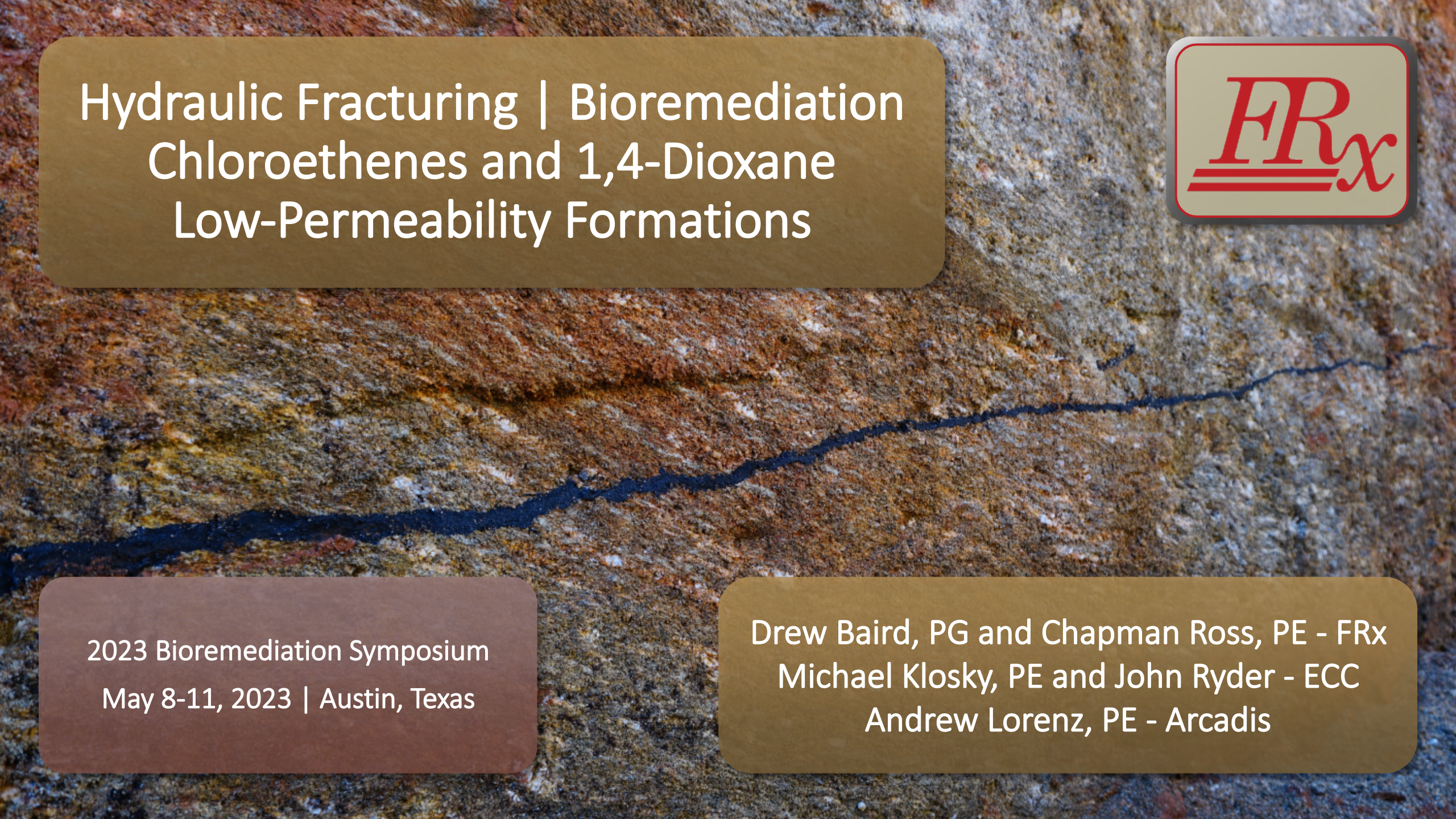
Hydraulic Fracturing | Bioremediation Chloroethenes and 1,4-Dioxane Low-Permeability Formations



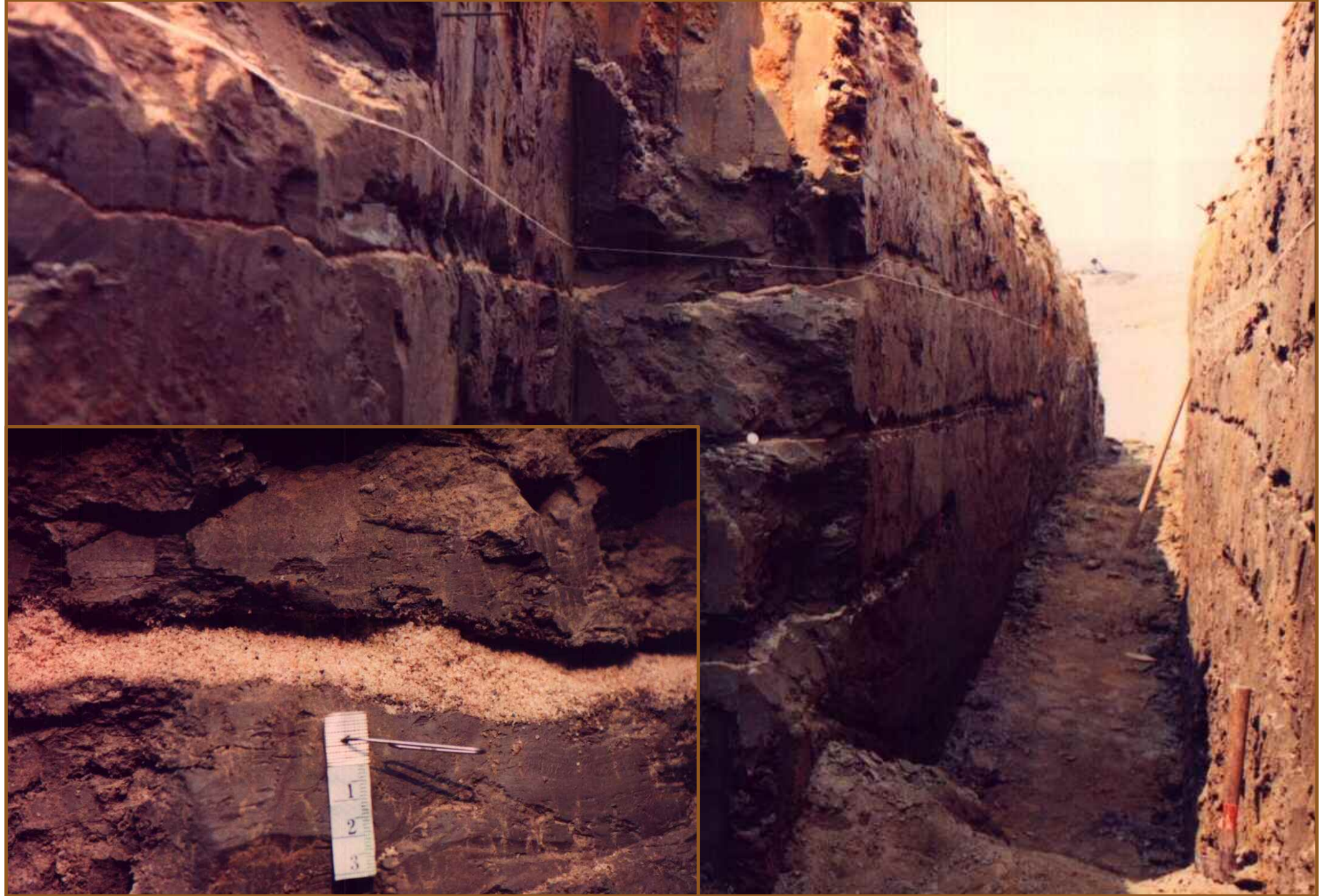
2023 Bioremediation Symposium

May 8-11, 2023 | Austin, Texas

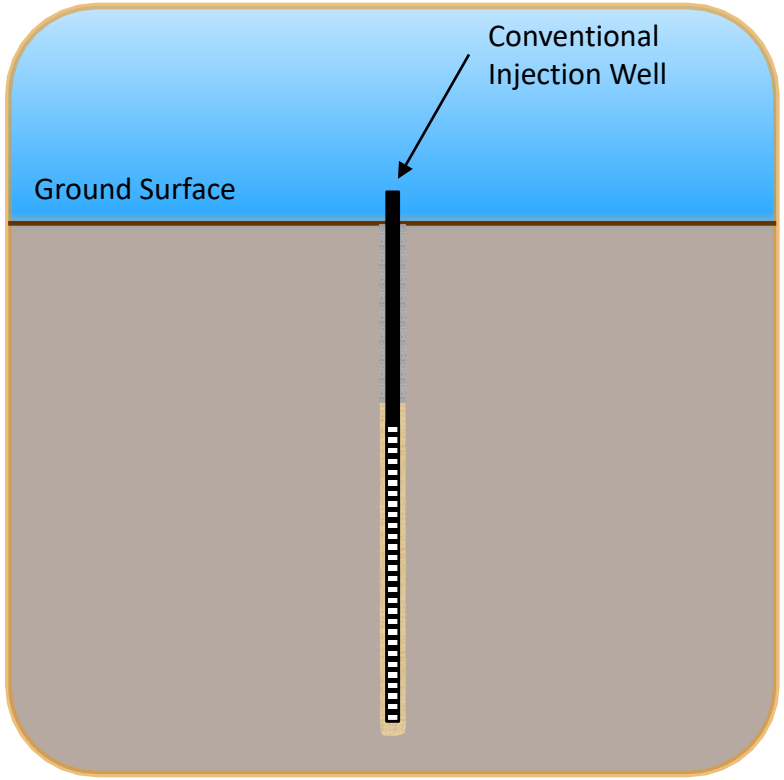
Drew Baird, PG and Chapman Ross, PE - FRx
Michael Klosky, PE and John Ryder - ECC
Andrew Lorenz, PE - Arcadis

Fractures to Enhance Flow & Distribution

- Fracture Form
- Enhanced Flow Concept
- Case Studies
  - Electron Donor Injections | CVOCs | Residuum & Weathered Shale
  - Biosparging | 1,4-Dioxane | Weathered Sandstone
- Conclusions



