

# Function and Performance of *PHYTO-INTEGRATED*<sup>TM</sup> Remediation Systems on Deep Groundwater and/or Targeted Horizons – Hydraulics and Treatment

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# What is *PHYTO-INTEGRATED*<sup>TM</sup> Remediation

**Traditional  
phytoremediation  
effectiveness is limited  
by natural conditions**

- ▶ **GW too deep**
- ▶ **Contaminants too high - toxic**
- ▶ **Incompatible soil conditions**
- ▶ **Etc....**



# What is *PHYTO-INTEGRATED*<sup>TM</sup> Remediation

## Phytoremediation + Traditional Technologies

*PHYTO-INTEGRATED*<sup>TM</sup>  
Remediation  
employs vegetation  
as a component of a  
designed and  
constructed system  
that:

- controls plant growth,
- manages site conditions and
- targets the zone of remedial effect

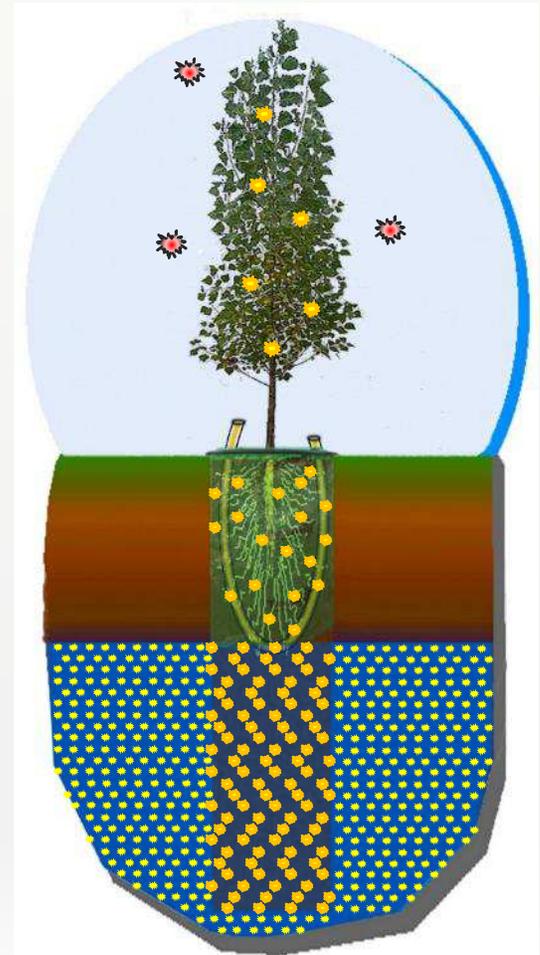


# TreeWell System

## – Patented *PHYTO-INTEGRATED* Pump & Treat System

Tree is the Pump & the *TreeWell* unit is the Treatment System

- ▶ Tree pumping draws contaminants into **TreeWell Treatment Column**
- ▶ Untreated contaminants from the **Treatment Column** are drawn to the **rhizosphere** and treated by a number of potential processes
- ▶ Residual contaminants may be taken up by the **plant** and treated within the plant
- ▶ A few remaining molecules may pass through the plant and may be emitted into the **atmosphere** in the transpiration stream
- ▶ ....and then **Photo-oxidized**



# Sites and Conditions

## - Source Areas & Groundwater Plumes

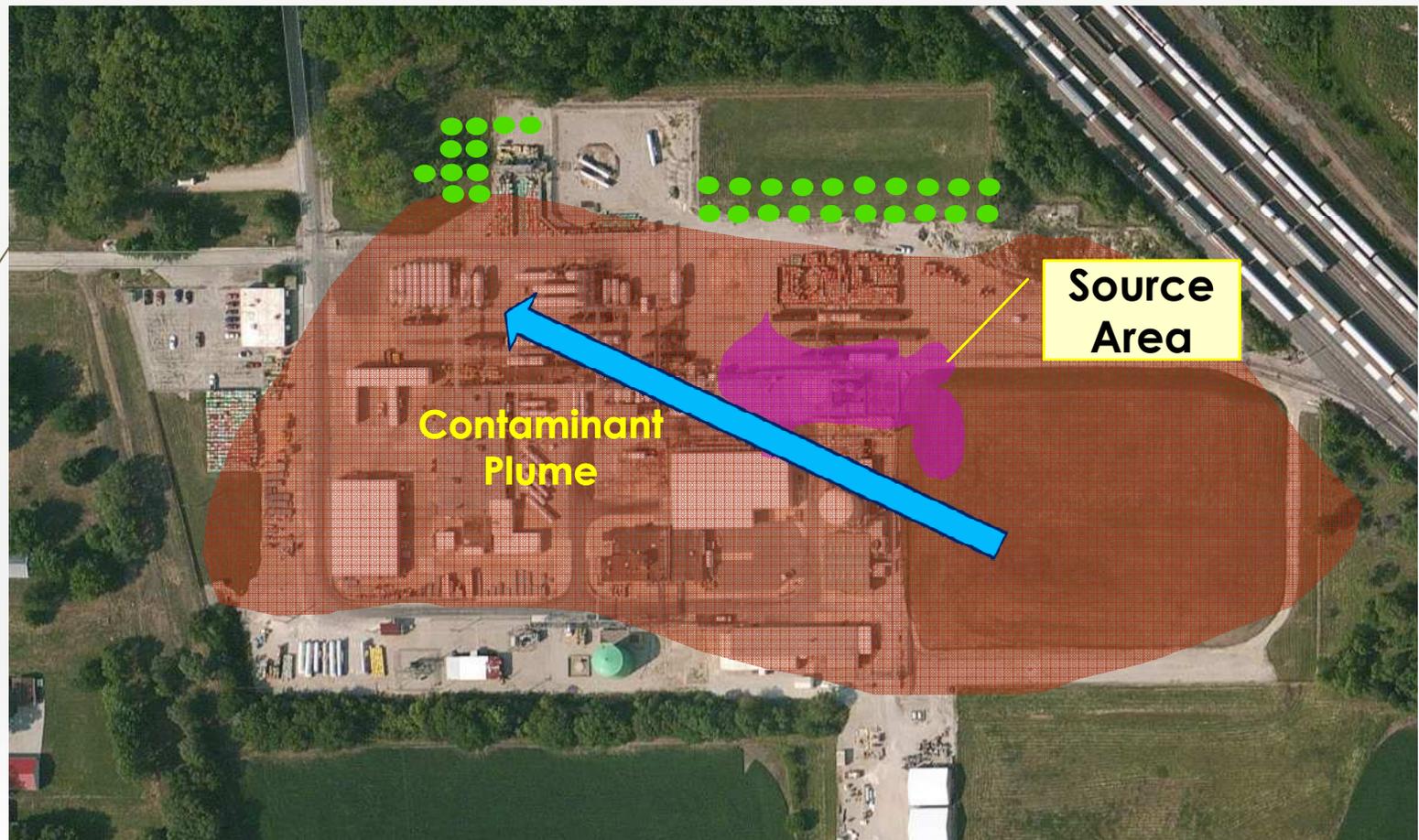
- ▶ **Eastern Illinois** –  
**CCl<sub>4</sub>** with plume in Silty Clay  
(Target Horizon (TH): 15-25 ft)
- ▶ **Western Pennsylvania** –  
**TCE/TCA** with plume in Soil  
(TH: 5-15 ft) & Fractured Bedrock  
(TH: 15-35 ft)
- ▶ **Near Sarasota Florida** –  
**1,4 Dioxane** with plume in  
Fractured Bedrock - TH: 7-15 ft



