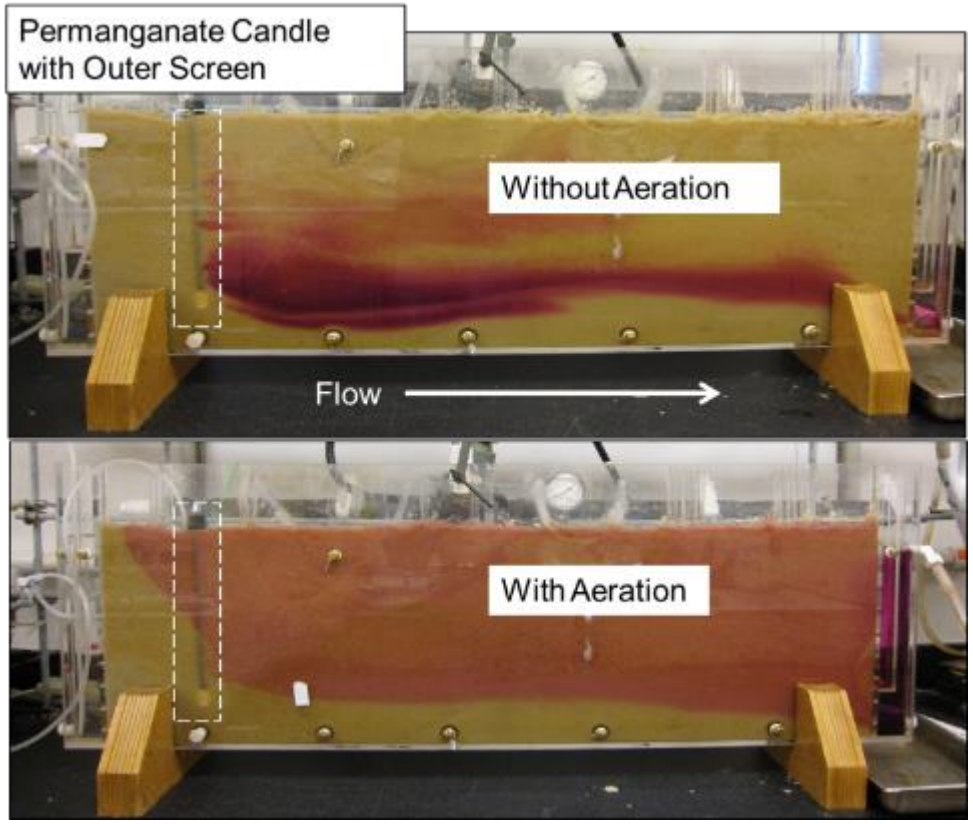
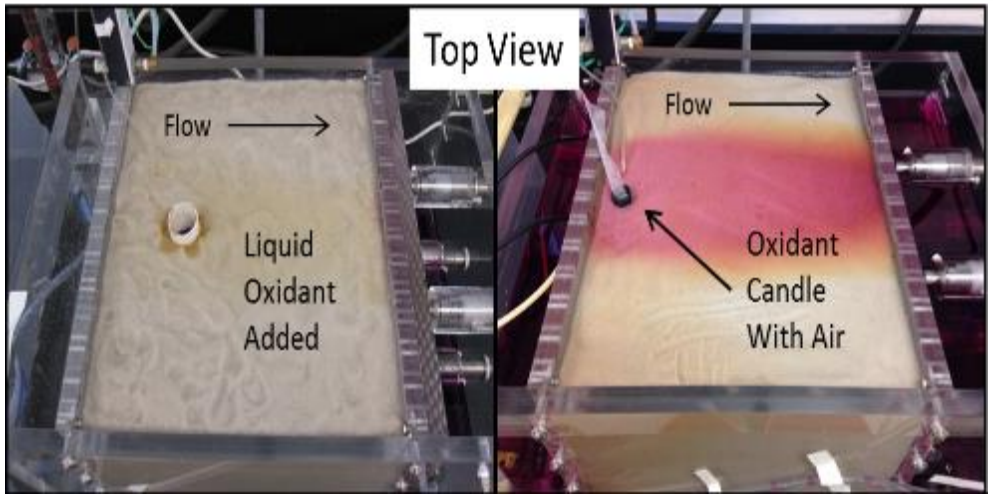
Remediating Petroleum-Contaminated Groundwater with an Aerated, Direct-Push, Oxidant Delivery System

International Petroleum Environmental Conference
San Antonio, Texas,
October 8th, 2019

Steve Comfort – University of Nebraska

University of Nebraska Lincoln





Outline

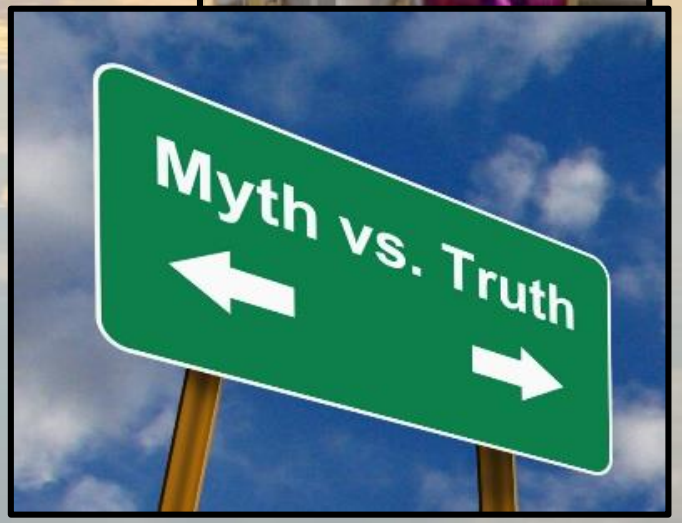
INTRODUCTION

Direct-Push, Aerated, Oxidant Delivery System

Why Use Air?

TRADITIONAL ISCO
VERSUS
AERATED OXIDANT CANDLES®

UNIVERSITY OF NEBRASKA

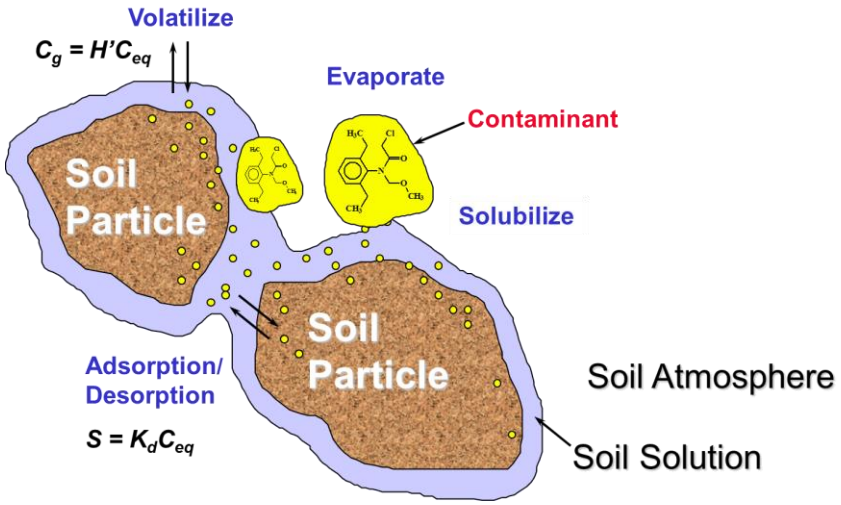


Introduction

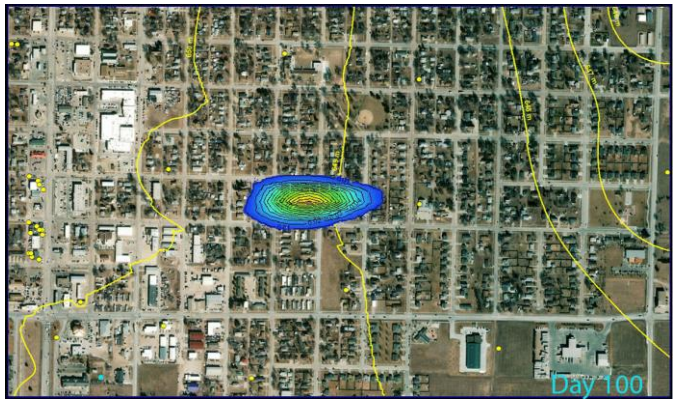
Steve Comfort
Professor of Soil and Water Chemistry,
School of Natural Resources
University of Nebraska (UNL)

Research Questions

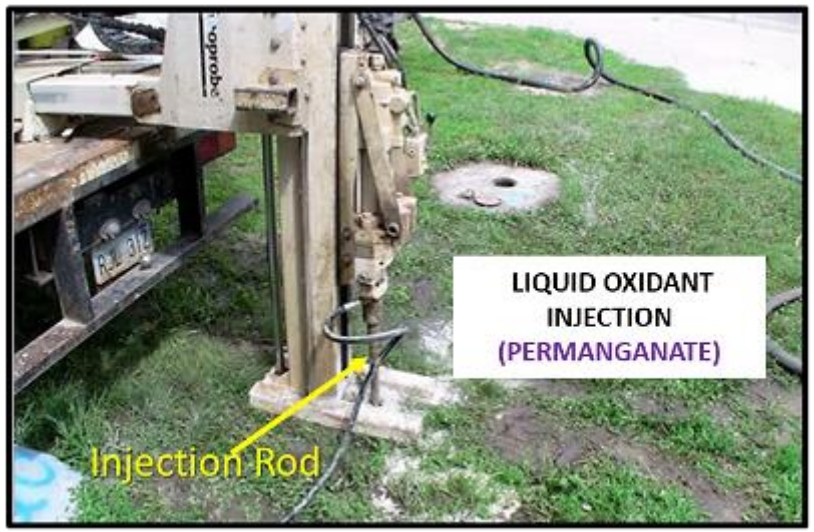
1. **What happens to Organic Chemicals Once Released into the Soil-Water Environment?**



Visual MODFLOW



2. **How Can We Remediate Contaminated Soil and Water?**



Contaminants-Remedial Treatments Performed at UNL

Pesticides
- Atrazine
- Cyanazine
- Metolachlor
- Dicamba
- Dinoseb

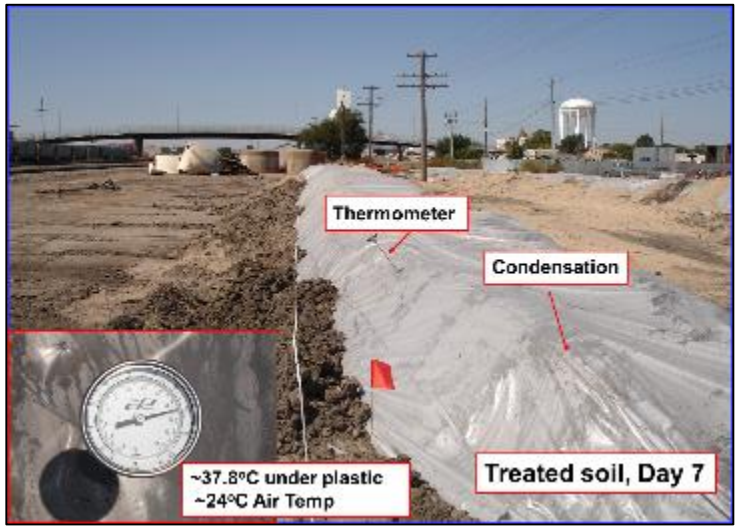
Explosives
- RDX, TNT, HMX

PAHs

NAPLs
- TCE, PCE, TCA
- BTEX

1,4-Dioxane

Soil Treatments

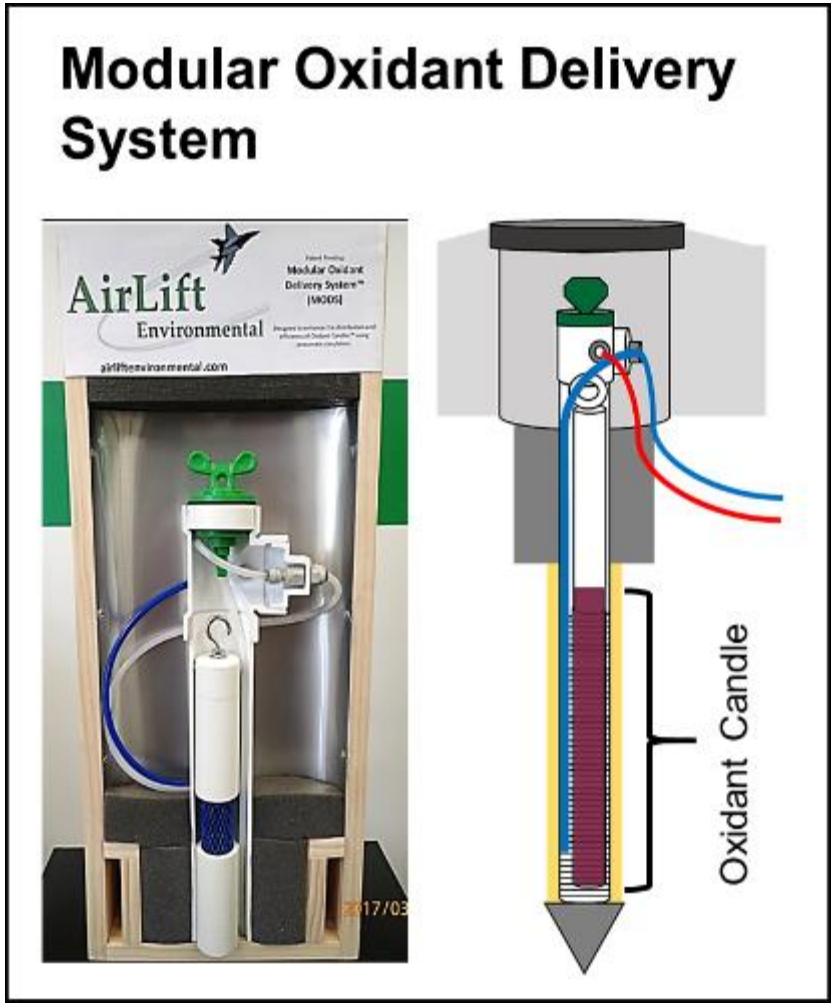


Chemical Oxidation Treatments
- Fenton's Reaction (·OH)
- Permanganate
- Persulfate
- Ozone

Chemical Reduction Treatments
- Zerovalent Iron (Fe^0)
- Dithionite (Redox barrier)
- Fe(II)

Groundwater Treatment

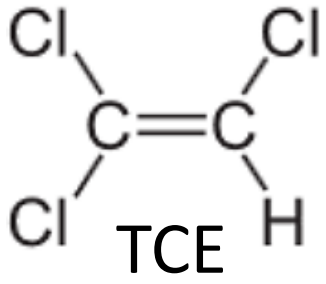
Development of Direct-Push, Oxidant Delivery System



How Aerated, Direct-Push Oxidant Candles were Developed

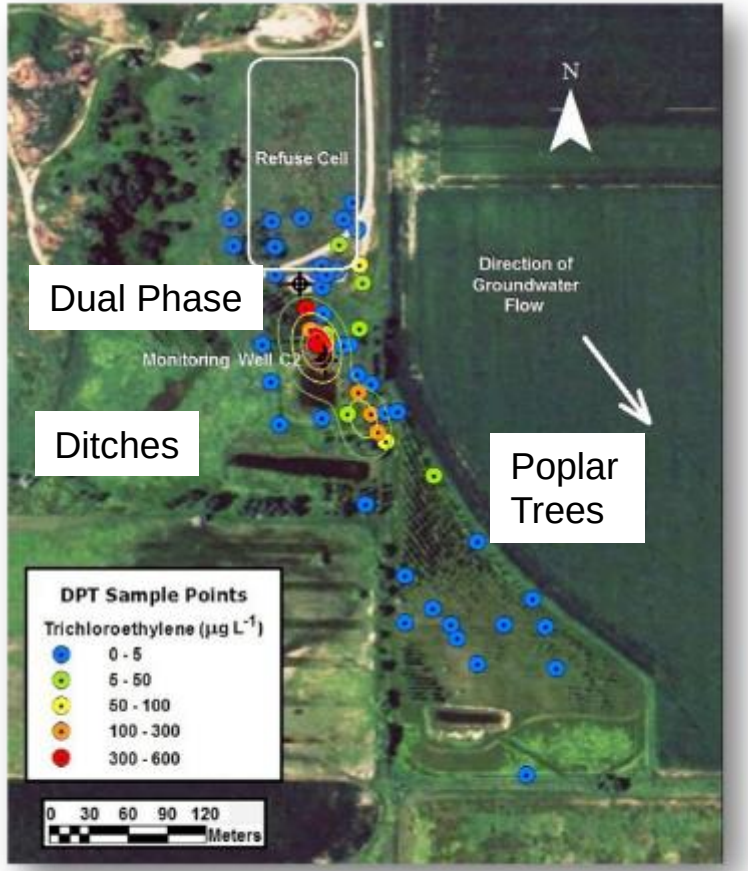
Background/Timeline:

- 2005 – Federal Earmark Grant - "***Developing Innovative Treatments for Contaminated Soil and Water***"
- 2009 – Nebraska Department of Environment and Energy (NDEE) → Cozad Landfill → TCE Contaminated Groundwater



TCE

Dual Phase
Poplar Trees
Ditches

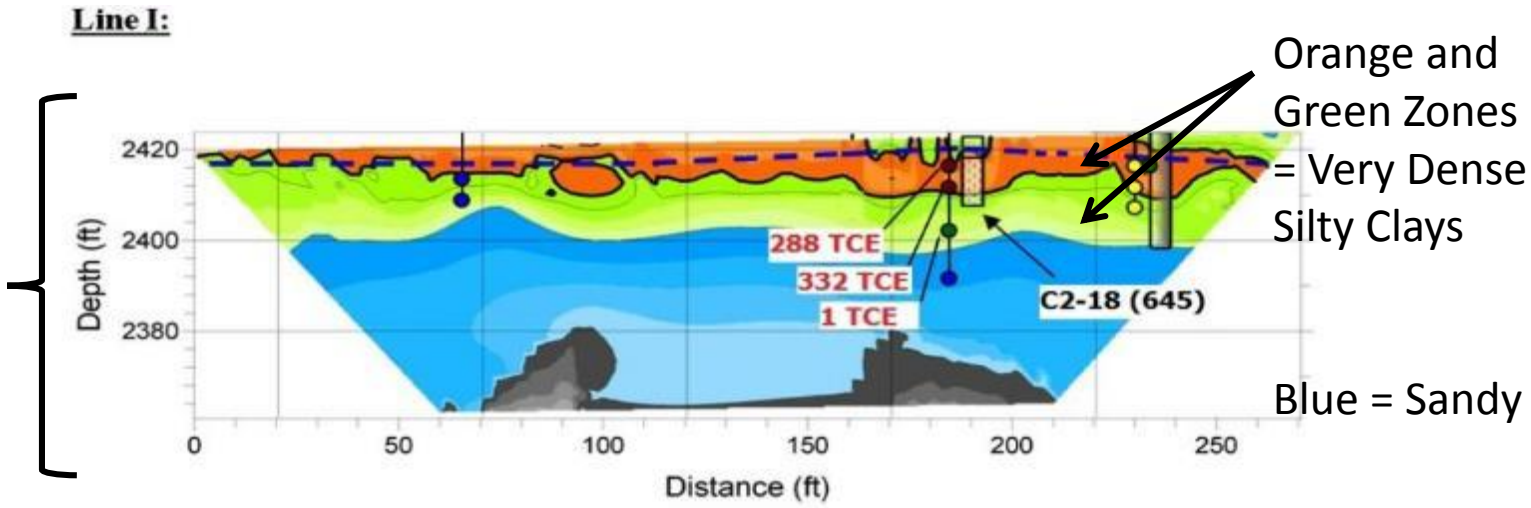


How Aerated, Direct-Push Oxidant Candles were Developed

Background/Timeline:

- 2005 – Federal Earmark Grant - "***Developing Innovative Treatments for Contaminated Soil and Water***"
- 2009 – Nebraska Department of Environment and Energy (NDEE) → Cozad Landfill → TCE Contaminated Groundwater
- 2009 - Extensive sampling/surveying finds VOCs located in low permeable zones of aquifer

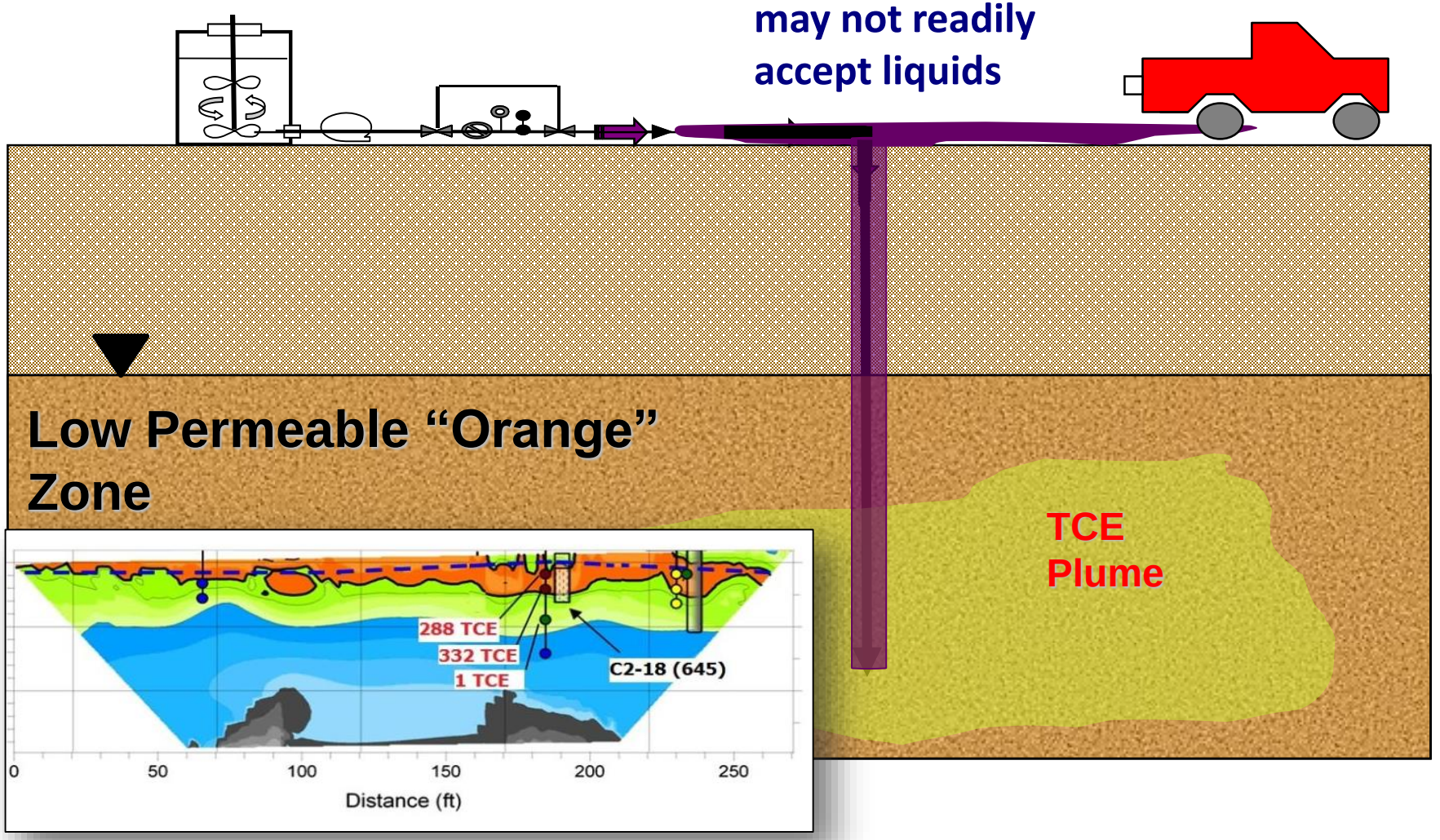
Colored Layers = Different Textures



All Contamination Confined to "Orange" Zone

Injecting Liquids Into Low Permeable Zones

Previous Project



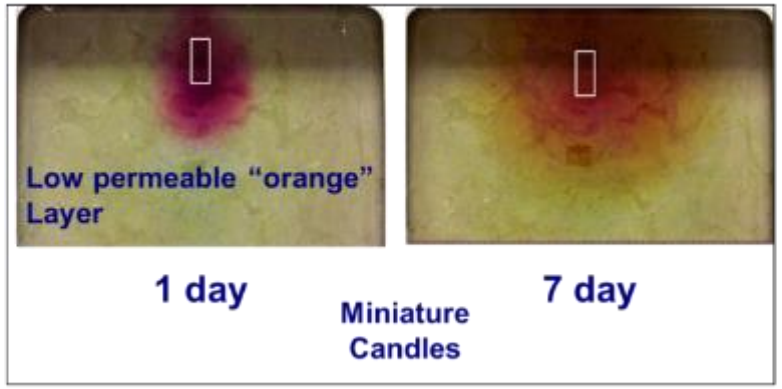
Aerated, Direct-Push Oxidant Candles

Background/Timeline (continued):

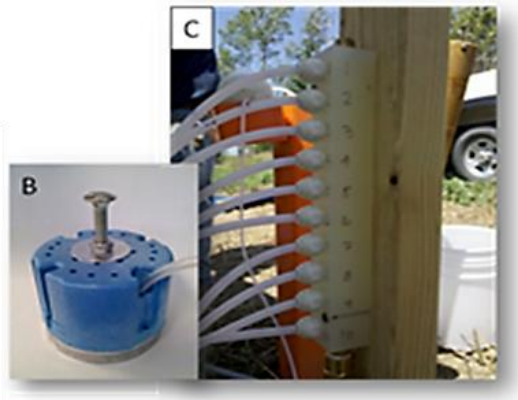
- 2010 – Manufactured “oxidant candles” and inserted into formation to intercept contaminant plume (Mark Christenson – lead graduate student).

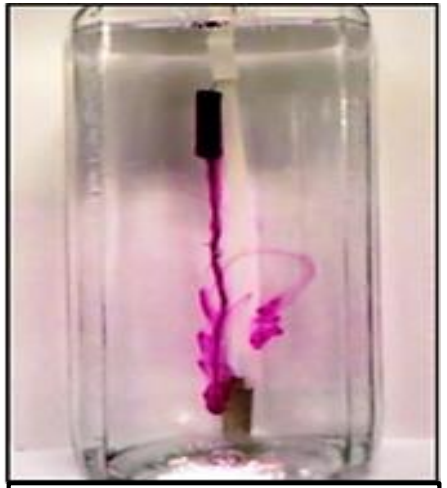
Wax + Permanganate

Permanganate candles



Added Aerators to Candles in Wells





Oxidant Candle In Water

Direct-Push, Oxidant Delivery System (2012 → Present)

STTR: **Phase I (2013)**
Phase II (2015)

NUtech VENTURES

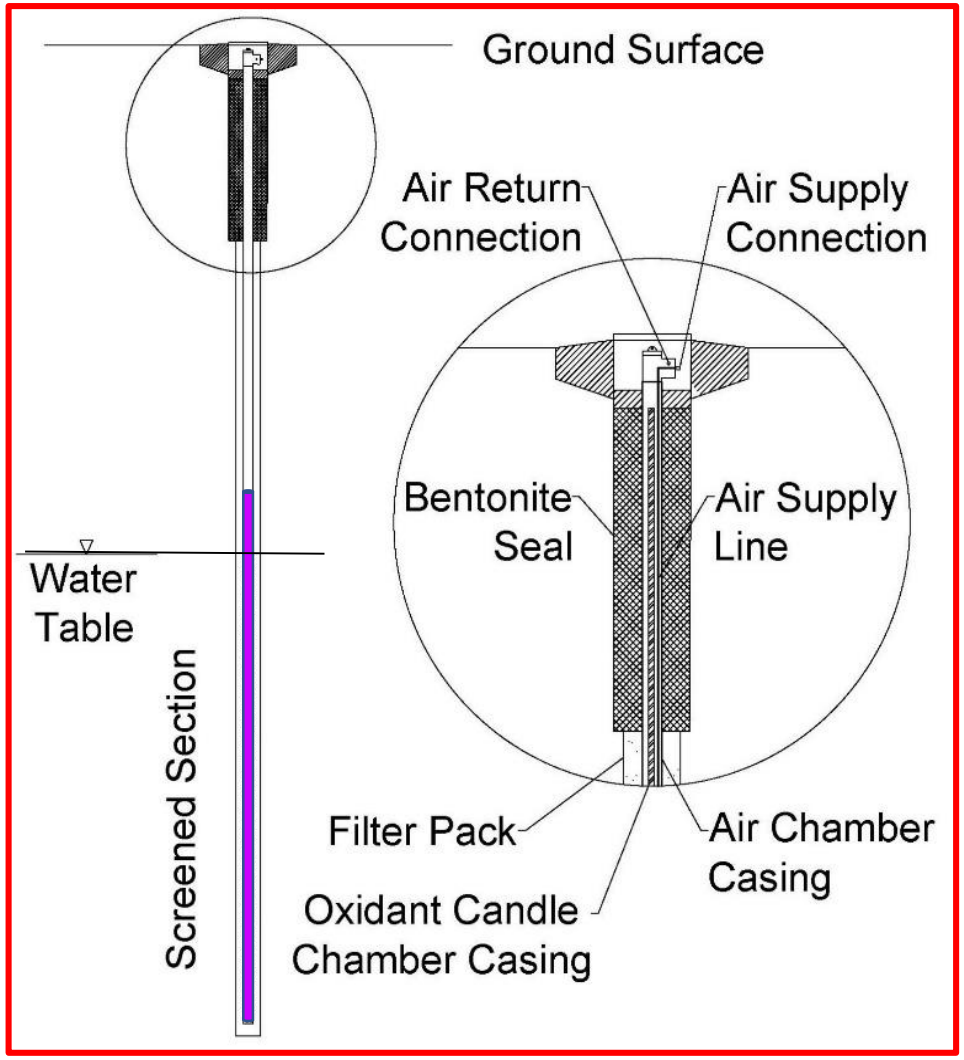
Patent (2018)

Steve Comfort
Professor, Soil and Water Chemistry
University of Nebraska

Mark Christenson
President - AirLift Environmental, LLC

Modular Oxidant Delivery System

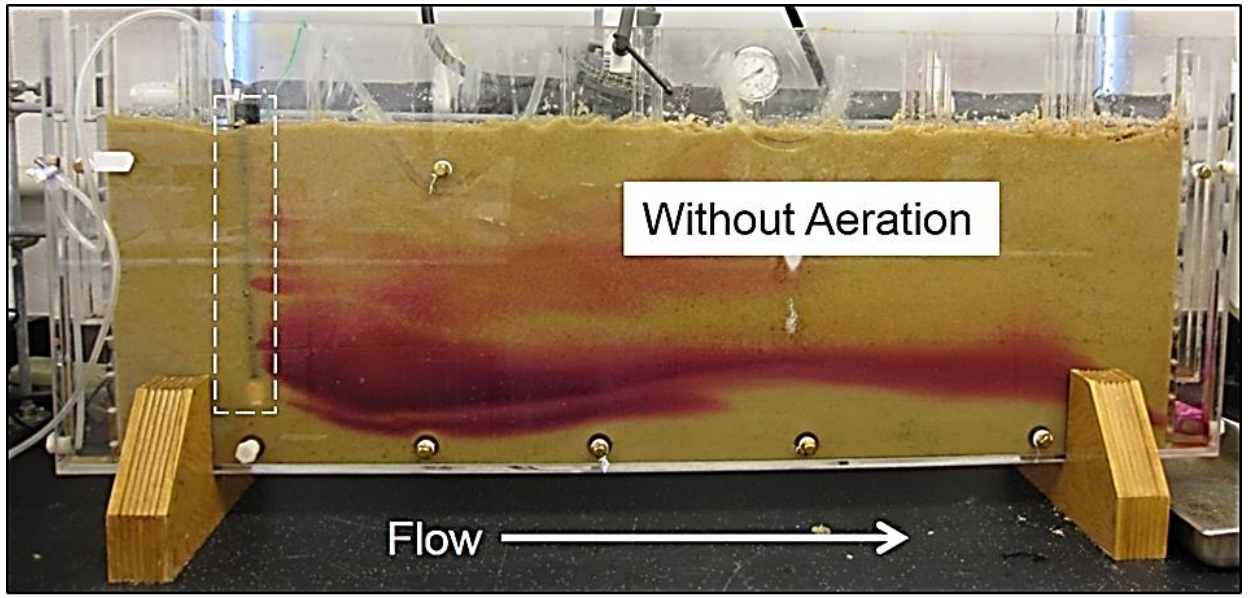
Drive Point w/Oxidant

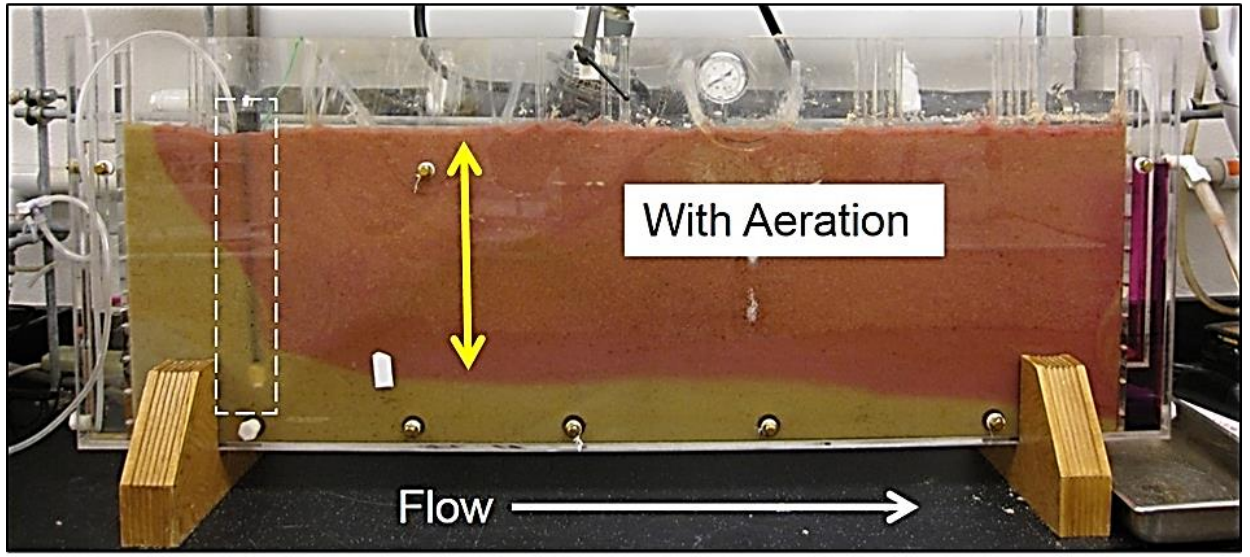


Manifold

Compressor

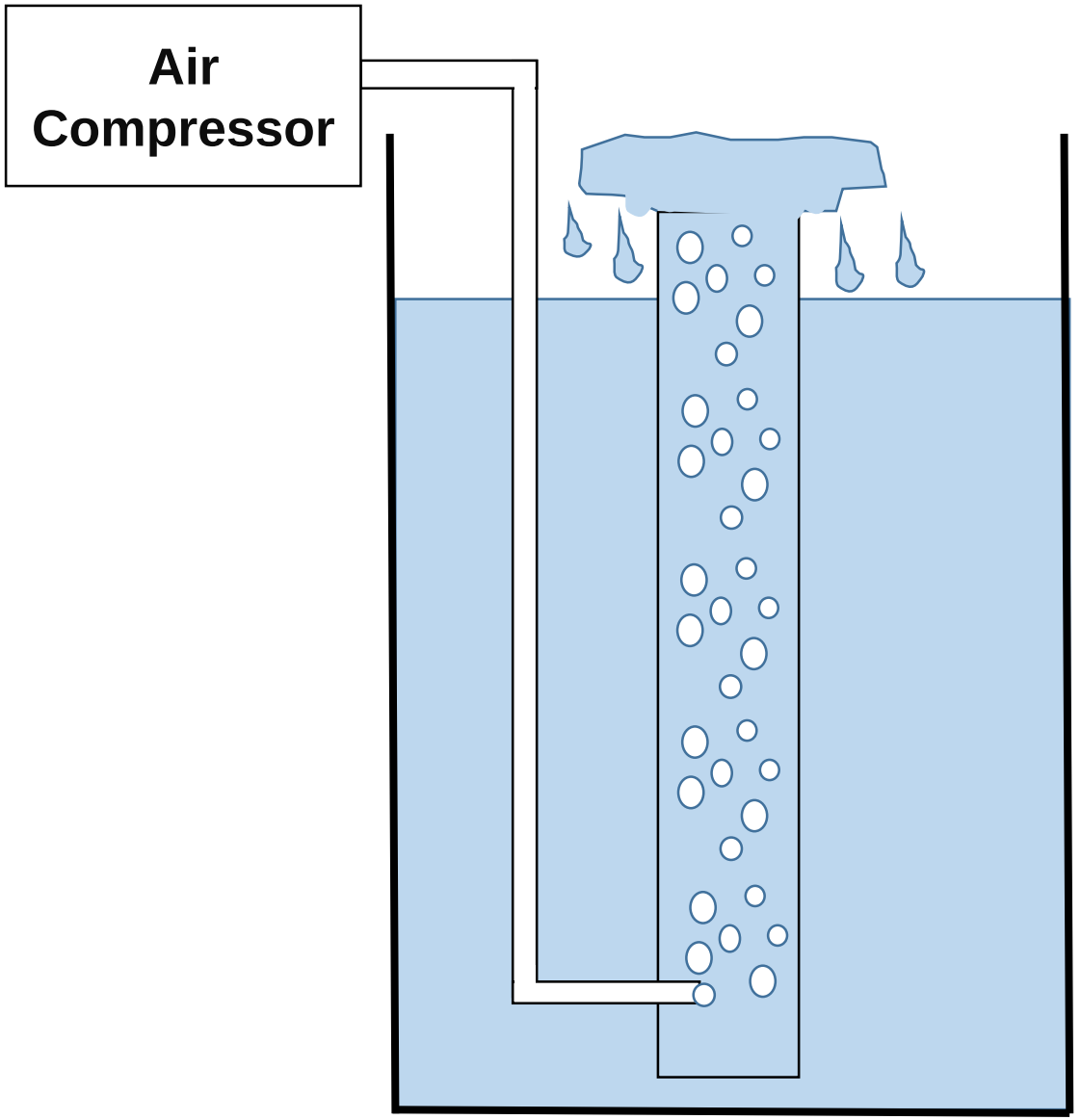
Why Use Air?





