



## SUCCESSFUL TREATMENT OF 1,4-DIOXANE WITH IN-SITU OZONE

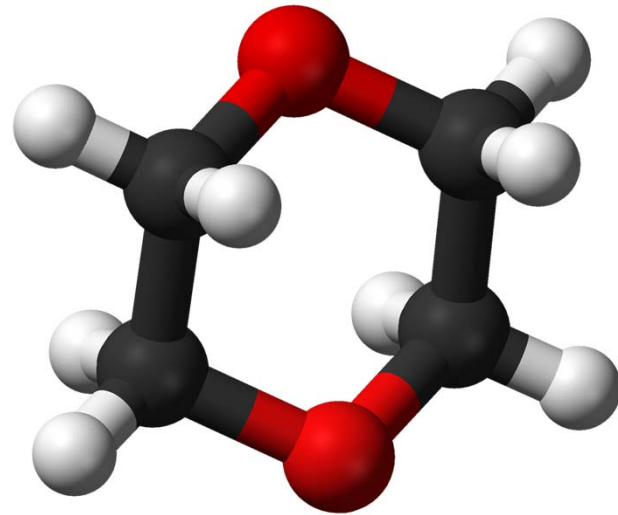
Fritz Krembs, P.E., P.G., George Mathes, P.E., Justin Pruis, P.E.  
Mitchell, R. Olson, Ph.D., P.E., Michael G. Sweetenham, P.G.,  
Kyle Power

# Acknowledgements

- “Project Owner”
- Environmental Consulting & Technology (ECT)
- Pace Analytical
- H2O Engineering
- SiREM
- Carus

# 1,4-Dioxane

- Likely human carcinogen
- Historical use as 1,1,1-TCA stabilizer
- Prolific because
  - Very high solubility
  - Low sorption
  - Recalcitrant to biodegradation (?)
- USEPA RSL 0.46 ug/L (no MCL yet)



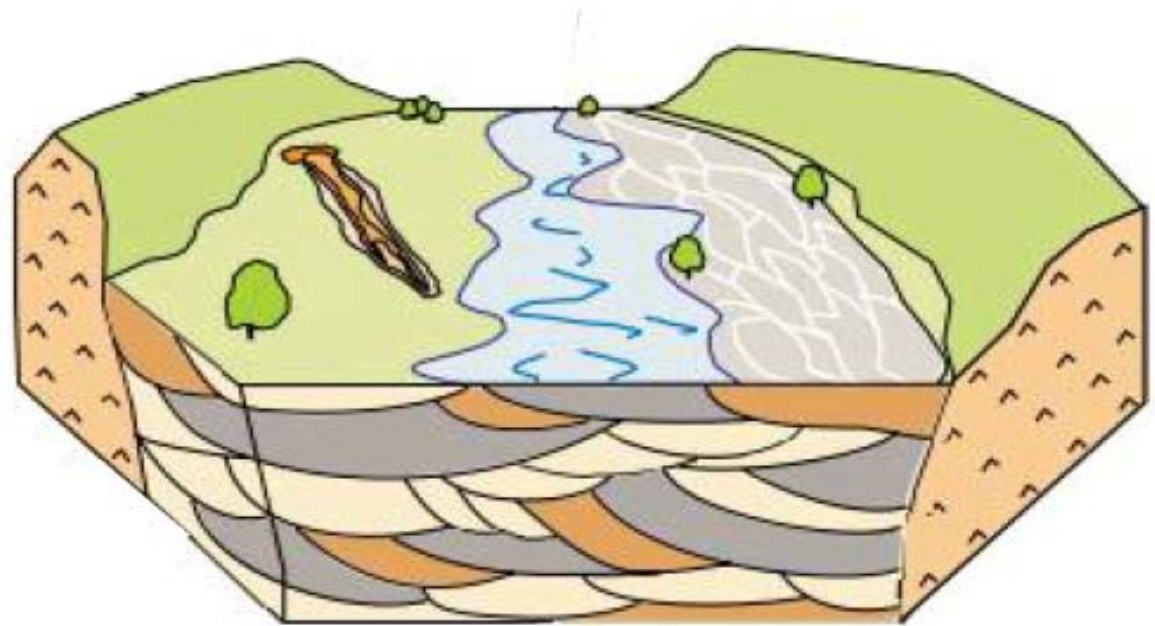
# Project Overview

- Industrial facility since 1973
- RCRA program / USEPA oversight





# CSM – General Geology

- Alluvial Valley Depositional System
  - Floodplains
  - Sand-Gravel Bars
  - Meanders
  - Alluvial Fans / Deltas