# Eastern Illinois – Operating Facility

## $\text{CCL}_4$ in Groundwater in Glacial Till Soils

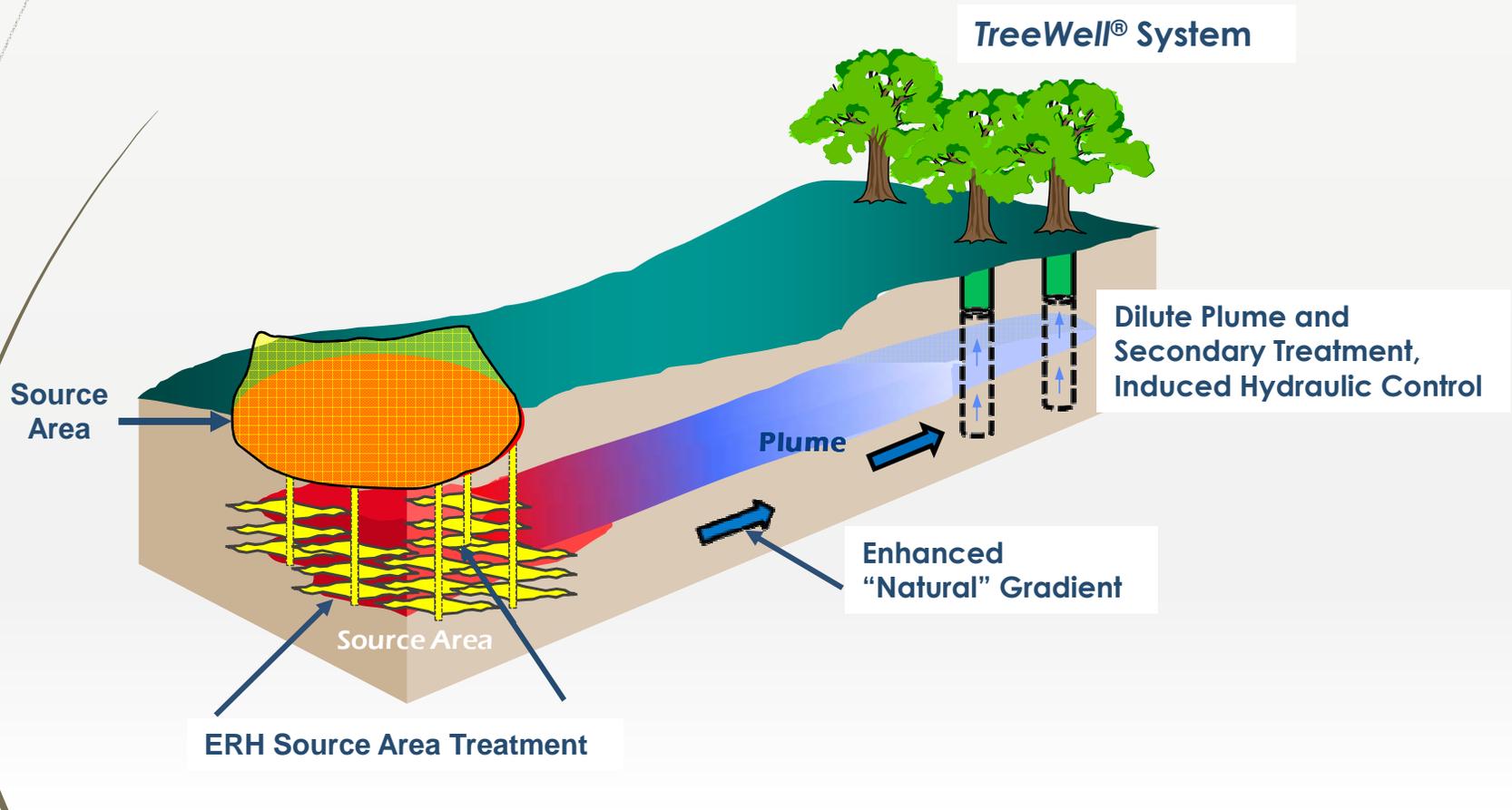
- ▶ 15-25 ft (silty clay with thin sand and silt seams)
- ▶ *TreeWell* System Pilot Study to control plume migration (Trees: Willows & Poplars)



# Eastern Illinois

## Combining Technologies

- Source area reduction with ERH
- Groundwater Plume Control with Expanded TreeWell system



# Eastern Illinois Plume Control & Groundwater Remediation

- Groundwater modeling indicated that 28 additional *TreeWell* units would insure plume control – completed Fall, 2016



# Eastern Illinois Plume Control & Groundwater Remediation

- ▶ Model at 20 GPD/tree
- ▶ Source Area Recovery Wells Shutdown



# Western Pennsylvania

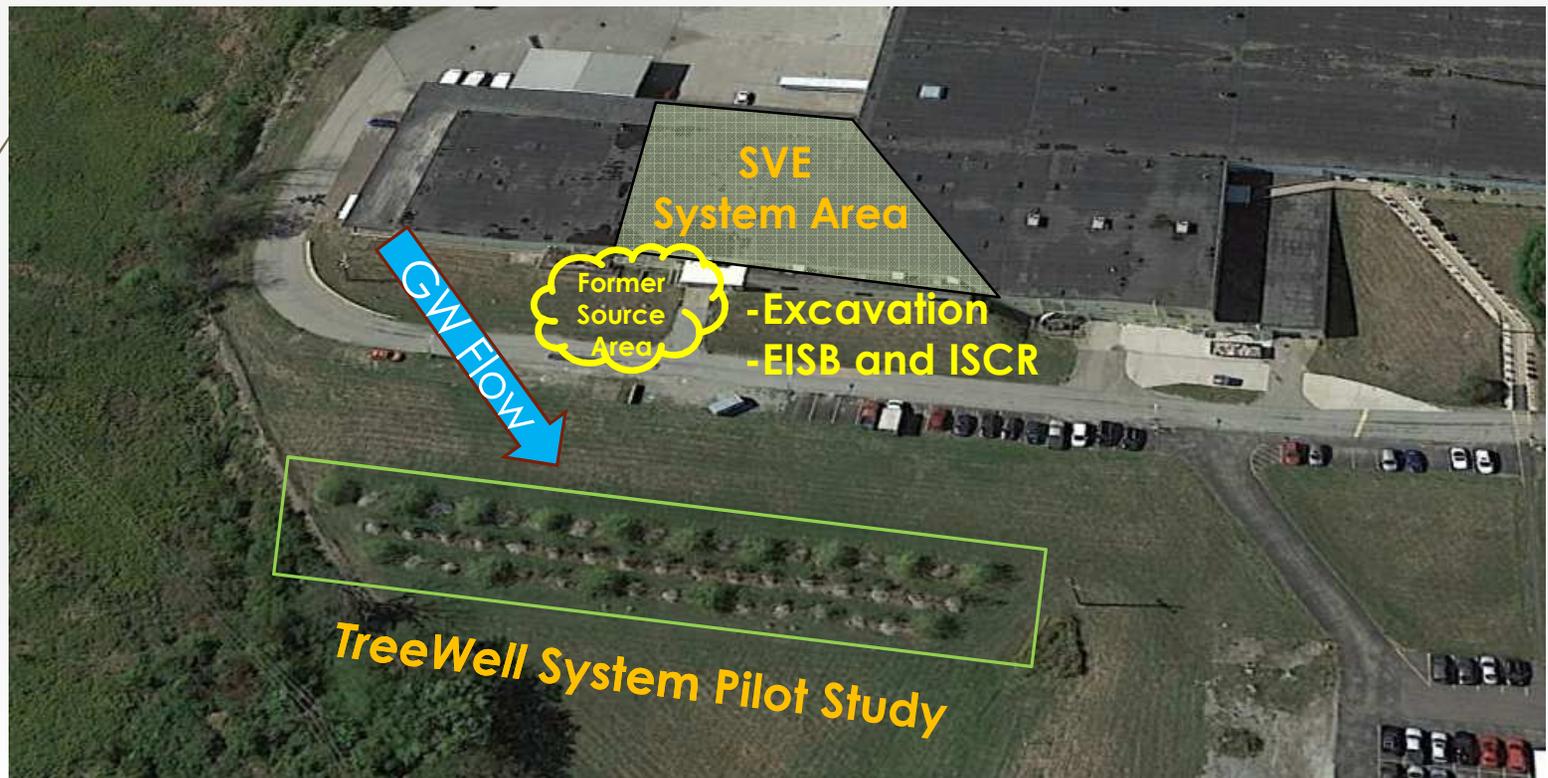
## Combined Technologies Approach

### Source area treatment

- **Excavation** of 1500 tons of highly impacted soil
- **EISB & ISCR**

### TCE/TCA in Two Groundwater Formations (5-15 & 15-35 ft)

- **TreeWell System** to address both aquifer horizons



# Western Pennsylvania TreeWell System Pilot Study

Three rows of *TreeWell* units to address two groundwater horizons

- Shallow Soil (5-15 ft)
- Deep Fractured Bedrock (15-35 ft)