Airlift Pump

German engineer Carl Emanuel Löscher in 1797



Airlift Pump with Oxidant Candles

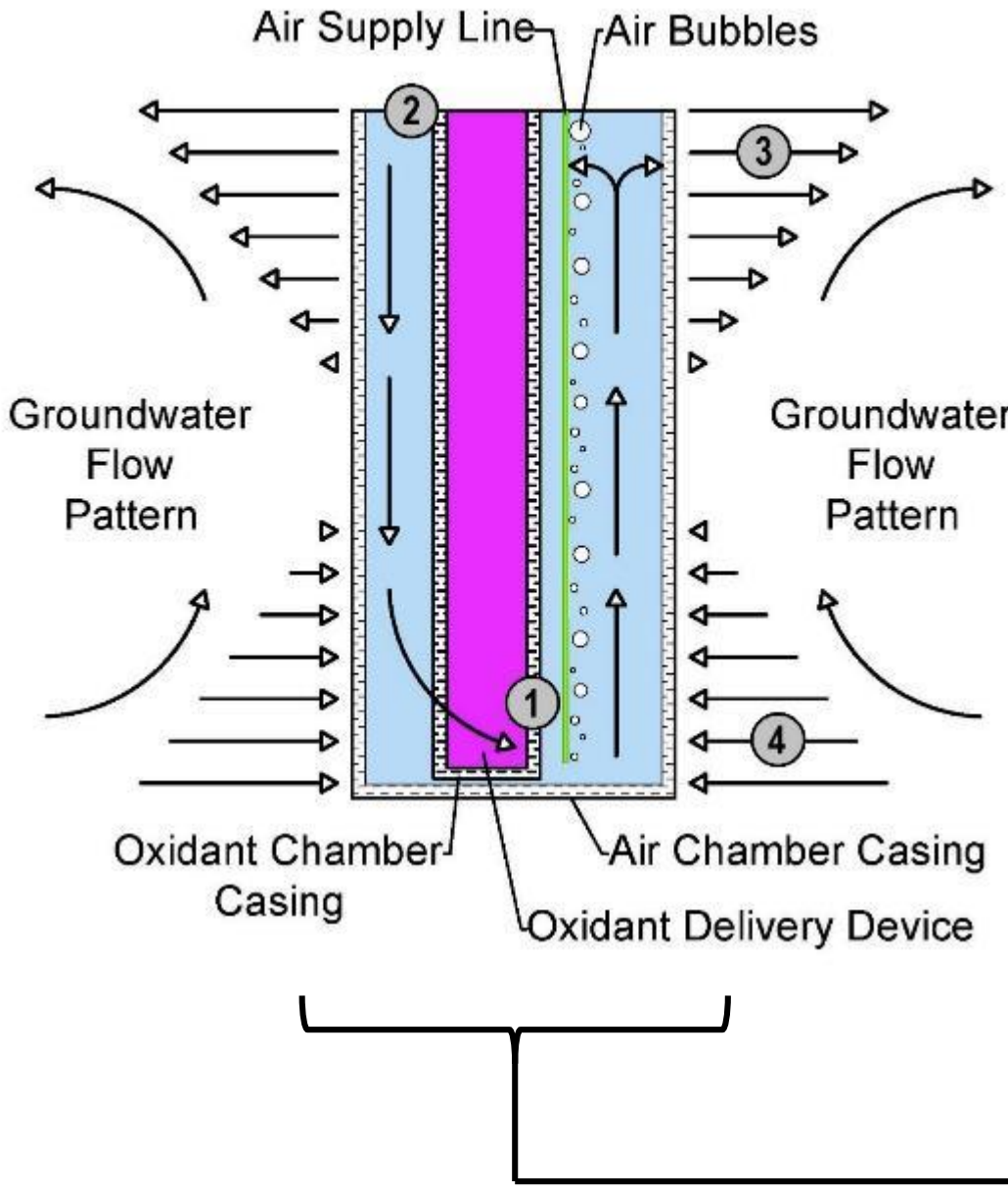
Time-lapse video of 5-foot Permanganate Candles placed in water tanks, with and without aeration

Air Bubbled Up Inside Screen

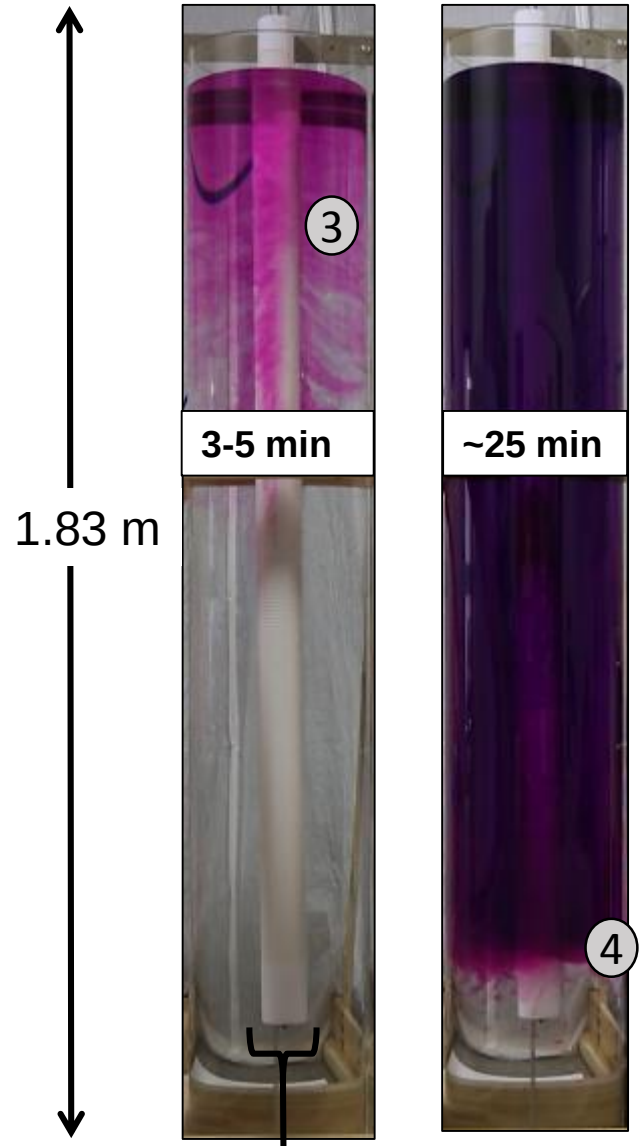
“Reloadable Design”

Density-Flow

Aeration – Induced Circulation



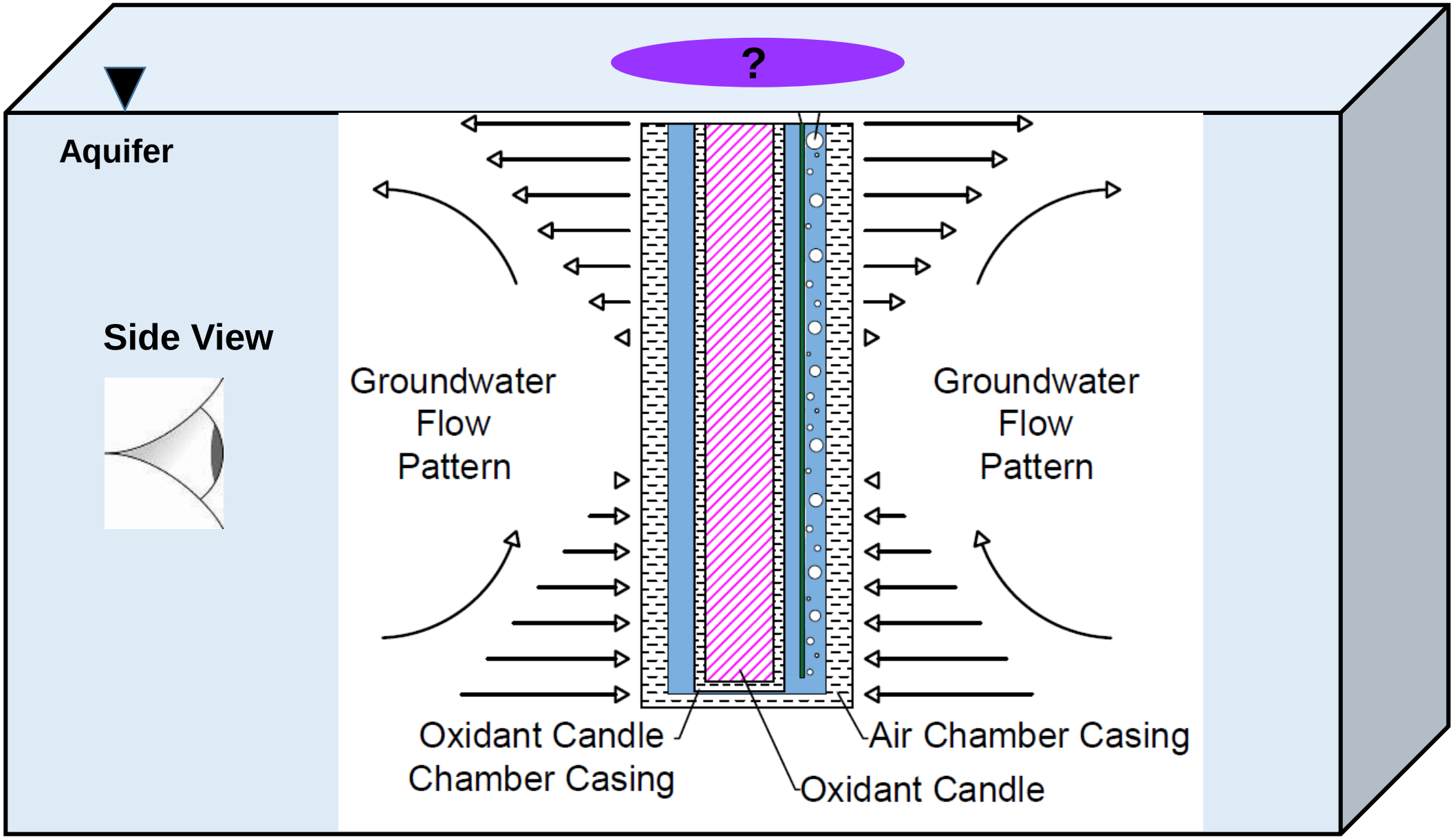
Double-Screened Aerated Oxidant Candle



Clear Double-Screens with Dye

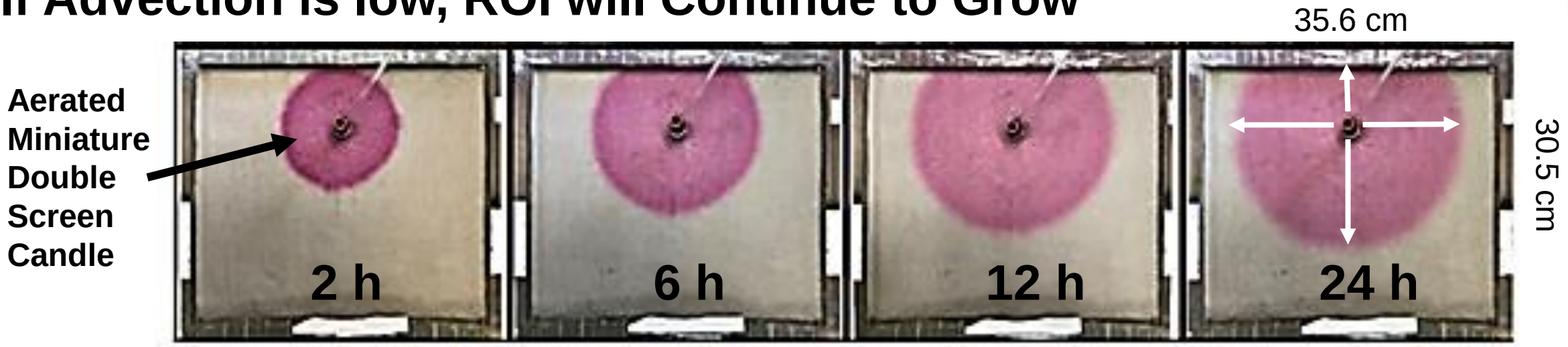
Radius of Influence

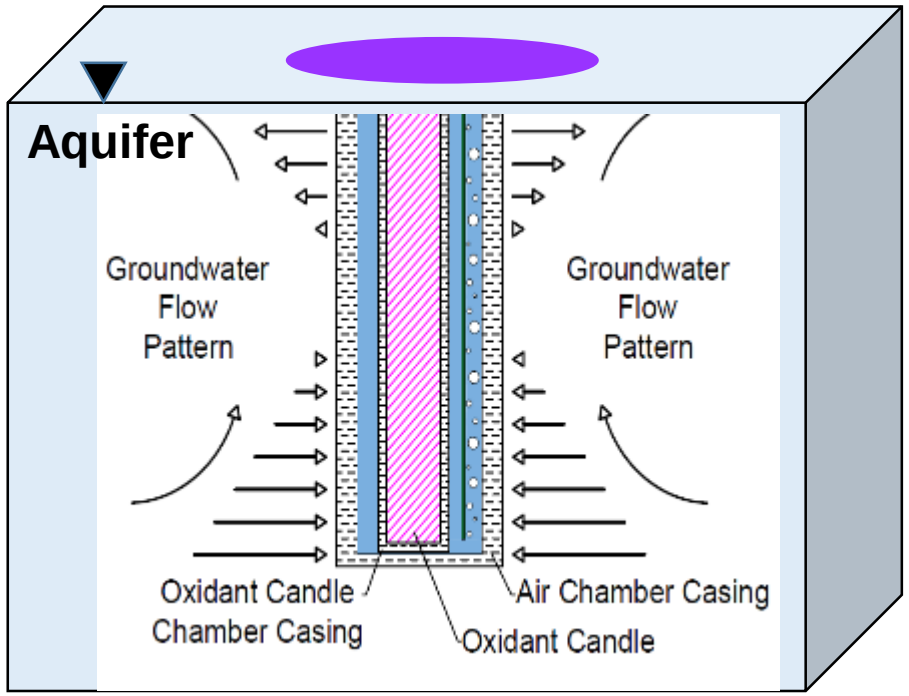
Top View



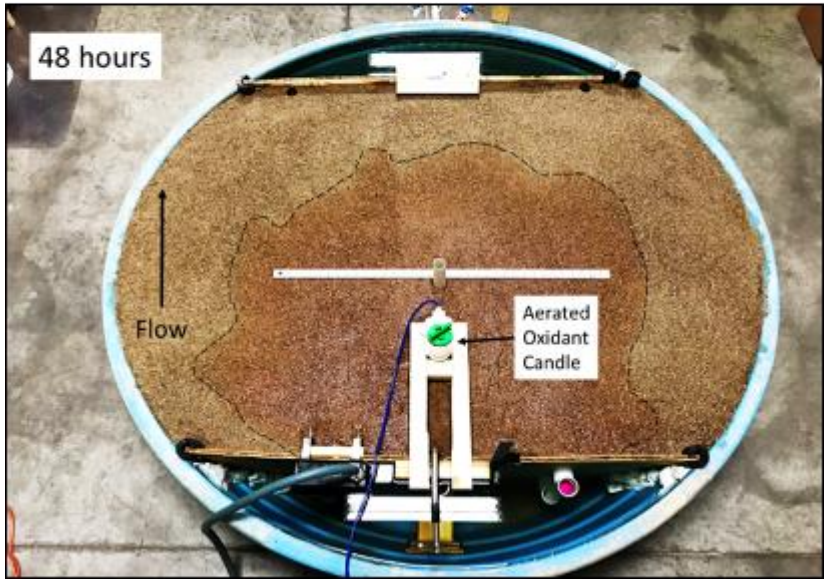
Radius of Influence

If Advection is low, ROI will Continue to Grow





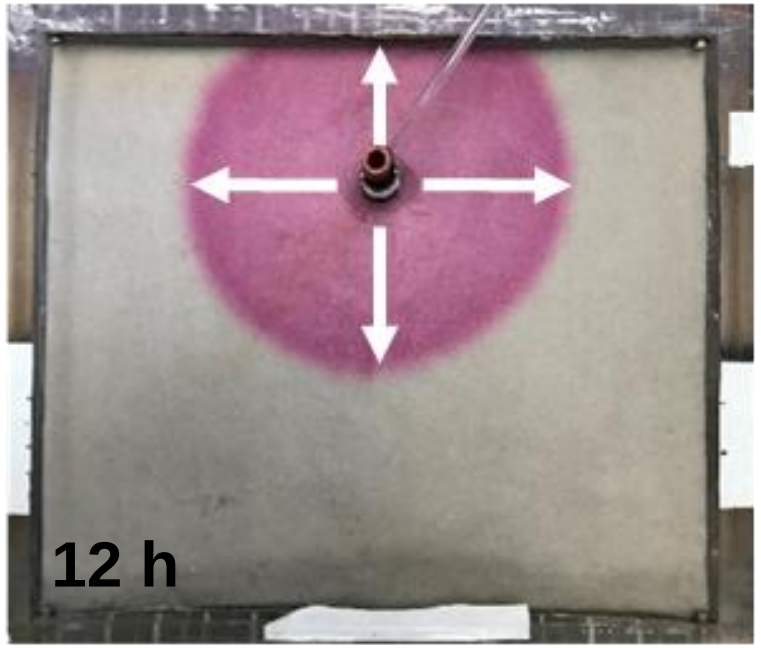
Horizontal Oxidant Spreading in 6 ft. tank



Radius of Influence

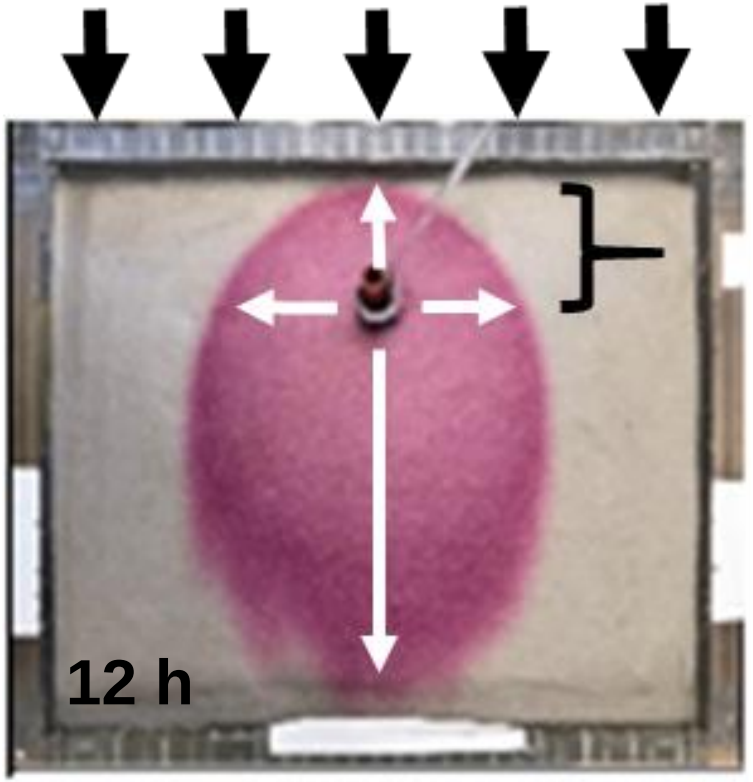
Seepage velocity will influence drive point spacing

Static
(No flow)



