

Pushing Beyond Limits, Engineered Phytoremediation Provides Cost-Effective, Nature Based, Sustainable Remediation Alternative

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Phytoremediation Applications

- Soil
 - Contaminant degradation
 - Mass removal
 - Stabilization
 - Revegetation
- Groundwater
 - Contaminant degradation / mass removal
 - Hydraulic Control



A photograph of a row of weeping willow trees in a grassy field. The trees are lush green and have long, drooping branches. They are planted in a line, with a grassy area in the foreground and a cloudy sky in the background. The trees are of varying heights, with some being taller and more mature than others. The overall scene is a natural, outdoor setting.

Phytoremediation Mechanisms

- Phytoextraction
- Phytostabilization
- Rhizofiltration
- Rhizodegradation
- Phytodegradation
- Phytovolatilization

Applicable COCs

- Most Soluble COCs
 - Agricultural Inorganics
 - Solubilized Metals
 - VOCs
 - SVOC
- PFAS



Limitations to “Typical” Phytoremediation Approach

- Shallow soil and groundwater
 - 10 – 15 ft bgs
- Adverse groundwater/soil chemistry & conditions
- Contamination underlying clean groundwater
- Contaminant concentrations
 - Avoid potential phytotoxic effects



Recent Advances

- Development of salt and metals tolerant tree species
- Addition of endophytes
- Incorporating agronomic properties into CSM
- Alternative planting methods

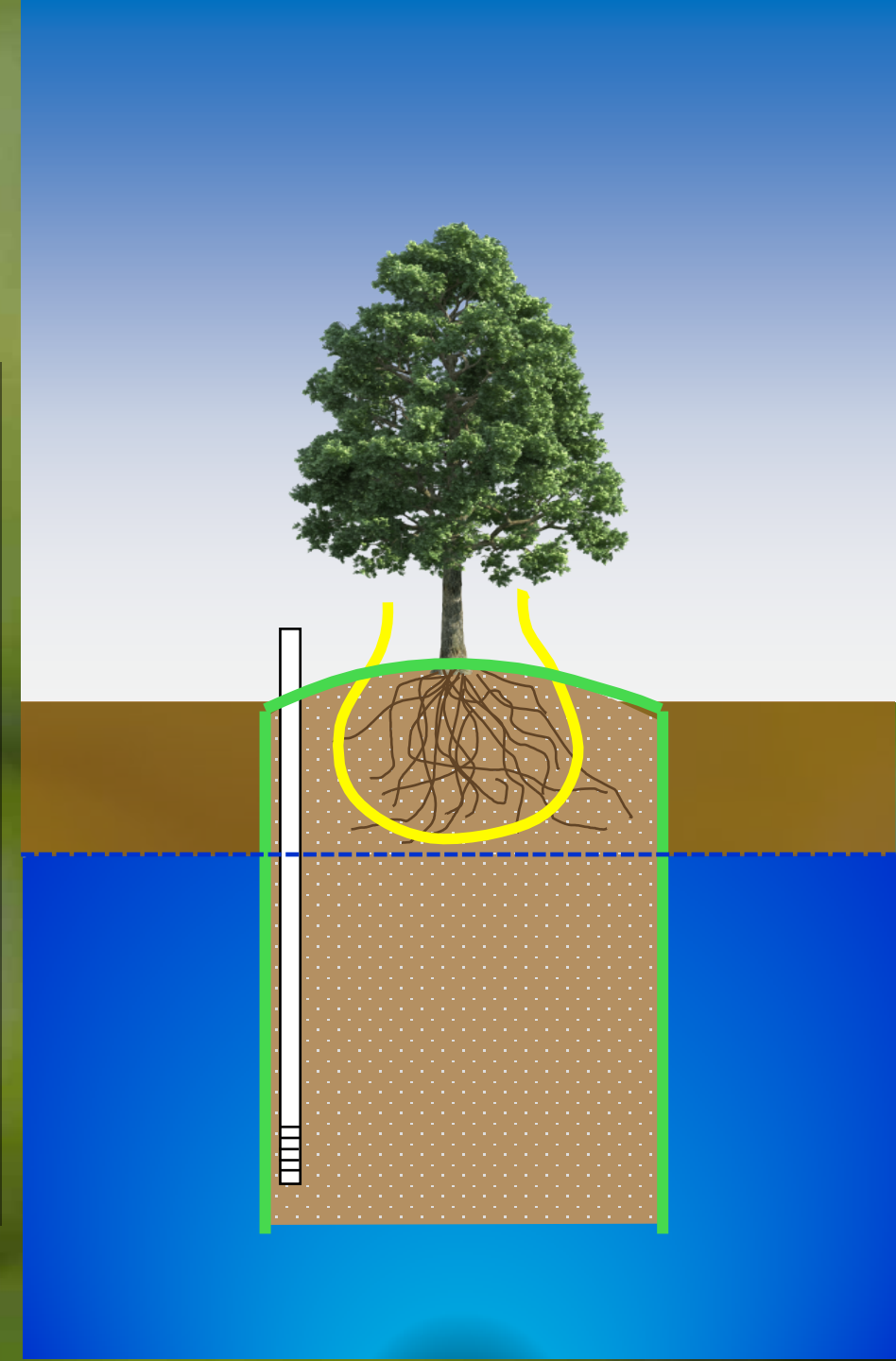
TreeWell® - Based Phytoremediation

What is different?

- Control plant water consumption and encourage deep rooting
- Target specific remediation depth – COCs underlying clean groundwater
- Access deep (up to 115 ft bgs to date) & fractured rock aquifers
- Remediate normally phytotoxic concentrations
- Integrate with other remedial technologies to capitalize on synergies
- Utilize trees as solar powered pumps, “bioreactor” effect
- Limit or eliminate need for irrigation

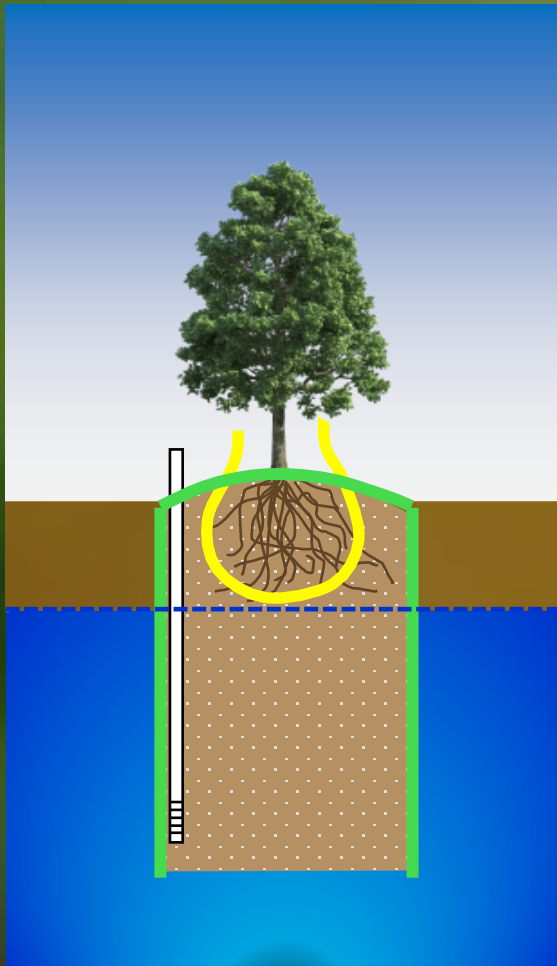
TreeWell Technologies

- Tree acts as solar pump
- Groundwater is drawn upward through soil column
- Hydraulic Control
- Bioreactor Effect – *in-situ* biodegradation of organic COCs
- Rhizodegradation
- Phytodegradation
- Phytovolatilization