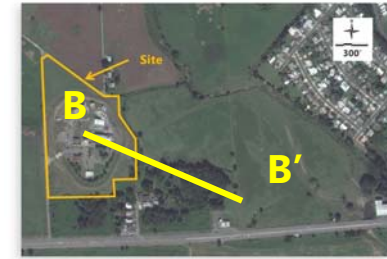


## LEGEND

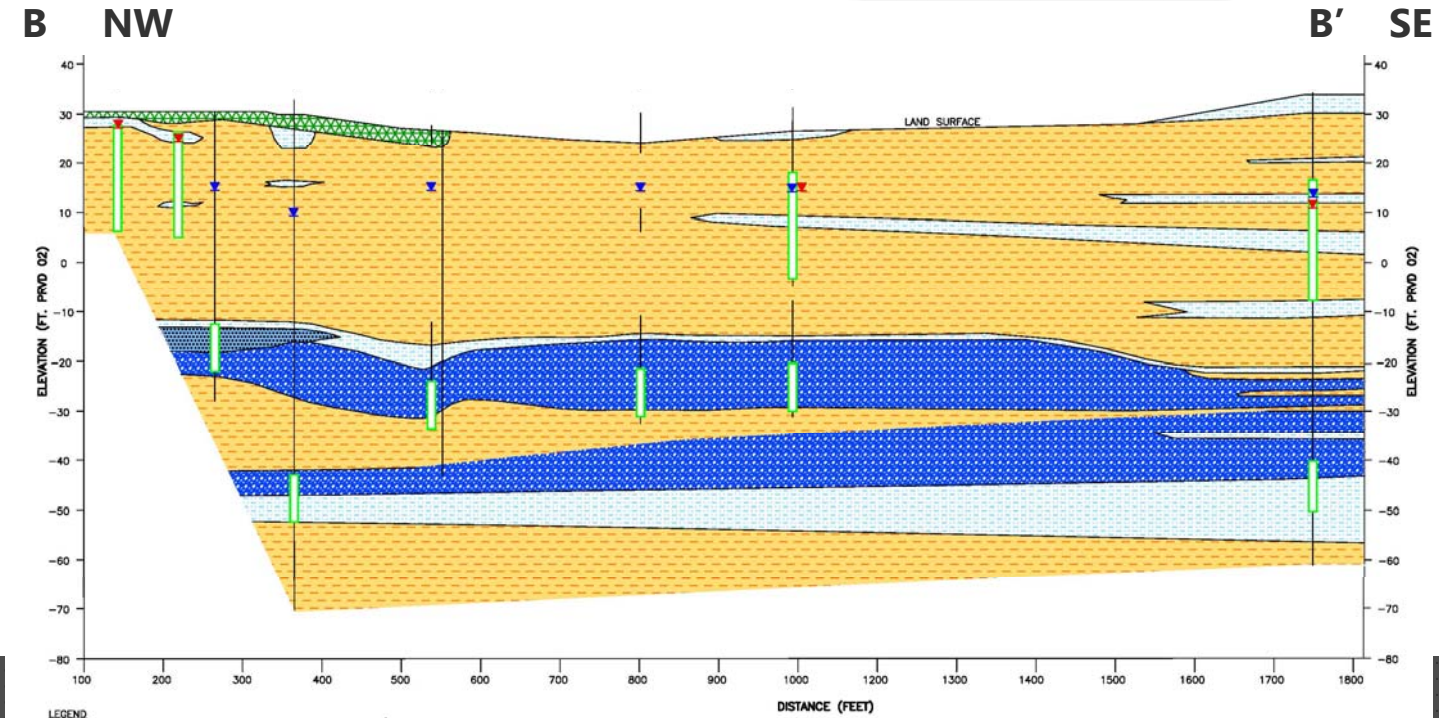
	Gravel, gravel-sand mixtures		Fine-grained silty sand
	Medium to coarse-grained sand		Bedrock
			Contaminant Plume

Source: USEPA, 2010

# CSM - Geology



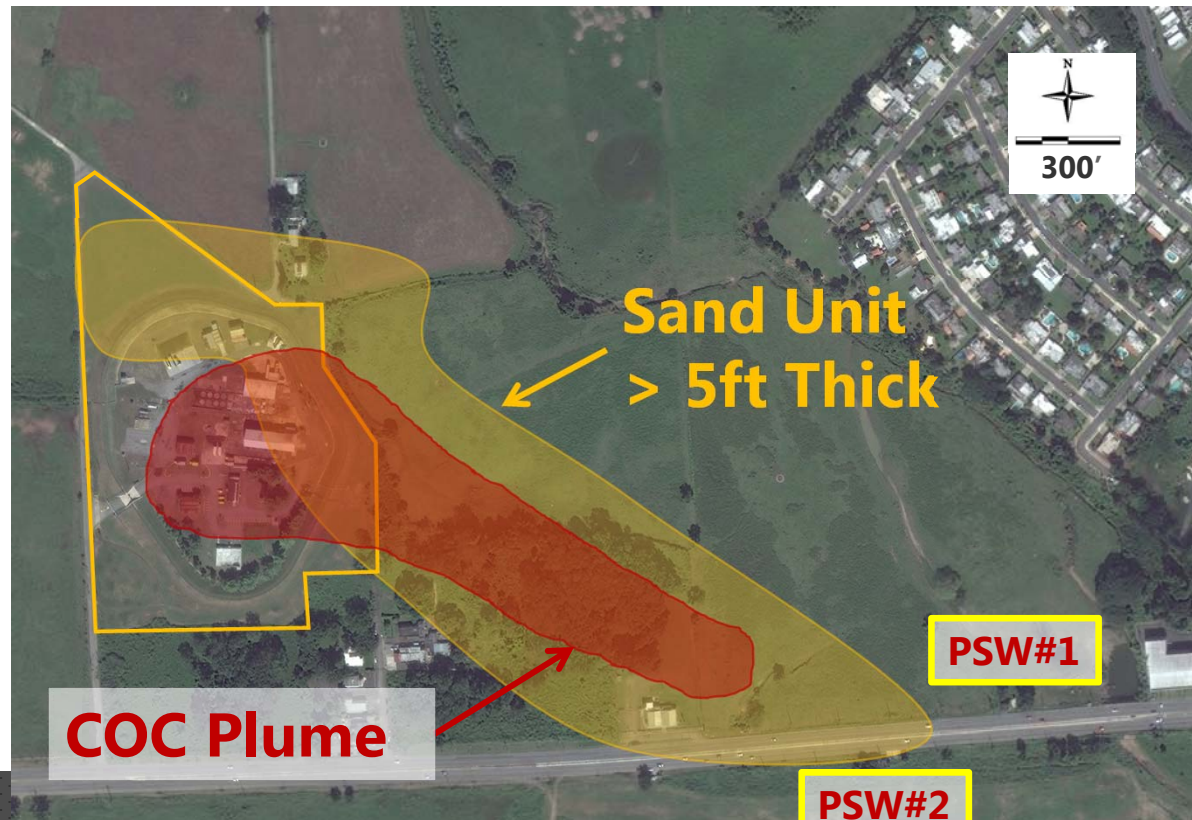
- Water Table Unit  
0 to 40 ft bgs  
Silt / Clay
- Sand Unit  
40 to 95 ft bgs  
Sand w/ Gravel  
and Silt