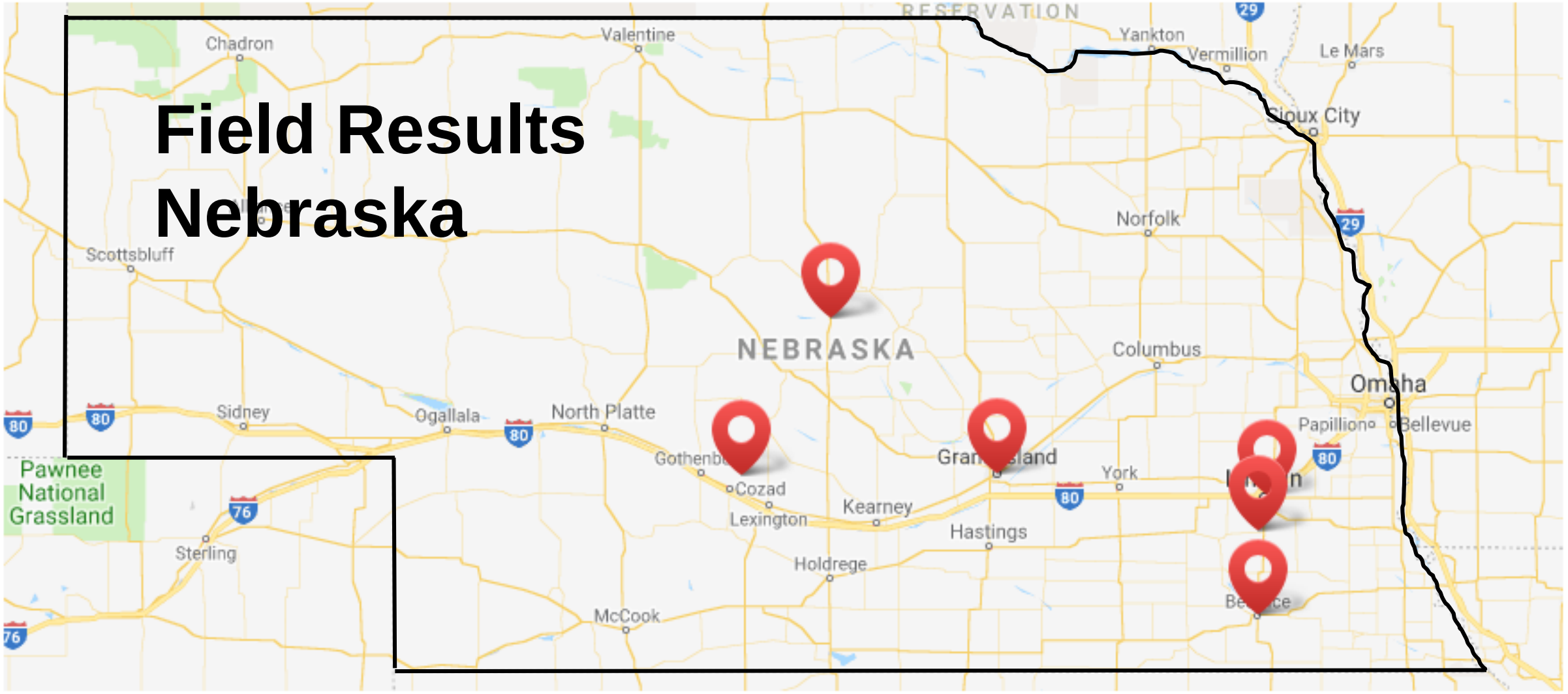
Concentric Growth

Flow ✓

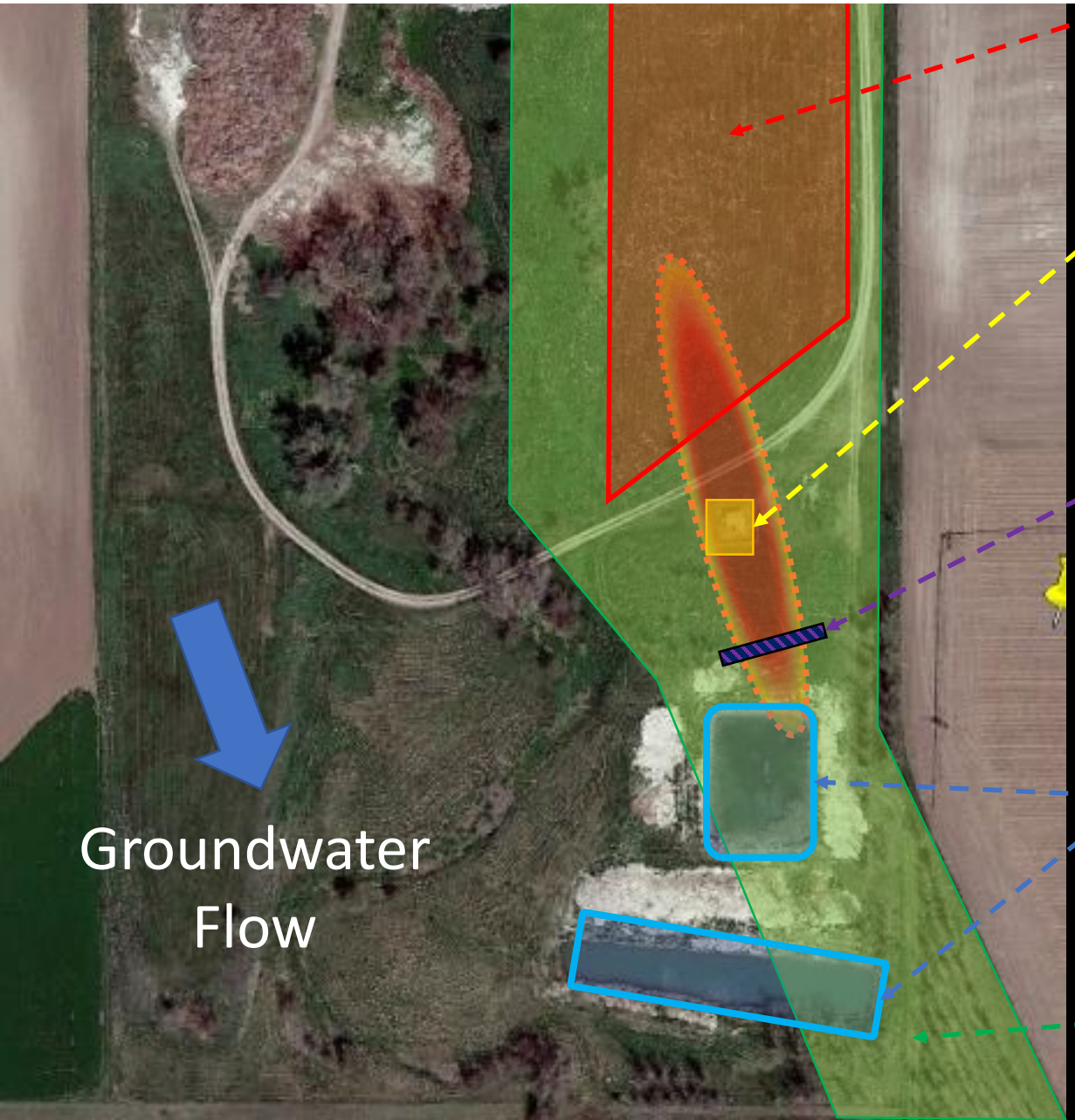


Up Gradient Flow

Field Results
Nebraska



#1 Landfill-Cozad, NE



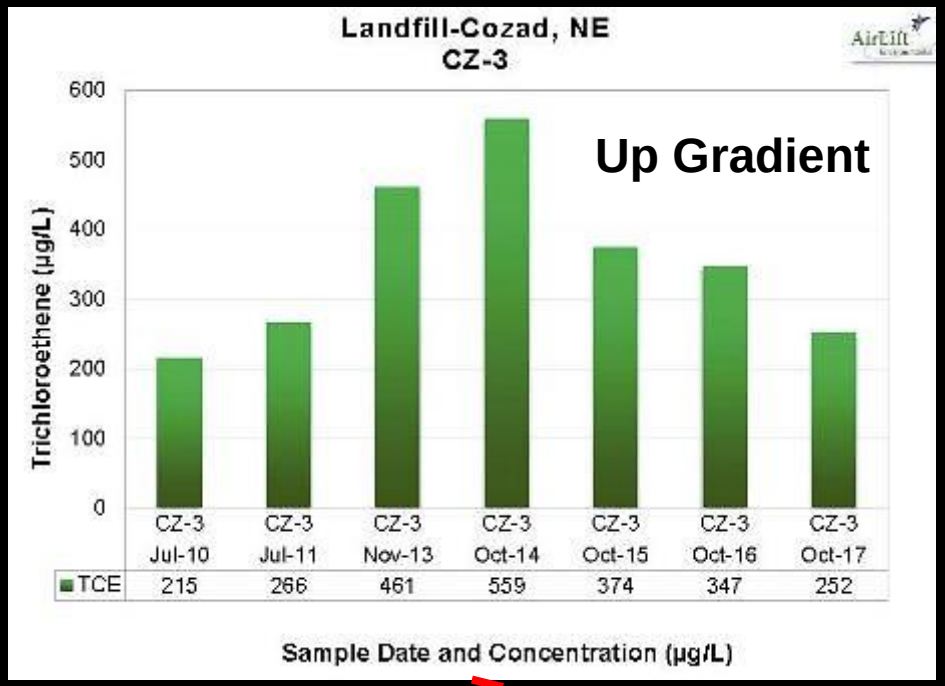
Refuse Cell

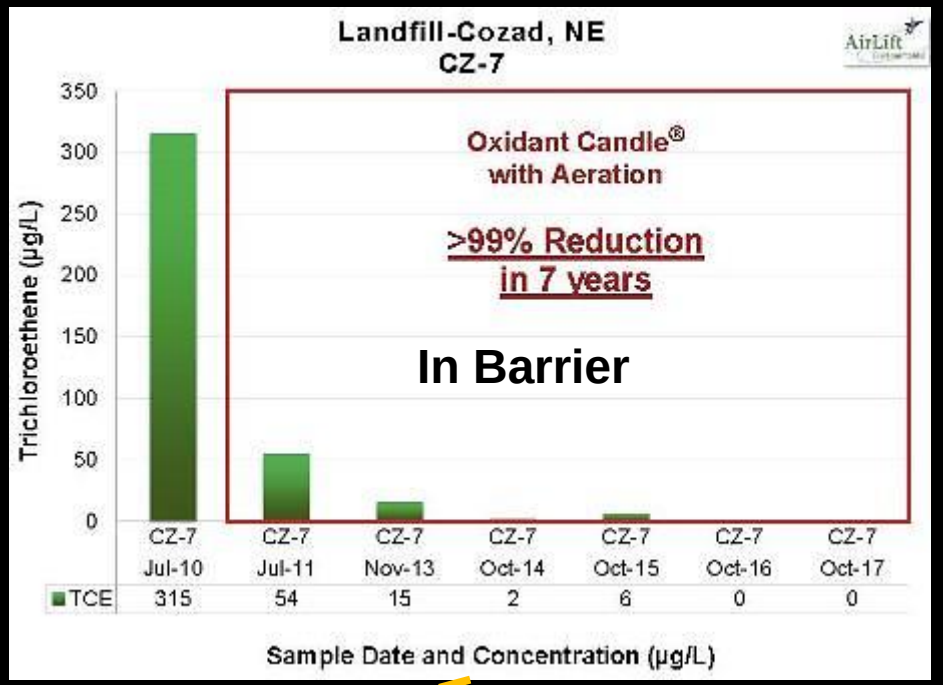
Dual Phase Extraction

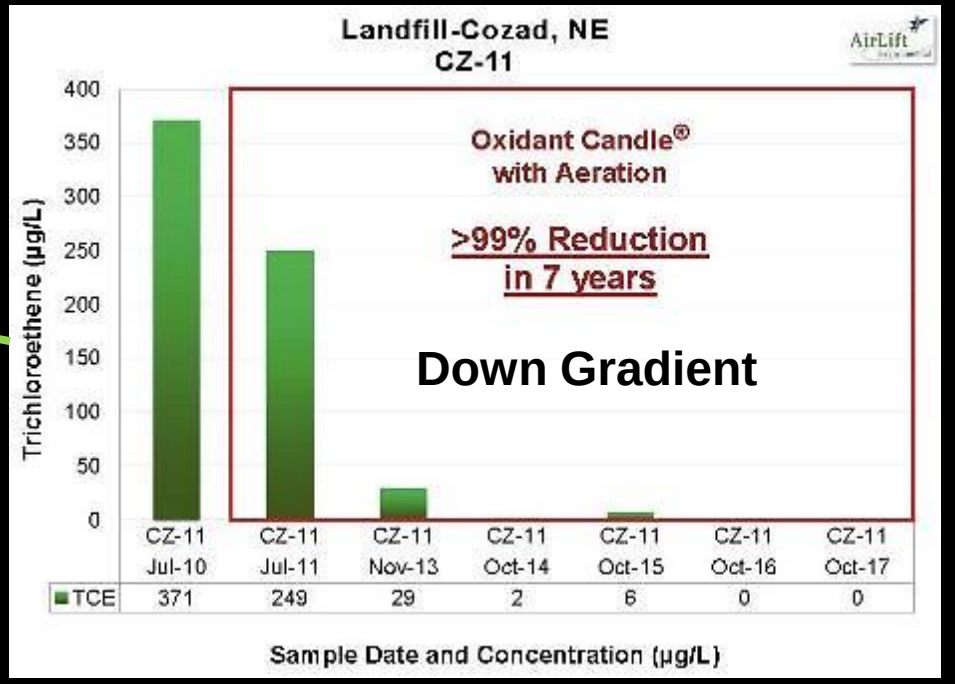
Permeable Reactive Barrier-
Oxidant Candles®

Volatilization Lagoons

Phyto-Remediation







Groundwater Flow

Aerated Permanganate Candle Barrier

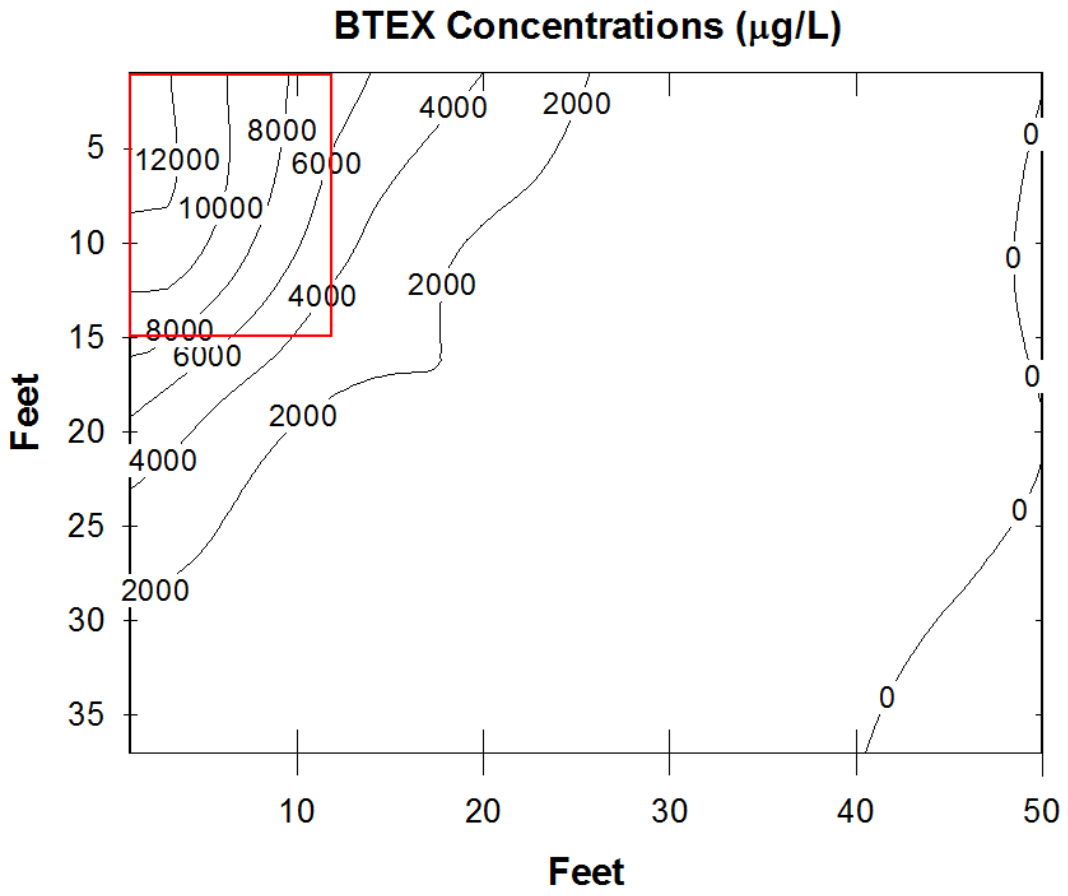
#2 Textron-Lincoln, NE

- Source Zone Treatment
- Oxidant Candle: Persulfate
- **"Reloadable"** Drive Points inserted by Direct-Push
- Site: Industrial/Manufacturing
- Contamination: BTEX
- Aquifer: Fine Sands and Clay

Small Business STTR (Phase II)

NIH National Institute of Environmental Health Sciences

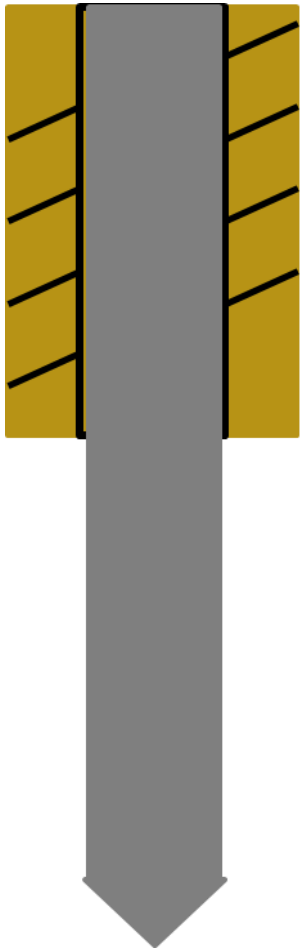
Results from Grid Sampling



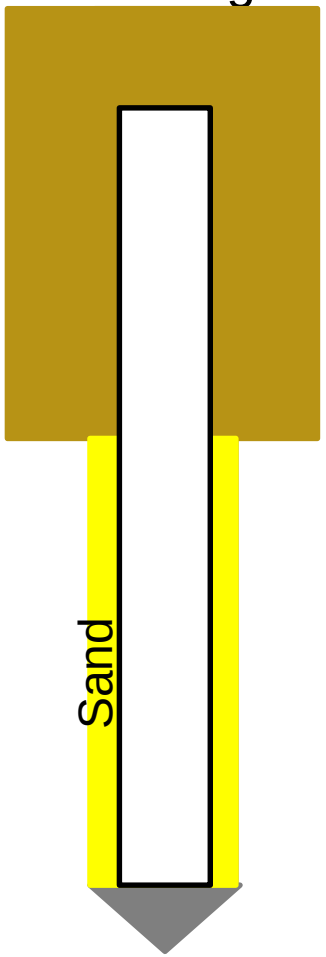
Installing Reloadable Direct-Push Oxidant Delivery System

Hollow Stem Auger (5 ‘)