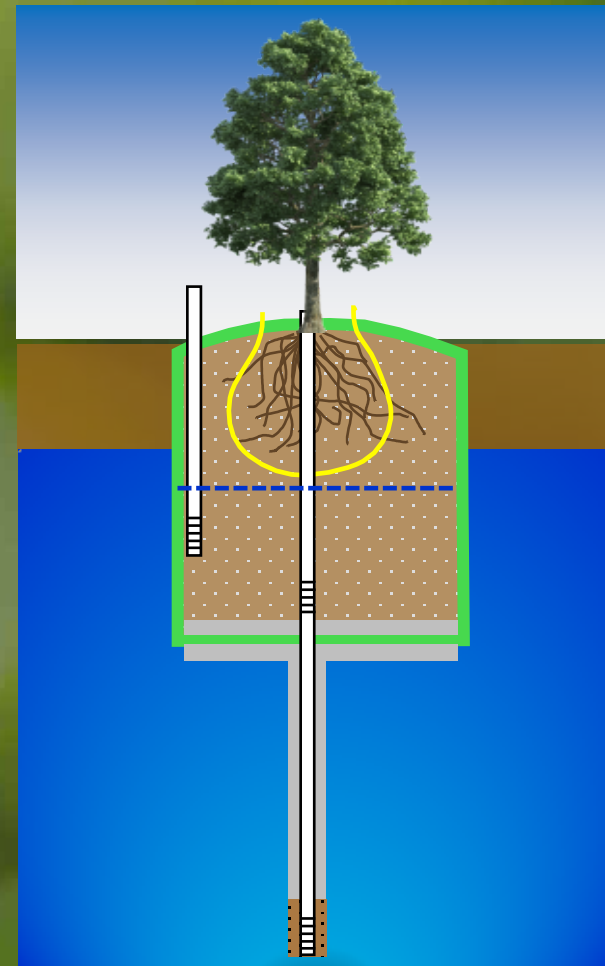


TreeWell Technology - Options

- "Shallow" groundwater up to ~35-40 ft bgs

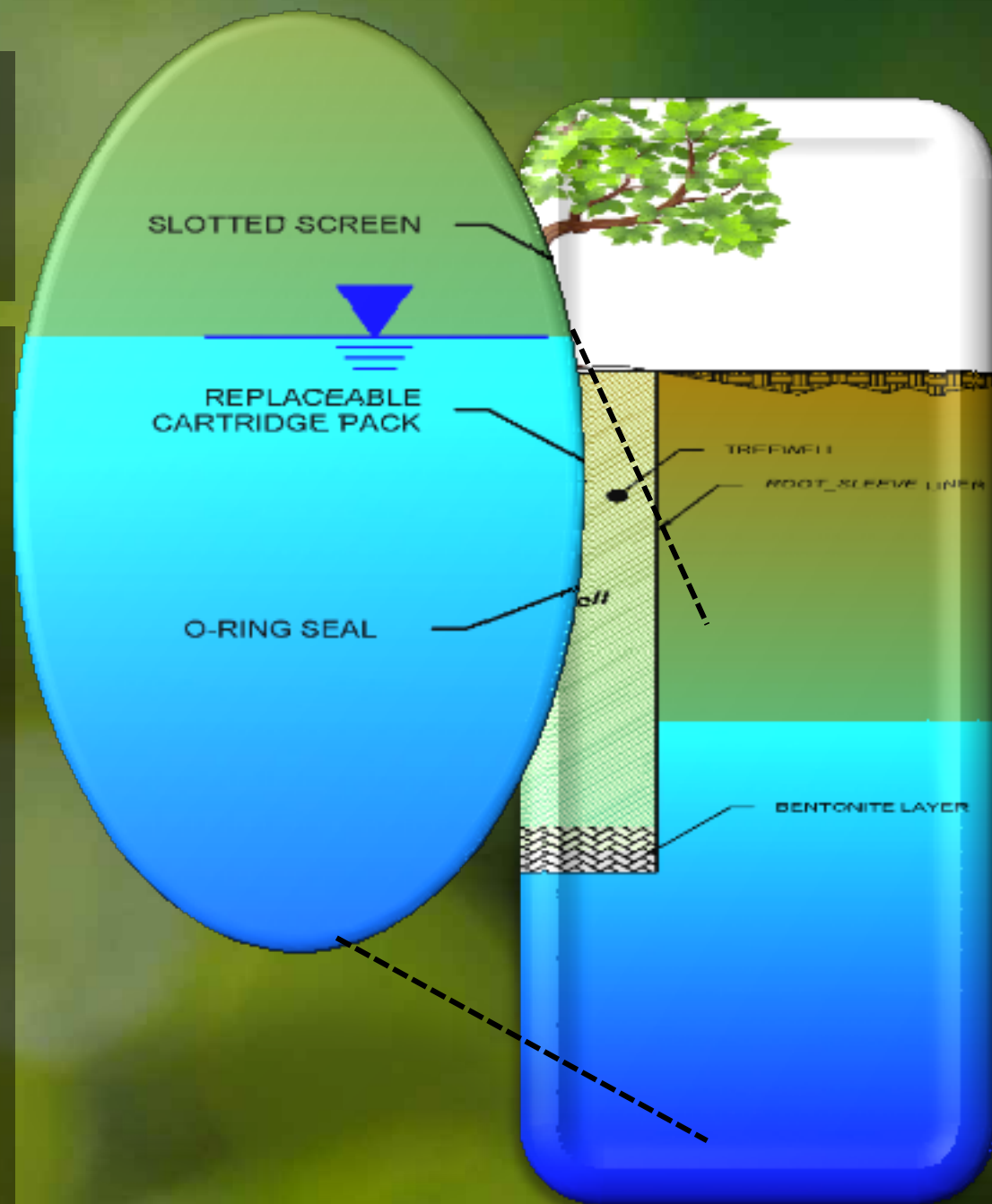


- Deep or fractured rock groundwater



Straw™ TreeWell System with replaceable cartridge

- ▶ Tree removes GW in closed-bottom system making use of hydraulic head to replenish water in *TreeWell* unit
- ▶ GW flows into the lower straw screen at targeted horizon into *TreeWell* unit through amendment cartridge for:
 - ▶ Treatment (proprietary reagents for VOCs/pesticides/oxidized metals)
 - ▶ Sorption (metals or PFAS)
- ▶ Treated water from cartridge then further treated in the *TreeWell* unit