Tree Species - willows & poplars

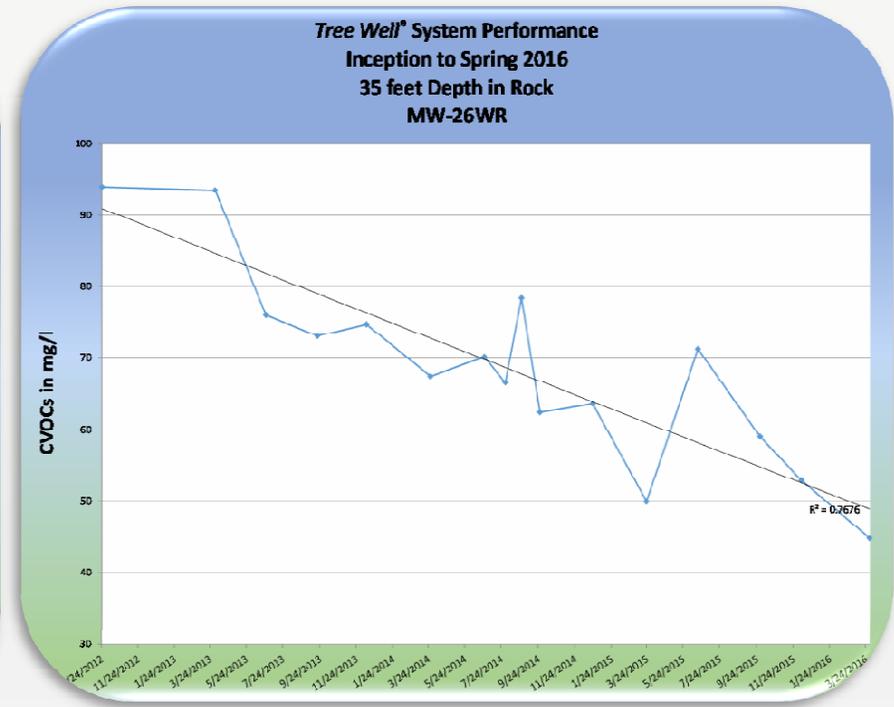
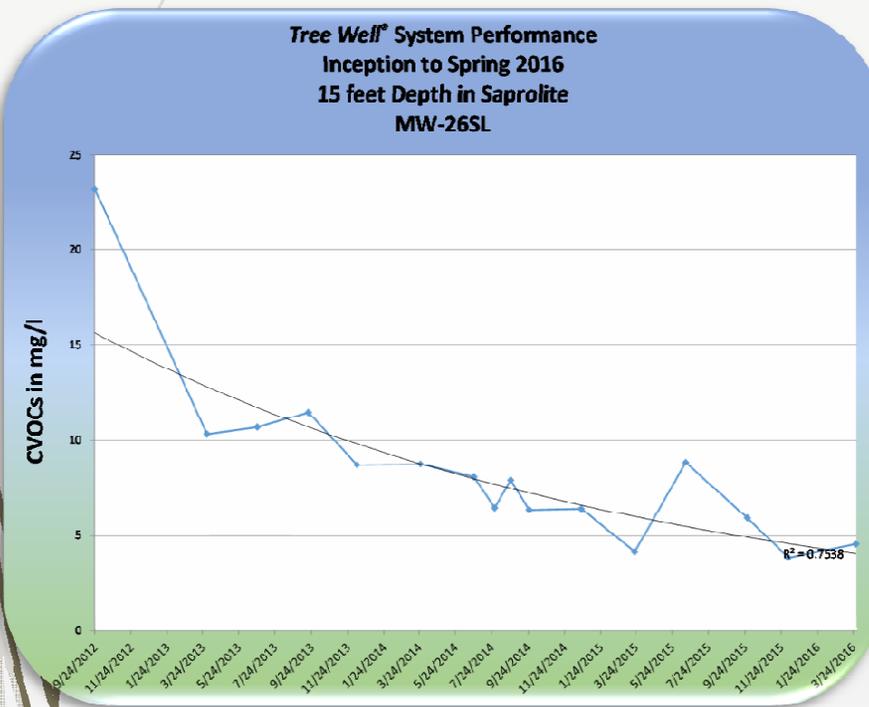


# Western Pennsylvania

## Source Area Total CVOCs - 262 mg/l

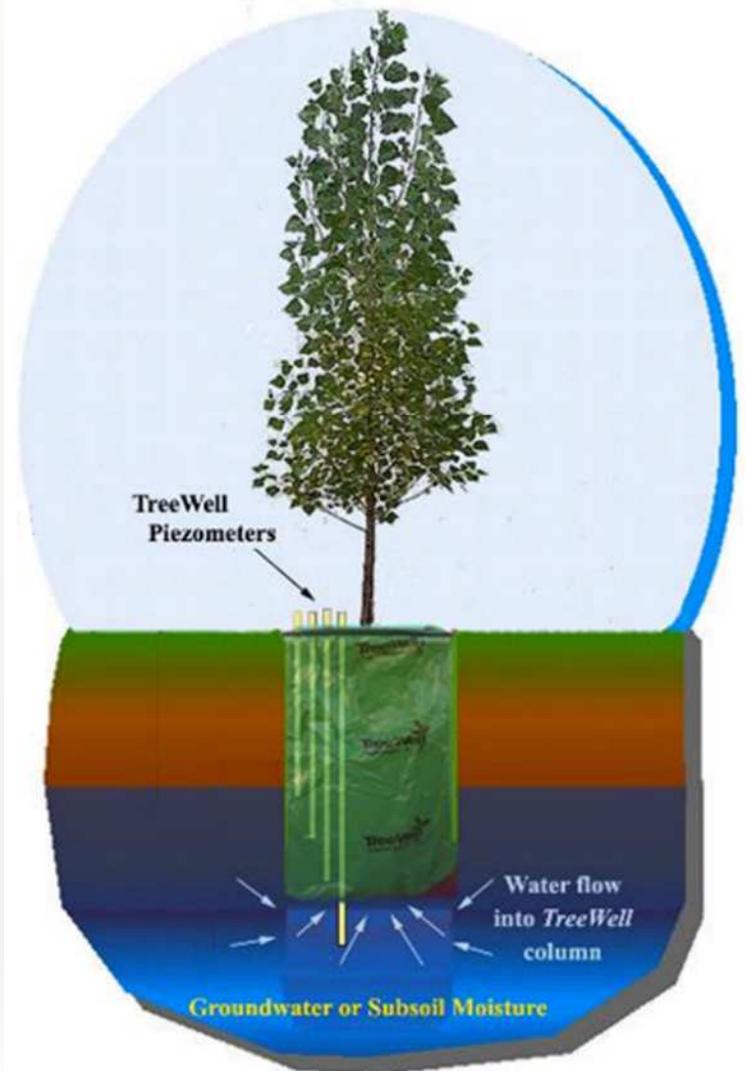
Downgradient Wells - From Sept.,2012 to Mar.,2016  
Shallow dropped from 25 to 5 mg/L