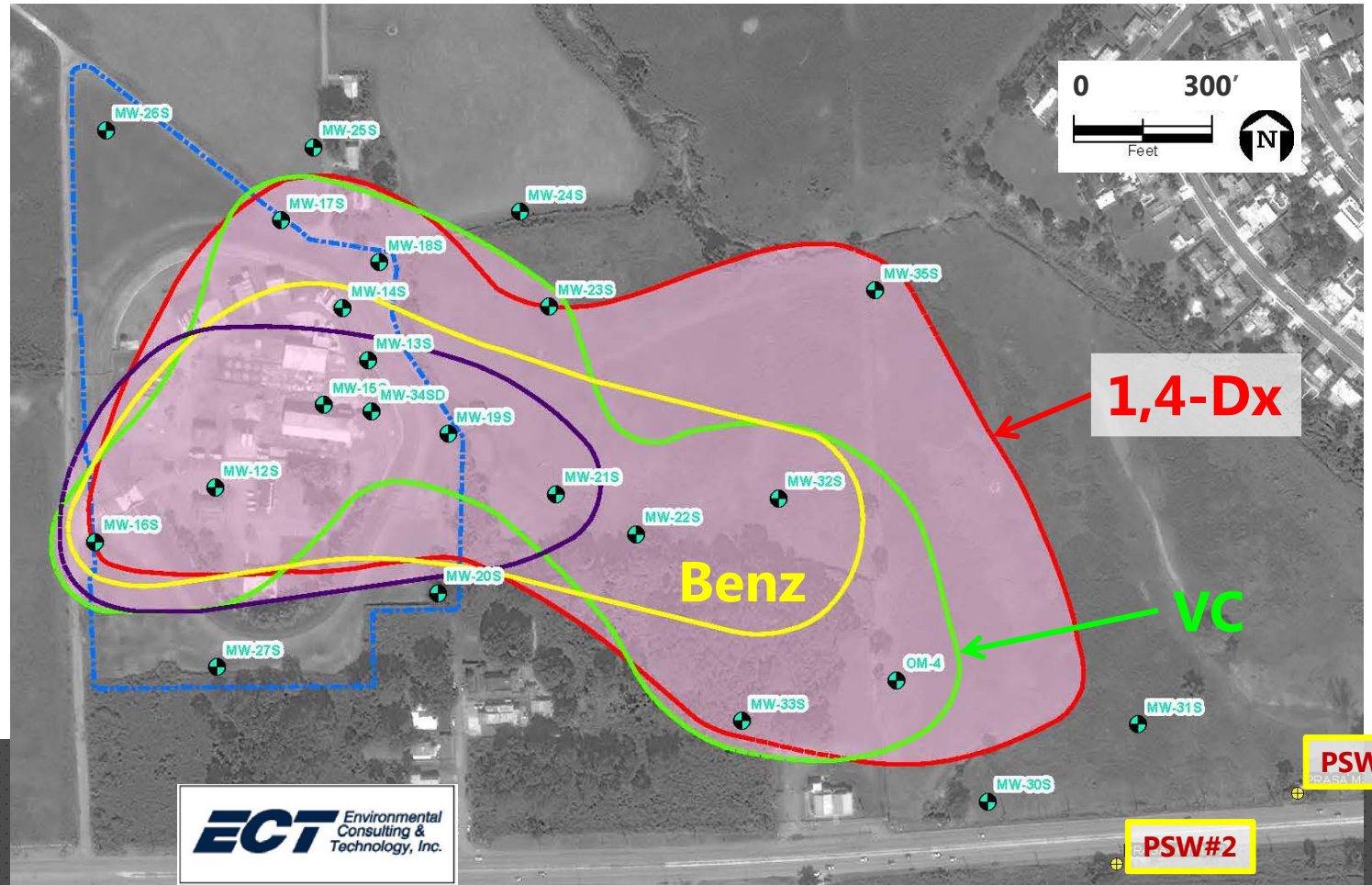


# CSM – Geology Cont.

- Sand Unit (high K)  
thickest along SE-NW axis
- COCs follow this axis
- Movement toward  
municipal supply wells  
PSW#1 and PSW#2



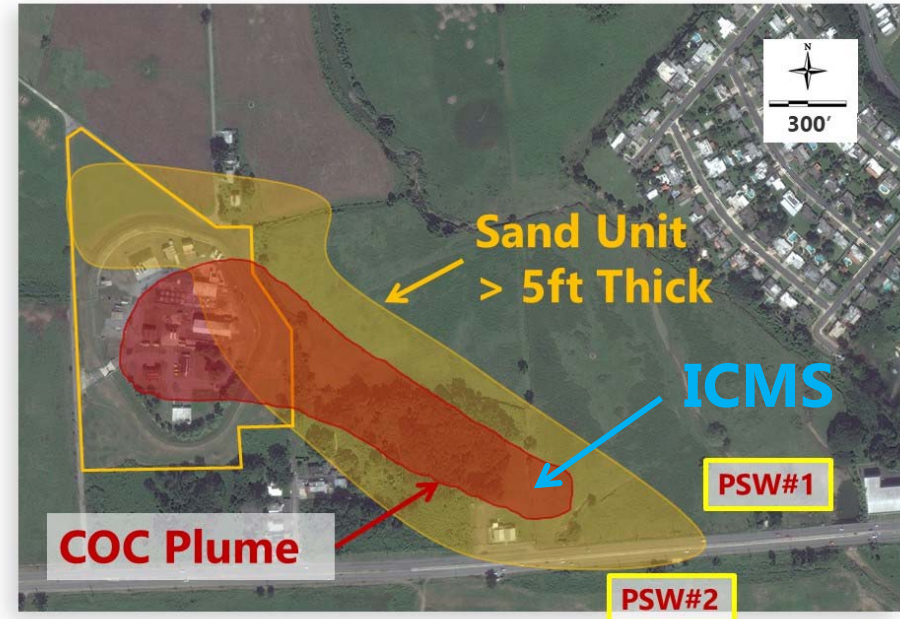
# COC Maps





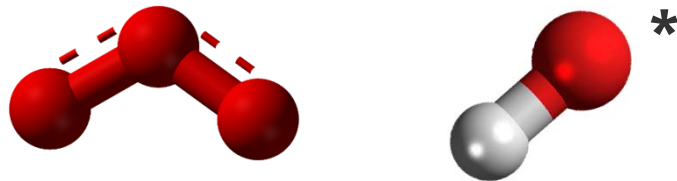
# Interim Corrective Measures Study (ICMS)