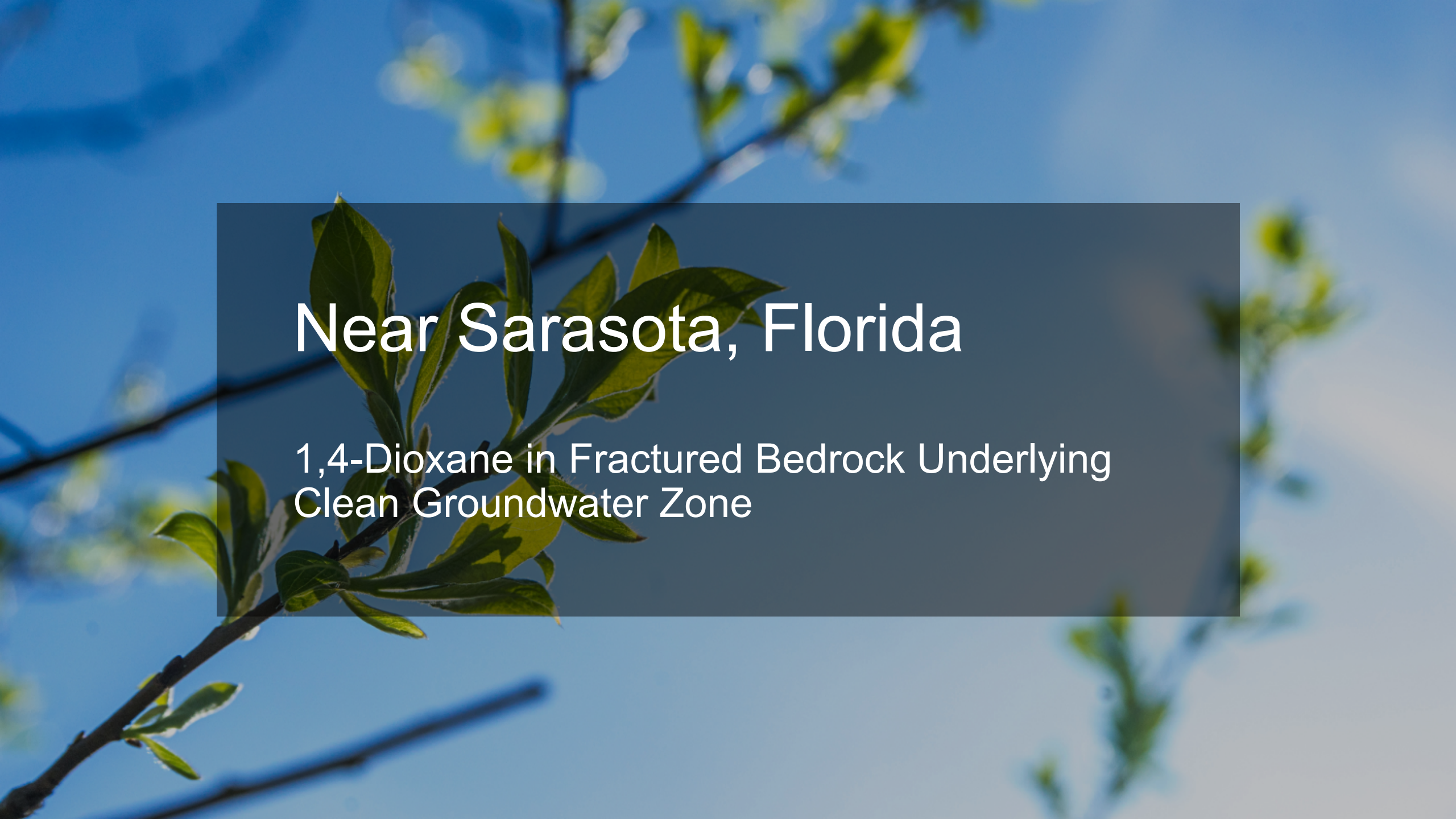


**Near Sarasota, Florida
Installed 2013**



**Louisiana
Installed, 2015**

Case Studies



Near Sarasota, Florida

1,4-Dioxane in Fractured Bedrock Underlying
Clean Groundwater Zone

Near Sarasota, Florida

2.5 Acre – mature, full vegetative canopy required removal

Problem:

- Remaining Source
- Pump & Treat not working
- 1,4-Dioxane plume migrating off-site via bedrock aquifer

Aquifer media:

- Shallow (0 - 2 meters)
 - Sand (clean)
- Deeper (2 - 4.5 meters)
 - Fractured Bedrock (contaminated)