Deep dropped from 95 to 45 mg/L

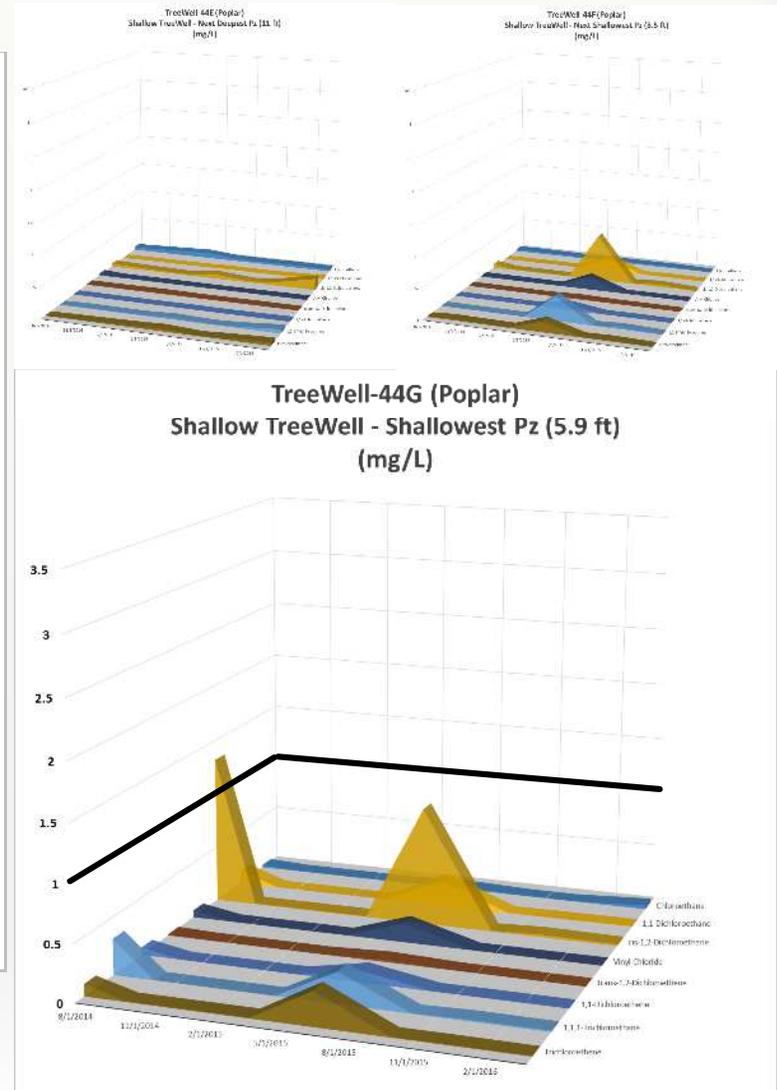
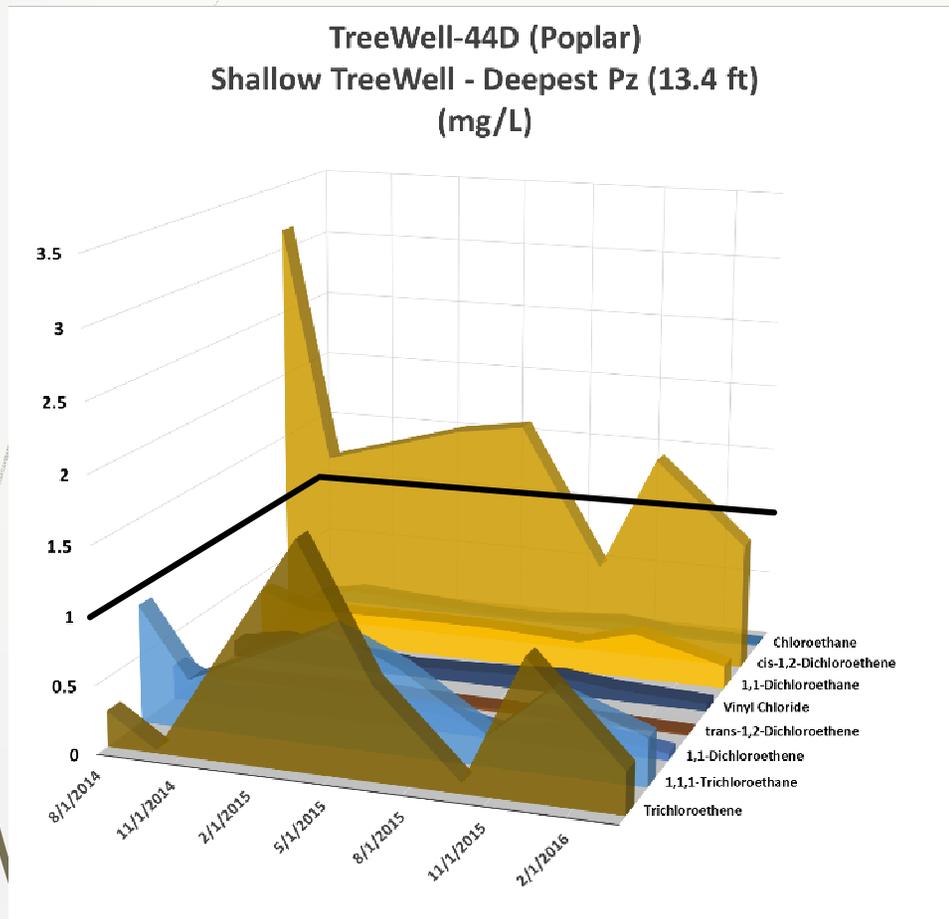