- Goal = Mitigate off-site Sand Unit groundwater
- First submittal 2013, finalized 2015
- ISCO with Ozone selected

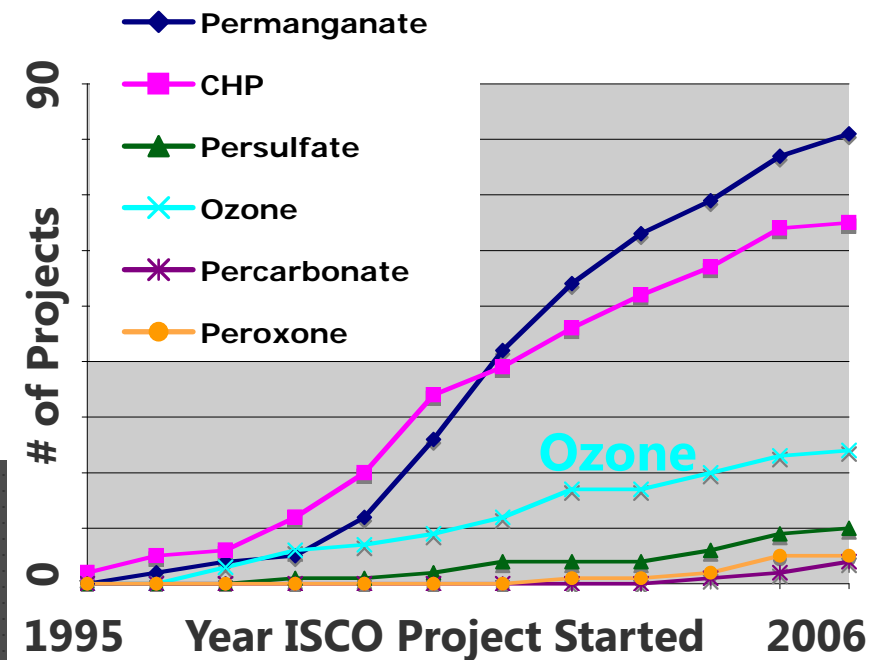


# Ozone for ISCO

- Ozone is strong oxidant (2.1v)
- Many industrial applications
- Produces  $\text{OH}^*$  (2.8v)



- Ozone has long history in ISCO
- Success w/ 1,4-dioxane as of early 2010s



# Ozone for ISCO Cont.

## Methods

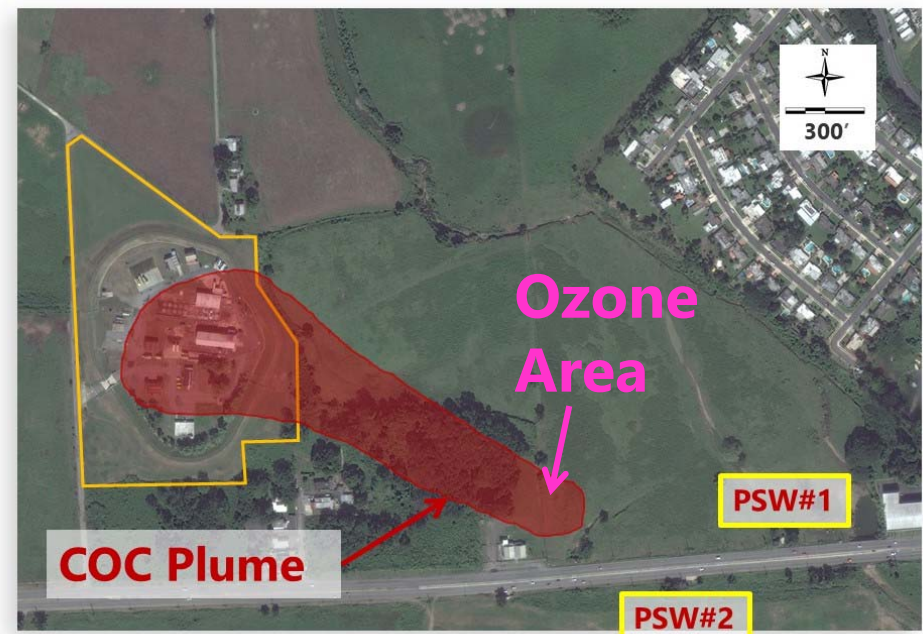
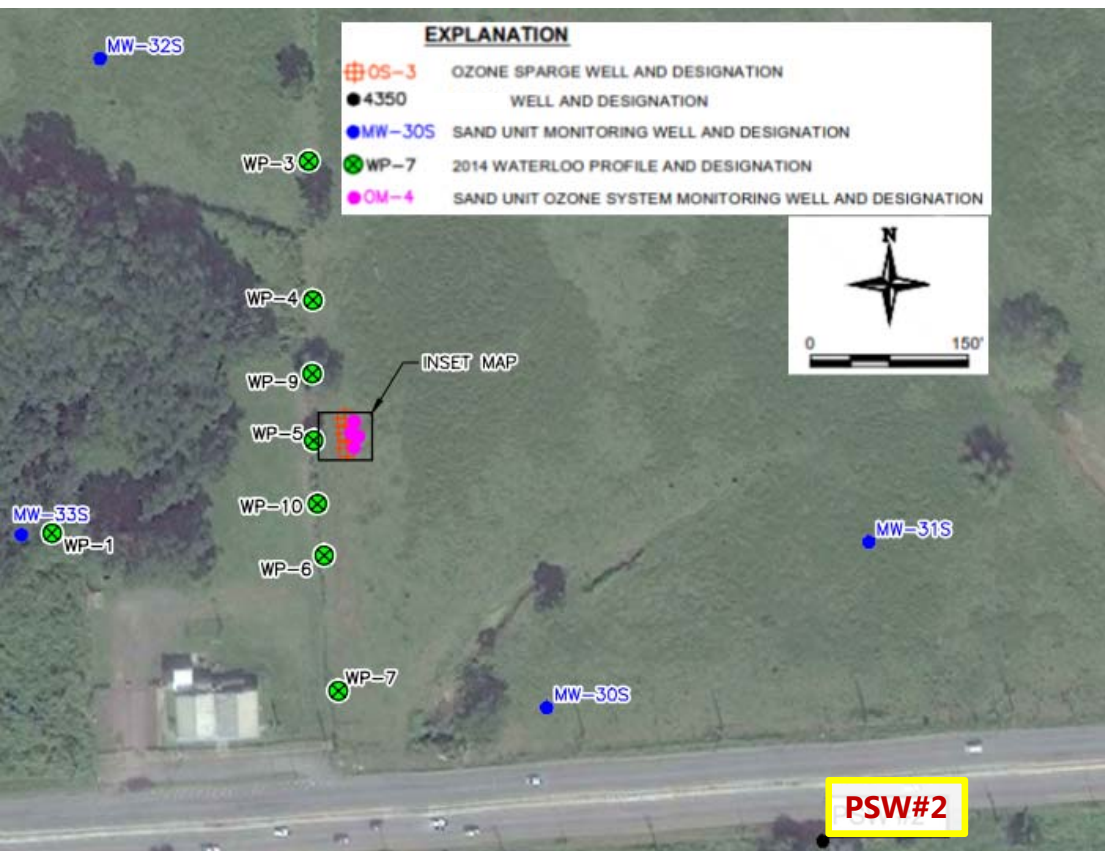
- Ozone gas made with on-site with ozone generator
- Injected through sparge wells