Near Sarasota, Florida

Initial groundwater flow conditions

154 Unit *TreeWell*
System

Plume Control &
Treatment

Trees: Slash Pine,
Willow, Sycamore,
Cypress, Laurel Oak





Near Sarasota, Florida

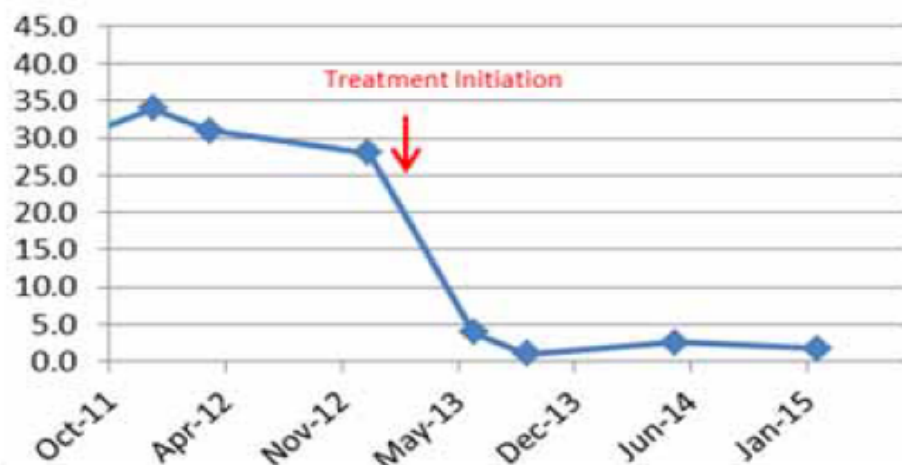
Groundwater flow results

Model predicted
groundwater capture
at 20 gpd/tree

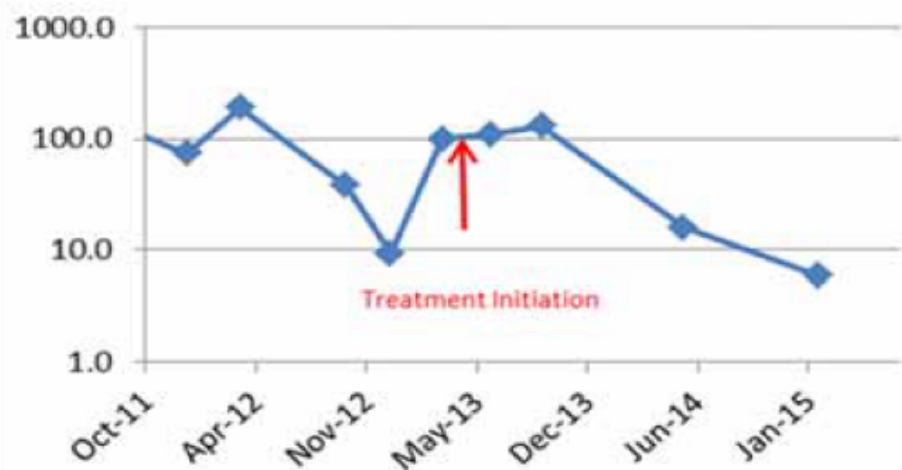
GW conditions in Nov
2014 demonstrate
capture



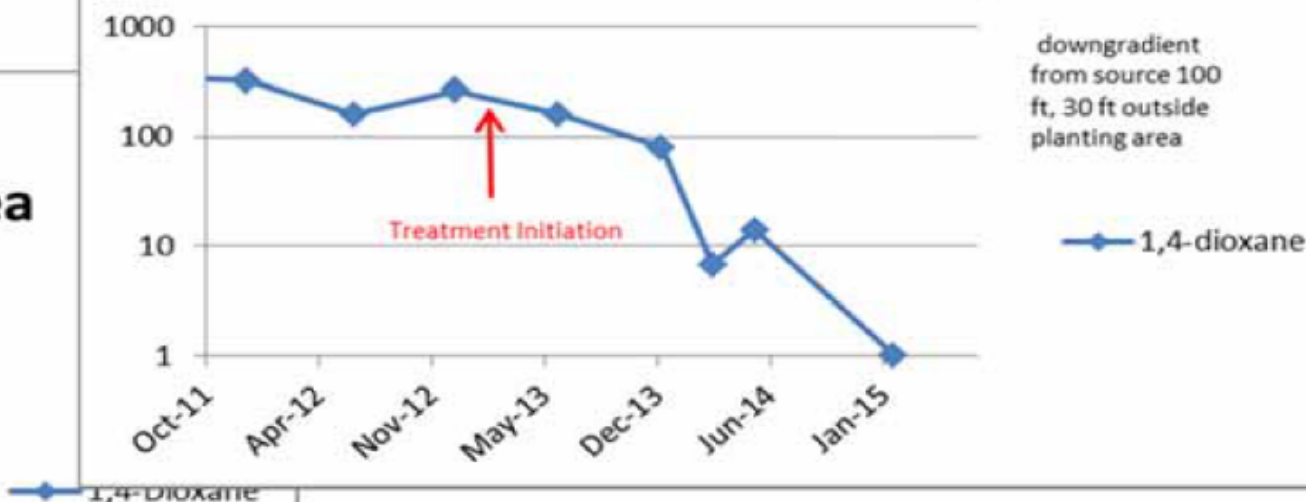
1,4-dioxane vs time IMW-10 - Inside Planting Area