# Western Pennsylvania TreeWell System Bioreactor Study

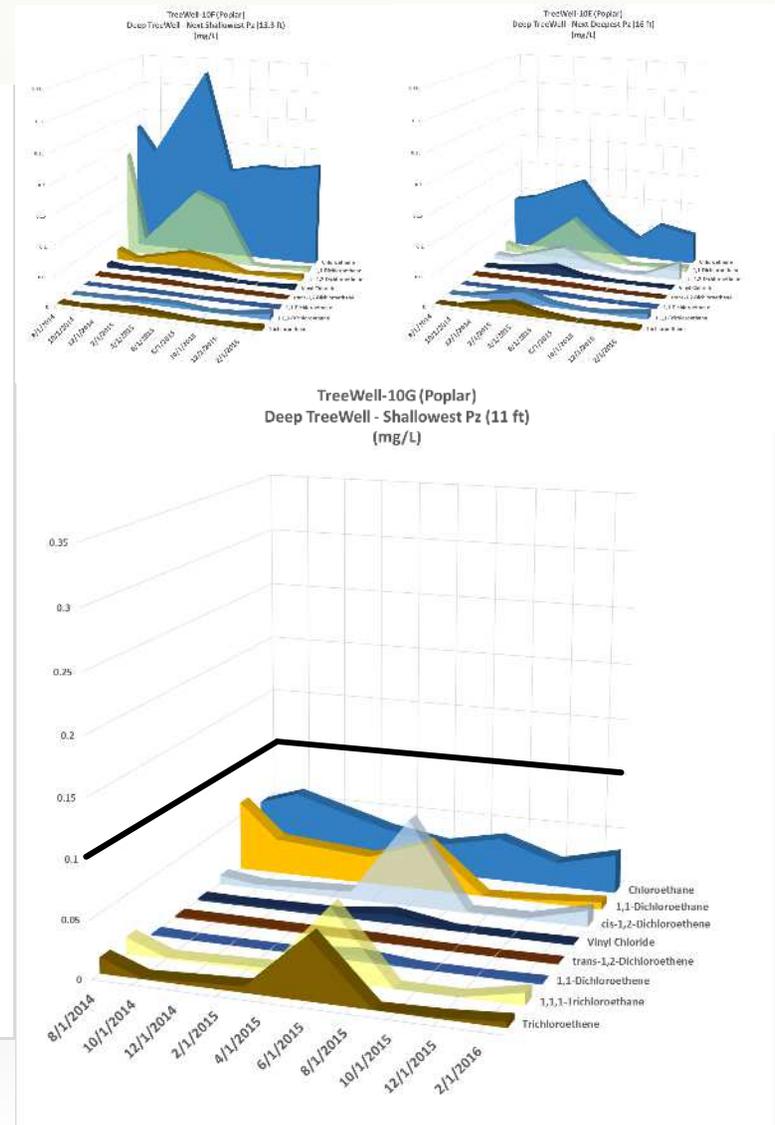
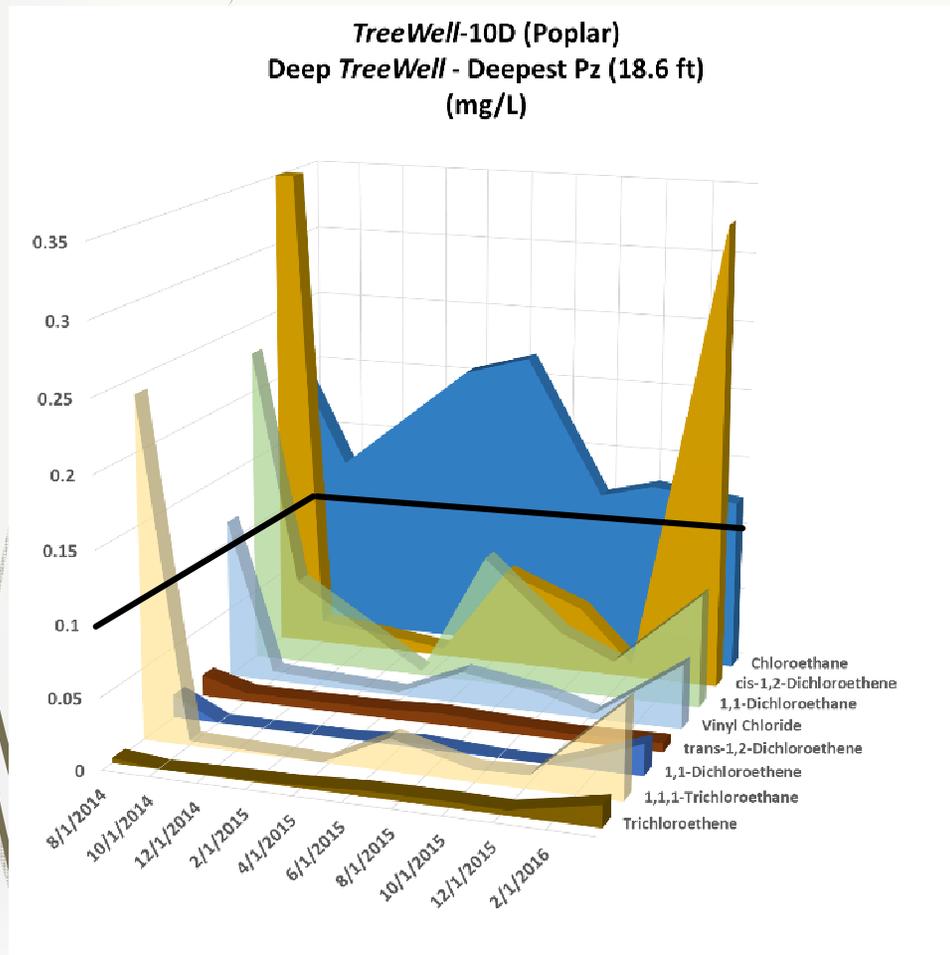
- ▶ Four piezometers with 1 ft screens were installed at progressive depths inside shallow & deep *TreeWell* Units
- ▶ GW samples were collected periodically from Aug., 2014 to present (Mar., 2016)



# Western Pennsylvania Bioreactor Study – Shallow Groundwater



# Western Pennsylvania Bioreactor Study – Deep Groundwater

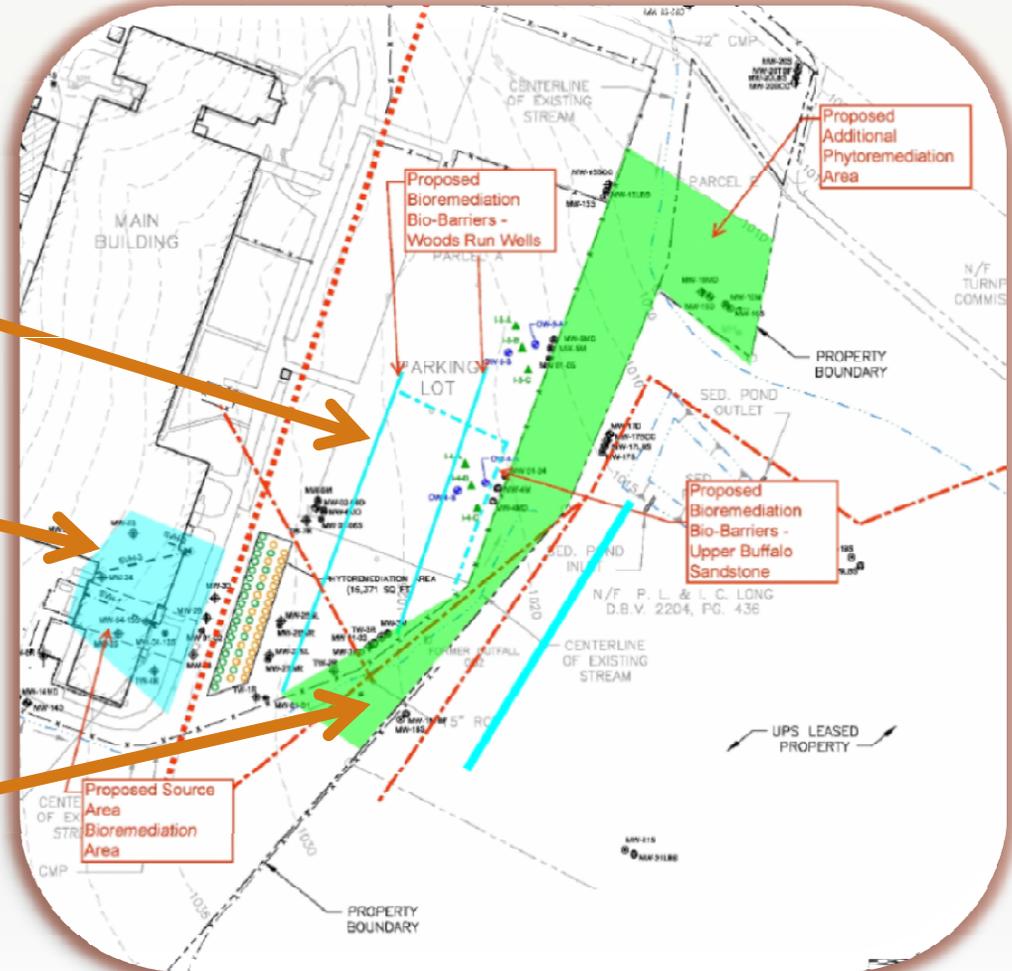


# Western Pennsylvania Successful Pilot Study

## > Additional Treatment Systems

### Multiple Technologies to be employed

- ▶ **Bioremediation – Surface Soil, Woods Run Formation (shale) and Buffalo Formation (Sandstone)**
- ▶ **SVE with Bioremediation beneath the floor slab**
- ▶ **Additional 200 unit *TreeWell* System along eastern boundary (soil and Woods Run, possibly Buffalo)**