Fractures for Enhanced Flow & Distribution

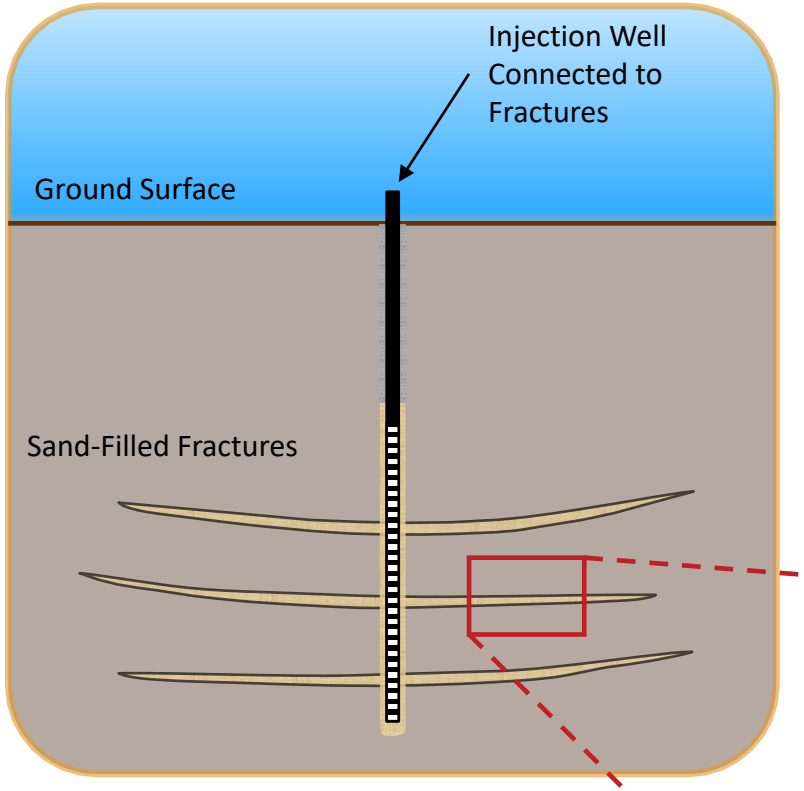


Conventional Well

- 2-inch diameter, 8-inch borehole
- 10-foot screen
- 12-foot sand filter pack
- Approximate 25 ft^2 surface **area**

$$Q = -KA\frac{dh}{dl}$$

Fractures for Enhanced Flow & Distribution



Fracture-Connected Well

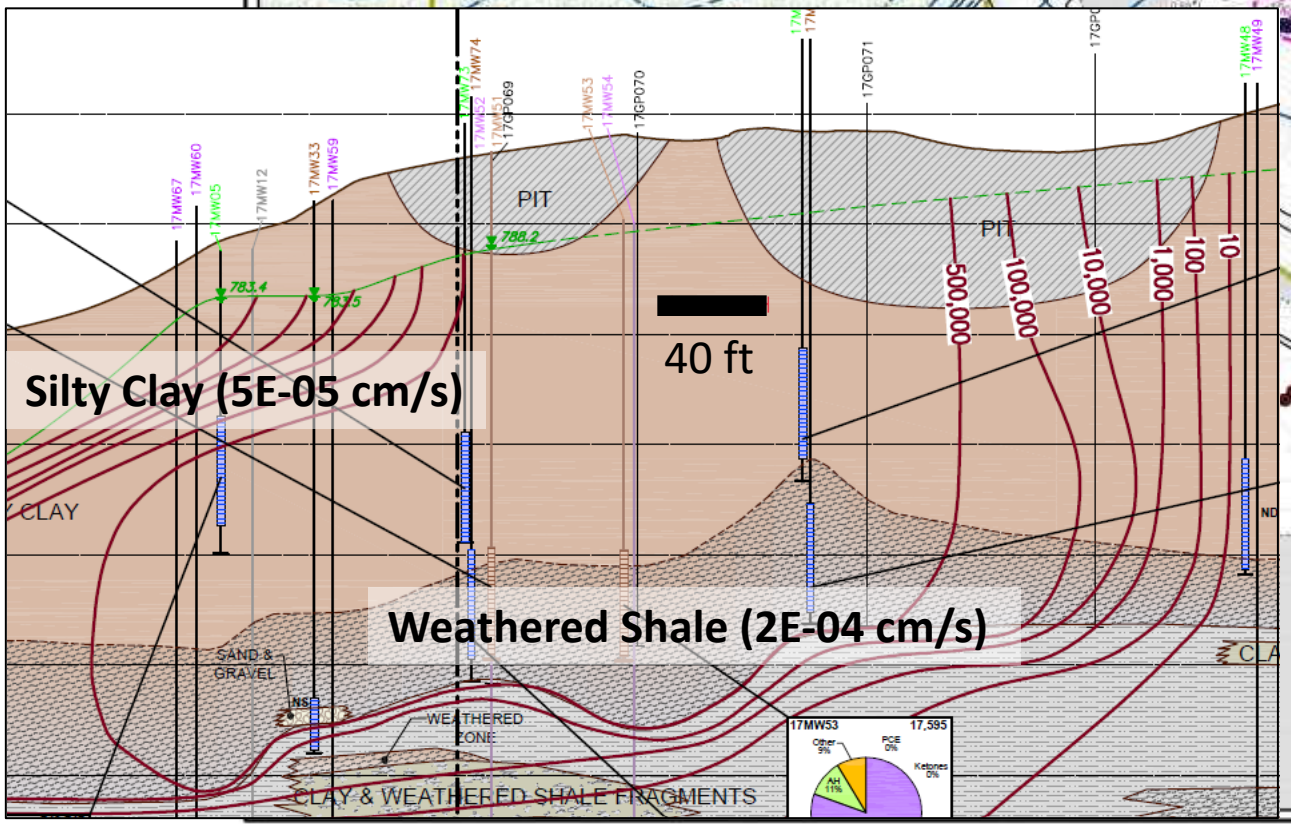
- ≤ 1-inch diameter, 2.3-inch borehole
- Sand-filled fracture, 15-ft radius
- Upper & lower bounding surfaces
- ≈1,400 ft^2 surface **area**, each fracture