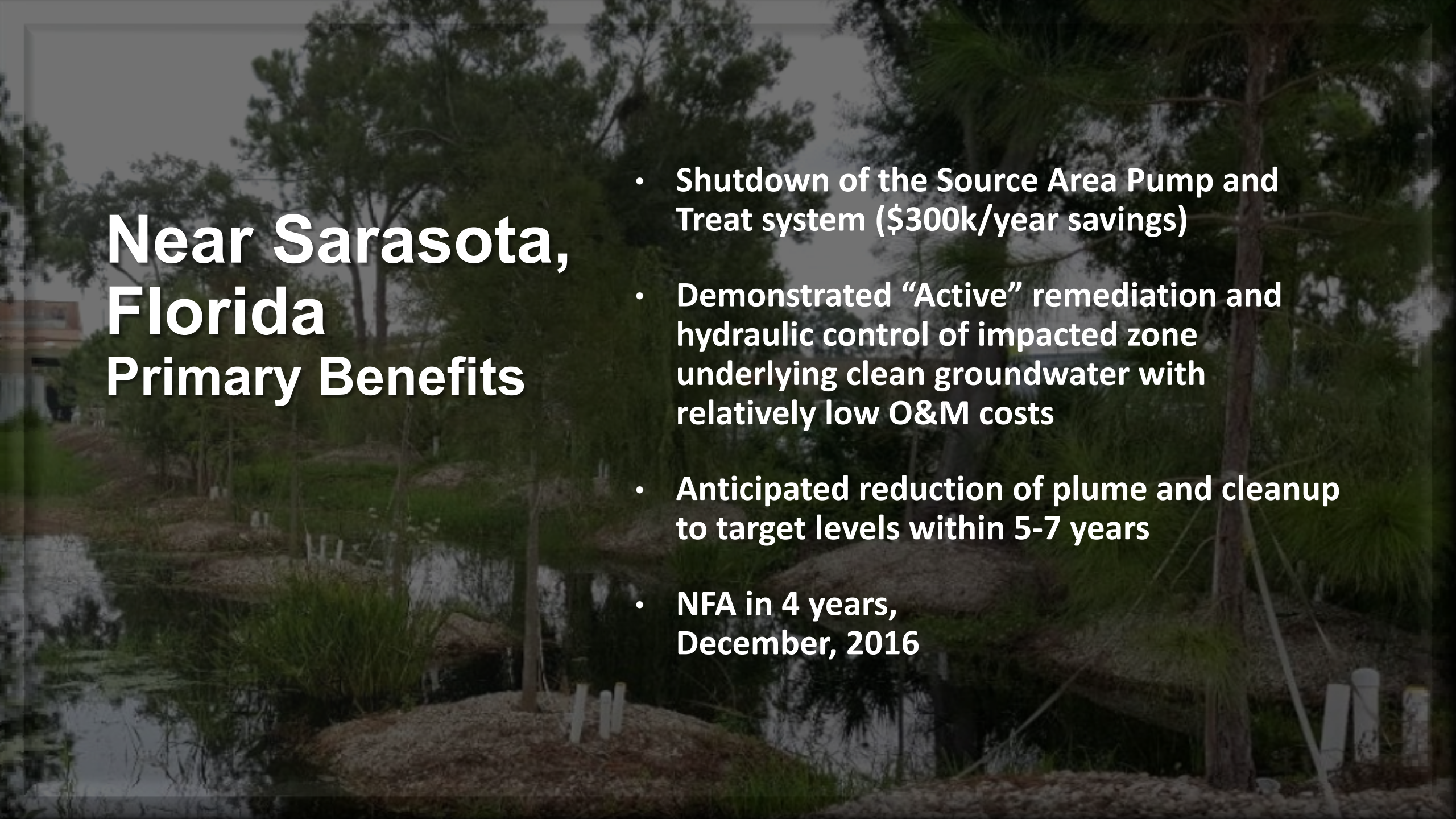


1,4-dioxane vs time IMW-12 - Inside Source Area



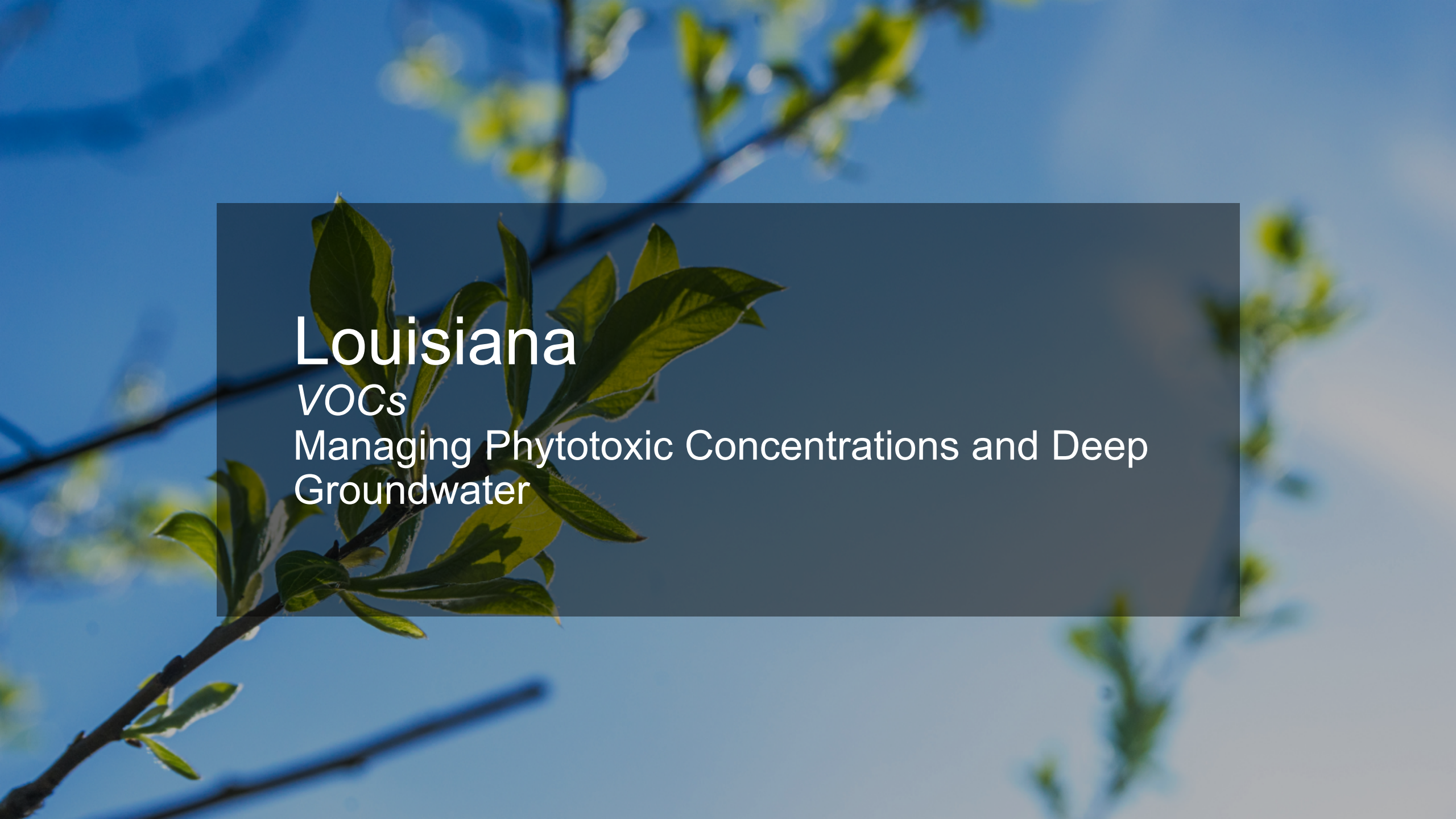
1,4-dioxane vs time FMW-24R - Outside Planting Area





Near Sarasota, Florida Primary Benefits

- Shutdown of the Source Area Pump and Treat system (\$300k/year savings)
- Demonstrated “Active” remediation and hydraulic control of impacted zone underlying clean groundwater with relatively low O&M costs
- Anticipated reduction of plume and cleanup to target levels within 5-7 years
- NFA in 4 years,
December, 2016