## Near Sarasota, Florida

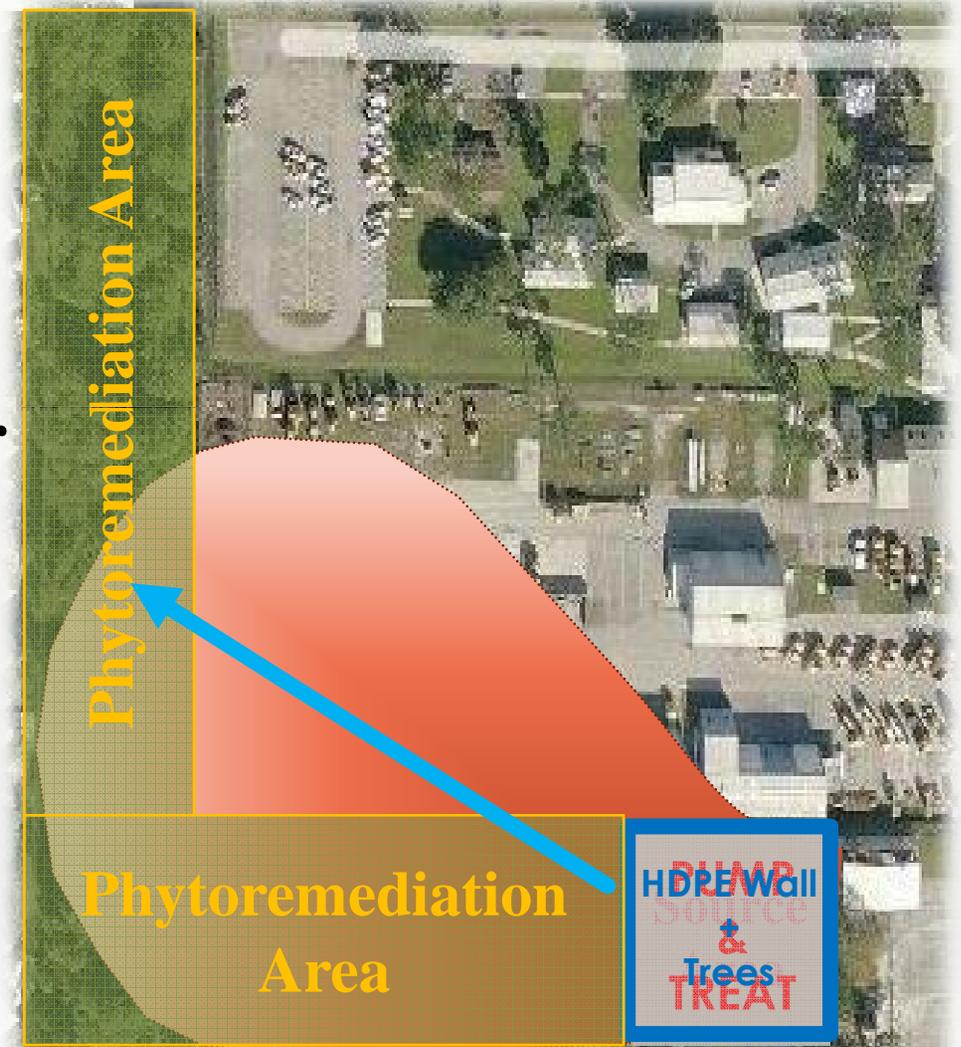
2.5 Acre – mature, full vegetative canopy

### Problem:

- Remaining Source
- 1,4-Dioxane plume migrating off-site via bedrock aquifer

### Aquifer media:

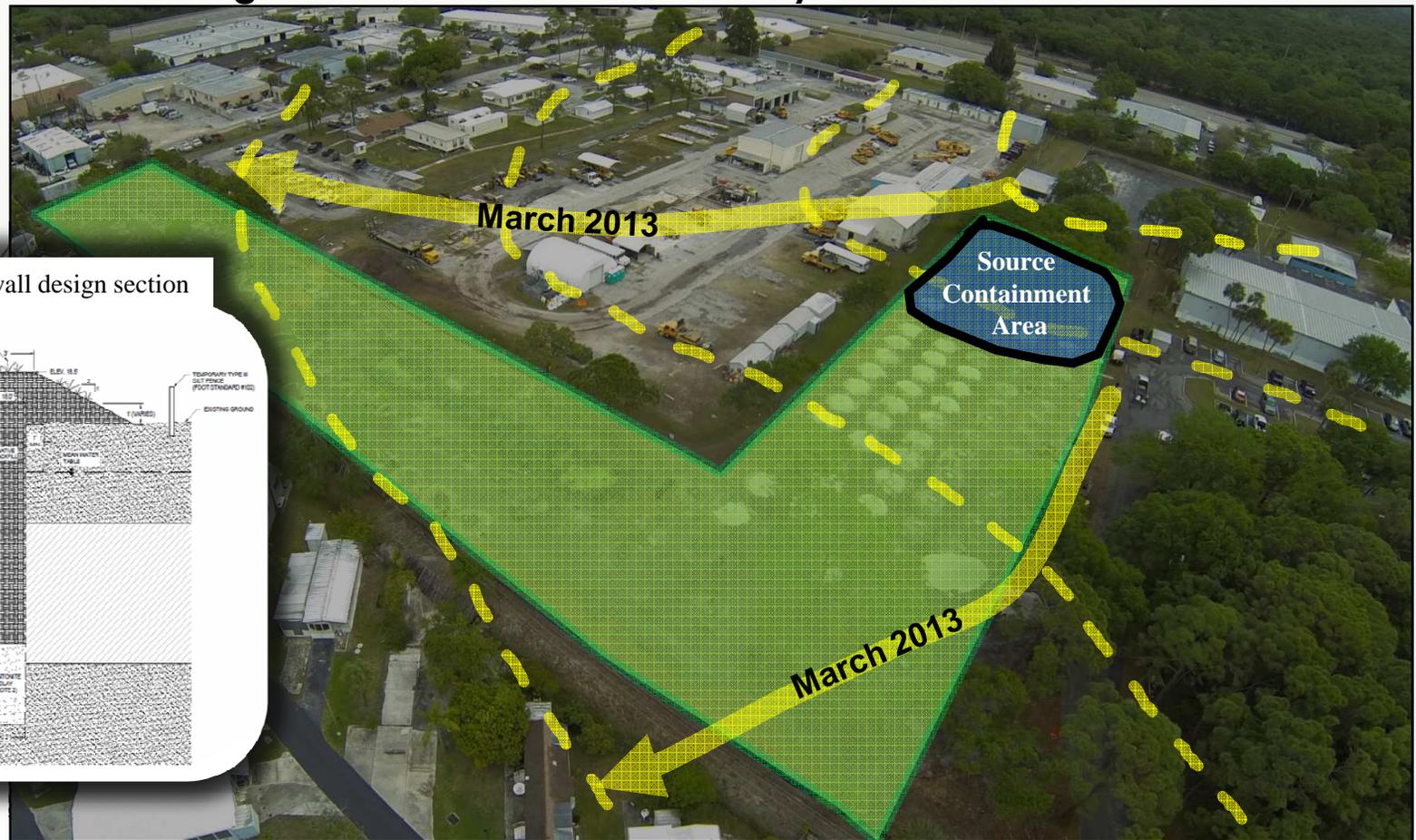
- Shallow (0-7 feet)
  - Sand (clean)
- Deeper (7-15 feet)
  - Fractured Bedrock (contaminated)



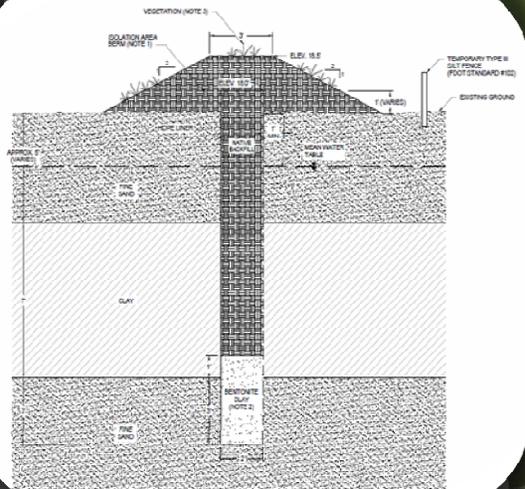
# Near Sarasota, FL

## Initial Groundwater Flow Conditions – March 2013

- ▶ 154 Unit *TreeWell System* for Plume Control & Treatment – (Trees: *Slash Pine, Willow, Sycamore, Cypress, Laurel Oak*)
- ▶ *HDPE Containment Wall* for Source Area Control - Including *TreeWell Units* and Existing Trees for Remediation and Hydraulic Control

