

# Remediating Low Level Chlorinated VOCs Using Cost-Effective, Slow Release Potassium Permanganate Cylinders in a Fractured Bedrock Aquifer



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## Remedial Objectives for Contaminated Groundwater Sites



1. Factors to determine site closure
2. Clean up objectives can be unobtainable in a reasonable time

Program/Agency	Number of Contaminated Facilities	Number of Contaminated Sites	Estimated Cost to Complete <sup>a</sup>
DoD		4,329	\$12.8 billion
CERCLA	1,364		\$16-23 billion
RCRA	2,844		\$32.4 billion
UST		87,983	\$11 billion
DOE		3,650	\$17.3-20.9 billion
Other Federal Sites		> 3,000	\$15-22 billion
State Sites		>23,000	\$5 billion <sup>b</sup>
Total	>126,000		\$110-127 billion <sup>c</sup>

Rough Estimate of the total number of currently known facilities or contaminated sites that have not reached closure and estimated costs to complete

Source: Peak Energy & Resources, Climate Change and the Preservation of Knowledge



## Typical Cleanup Goals



- **Drinking water requirements and/or background concentrations**
- **Requirements may be waived**
- **Set 5-10 year goals**
- **126,000 hazardous waste sites**

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## Things to Consider



- ▶ **Site setting**
- ▶ **Time**
- ▶ **Weigh the benefits**
- ▶ **Cost**



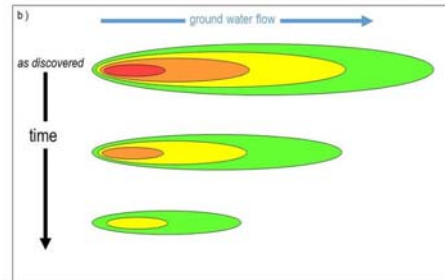
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## Monitored Natural Attenuation (MNA)



- ❖ Requires less equipment and labor than most methods
- ❖ Cost of many years of monitoring can be high



Evolution of a plume when the source and concentrations in groundwater both attenuate

Source: Environmental Restoration

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## In some cases MNA is not the best choice



- ❖ May take several years to decades to clean up a site

### Especially when:

- Contaminant concentrations are higher
- Contaminated area is large
- Site conditions are less favorable (Temp, GW flow, Soil type)



## What is another option?



## RemOx SR ISCO Potassium Permanganate



- Chemical oxidants in contaminated media to convert hazardous compounds to nonhazardous or less toxic compounds
- Demonstrated effectiveness
- No visible ongoing activities

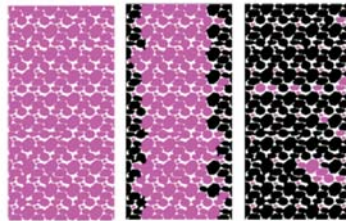


Figure 1. Representation of Permanganate Release  
A. Early-stage release B. Mid-stage release C. Late-stage release

**CARUS**  
REMEDICATION

RemOx® SR ISCO Reagent





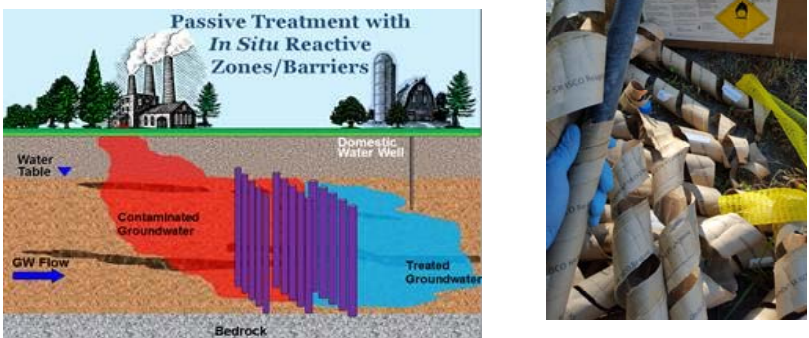
- First used in 2011  
- 50 sites in the United States and Europe

Source: Carus Group Inc.