Louisiana

VOCs

Managing Phytotoxic Concentrations and Deep
Groundwater

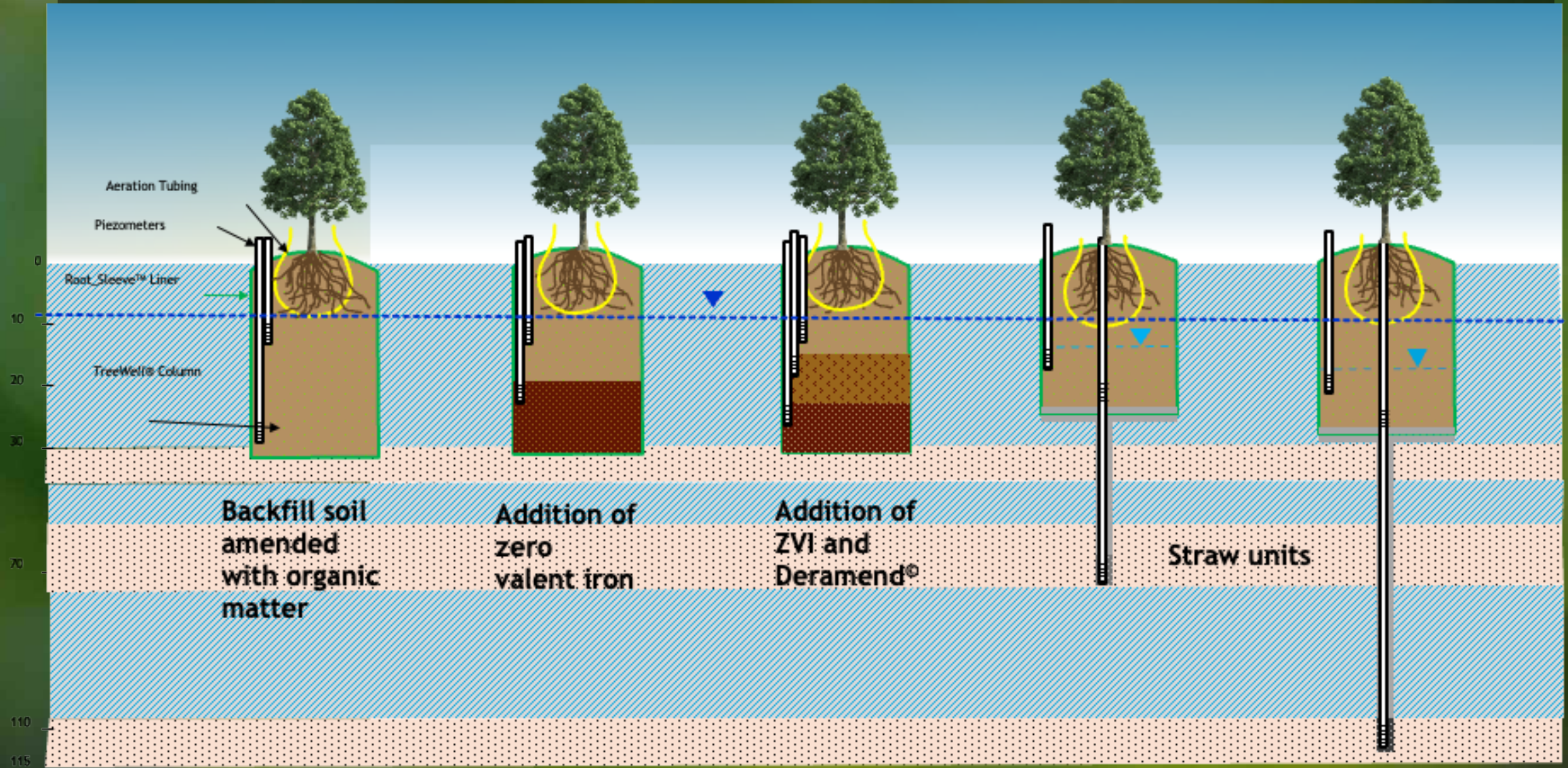
Louisiana

VOC Impacts associated with former waste handling facility
(including DNAPL)



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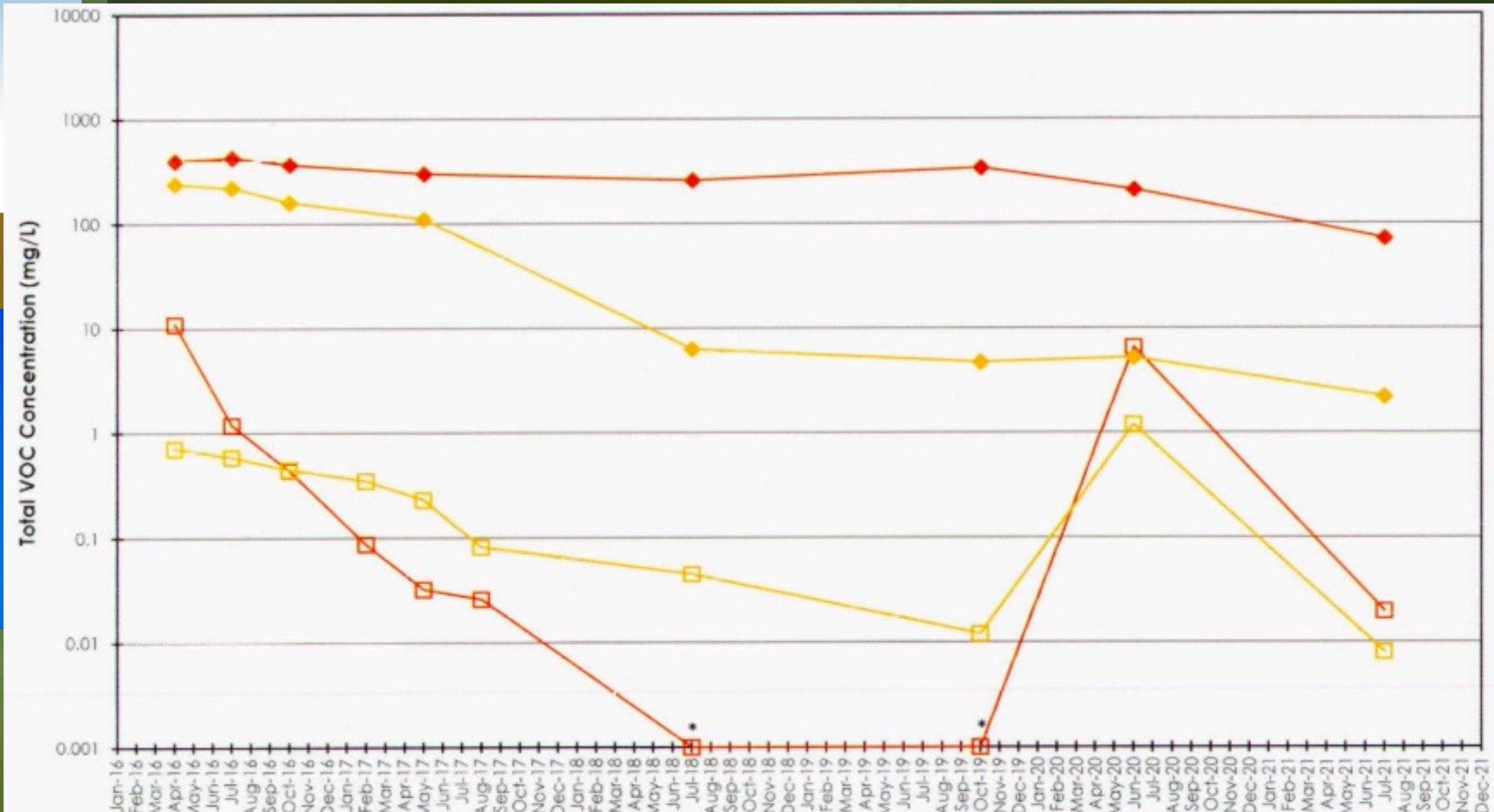
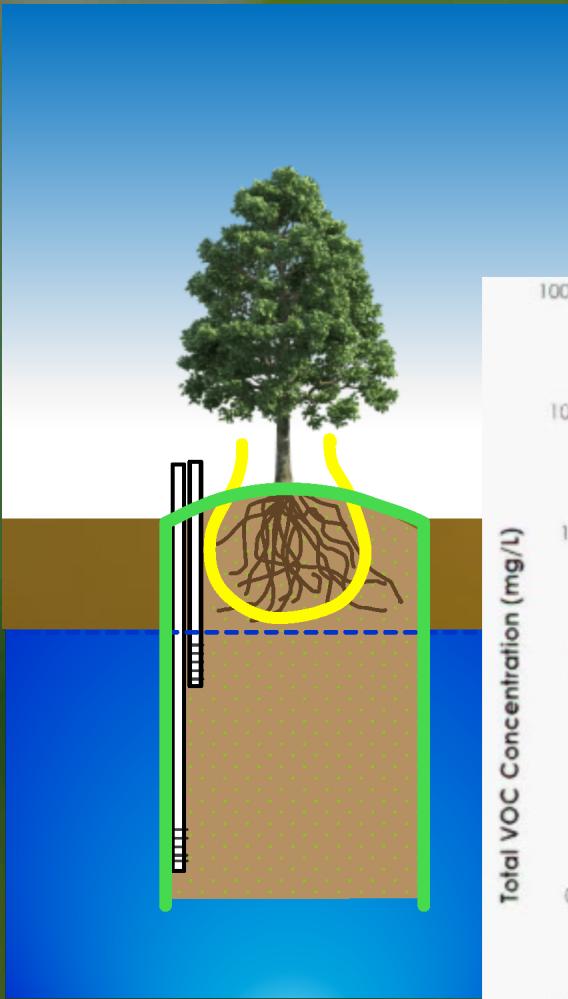
CVOCs and Deep Groundwater