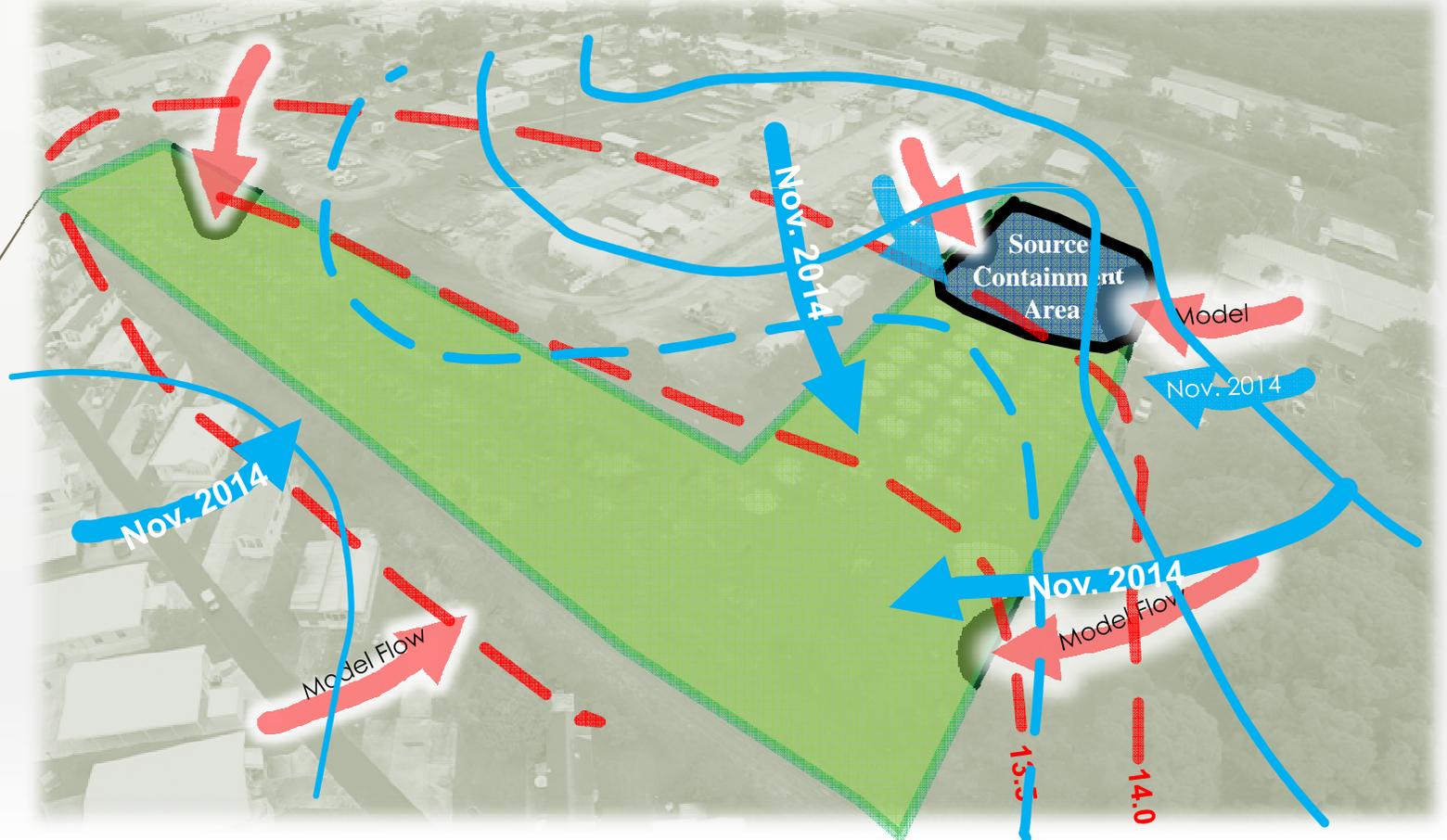


HDPE barrier wall design section



## Near Sarasota, FL Groundwater Flow Results

- ▶ Model predicted groundwater flow conditions at 20 gpd/tree
- ▶ Compared to Actual Conditions in Nov., 2014