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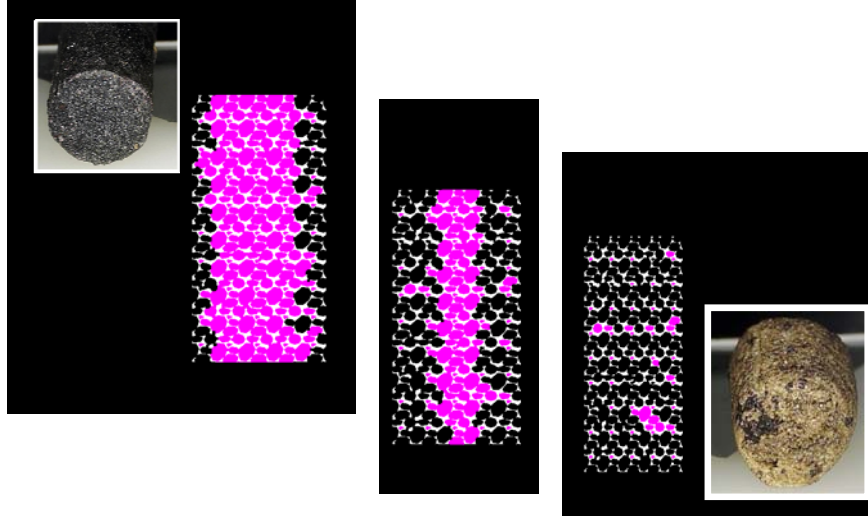
### Passive Treatments with In Situ Reactive Zones/Barriers

- ▶ Easy Installation: Does not require activation
- ▶ Applicable over a wide pH range
- ▶ The presence of a protective wax barrier slows down and controls oxidant release



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## Oxidant Release Mechanism

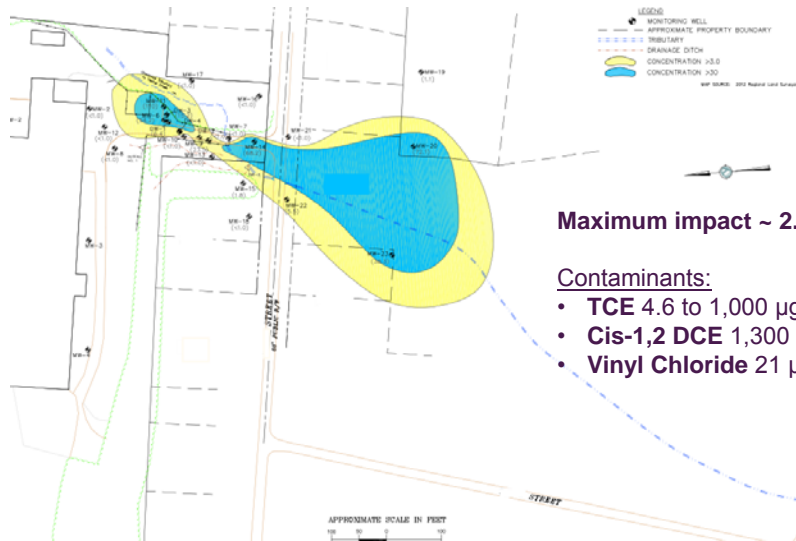


Source: Carus Group Inc.

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## Our Site: Piedmont Region of North Carolina



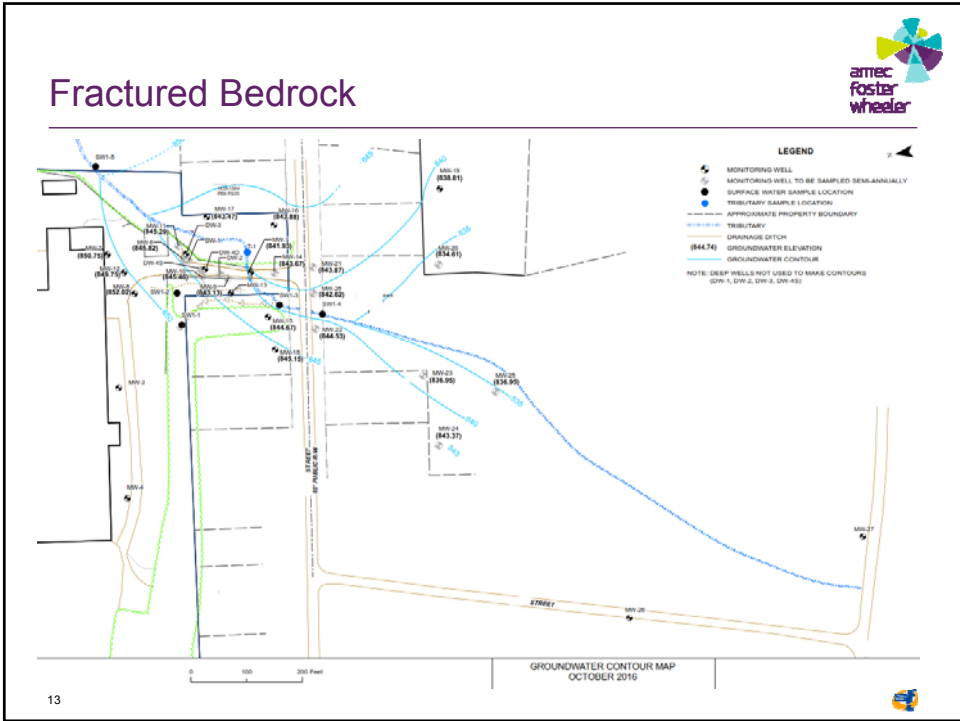
**Maximum impact ~ 2.9 acres**

Contaminants:

- TCE 4.6 to 1,000 µg/L range
- Cis-1,2 DCE 1,300 µg/L max.
- Vinyl Chloride 21 µg/L max.