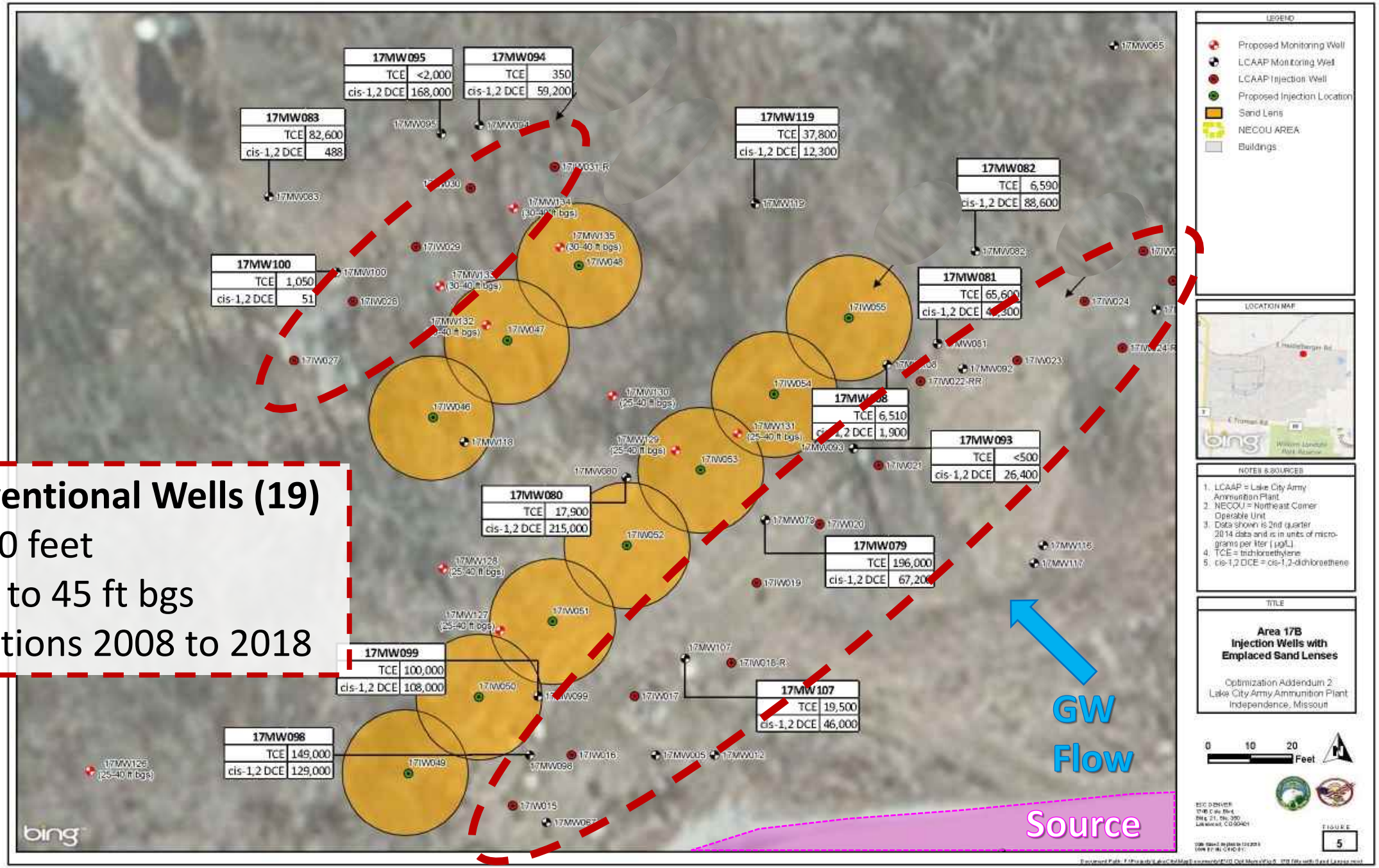
$$Q = -KA\frac{dh}{dl}$$

Case Study: Lake City Army Ammunition Plant

Electron Donor Injections for CVOCs

Area 17B: Oil & Solvent Waste Pits





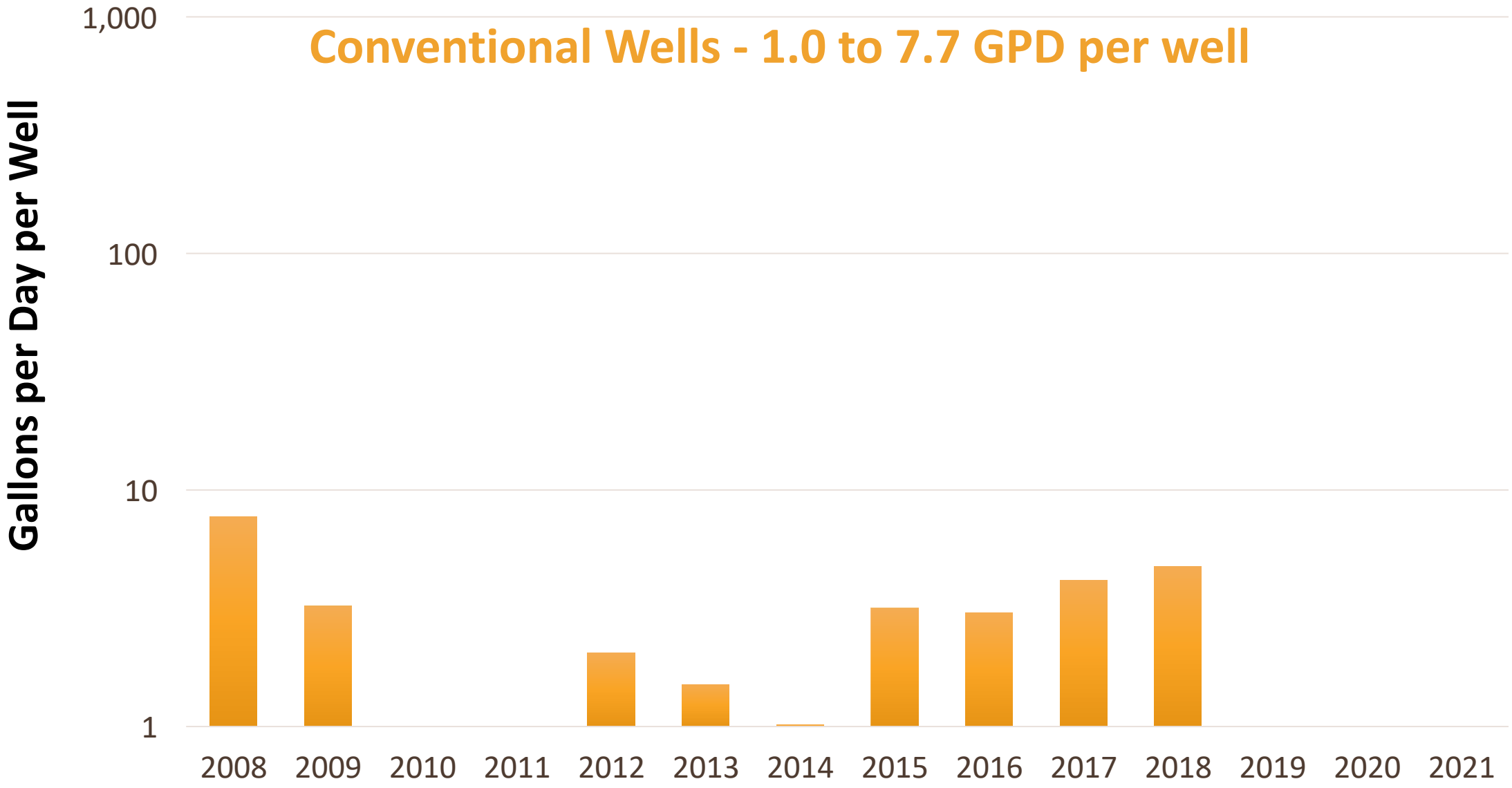
2007: Conventional Wells (19)

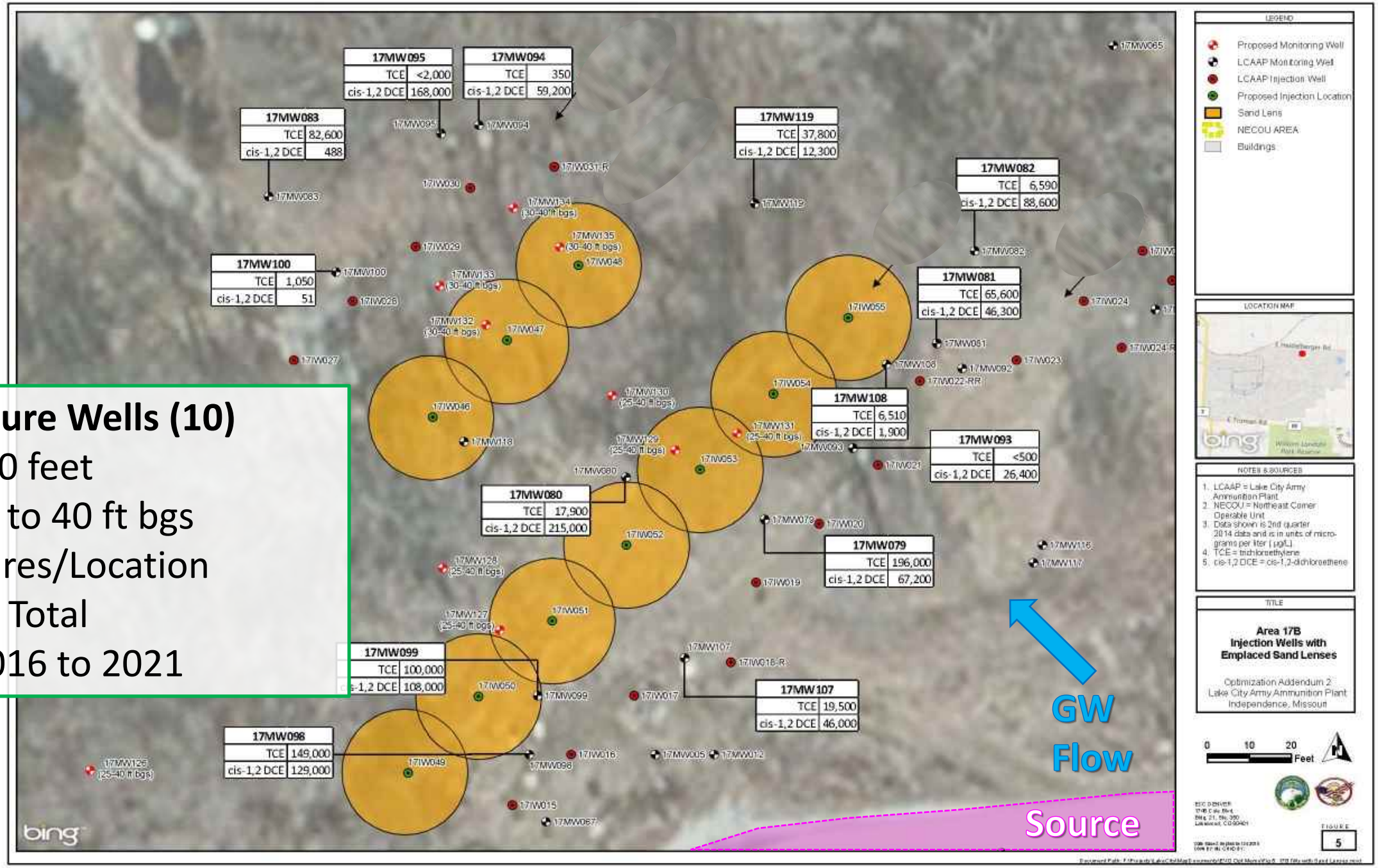
Spanning 340 feet

Targeting 28 to 45 ft bgs

Gravity Injections 2008 to 2018

Normalized Flow in One Row of Injection Wells





2015: Fracture Wells (10)