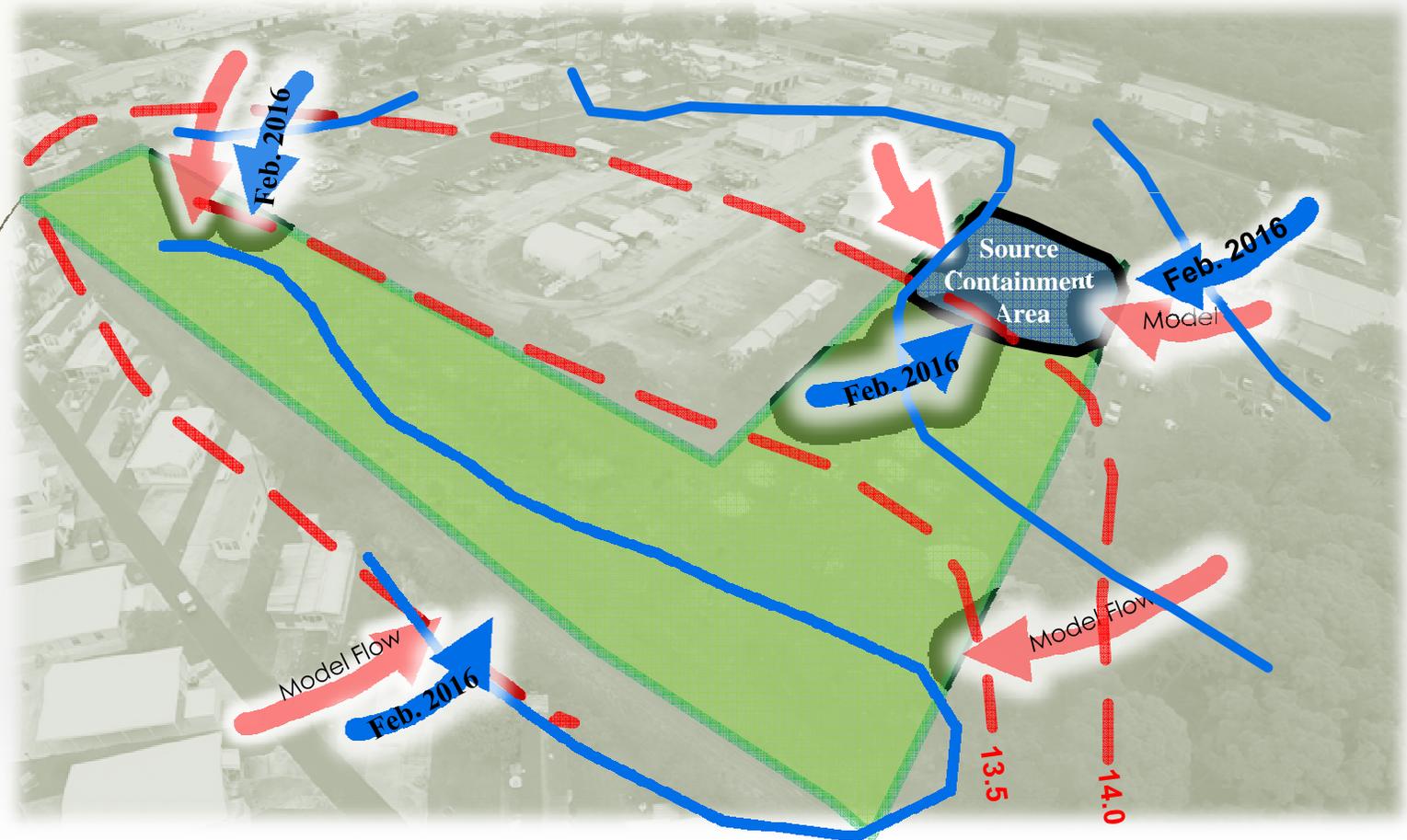


# Near Sarasota, FL

## Groundwater Flow Results

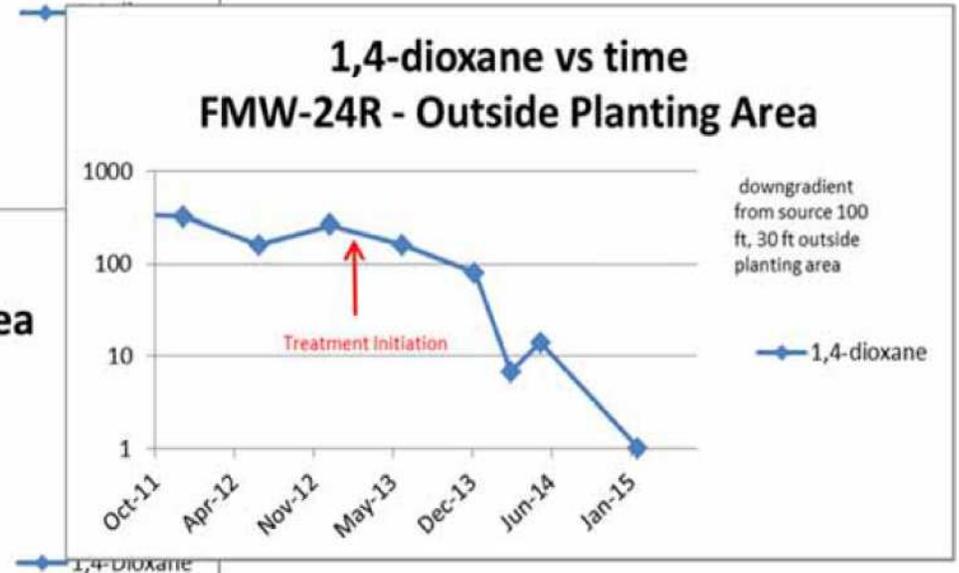
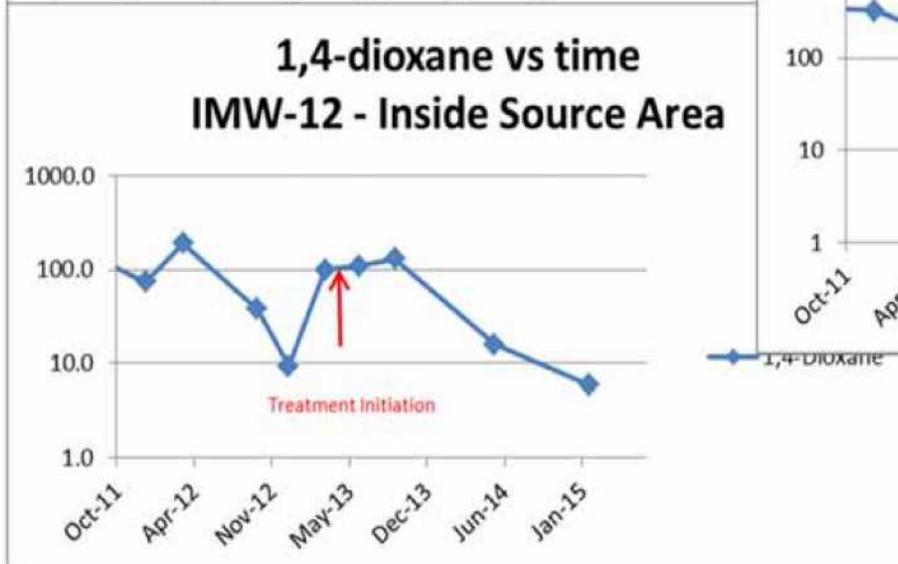
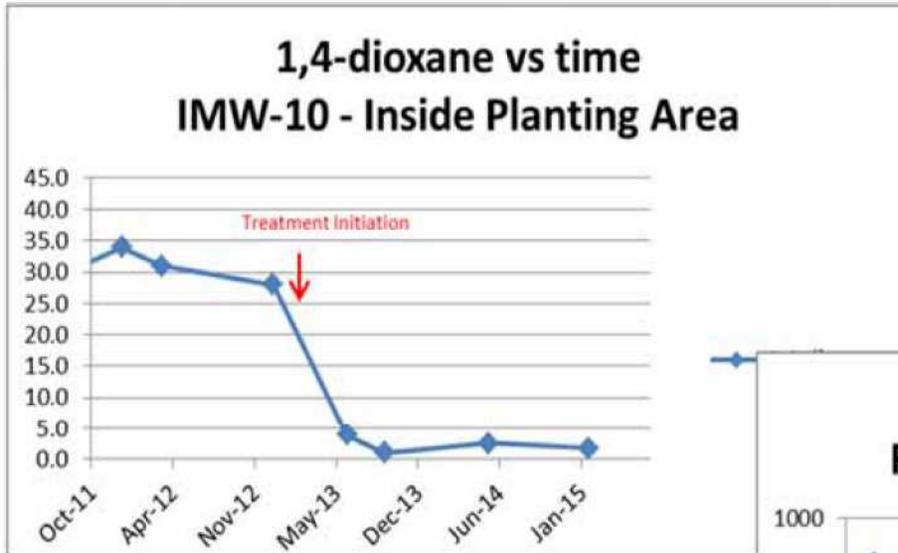
Hydraulic conditions in February, 2016

- Comparison with the model continues to improve despite above-average precipitation during winter of 2015-2016



# Near Sarasota Florida

## - Remediation Results (1,4-Dioxane $\mu\text{g/L}$ )

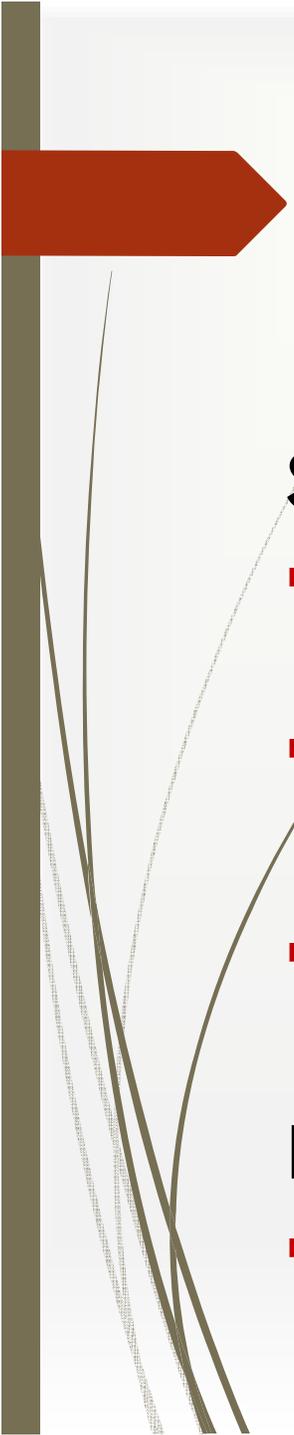


# Near Sarasota Florida

## Primary Benefits

- **Shutdown of the Source Area Pump and Treat system (\$300k/year savings)**
- **Demonstrated “Active” remediation and hydraulic control with relatively low O&M costs**
- **Anticipate reduction of plume and cleanup to target levels within 5-7 years**





## Summary

Combining *PHYTO-INTEGRATED™* Remediation with other Technologies for Source Area Treatment and Plume Control

### Source Area

- **Eastern Illinois** –  
Electrical Resistance Heating (ERH)
- **Western Pennsylvania** –  
Soil Vapor Extraction (SVE), Enhanced In-Situ Bio (EISB)  
& In-Situ Chemical Reduction (ISCR), Limited Excavation
- **Near Sarasota Florida** –  
Pump & Treat, HDPE Containment Wall + Trees + *TreeWell®*  
Units

### Plume

- **All Sites** - *TreeWell®* Pump & Treat System



# General Benefits

## Combining *PHYTO-INTEGRATED*<sup>TM</sup> Remediation with other Technologies for Source Area Treatment and Plume Control

- ▶ **Adaptable to a large range of settings, contaminants and contaminant levels**
- ▶ **Multiple technology combinations possible**
- ▶ **Lower capital costs vs many other traditional technologies and even when comparable – lower O&M costs are usually significant**
- ▶ **Lower maintenance costs vs other traditional technologies and traditional phyto**
- ▶ **Effectiveness improves with time**
- ▶ **Aesthetically pleasing**

# PHYTO-INTEGRATED™ Remediation Systems Site locations – 1988 to 2016