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### Over the years...

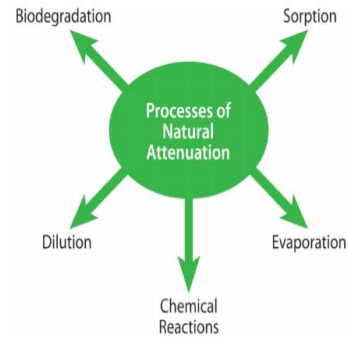
- ▶ 1999 → Low levels of VOCs detected
- ▶ 2003-2005 → Voluntary Registered Environmental – Consultant Directed Assessment and Remedial Action
- ▶ 2008-2009 → Natural attenuation and degradation of TCE was continuing to occur.
- ▶ 2009-2013 → Remedial investigation activities

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## Monitored Natural Attenuation



- ▶ Low levels of TCE in the impacted soils source area
- ▶ Source area expected to naturally degrade below its IHSB Soil Remediation goal
- ▶ Cost
- ▶ Operating costs: monitoring and reporting 4 times a year.



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## After a few years of monitoring...




- ▶ The contaminants however were appearing to migrate
- ▶ 2014 → VOCs remained present on and offsite
- ▶ Pilot testing for in-situ passive groundwater remedial action



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## Pilot Test for In-Situ Groundwater Remedial Action


- ▶ RemOx SR ISCO
- ▶ Cylinders suspended in the water column of several wells
- ▶ Permanganate will dissolve and flow down-gradient to oxidize and reduce concentrations
- ▶ Injection permits not required since passive

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## Process



Well ID	Well Depth (ft below TOC)	Well Screen (ft below TOC)	Depth to Water (ft below TOC)*	Saturated Screen Section Length (ft)	Number of Cylinders
MW-11	18	3-18	6.89	11.11	5
MW-21	24	14-24	1.60	22.40	5
MW-24	35	25-35	12.31	22.69	5
DW-3	120	115-120	9.85	110.15	3


\*April 2014 measurements

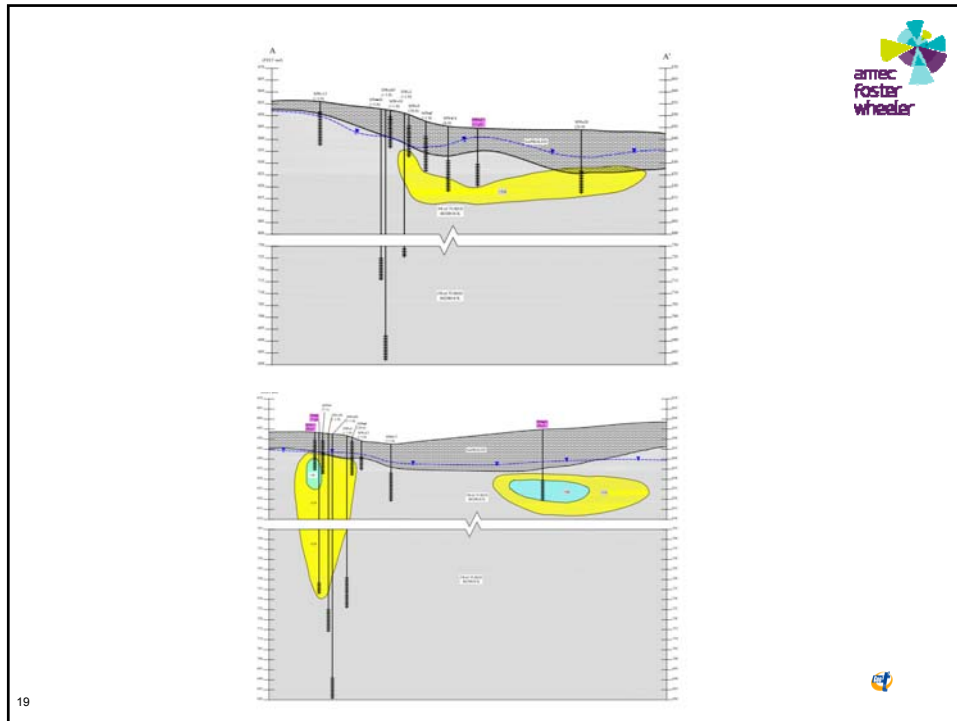
Cylinder placement in pilot test wells.  
(Each cylinder is 1.5 feet in length)



