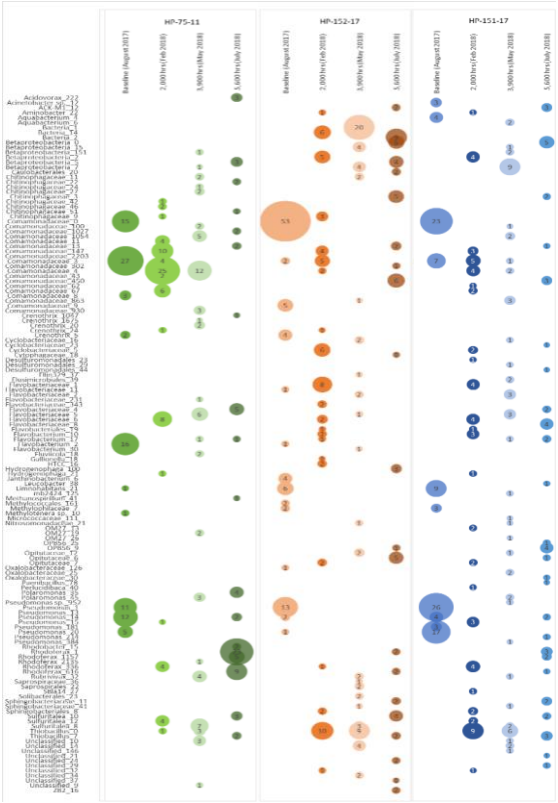


E&PS GOLDER SiREM

$C_4H_8O_2S + 6.5O_2 \rightarrow 4CO_2 + 3H_2O + 2H^+ + SO_4^{2-}$ (Greene et al., 2000)

Microbial Community Analysis

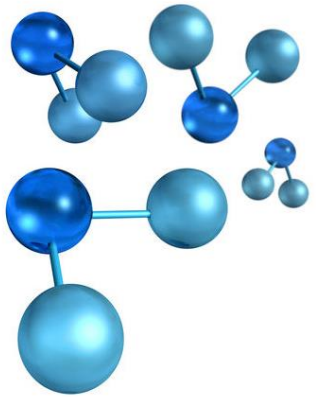
- Quarterly samples collected for community analysis (16s rRNA gene)
- Coupled to culture-based isolation effort
- **Goal:**
  - Track increases/decreases of key sulfolane degraders in count and abundance over space and time
- Key sulfolane-degrading genera being tracked
  - *Acidovorax*
  - *Acinetobacter*
  - *Pseudomonas/Stenotrophomonas*
  - *Rhodoferax*
  - *Shinella*



Conclusions

Conclusions

- Objectives:
  1. Increase dissolved oxygen concentration ✅
  2. Decrease dissolved plume sulfolane concentration ✅
  3. Provide supporting evidence that *in situ* biodegradation is occurring due to biostimulation with oxygen ✅
- Further work needed to identify and track dominant sulfolane degraders to show enhancement of *in situ* biodegradation



Questions?

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Extra Slides