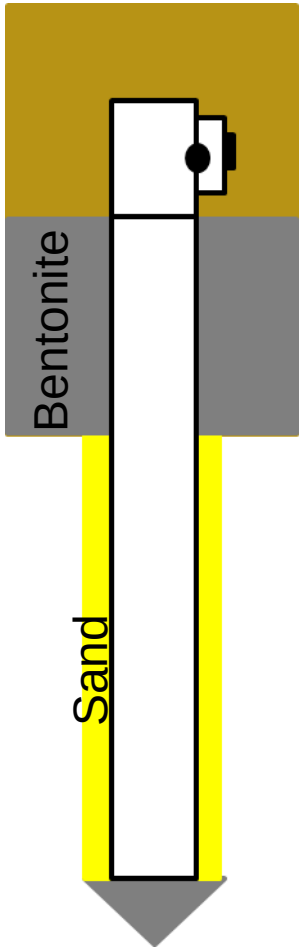
Drive Down 3” Rod



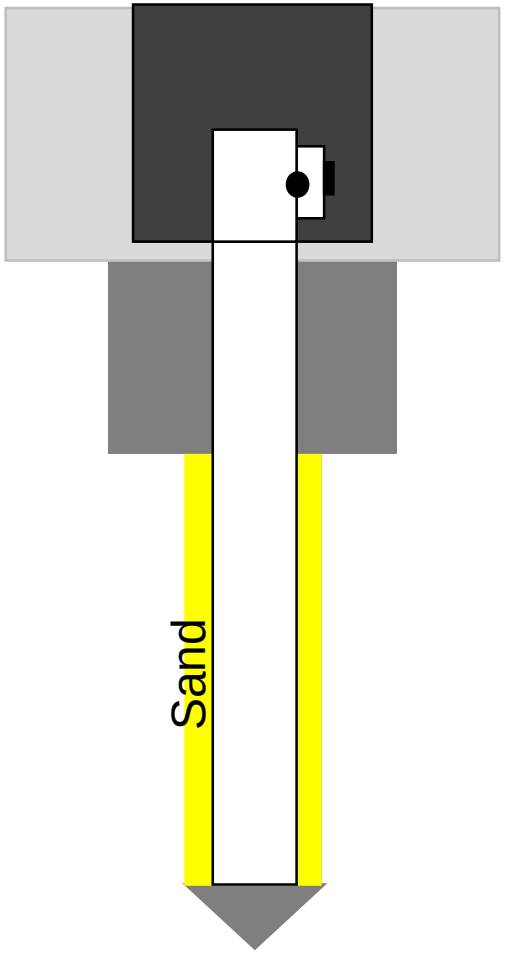
Add Outer Chamber Remove Rod/Auger



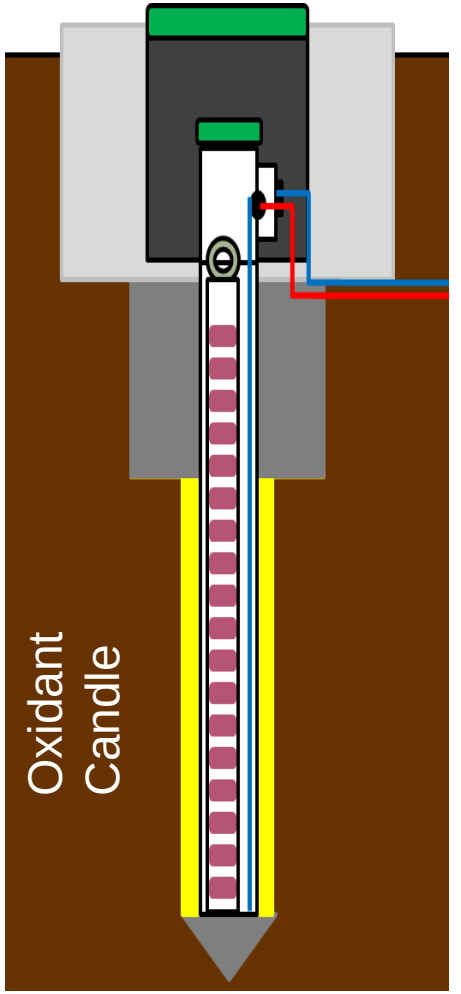
Add Cap and Bentonite



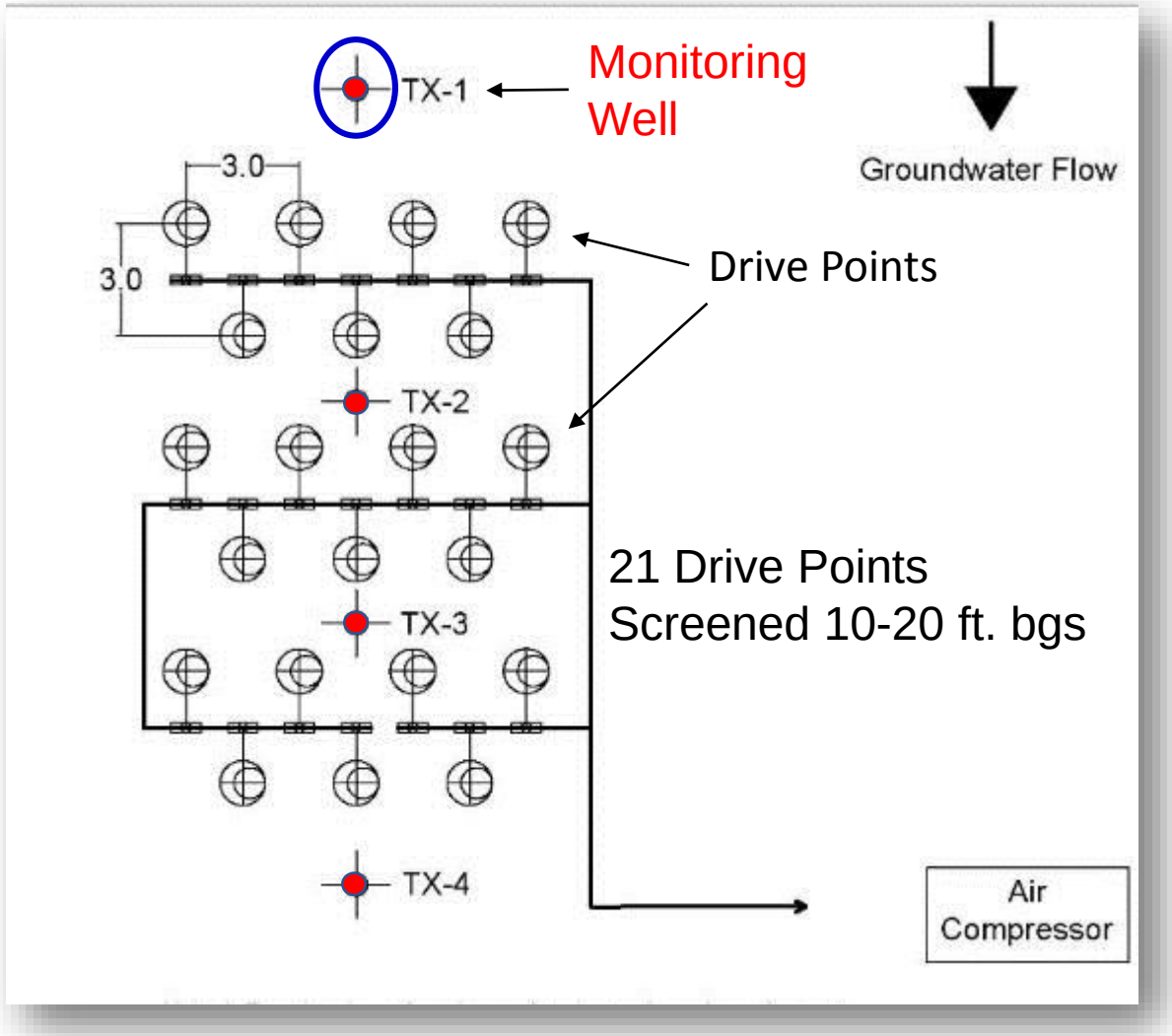
Install Flush-Mounted casing

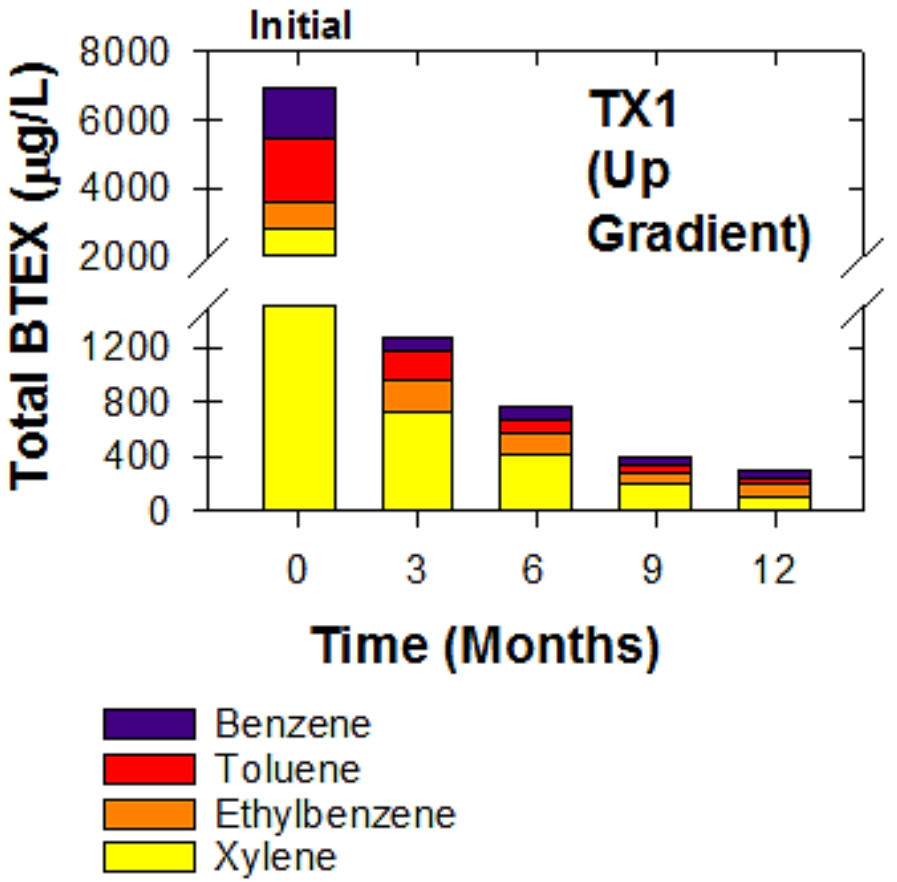


Insert oxidant Candle with air and vent lines

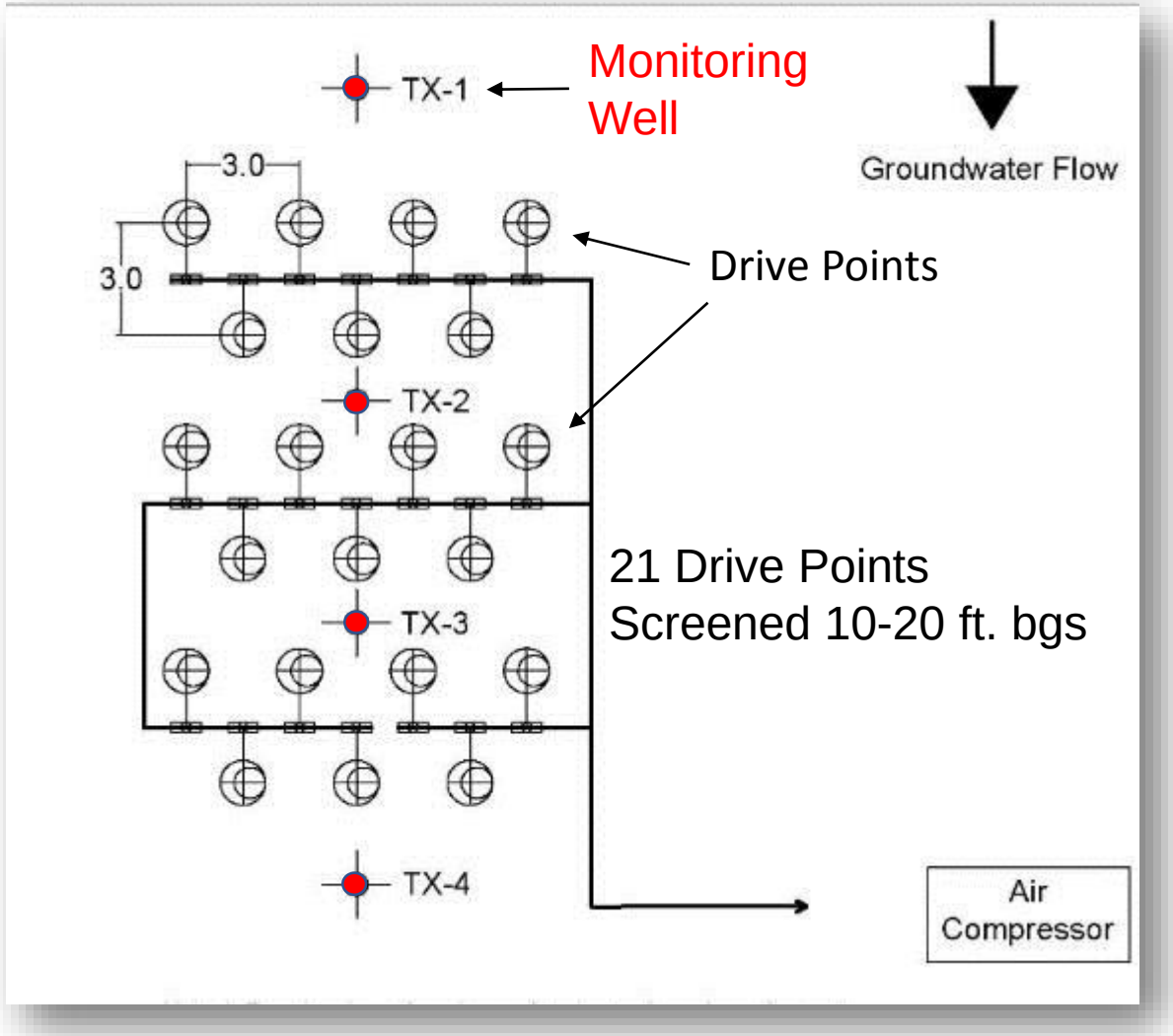


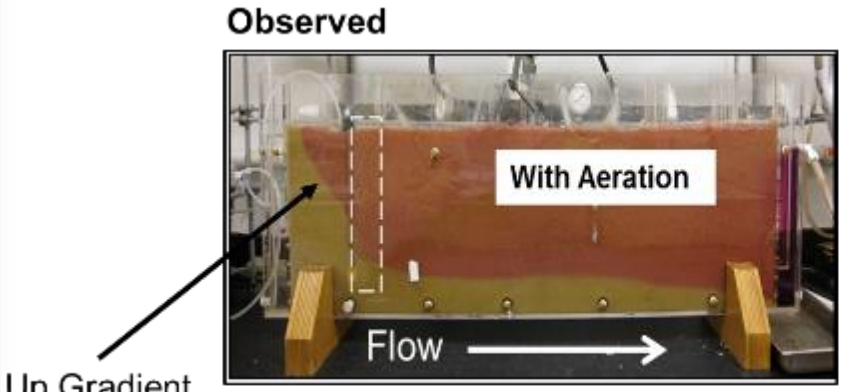
#2 Textron (BTEX Site, Lincoln, NE)

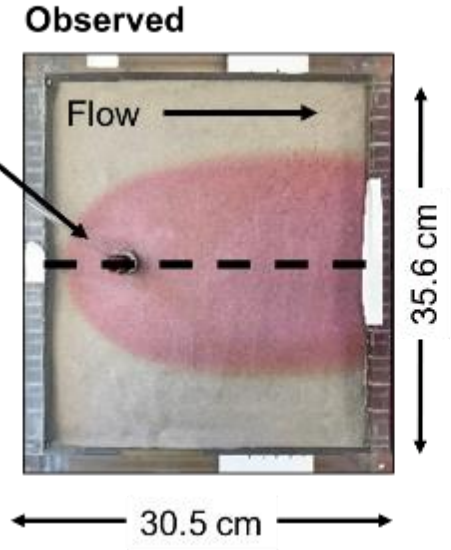


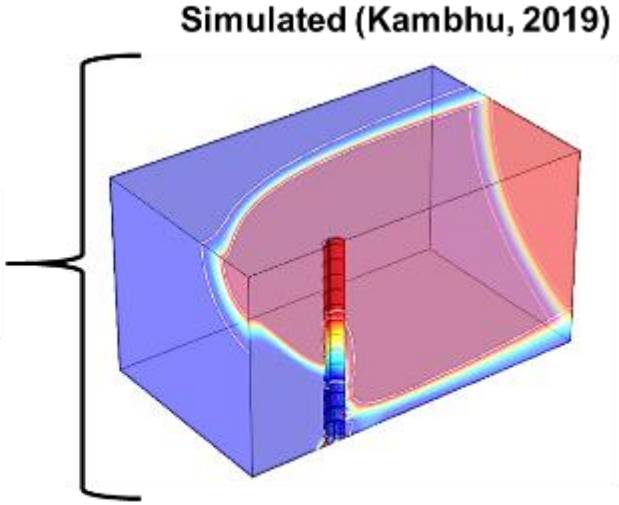


#2 Textron (BTEX Site, Lincoln, NE)