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- **Bioreactor effect observed**

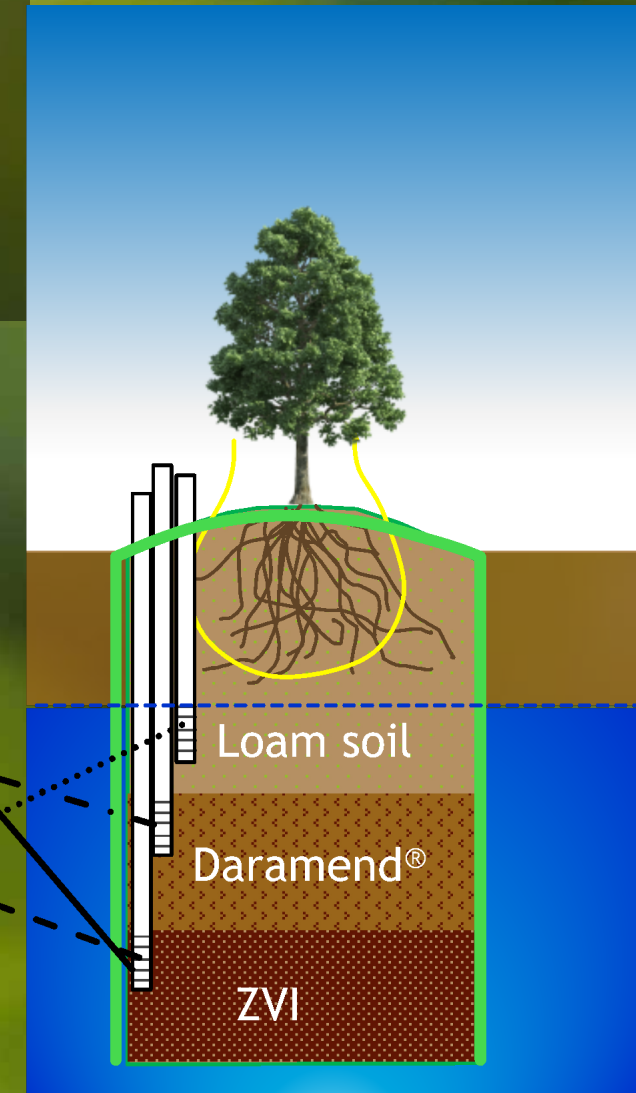
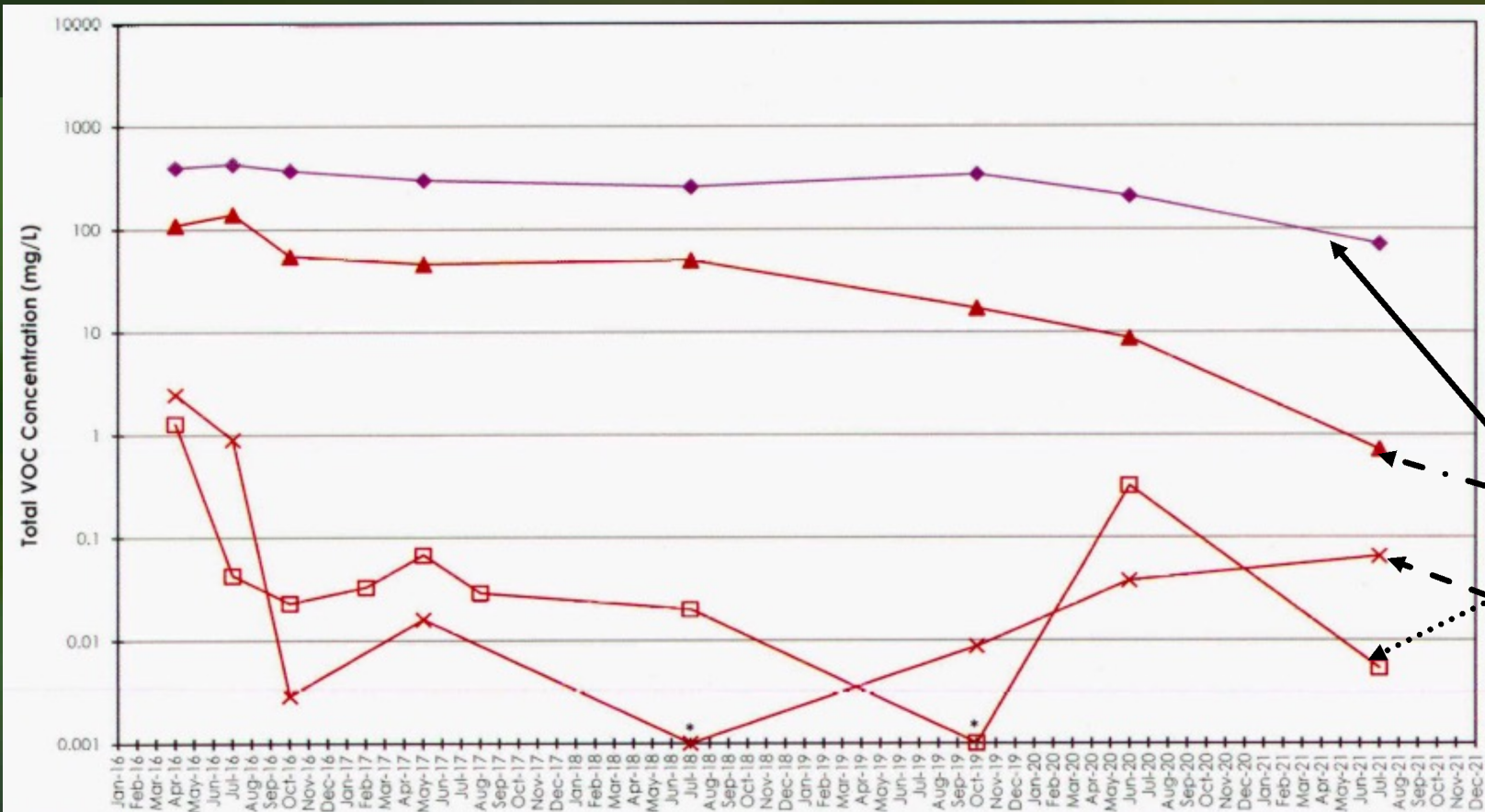
- Natural degradation observed as water migrates vertically upwards within *TreeWell* soil column