## Site-Specific Benefits

- Constant (pulsed) injection for barrier treatment
- O<sub>2</sub> is only residual
- Documented success in literature as of 2013

# Ozone ICMS Location





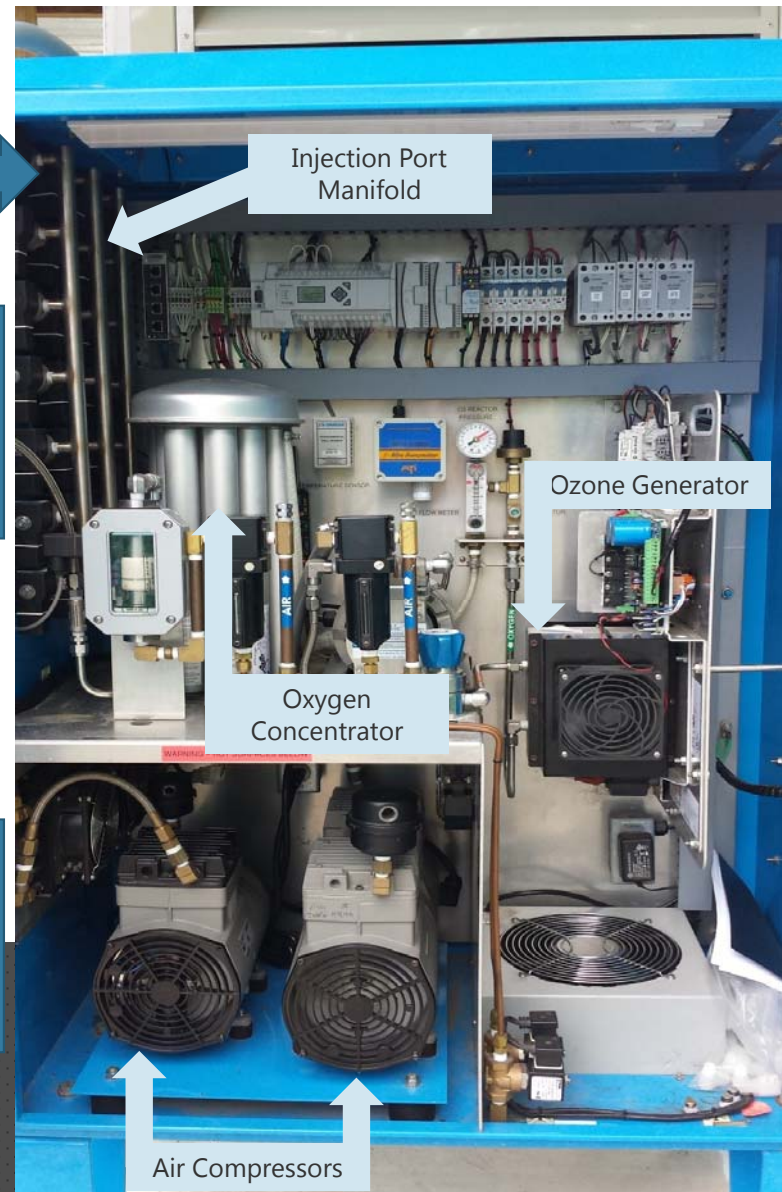


Ozone System

Compound & OM Wells



Inside Compound Ozone Sparge Wells



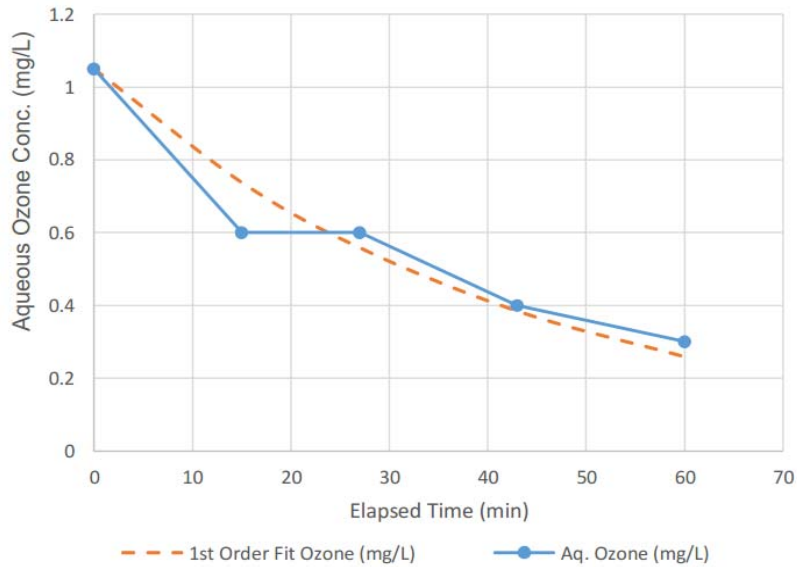
Injection Port Manifold

Ozone Generator

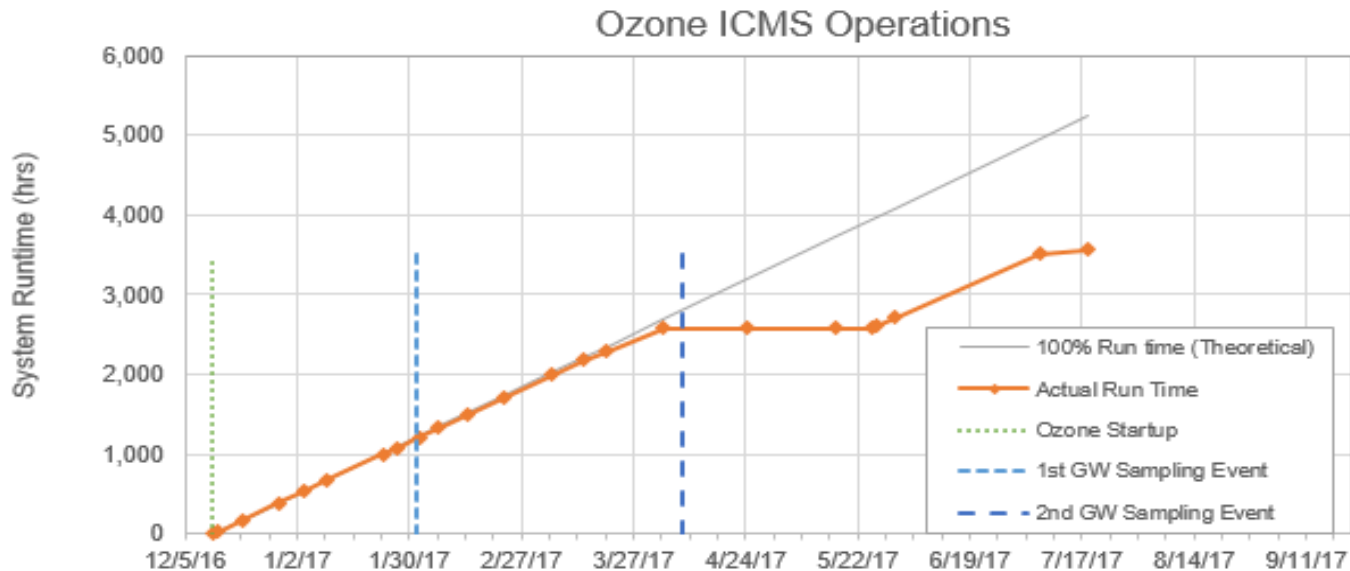
Oxygen Concentrator