Spanning 260 feet

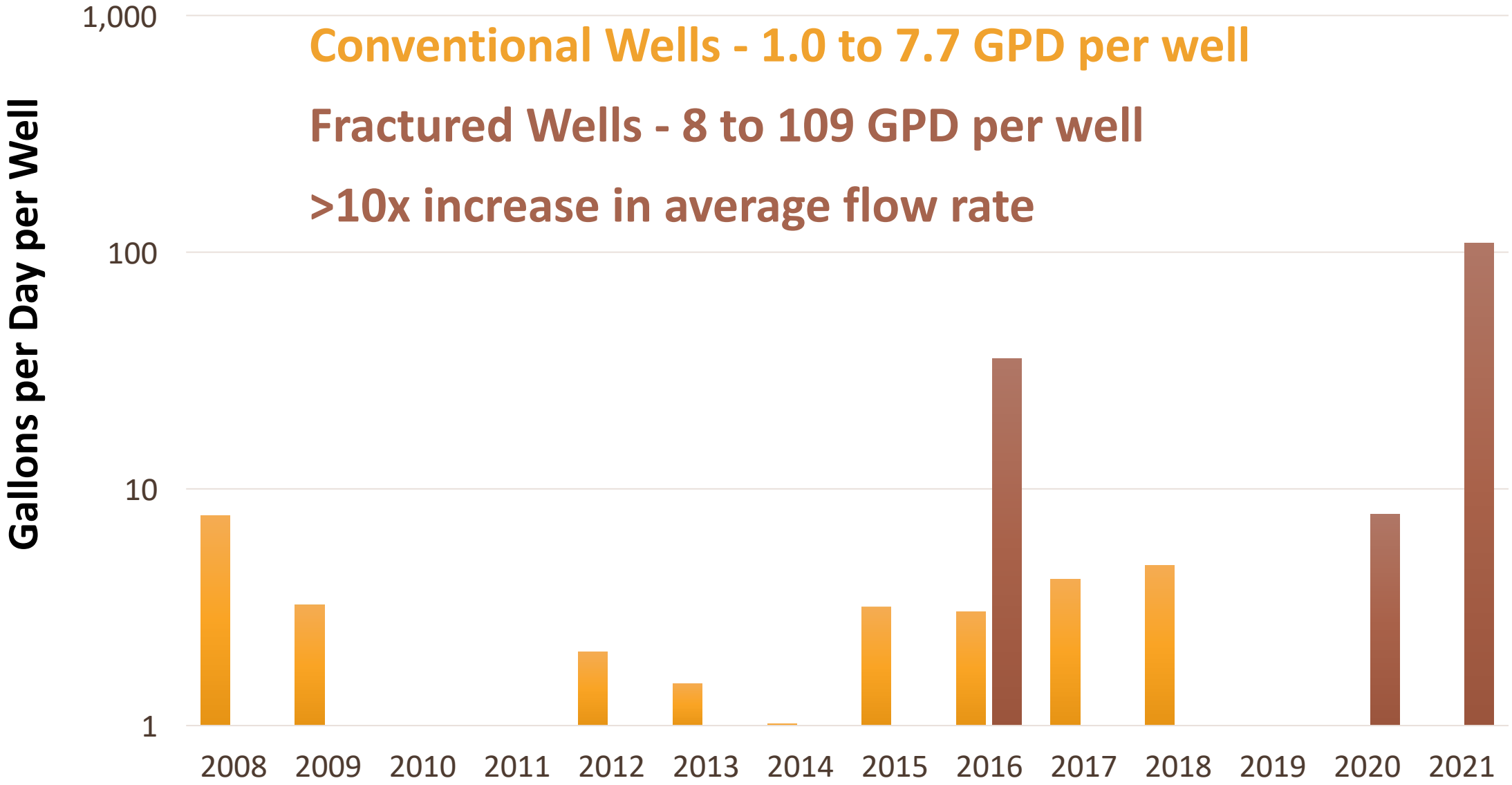
Targeting 25 to 40 ft bgs

3 to 4 Fractures/Location

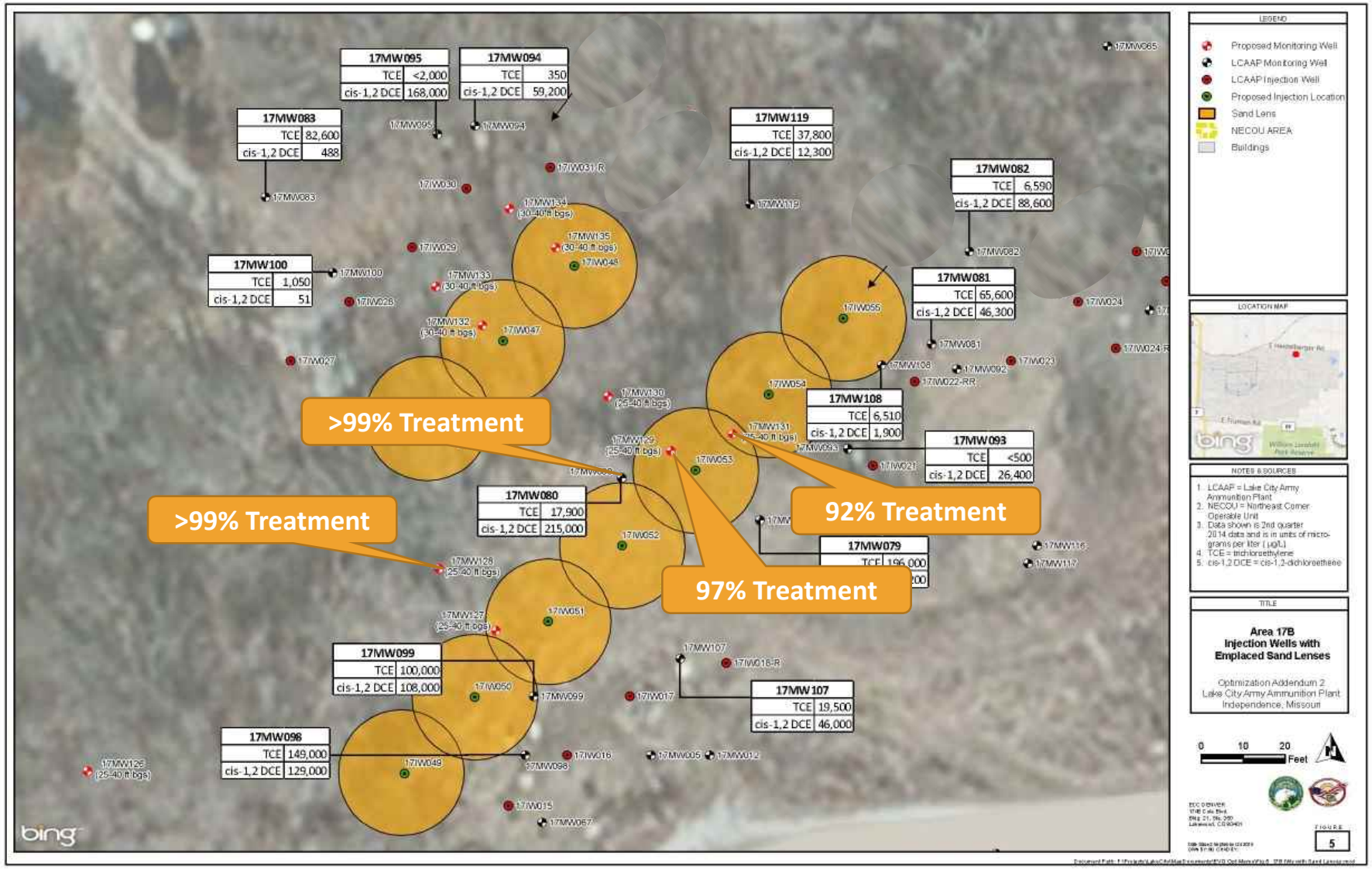
37 Fractures Total

Injections 2016 to 2021

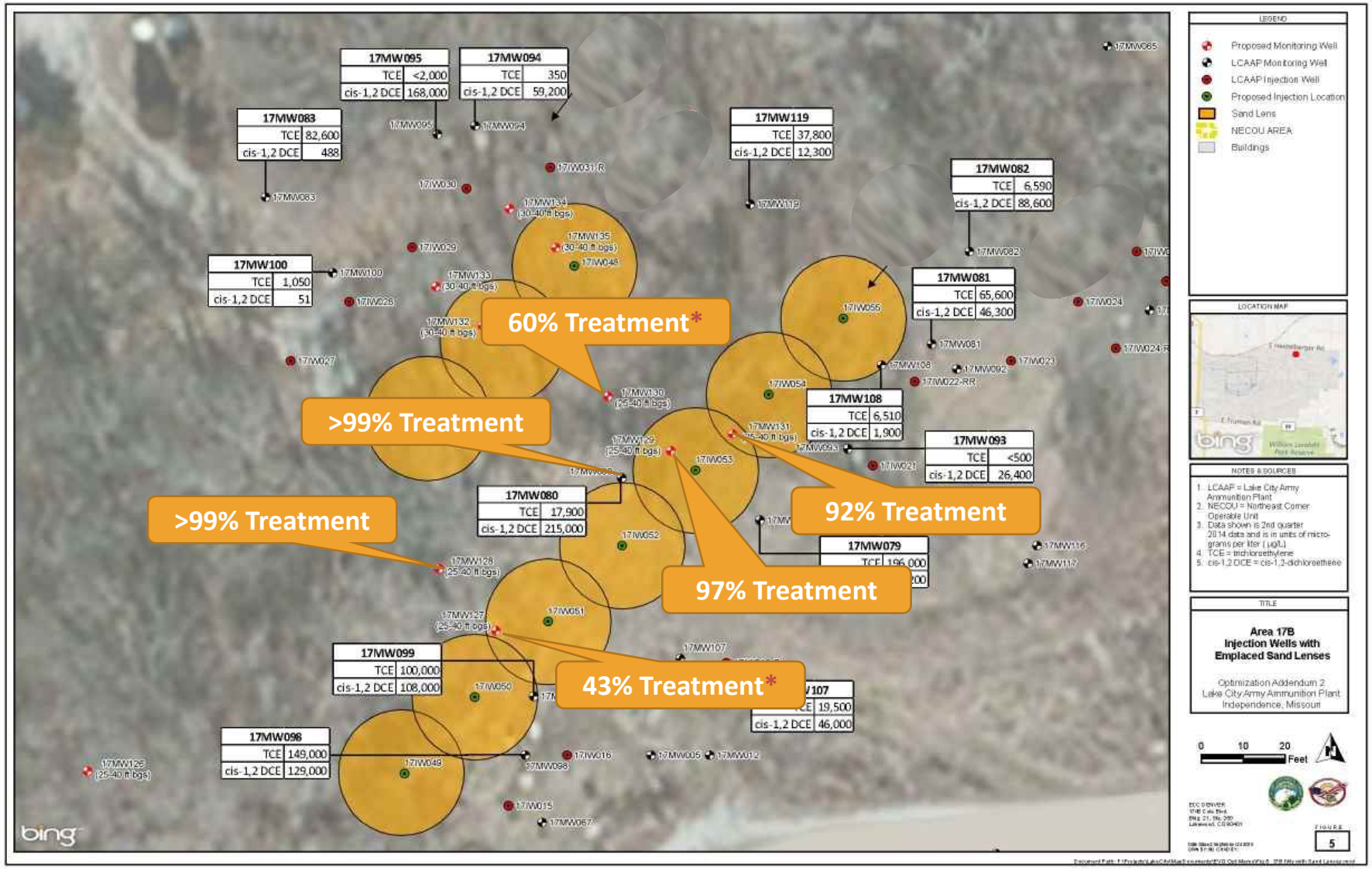
Normalized Flow in One Row of Injection Wells