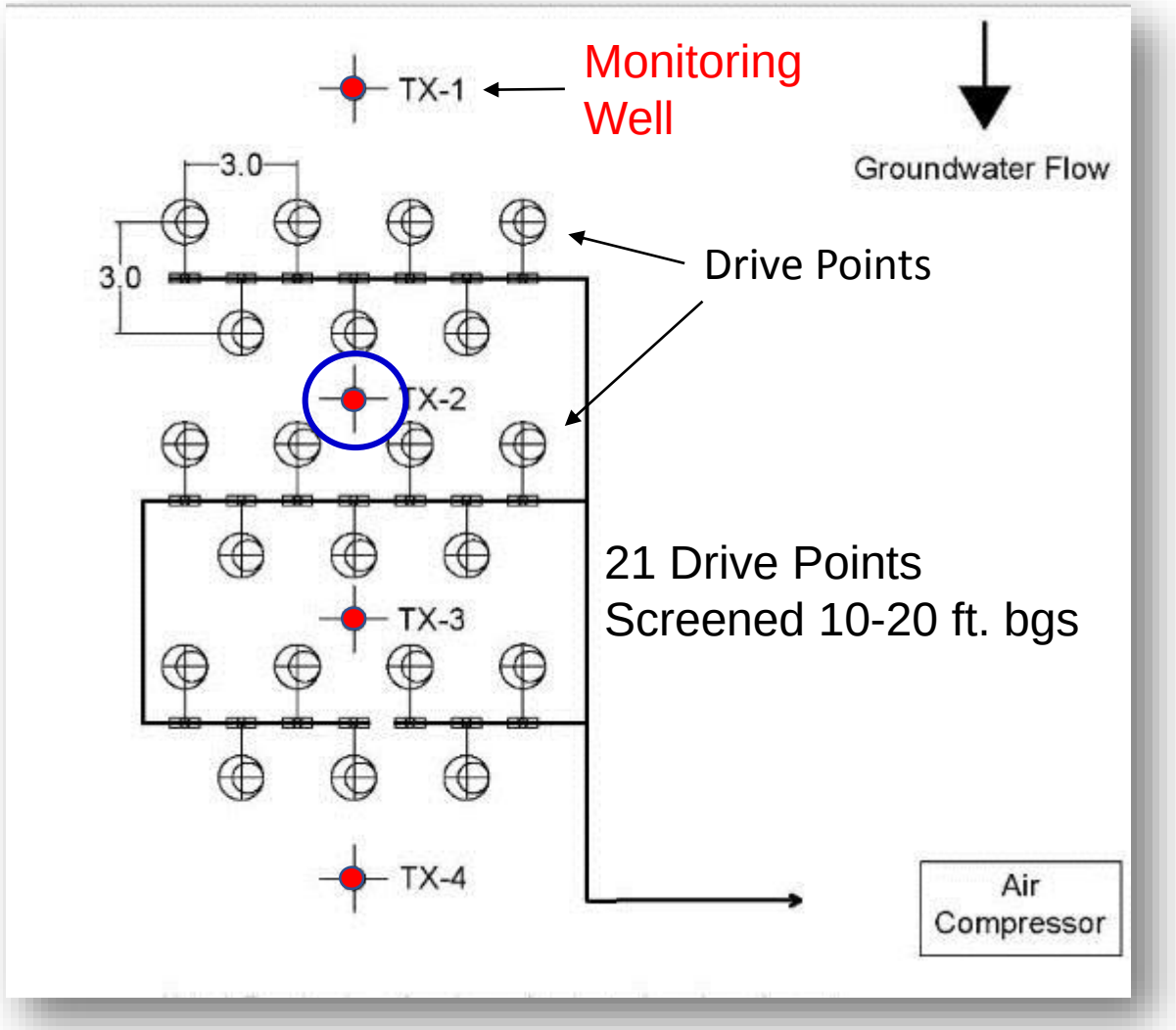


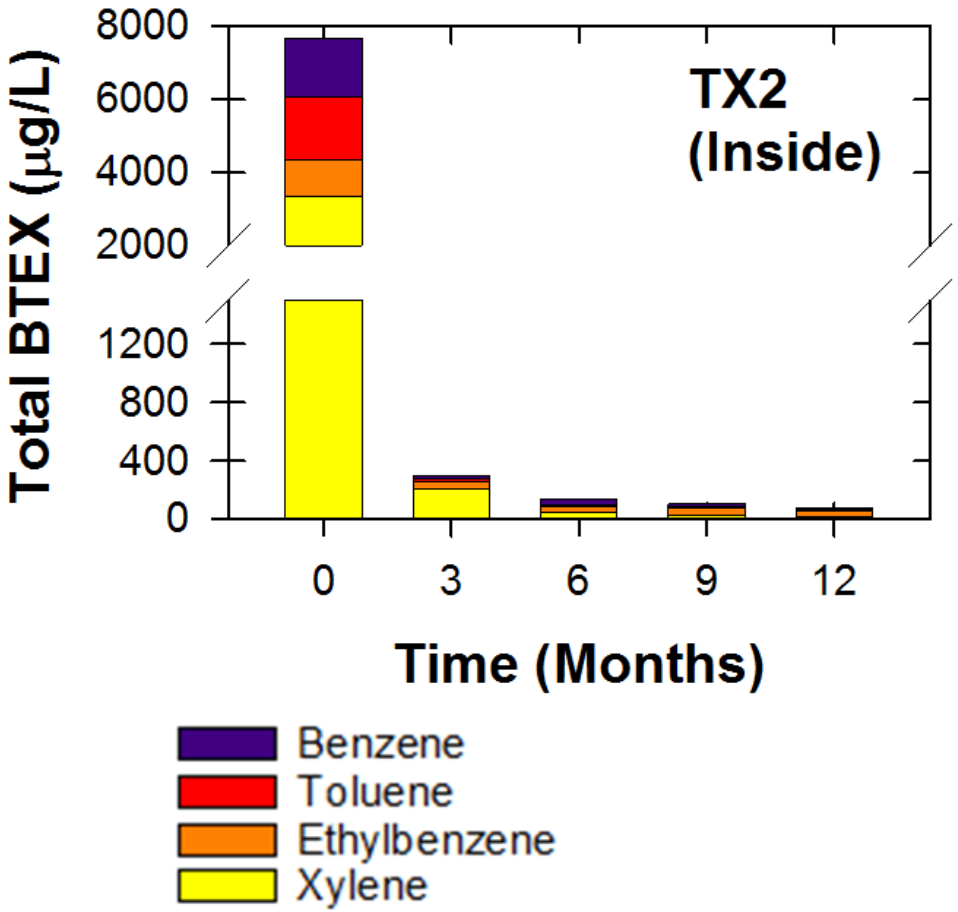




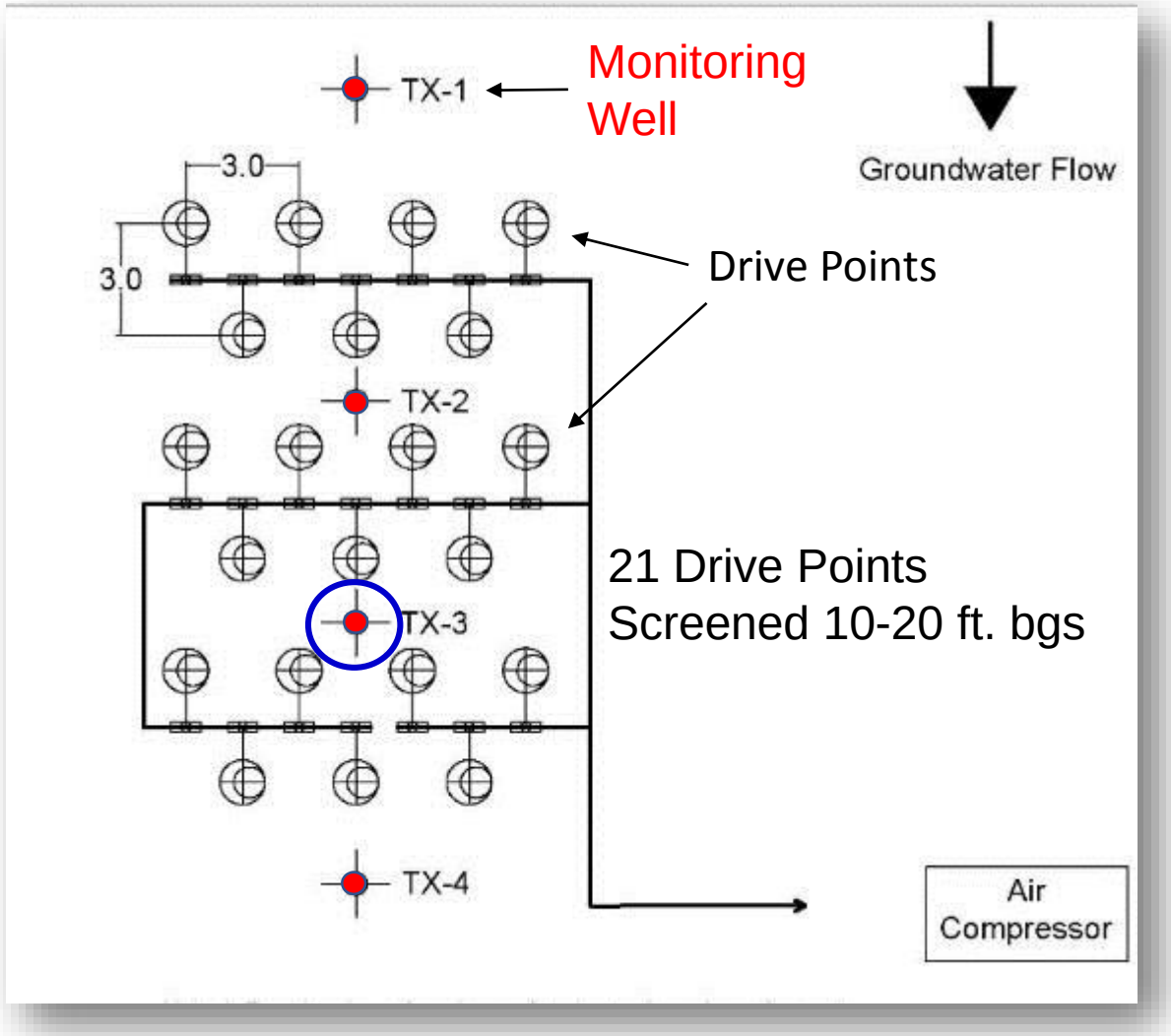


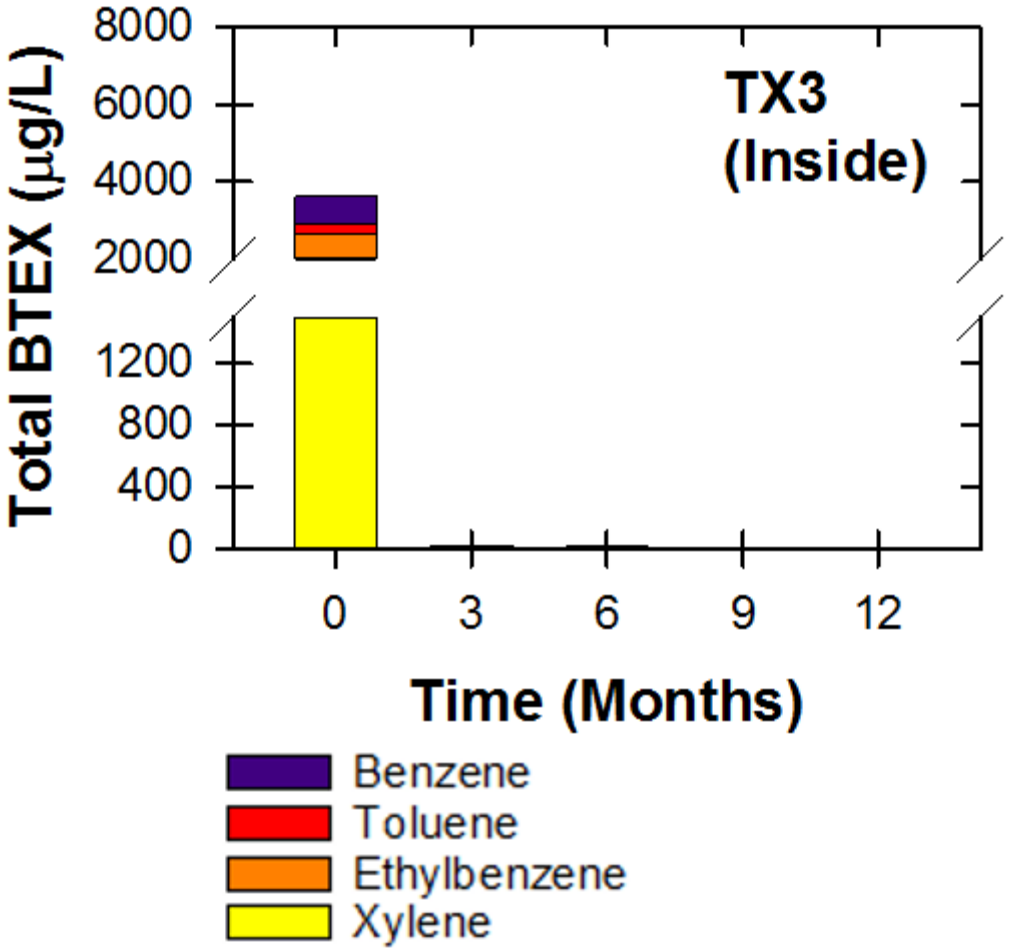
#2 Textron (BTEX Site, Lincoln, NE)



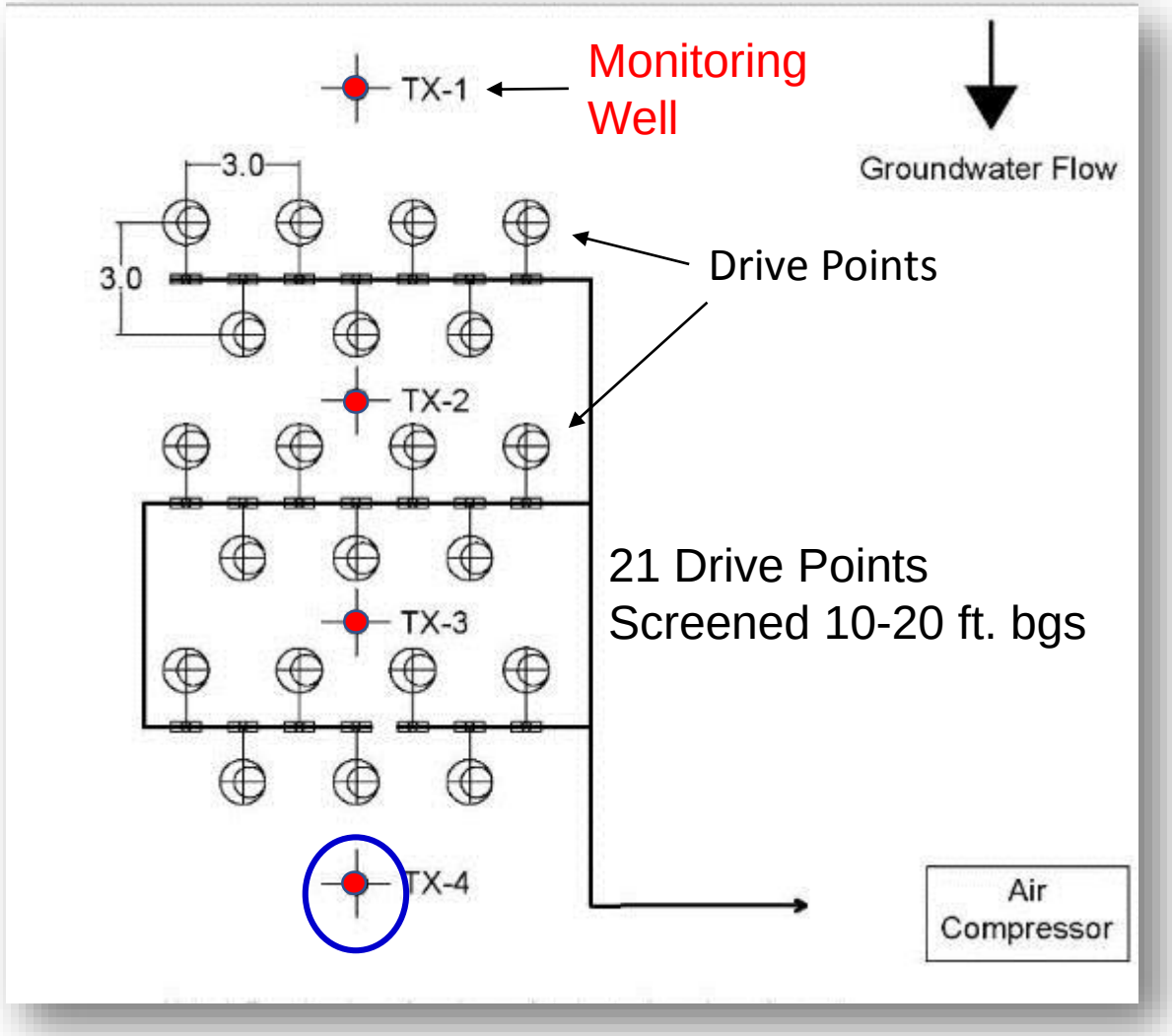


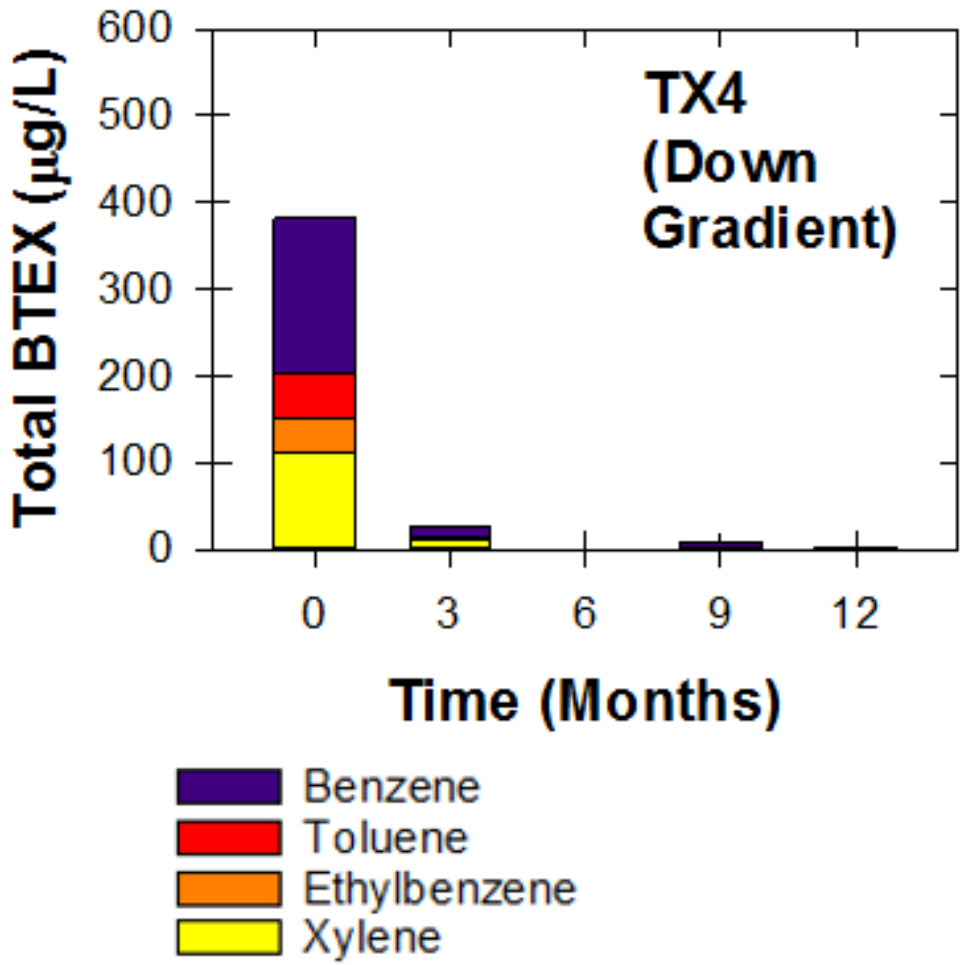
#2 Textron (BTEX Site, Lincoln, NE)



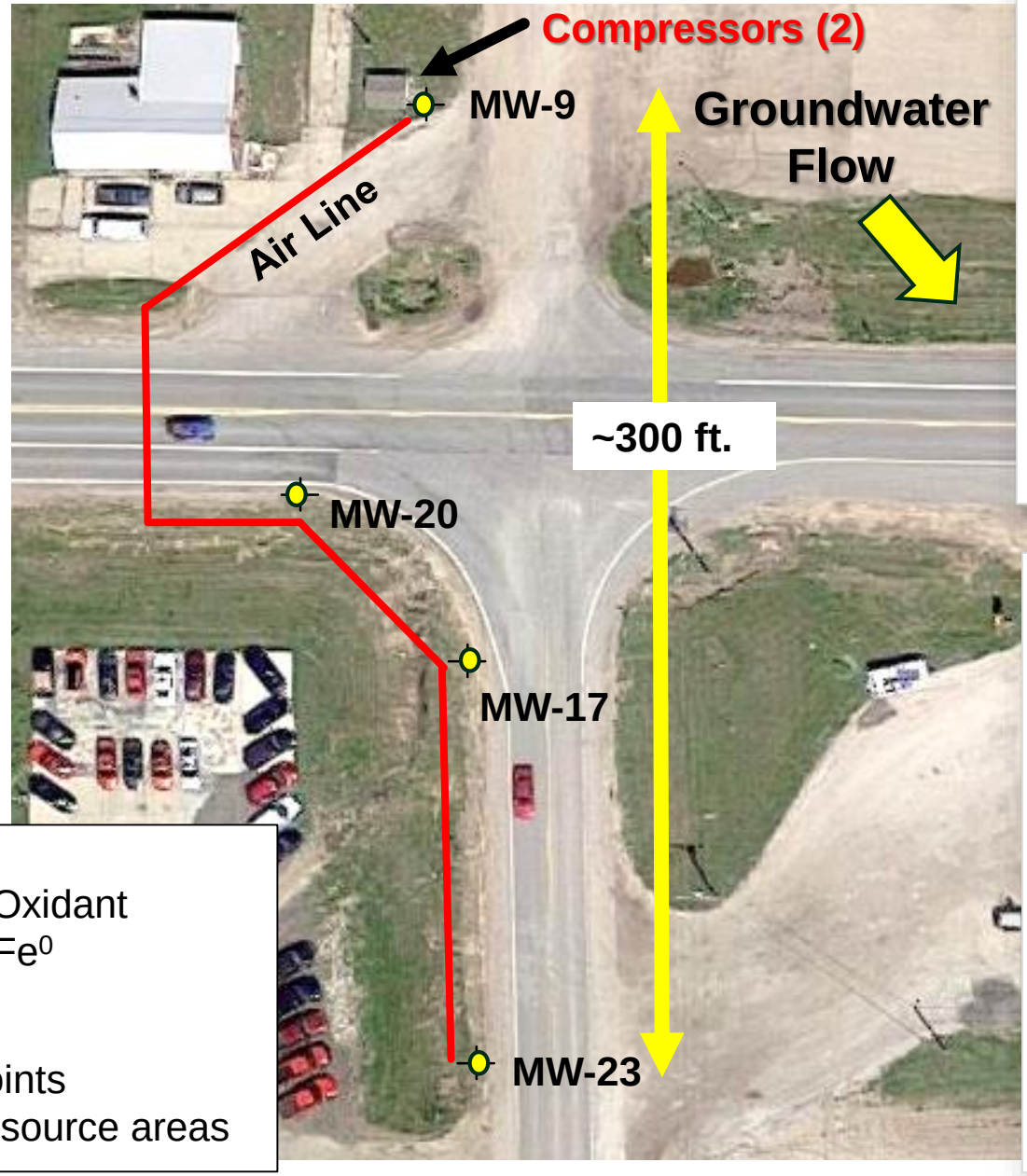


#2 Textron (BTEX Site, Lincoln, NE)





#3 Konecky (BTEX Site)



Treatment:

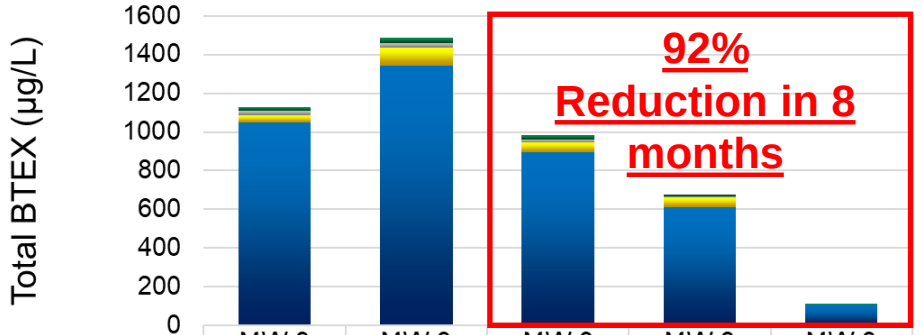
- Persulfate Oxidant Candles + Fe^0

Summary:

- 16 Drive points
- 4 separate source areas

Konecky MW-9

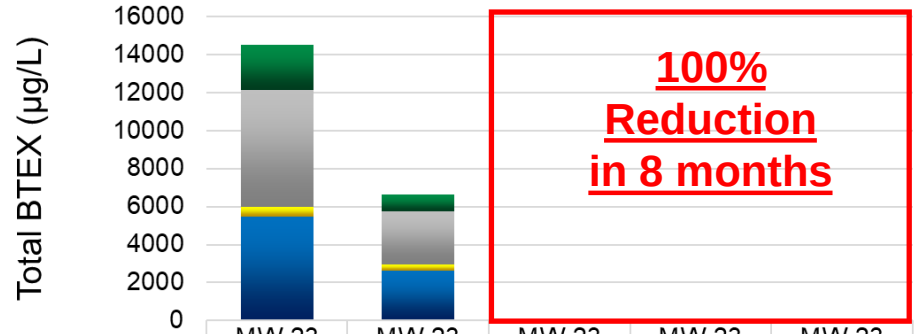
AirLift Environmental LLC



	MW-9 Sep-16	MW-9 May-17	MW-9 Sep-17	MW-9 May-18	MW-9 Oct-18
Benzene	20.1	31.8	21.2	8.39	3.01
Toluene	22.3	19	15.8	7.7	0
Ethylbenzene	36.9	97.6	52.2	49.4	3.11
Xylenes	1050	1340	894	612	107

Konecky MW-23

AirLift Environmental LLC



	MW-23 Sep-16	MW-23 May-17	MW-23 Sep-17	MW-23 May-18	MW-23 Oct-18
Benzene	2360	896	12.5	0	0
Toluene	6180	2770	13.8	0	0
Ethylbenzene	478	317	4.62	0	0
Xylenes	5490	2640	17.2	0	0

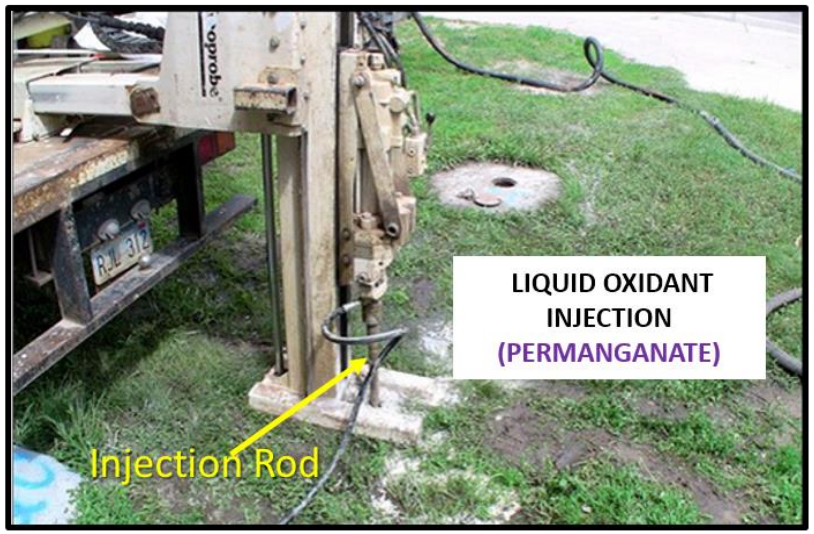
TRADITIONAL ISCO

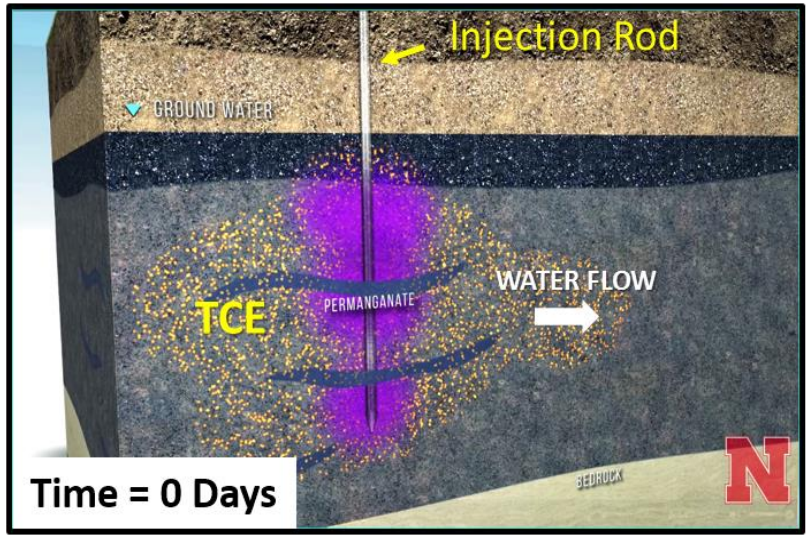
VERSUS

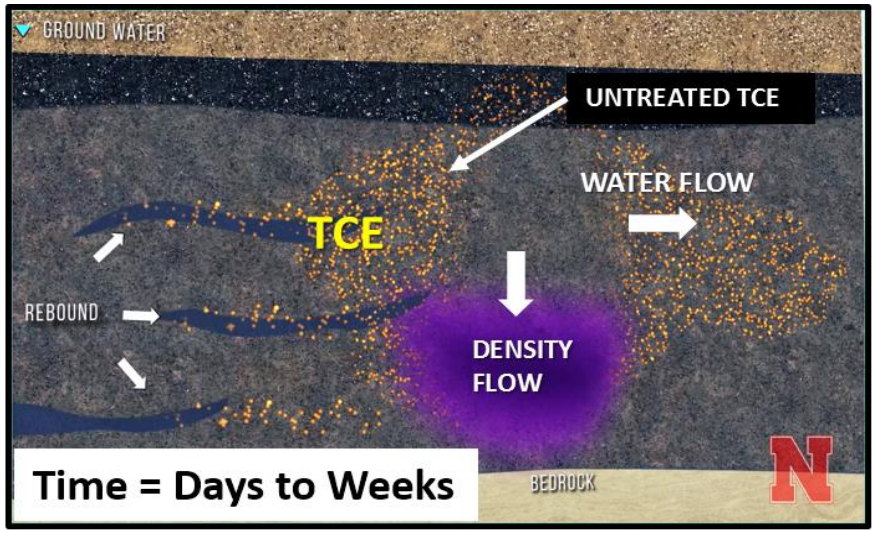
AERATED OXIDANT CANDLES®

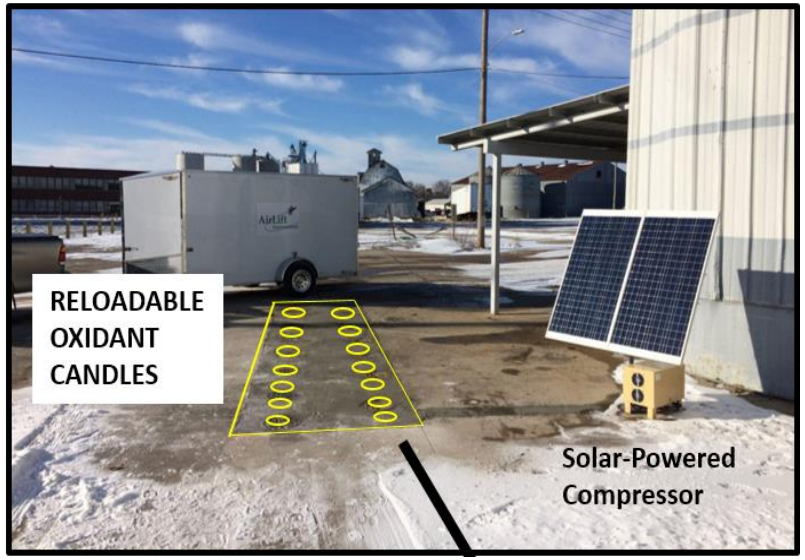
UNIVERSITY OF NEBRASKA

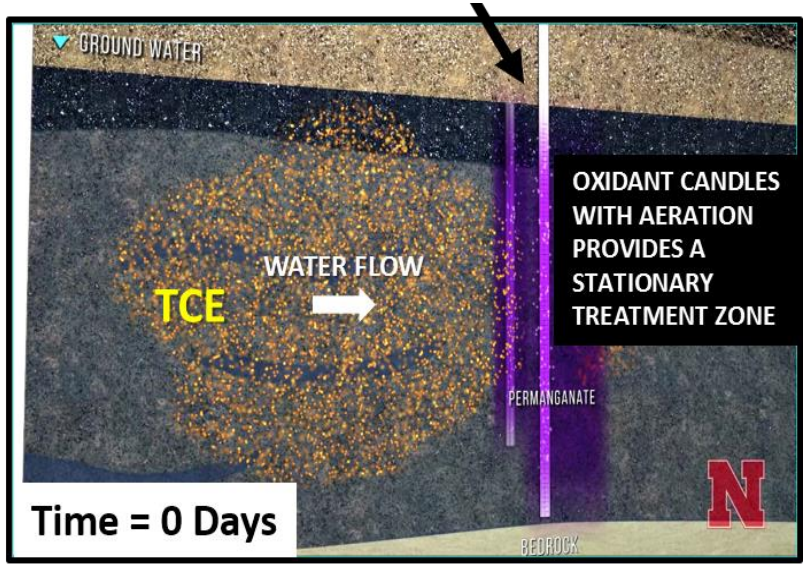
Traditional ISCO *versus* Aerated Oxidant Candles

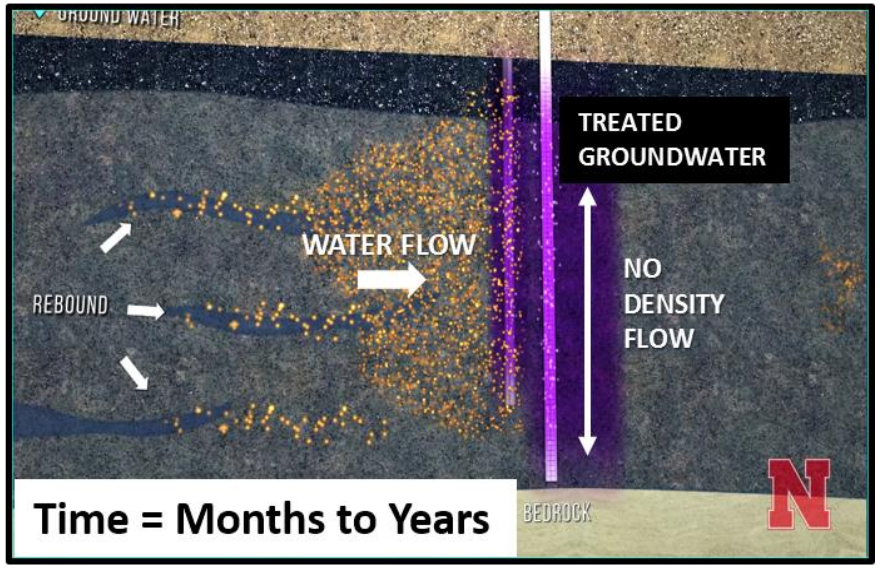




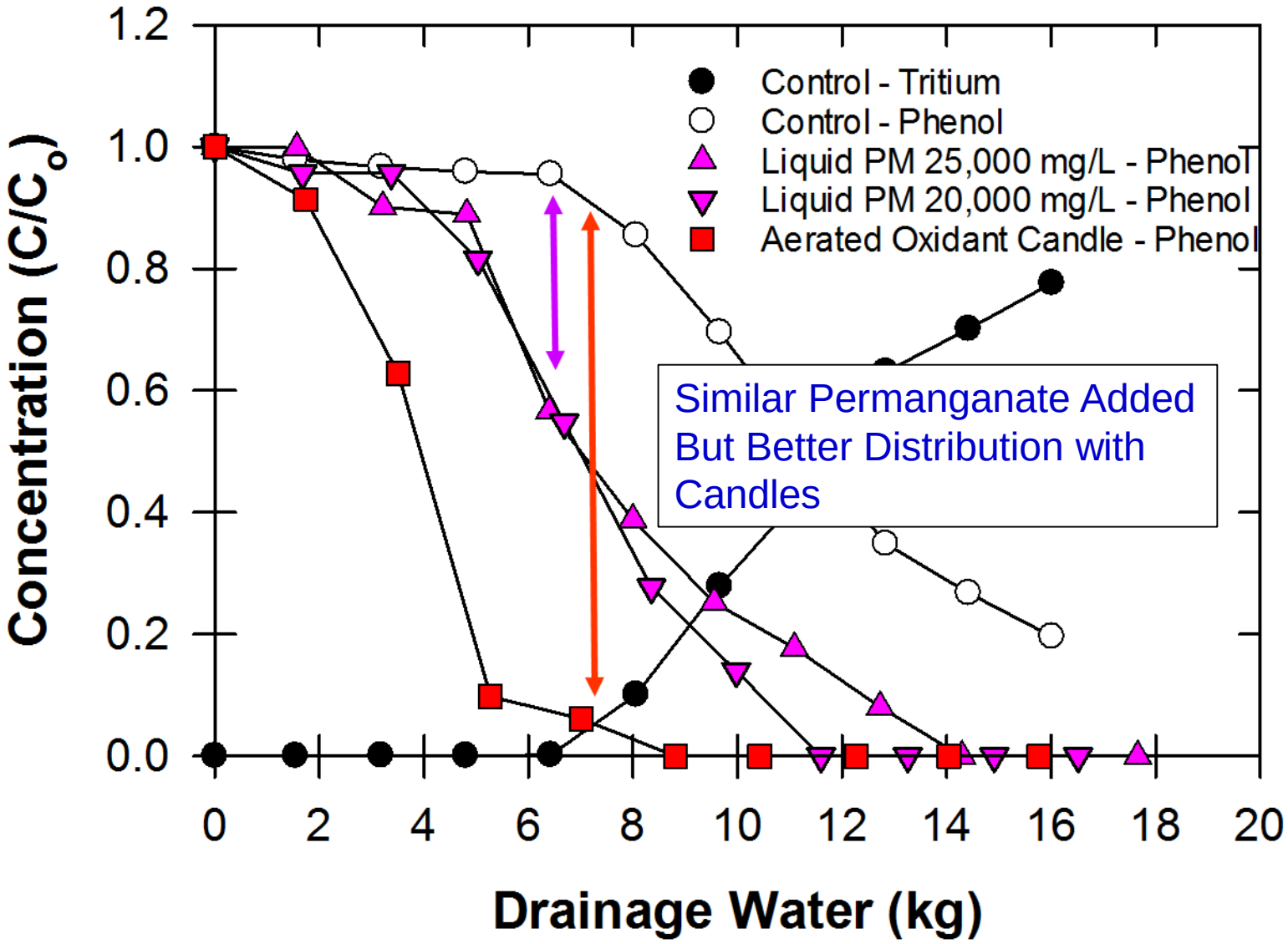




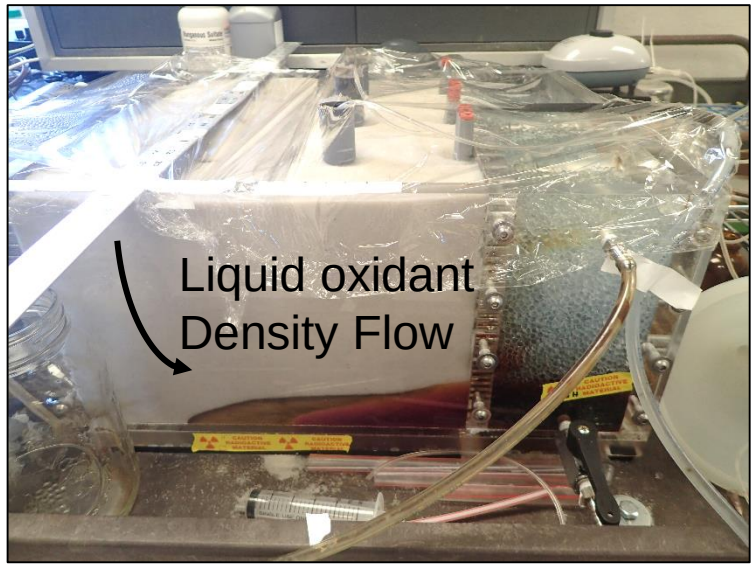




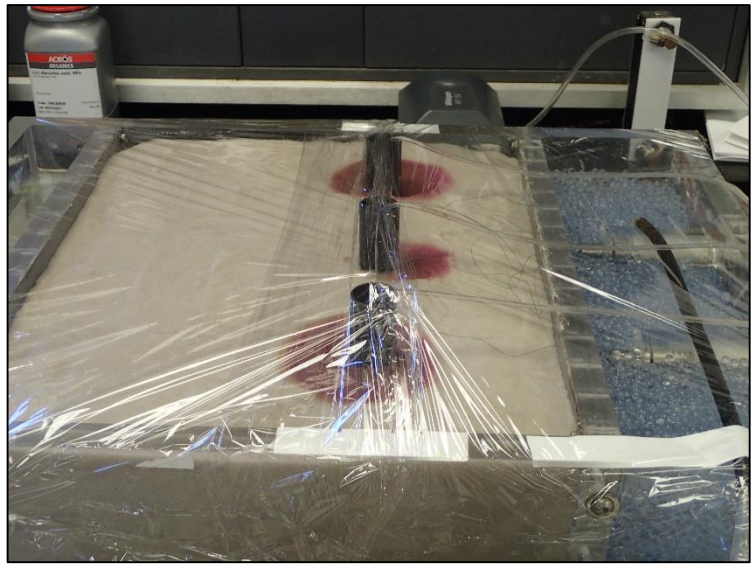
Comparing Liquid ISCO with Oxidant Candles During Transport