Air Compressors

# Ozone Operational Data



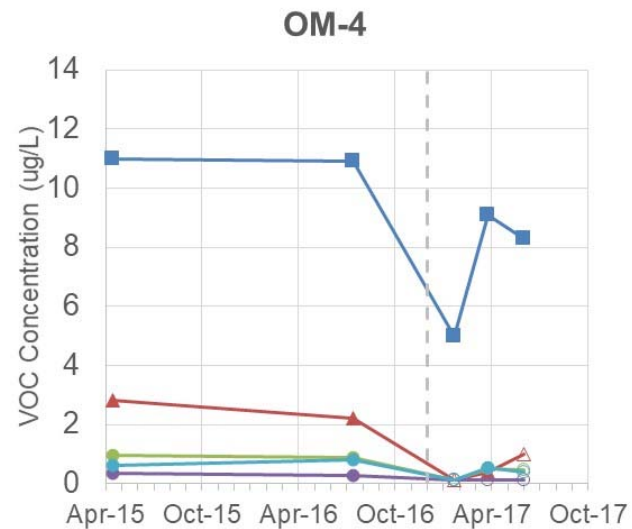
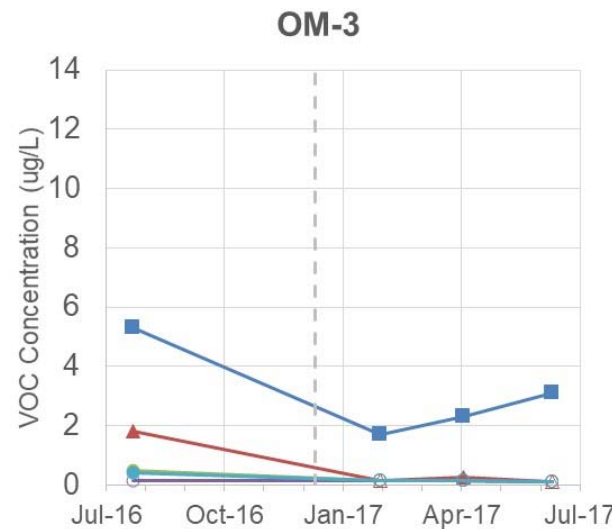
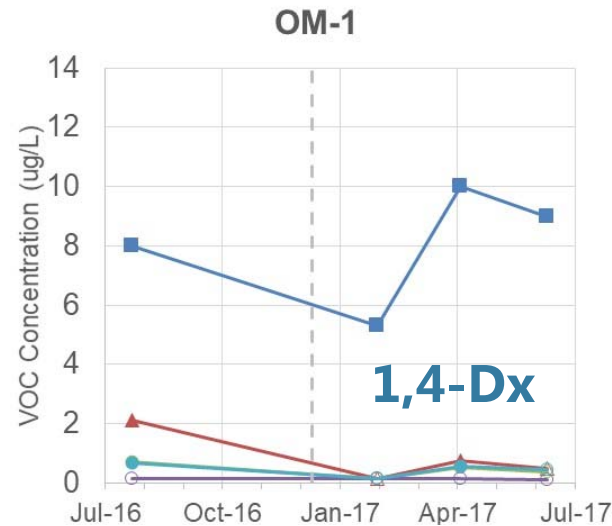
- 30 minute ozone half-life in-situ during startup



- Very good runtime for several months followed by brief upset

# Ozone Performance Results

- Up to 85% treatment of 1,4-dioxane
- Treatment of other VOCs to non-detect
- Best results in Feb '17, less treatment Ap '17 and June '17