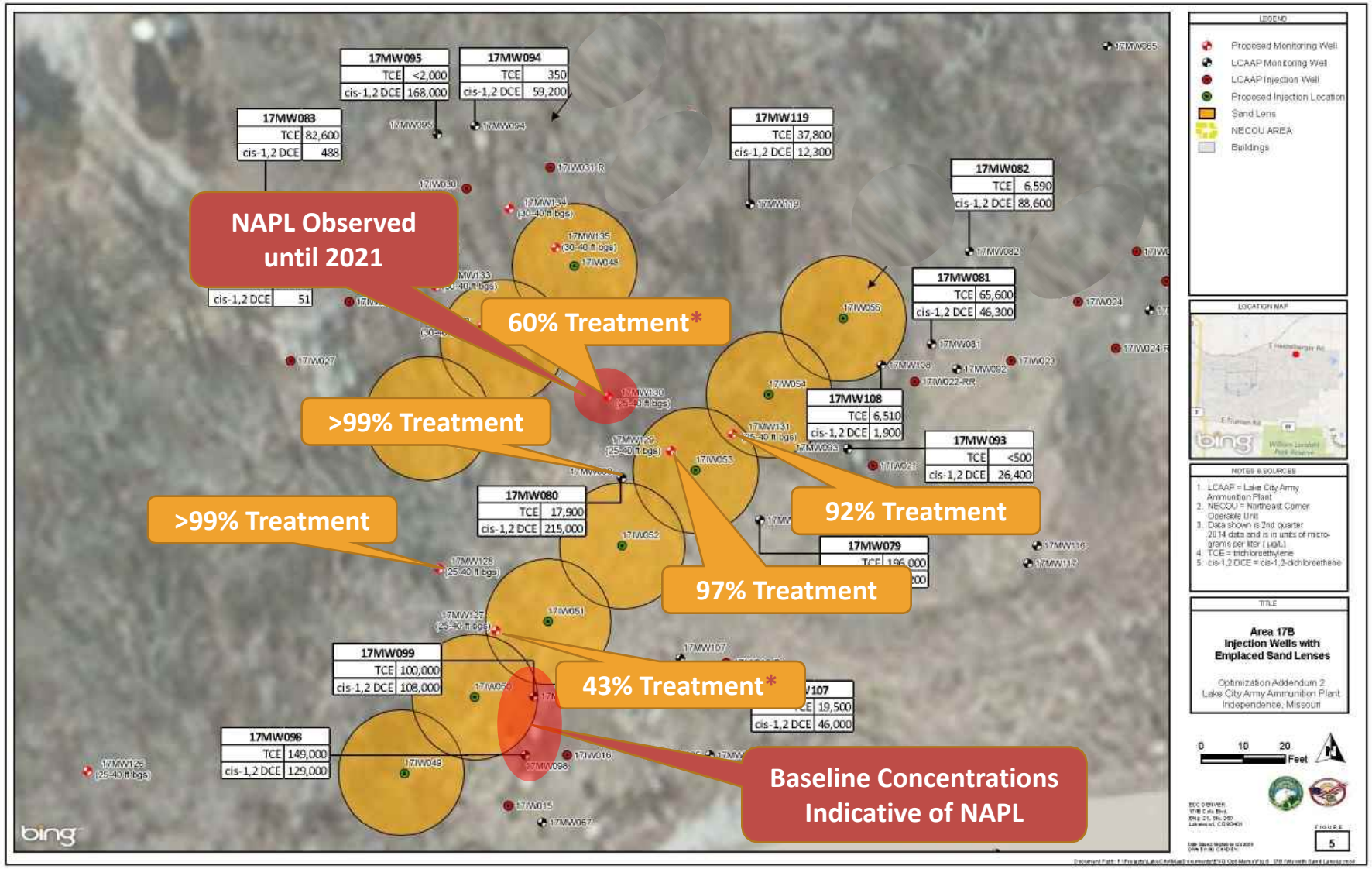
Total Chloroethenes in Groundwater



Total Chloroethenes in Groundwater



Total Chloroethenes in Groundwater

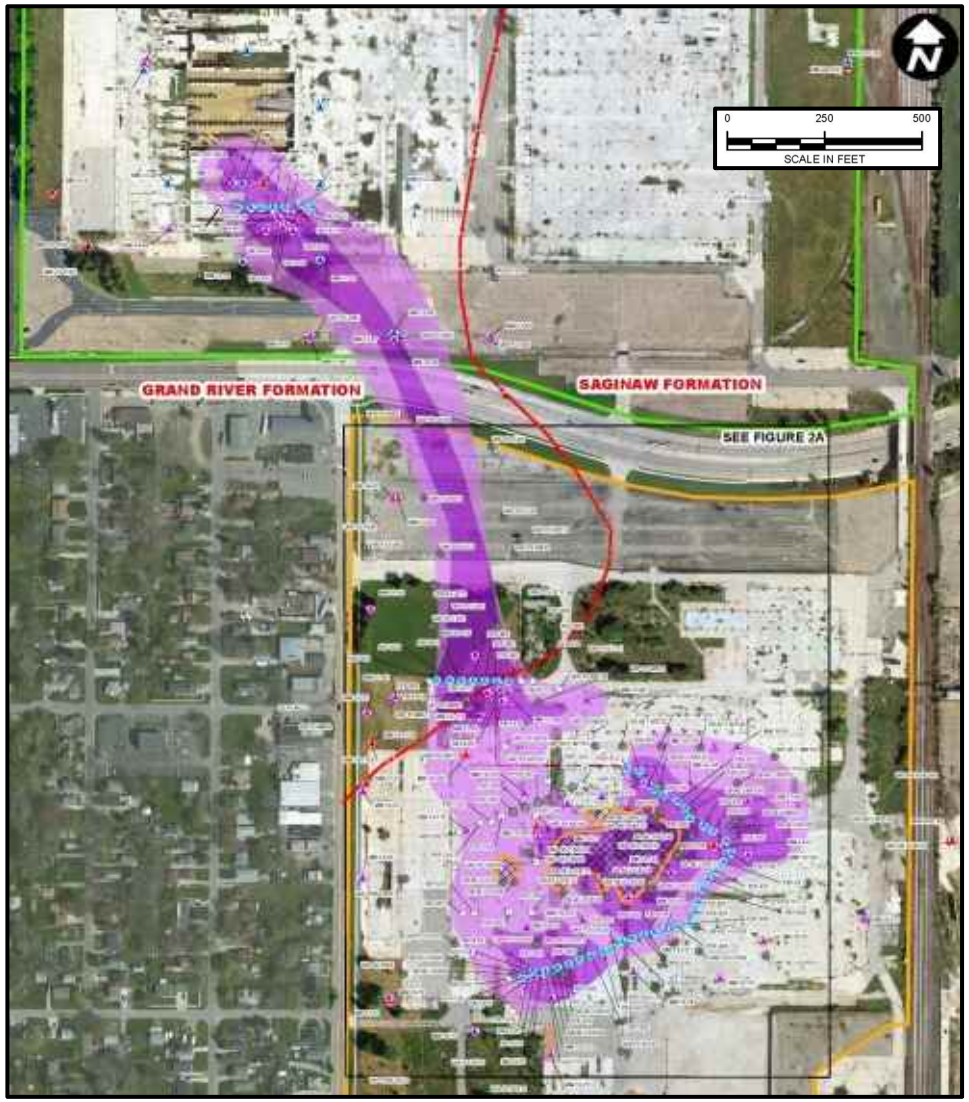


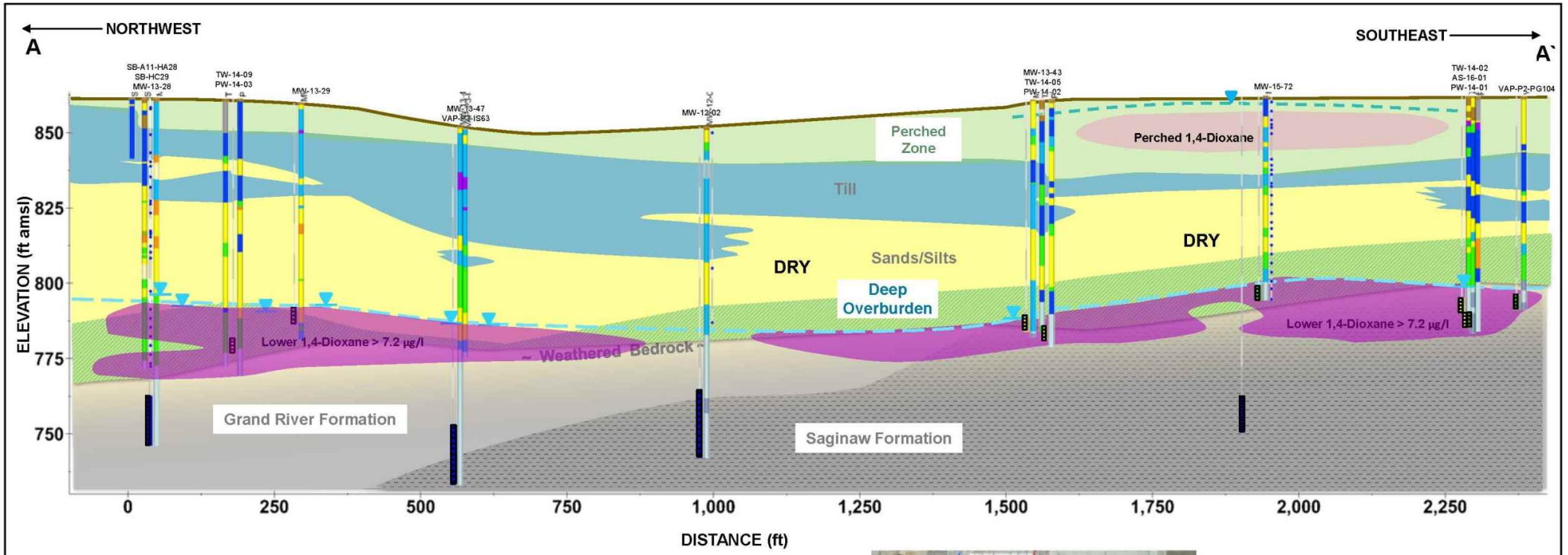
Case Study: Former Auto Manufacturing Facility, Michigan

Biosparging for 1,4-Dioxane

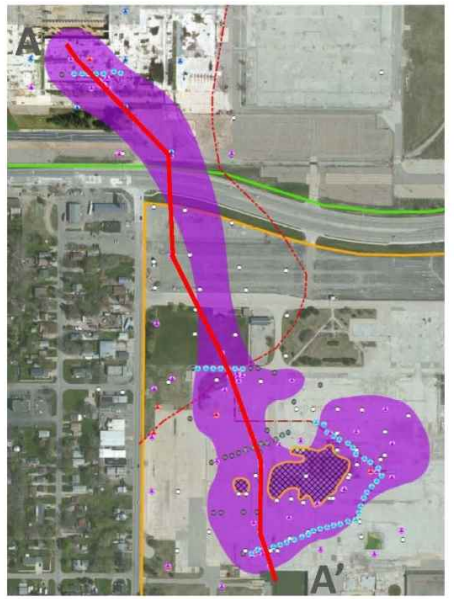
Michigan Site Setting

- Former automobile manufacturing
- 1,4-Dioxane associated with 1,1,1-TCA used as degreasing solvent
- Remedial goal: Prevent 1,4-DX plume migration offsite





- Glacial deposits overlying sedimentary BR
  - Grand River: Fine-medium grained sandstone
  - Saginaw: Fine-grained sandstone w/ shale lenses
- 1,4-Dioxane transport primarily through weathered sedimentary bedrock
- Variable target depth - 55 to 100 feet bgs



V.E. = 5x

LOWER 1,4-DIOXANE PLUME
CROSS SECTION
NORTH - SOUTH

ARCADIS Design & Consultancy for natural and built assets

FIGURE
4

Developing Remedial Approach: Propane Biosparging

Air Sparge Field Pilot → Lab Treatability → Biosparge Field Pilots

Determine ROI & Well Spacing

Demonstrate Cometabolism

Vet Design & Assess Field Treatment

Comparison of Field Pilot Results

Pilot test in 2016 using conventional wells did not achieve distribution goals. Fracturing completed in 2017 achieved 15-foot fracture radius and enhanced sparging performance.