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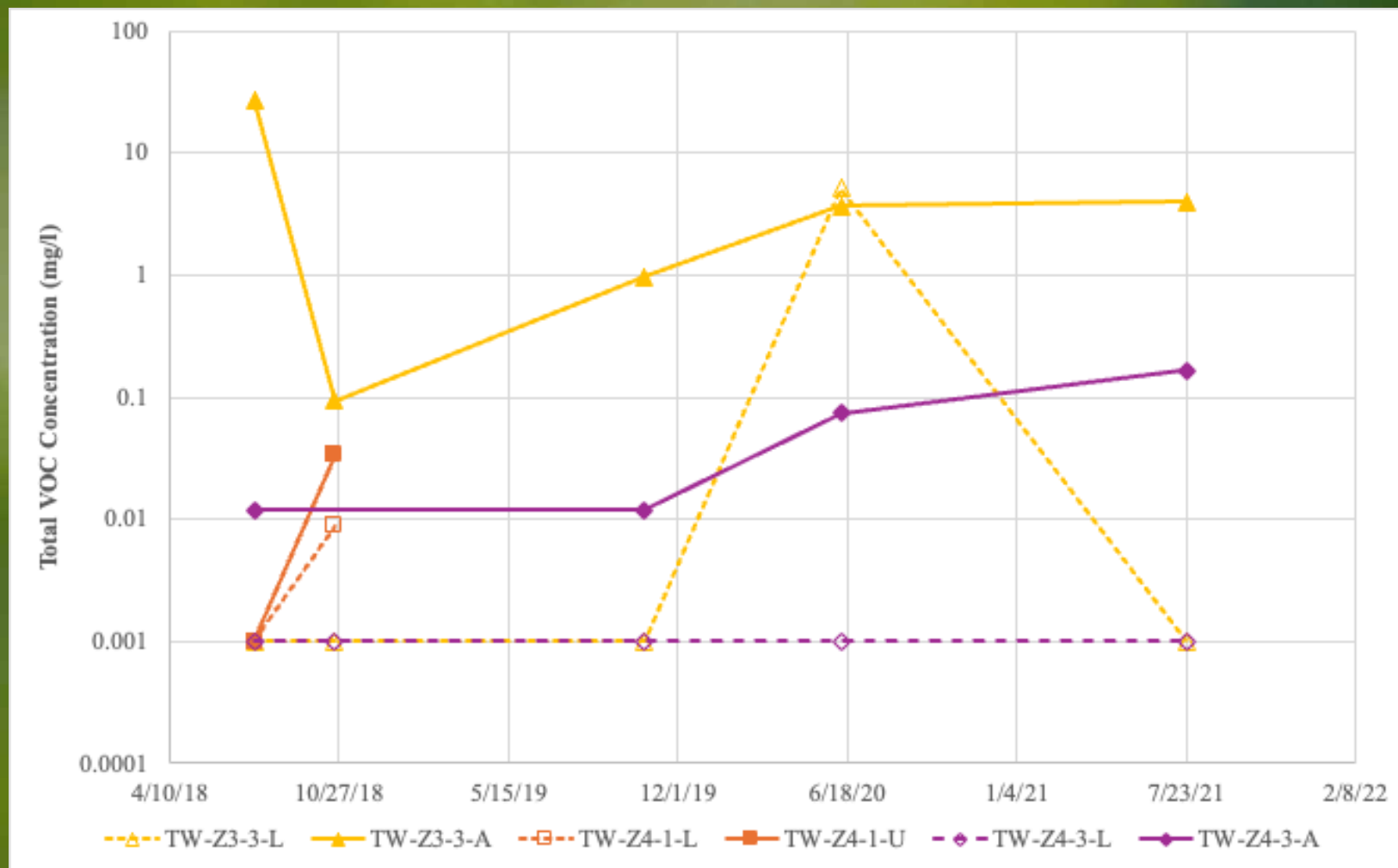
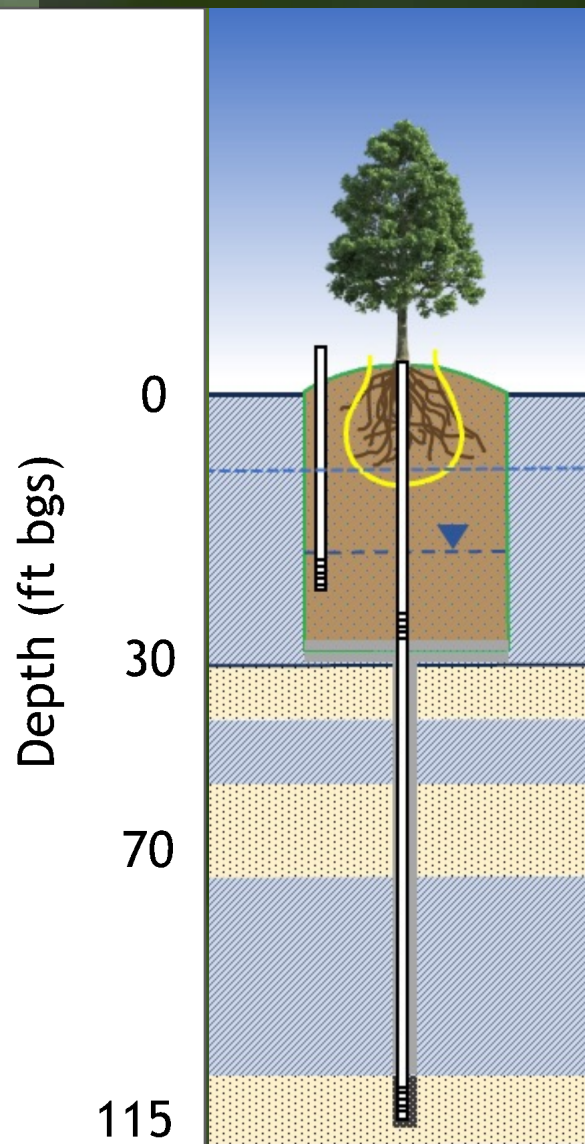
- **Bioreactor effect observed**

- Backfill soil amended with reactive (i.e., ZVI) or adsorptive (i.e., GAC) media



Louisiana

Deep Groundwater





Questions?
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