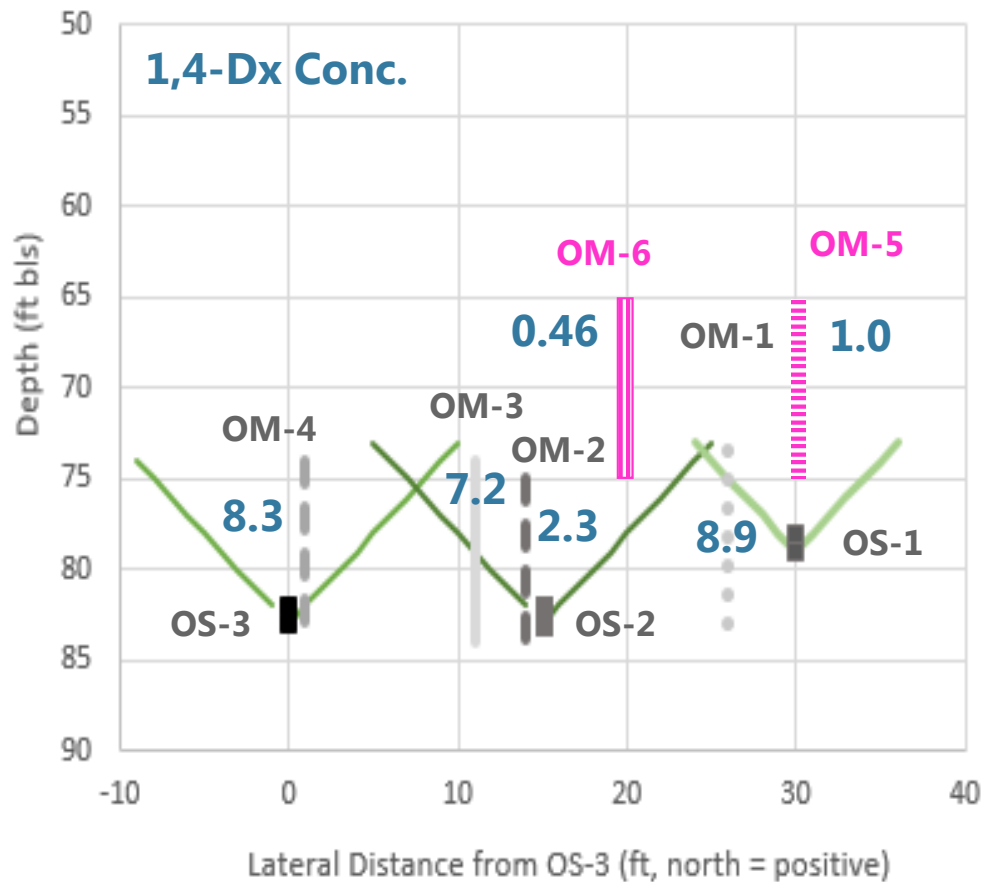
■ 1,4-Dioxane      ▲ Vinyl Chloride  
■ 1,1-DCA      ● 1,2-DCA  
● MTBE      - - Start Ozone

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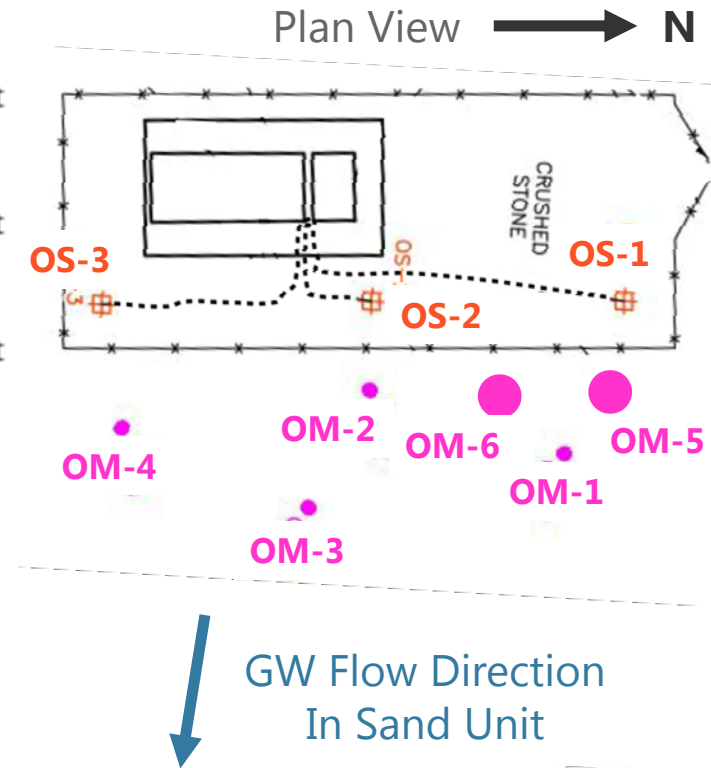


# Ozone Performance vs. Location

Cross Section Facing West (south to left)



- OS-3 Sparge Point
- OS-3 Conical ROI
- OS-2 Sparge Point
- OS-2 Conical ROI
- OS-1 Sparge Point
- OS-1 Conical ROI
- OM-1 Screen
- OM-2 Screen
- OM-3 Screen
- OM-4 Screen





# Permanganate / Persulfate Lab Test

- Good treatment of 1,4-dioxane
- High oxidant concentration required
- Reagent requirements challenging for dilute plume
- Potential residuals at muni. wells