	2016 Field Pilot		2018 Field Pilot
Well Construction	Conventional		Fracture Enhanced
Sparge ROI	5 to 15 feet		15 feet
Wellhead Pressure	20 to 30 psi		6 to 10 psi
Flow Rate	2 scfm	VS	5 scfm
Sparge Operation Time	50%		25%
Propane Use	205 lbs		59 lbs

Fracturing Provided	
Larger ROI	Better Performance
Lower injection pressures	
Higher flow rates	
Decreased sparge frequency	Lower Operating Cost
Less propane usage	

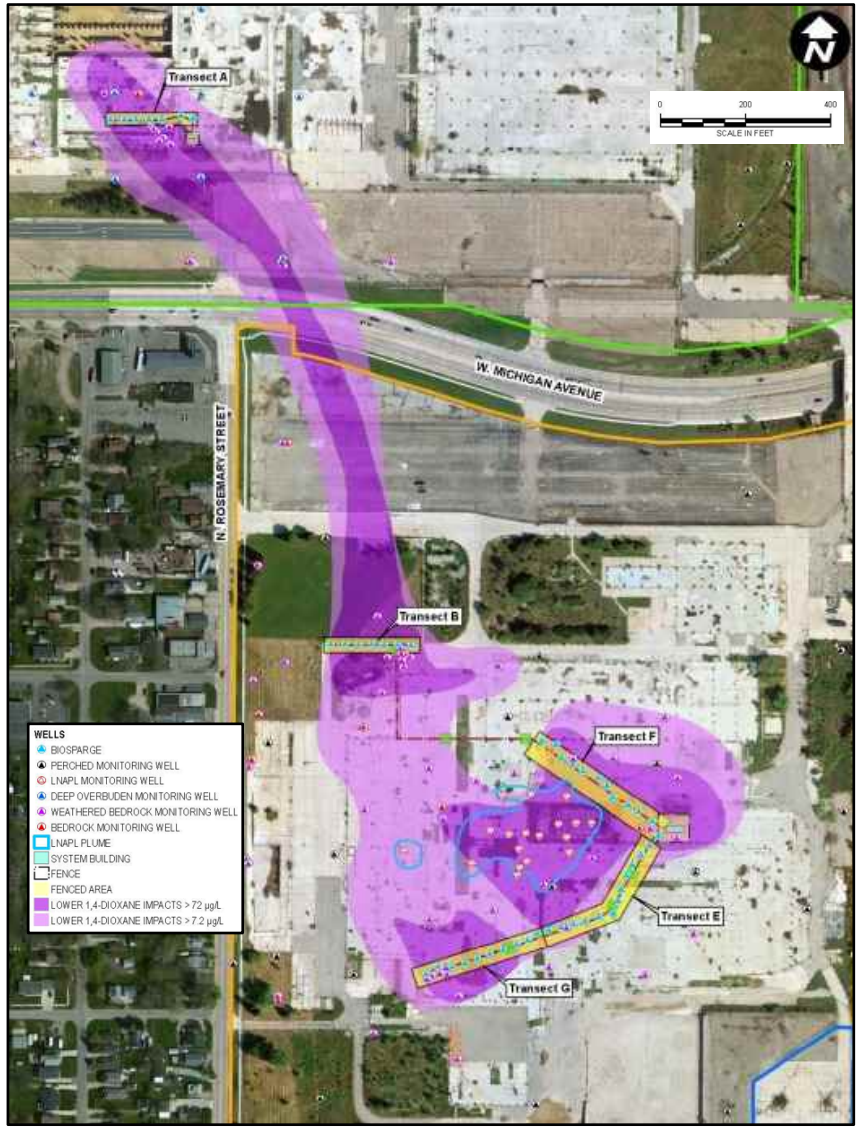
Full Scale Design & Implementation

Five Transects

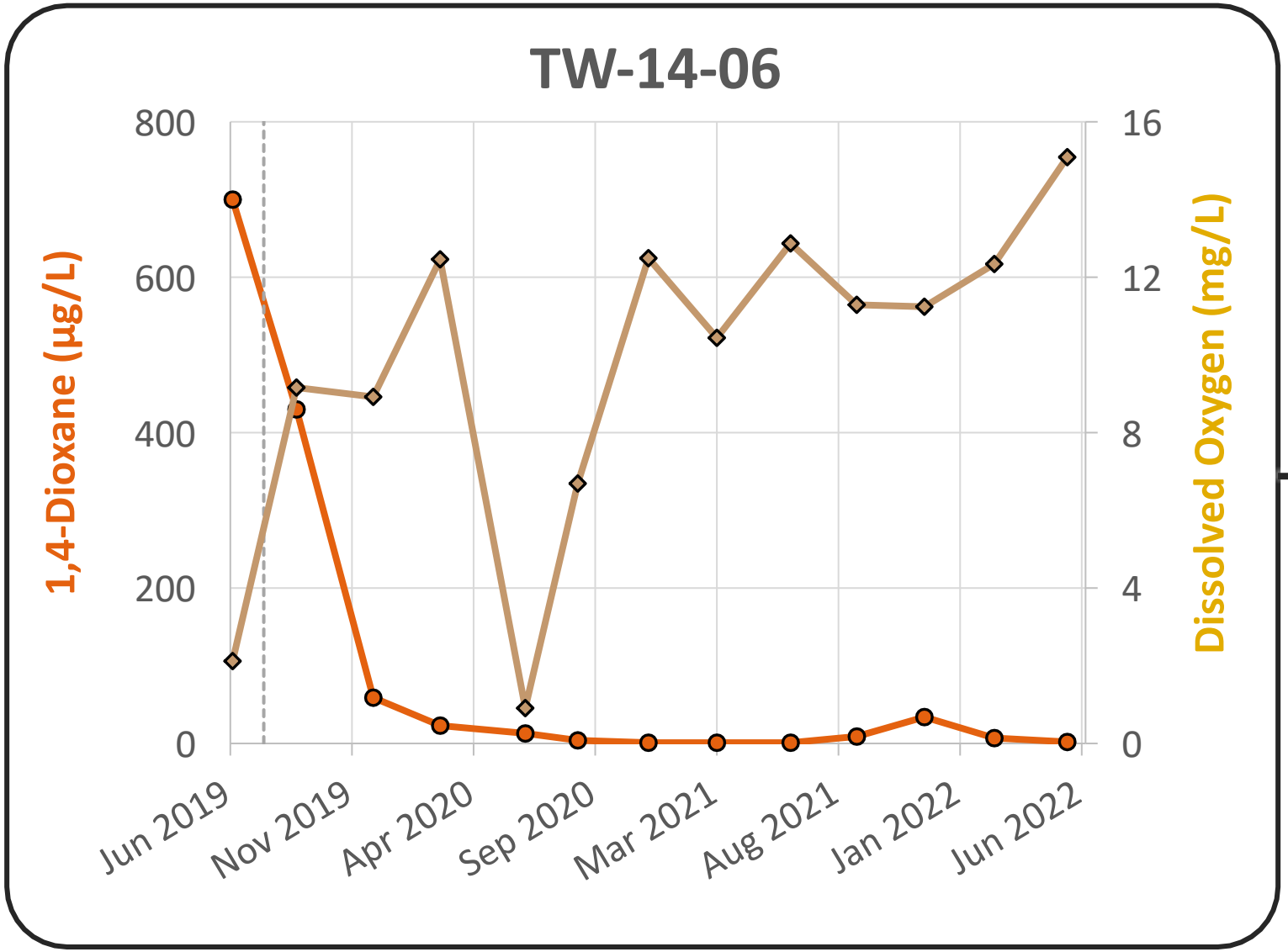
- 48 casings (4-in PVC) on 30-ft centers
- Two sand fractures per location
- Two-inch sparge wells, 5-ft screens