Liquid Oxidant

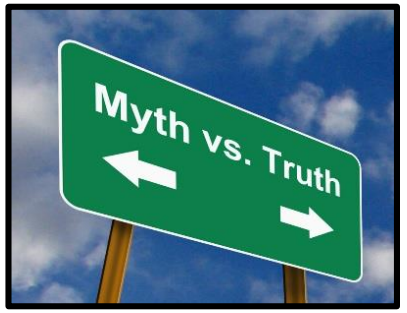


Oxidant Candles



Truths and Misconceptions

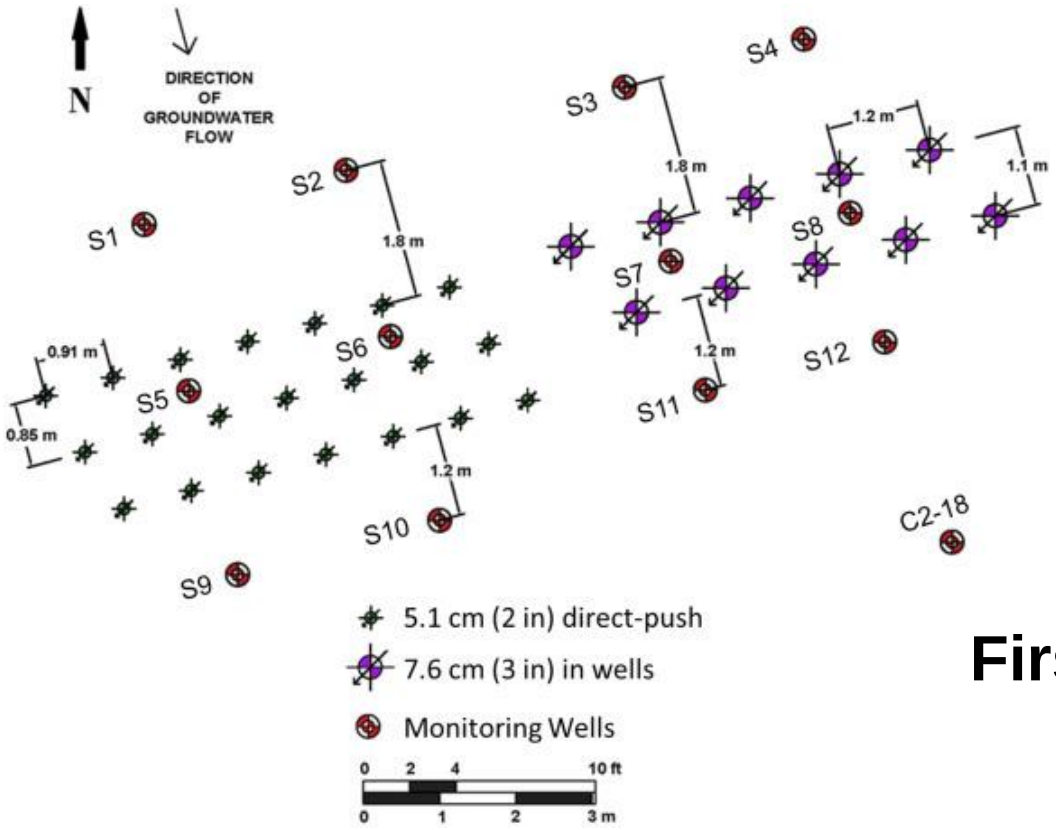
Truths and Misconceptions

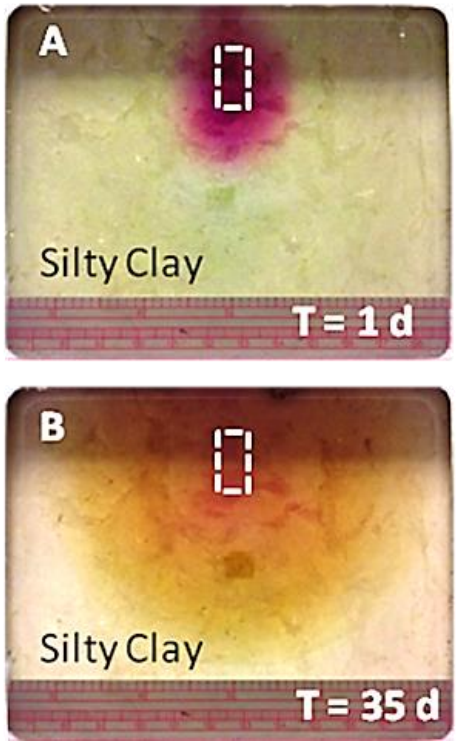


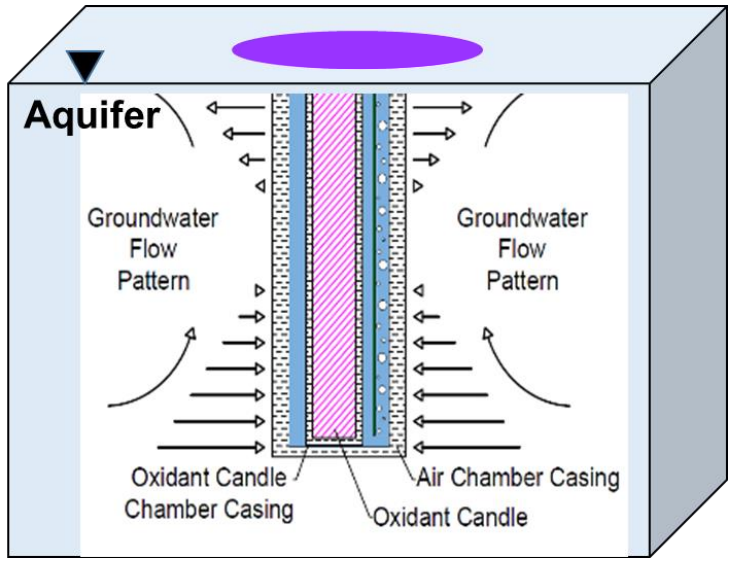
1. Oxidant candles must be spaced 3 feet apart.

Based on Diffusion, First Field Site used Close Spacing.

Cozad Site (2010)



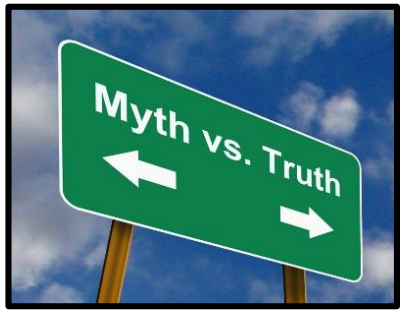




Aeration allows Wider spacing

First Candles were inserted into Low permeable Silty Clay (Aeration <u>not</u> Considered)

Truths and Misconceptions

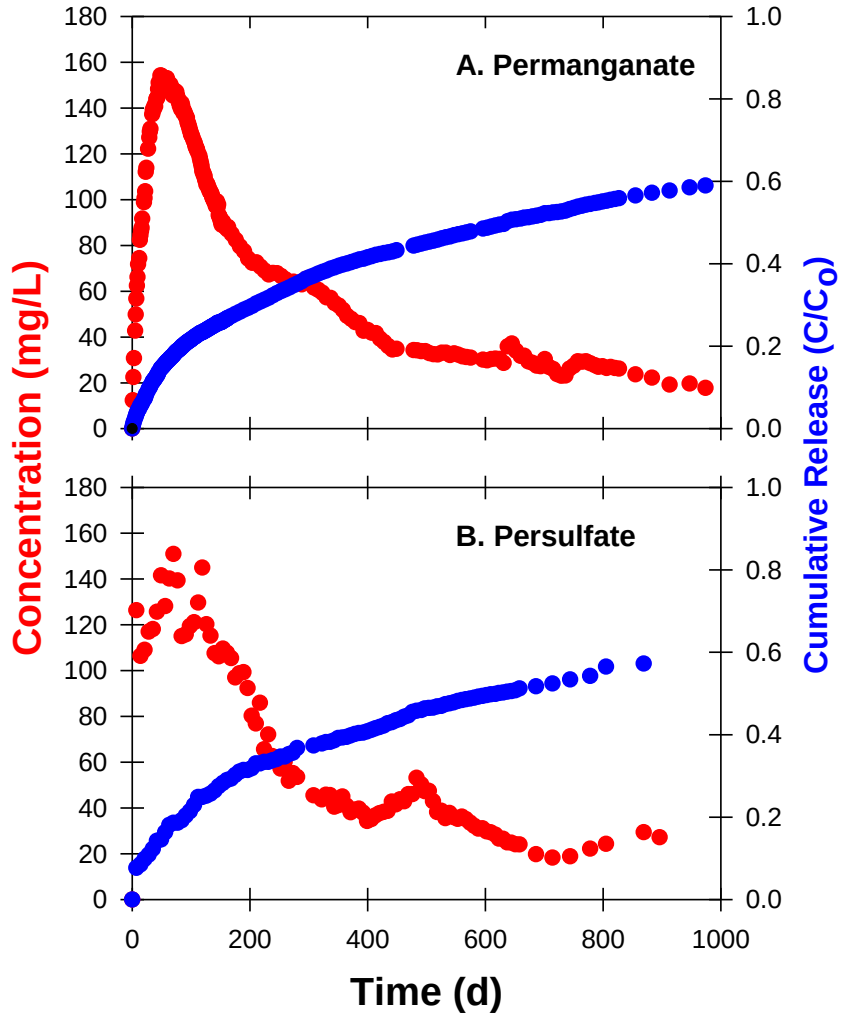


1. Oxidant candles must be spaced 3 feet apart.
2. Oxidant candles must be scraped each year.

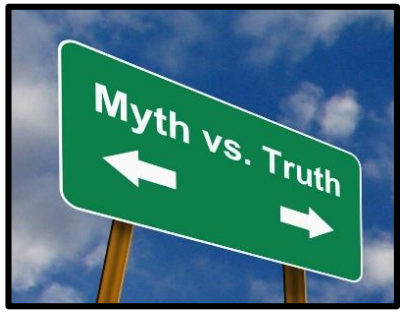
Original 3” Permanganate Oxidant Candles

Added Anti-Scaling Agent

Wax-less Candles



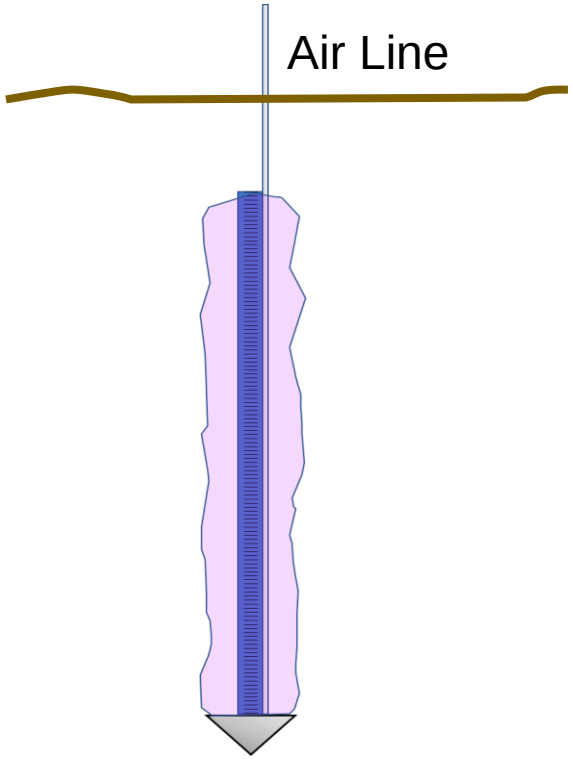
Truths and Misconceptions



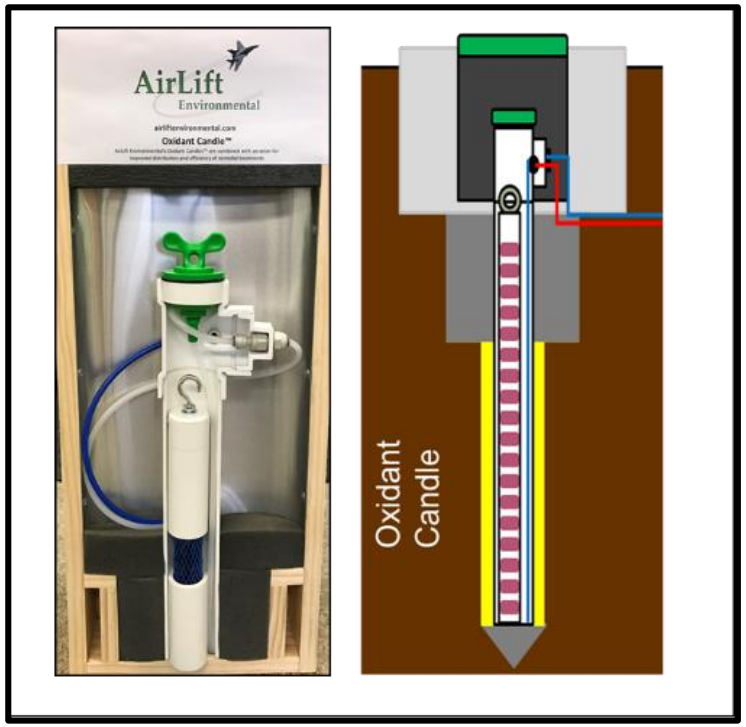
1. Oxidant candles must be spaced 3 feet apart.
2. Oxidant candles must be scraped each year.
3. **Oxidant candles do not apply enough oxidant mass**

Reloadable Design Allows Oxidant to be Replenished as Needed

Initial Design (2012)



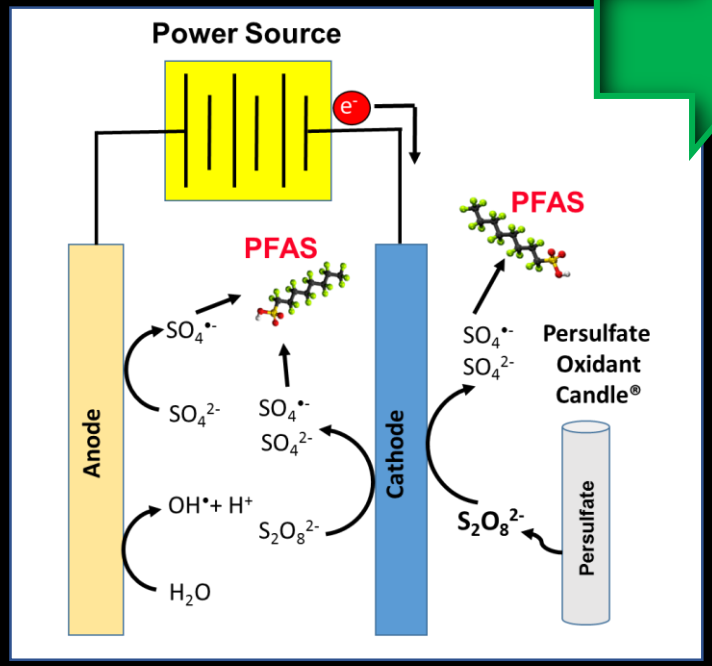
Reloadable Design (2016)



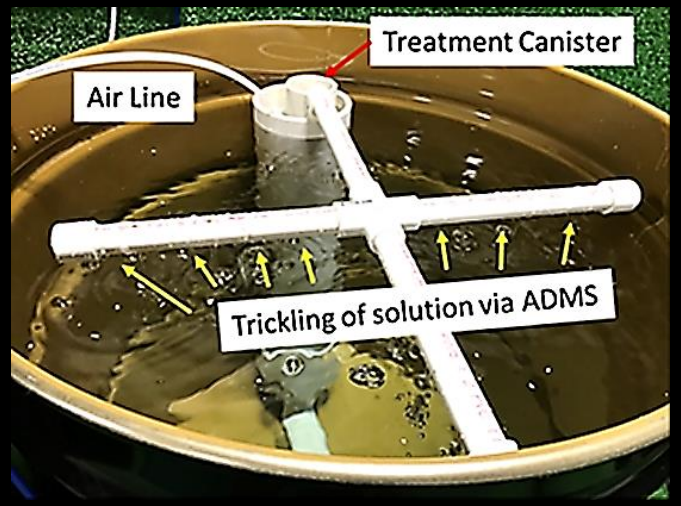
“Easy” Oxidant Replacement

PFAS Related Research

Laboratory Scale



Containerized Waste (IDW)



?

Field Drive Points

AirLift Environmental LLC

Aerated, Direct-Push Oxidant Delivery System

Contact / More Information

AirLift Environmental, LLC
5900 N. 58th Street, Suite #5
Lincoln, NE 68507
(402) 467-6422

Mark Christenson
(402) 617-0434
mark@airliftenvironmental.com

James Reece
(402)-770-1870
james@airliftenvironmental.com

MAXIMIZE COVERAGE • MINIMIZE COST

Website: http://airliftenvironmental.com/

Questions?

AirLift Environmental LLC

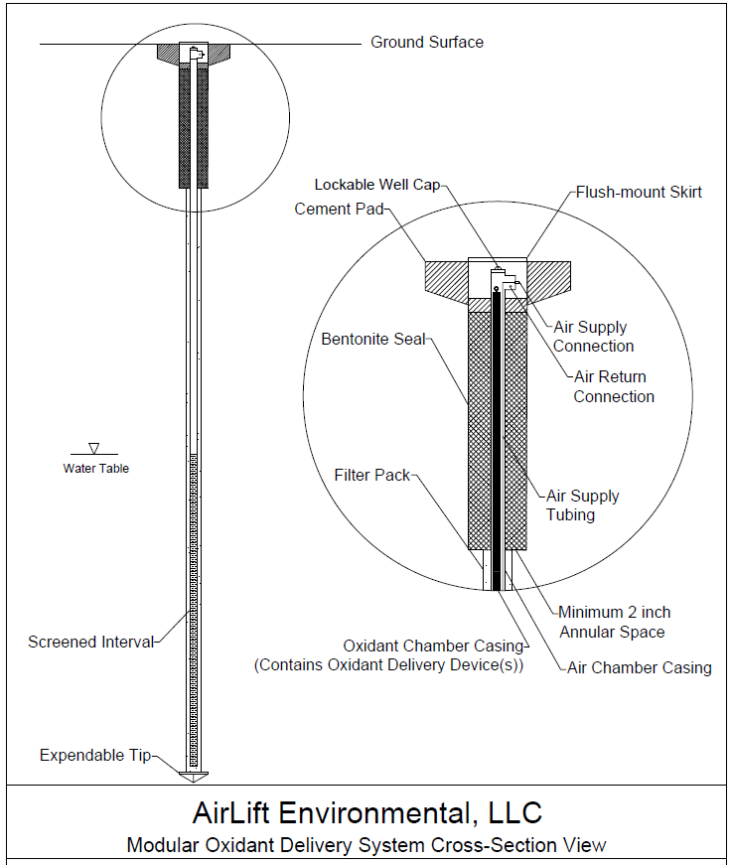
Backup Slides

Aerated, Direct-Push Oxidant Delivery System

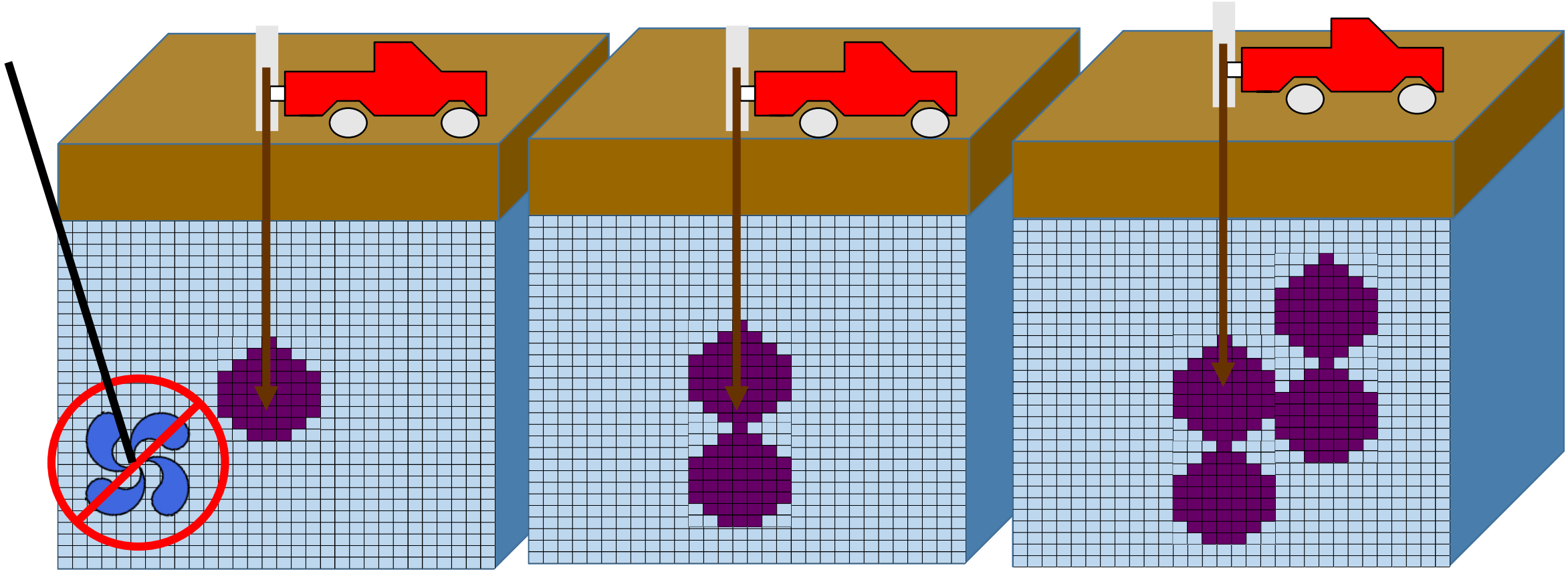
Patent

Christenson, M., Comfort, S.D. 2018. *Modular Oxidant Delivery System*. United States Patent. Patent No. US 9,925,574 B2. March 27, 2018.

This patent was submitted by NUtech Ventures.



Volume Injected



5%

10%

20%