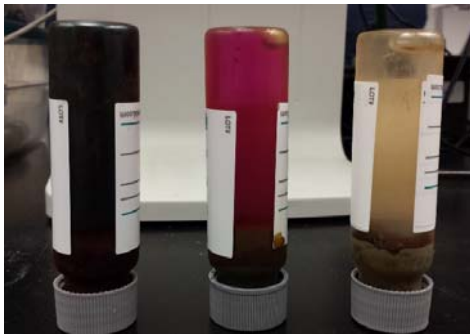
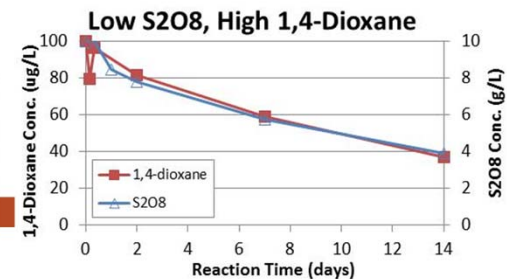
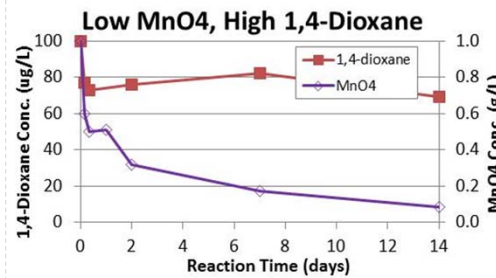
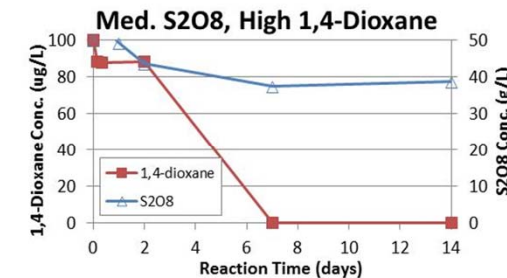
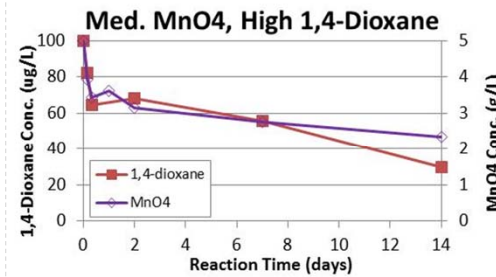
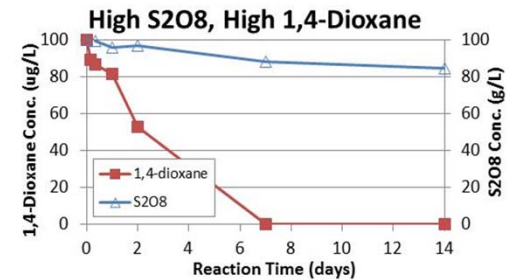
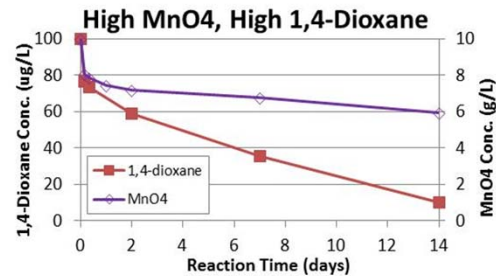


Photo by Carus Corp.



**1,4-Dioxane in Red**

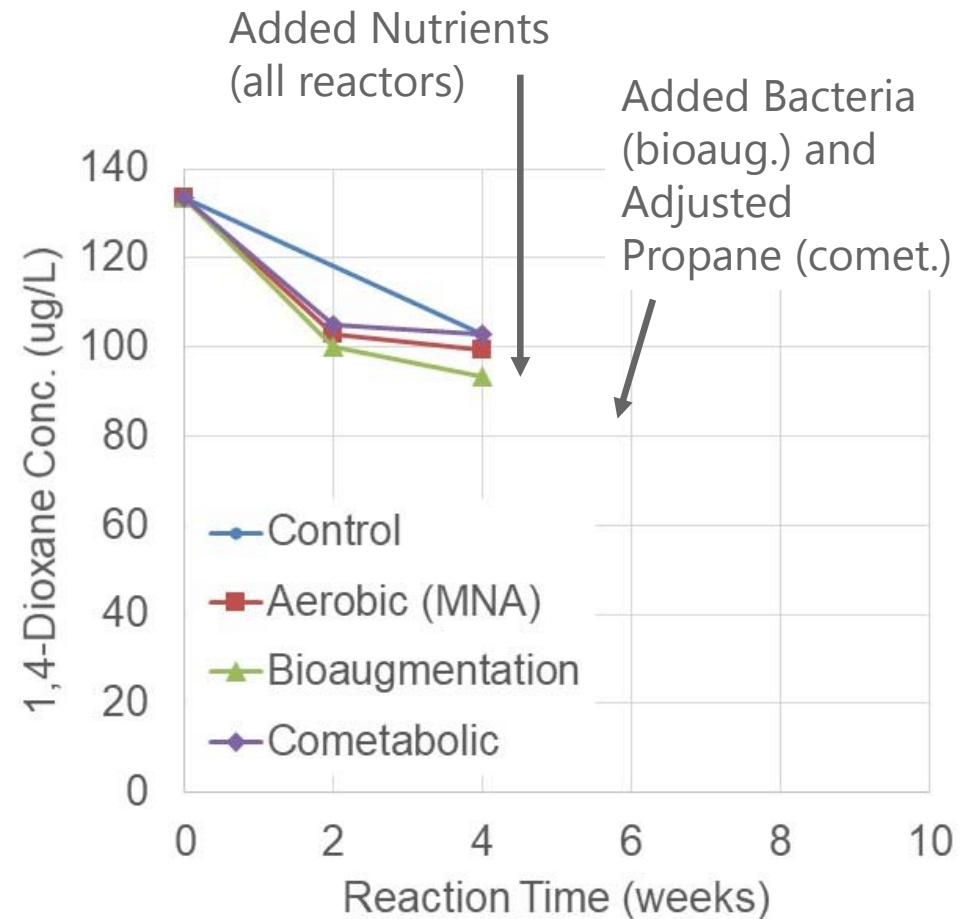


# Bioremediation Bench Test

- Aerobic (MNA), Bioaugmentation, Cometabolic w/ propane, Sterile Control
- Test ongoing



Photo by SiREM



Analytical by Pace



# Summary and Conclusions

- 1,4-Dioxane successfully treated by ozone as Interim Measure
- Ozone also effective for co-contaminants
- Final remedy pending
  - Bioremediation and MNA evaluations
  - Longer-term ozone data record





Fritz Krembs, P.E., P.G.

[fkrembs@trihydro.com](mailto:fkrembs@trihydro.com)

QUESTIONS?