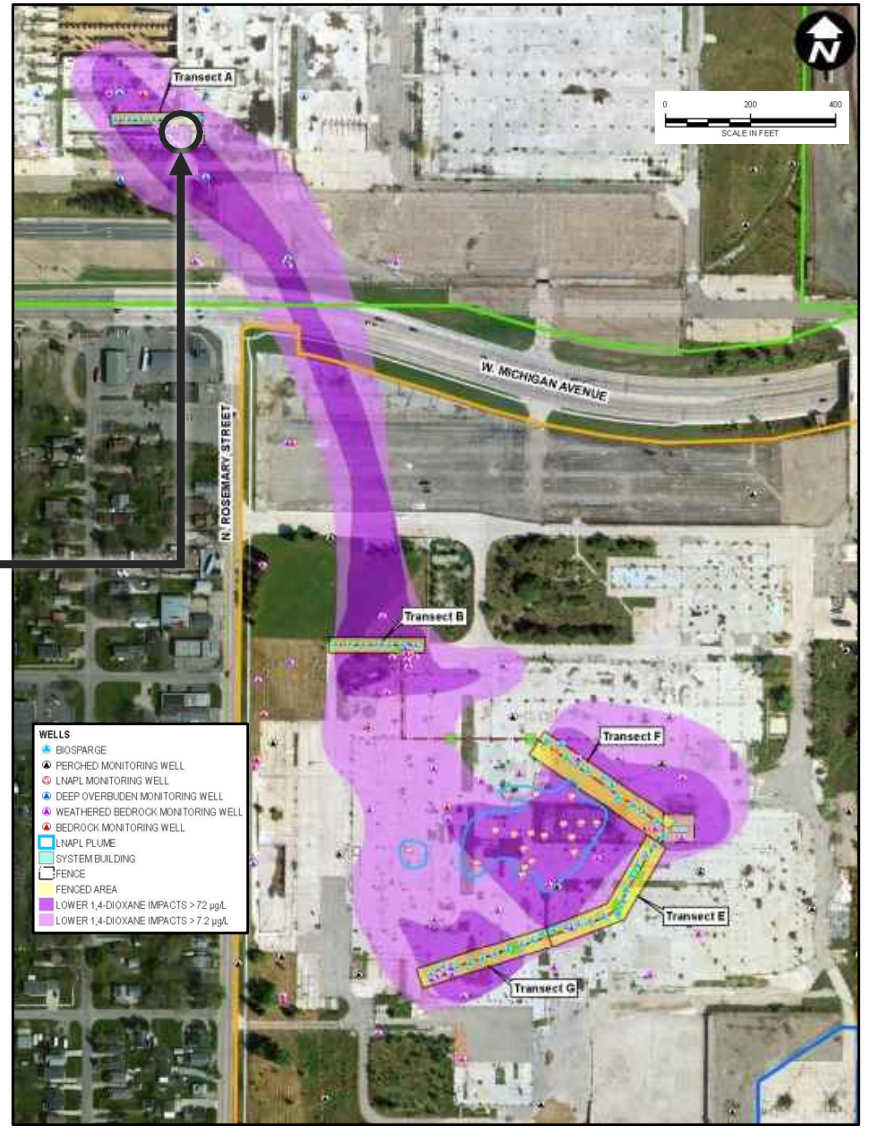
Biosparge System

- Propane, oxygen, nutrients
- Episodic sparging

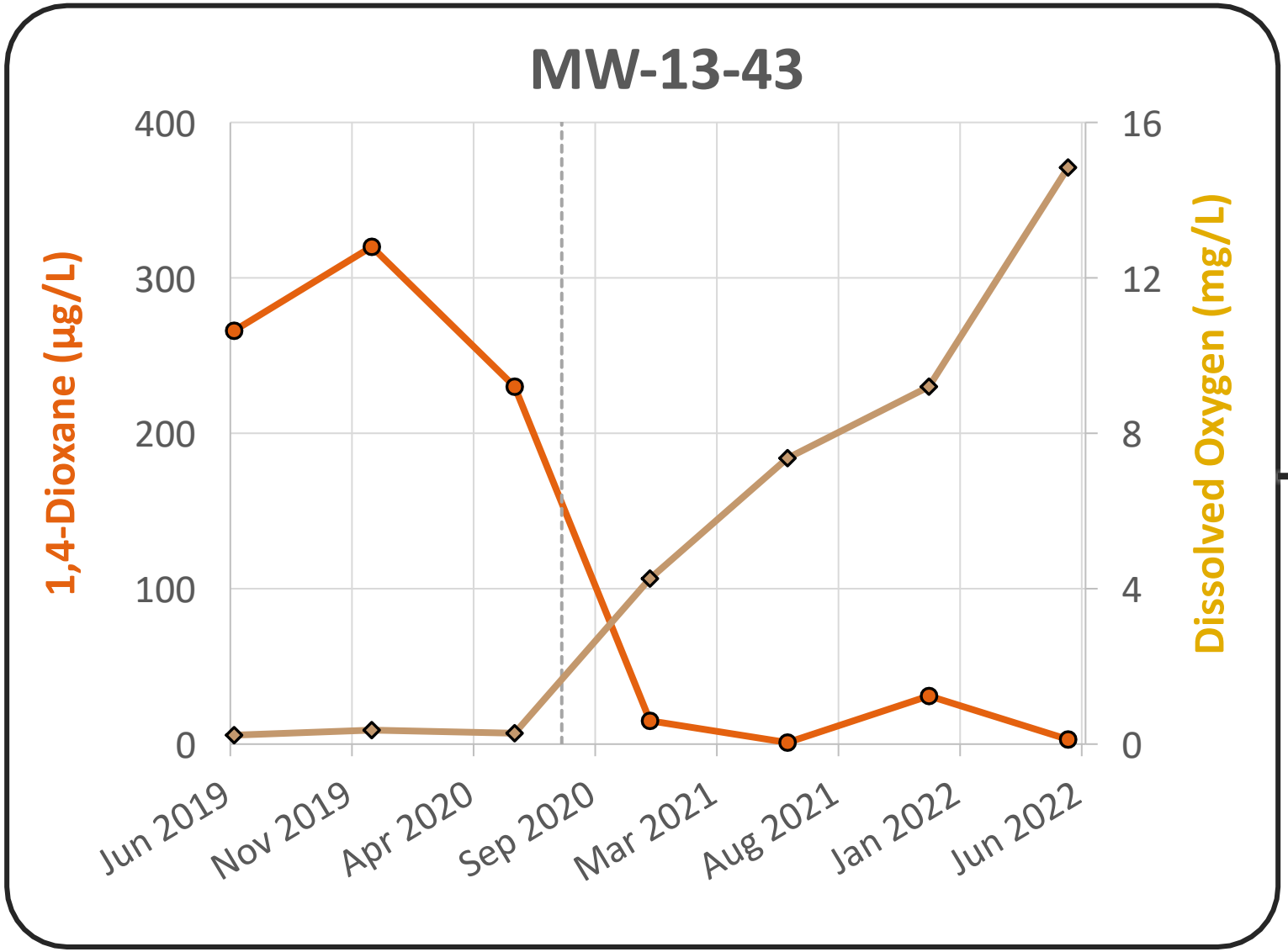


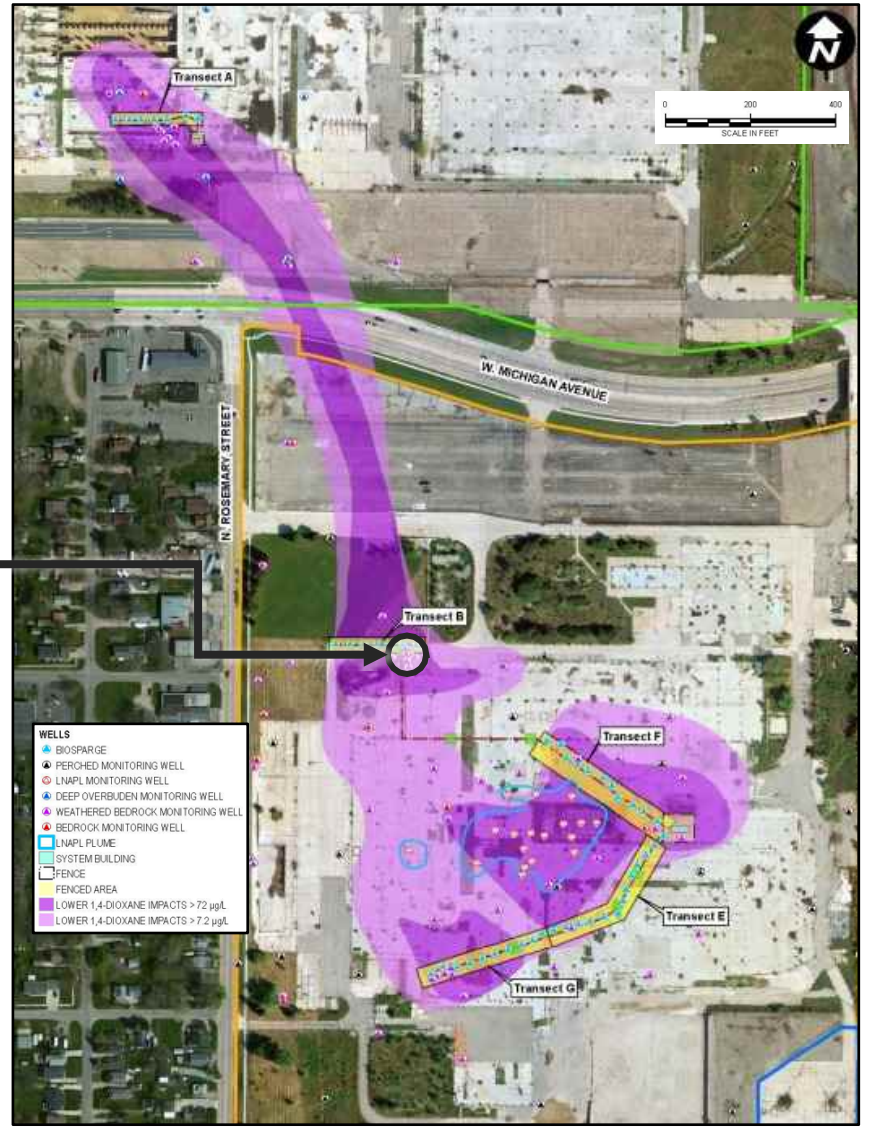
Performance Monitoring Data – Transect A



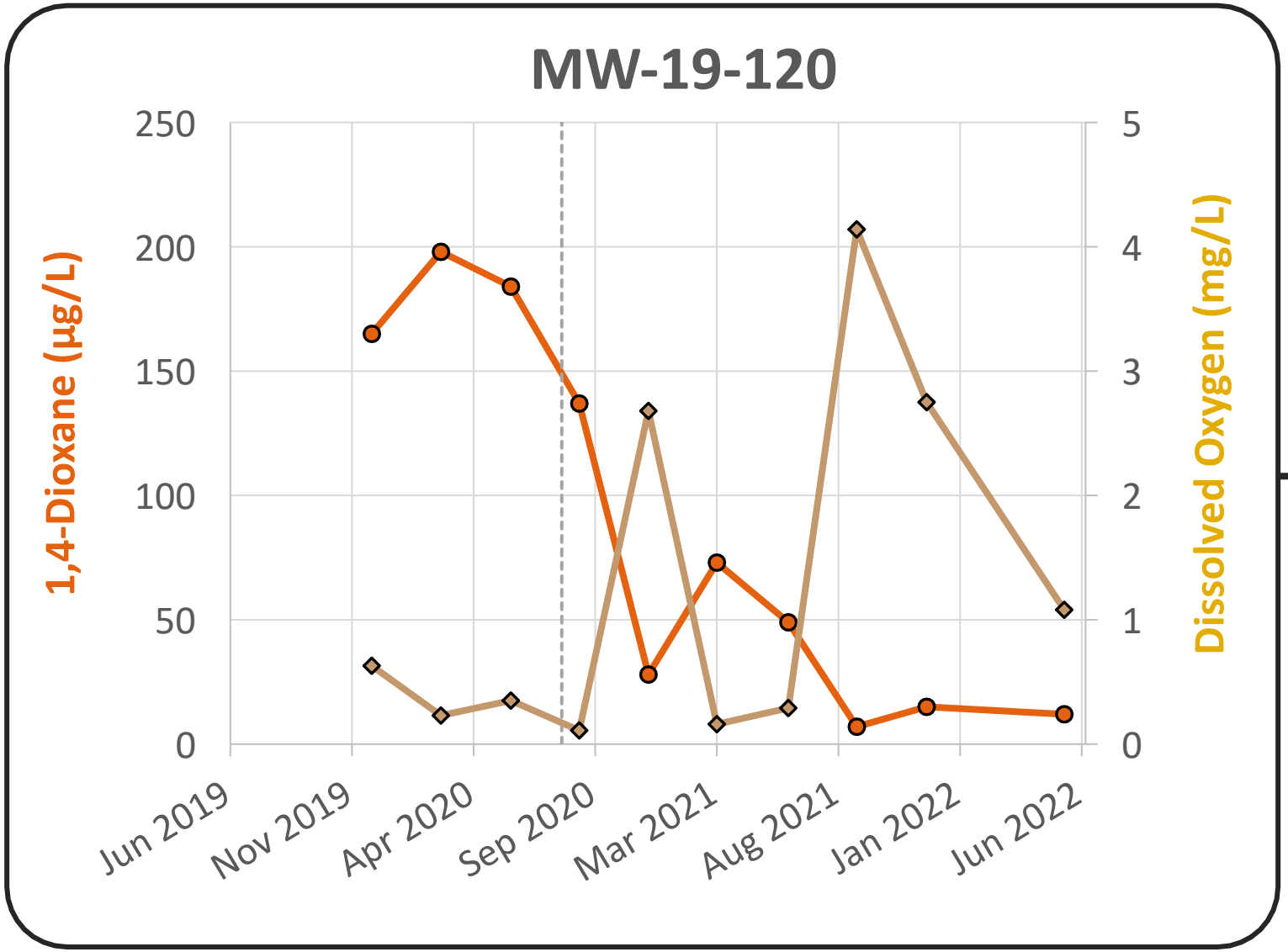


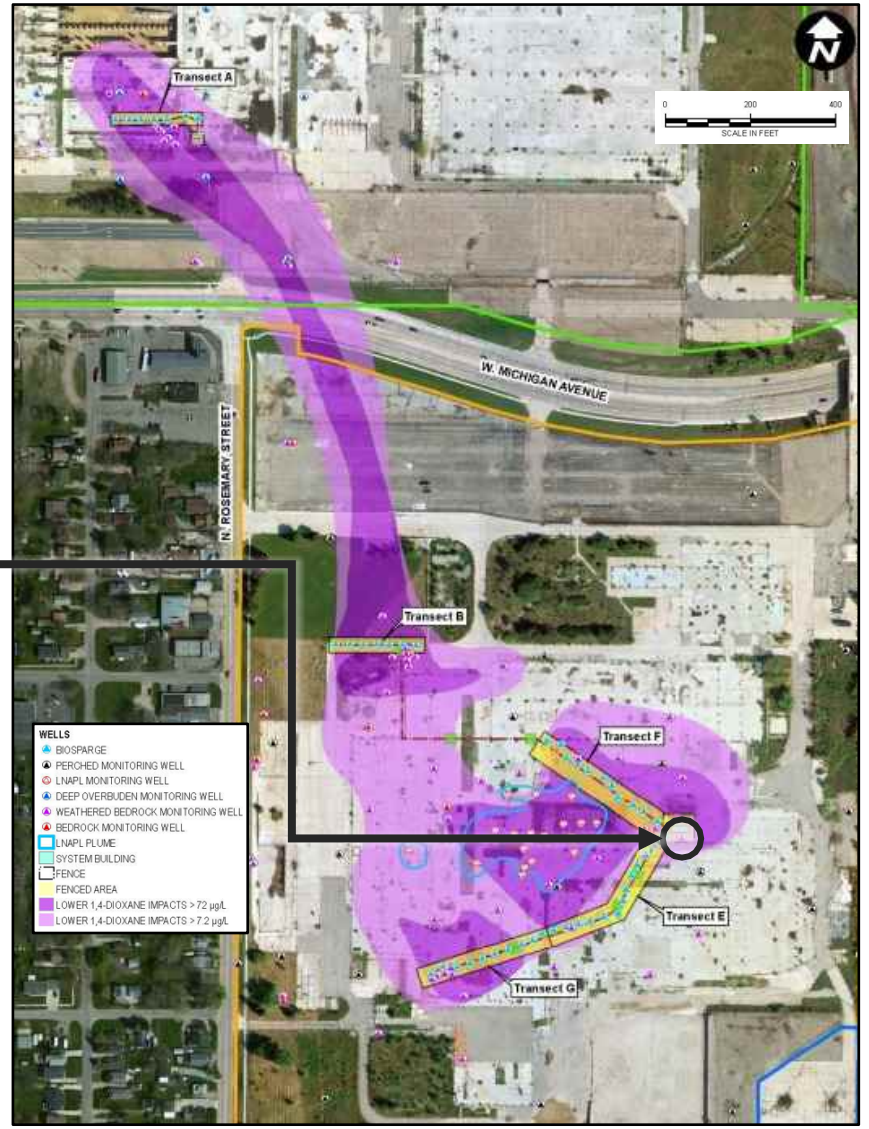
Performance Monitoring Data – Transect B



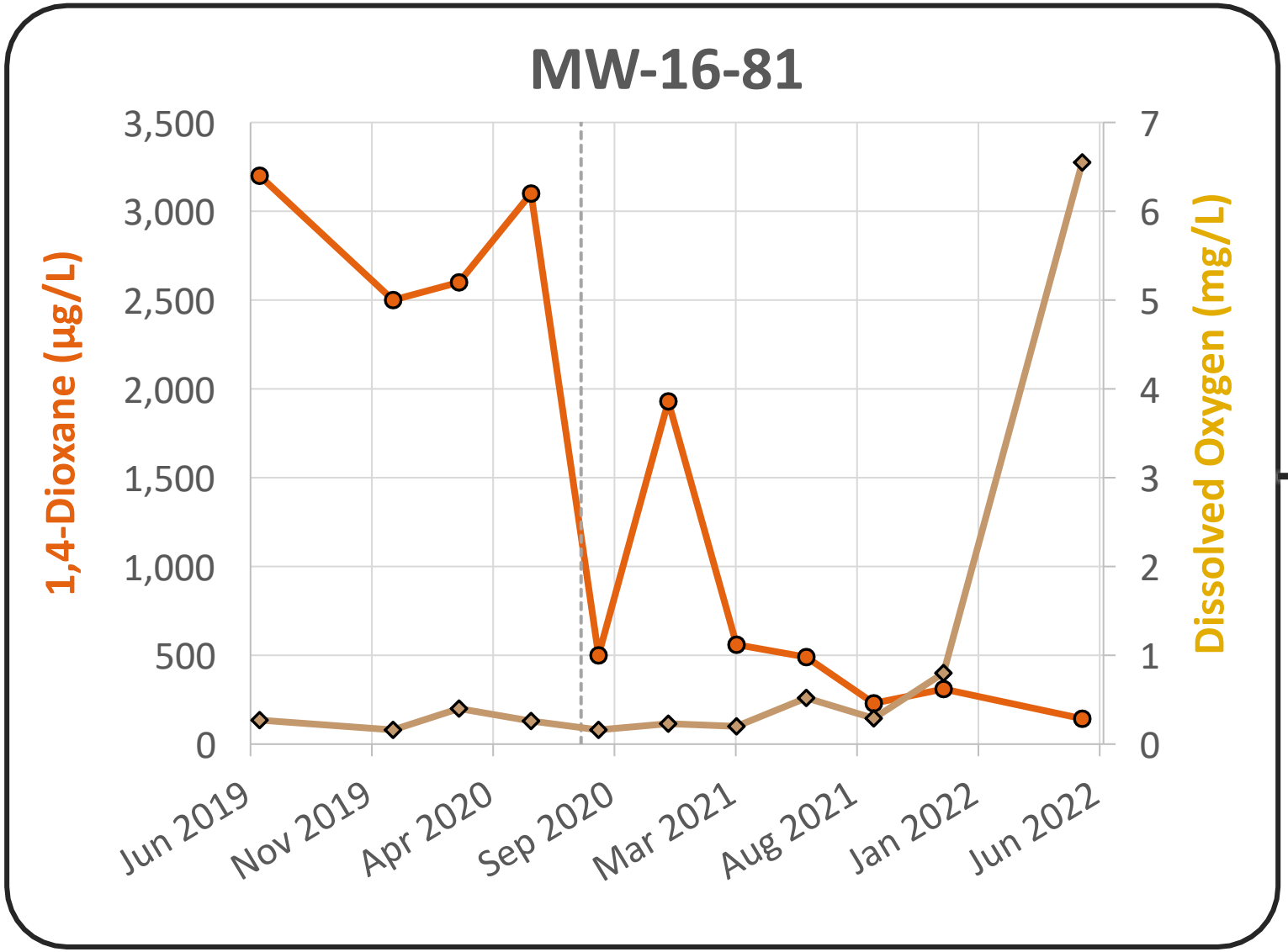


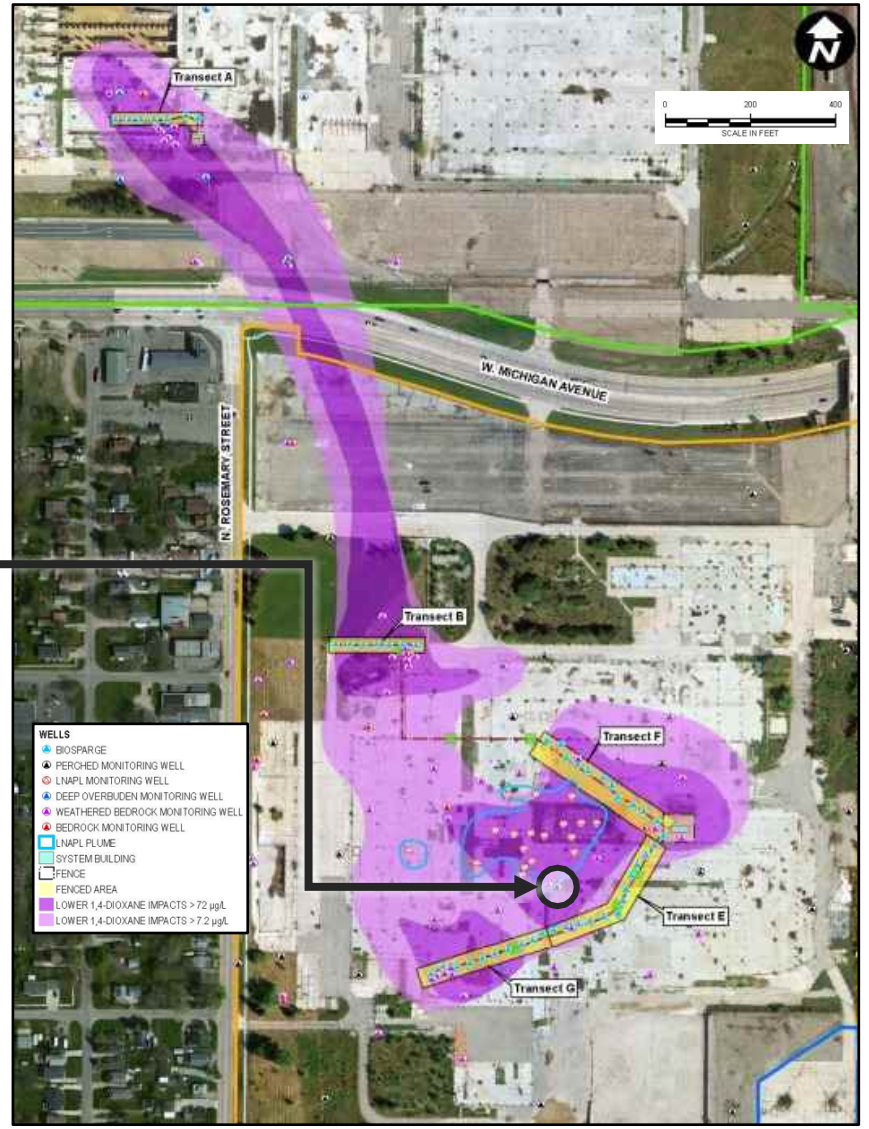
Performance Monitoring Data – Transect F





Performance Monitoring Data – Transect G





Conclusions

- Fractures with predictable form can be reliably created in varied geologic settings
- Fracture-connected wells support varied remedial approaches
- Multiple lines of evidence support utility of fractures in low-permeability settings

Questions?

Groundwater Monitoring&Remediation

Advances in Remediation Solutions

Volume 39, no. 4, Fall 2019

Bioremediation of 1,4-Dioxane: Successful Demonstration of In Situ and Ex Situ Approaches

by John F. Horst, Caitlin H. Bell, Andrew Lorenz, Monica Heintz, Yu Miao, Jackie Saling, David Favero and Shaily Mahendra

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