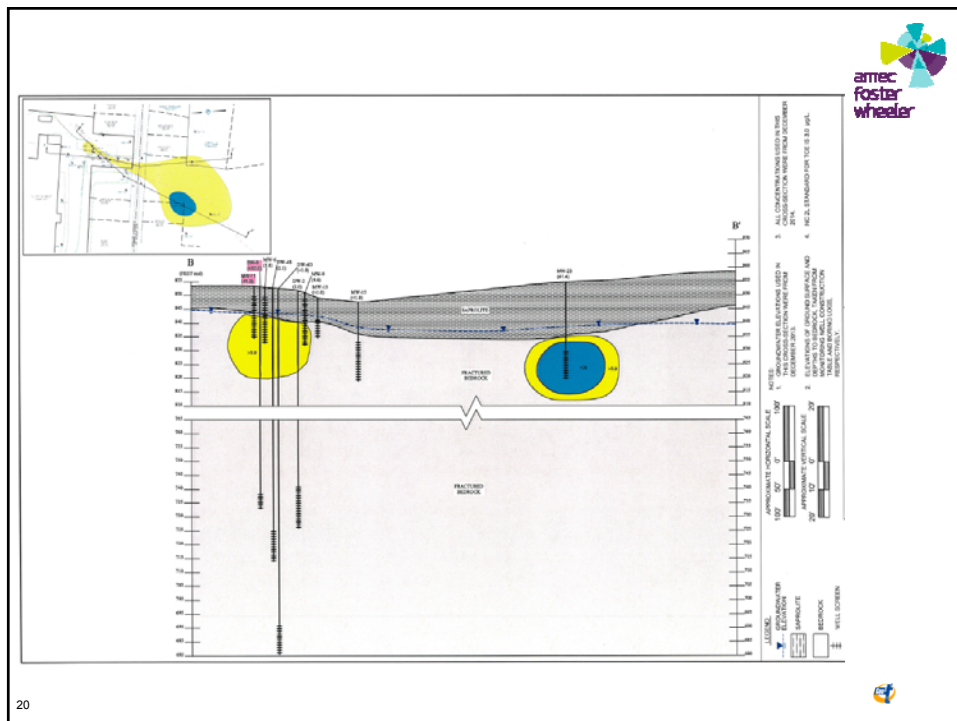
Colorimeter  
Source: Pine Environmental

- ▶ Four Wells
- ▶ Continued monitoring
- ▶ Monthly site inspections

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## Pilot Test Results

- TCE concentrations decreased or remained below the remediation goals
- Permanganate became measurable in observation wells
- Proposed a full scale implementation

Constituent	Remediation Goal
TCE	3.0 µg/L
Cis-DCE	70 µg/L
Vinyl Chloride	0.03 µg/L



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Monitoring Well	Date Collected	Trichloroethene (TCE)	cis-1,2-Dichloroethene (DCE)	Vinyl Chloride
MW-6	9/30/14	6.0	3.6	<1.0
	11/24/14	5.7	2.1	<1.0
	12/17/14	5.8	3.5	<1.0
	3/9/15	19.5	3.7	<1.0
	4/19/16	<1.0	<1.0	<1.0
10/24/16	<1.0	<1.0	<1.0	
MW-9	9/30/14	7.3	7.7	<1.0
	11/24/14	6.8	6.8	<1.0
	12/17/14	4.6	11.3	<1.0
	3/10/15	5.9	3.5	<1.0
	4/19/16	<1.0	<1.0	<1.0
10/24/16	<1.0	<1.0	<1.0	
MW-11	11/24/14	30.8	7.6	<1.0
	12/17/14	<1.0	<1.0	<1.0
	3/9/15	18.0	14.6	<1.0
	04/19/16	2.9	4.8	<1.0
10/24/16	8.5	7.1	<1.0	
MW-14	9/30/14	4.8	9.1	<1.0
	11/24/14	5.6	8.3	<1.0
	12/18/14	1.4	14.8	<1.0
	3/10/15	2.9	5.6	<1.0
4/19/16	<1.0	<1.0	<1.0	
10/24/16	<1.0	<1.0	<1.0	
MW-20	9/30/14	12.1	11.9	<1.0
	11/25/14	13.6	13.2	<1.0
	12/18/14	15.8	18.2	<1.0
	3/10/15	13.2	17.9	<1.0
	4/19/16	<1.0	<1.0	<1.0
10/24/16	<1.0	<1.0	<1.0	
MW-21	11/24/14	<1.0	<1.0	<1.0
	12/18/14	<1.0	<1.0	<1.0
	3/10/15	<1.0	<1.0	<1.0
	4/19/16	<1.0	<1.0	<1.0
10/24/16	<1.0	<1.0	<1.0	

Monitoring Well	Date Collected	Trichloroethene (TCE)	cis-1,2-Dichloroethene (DCE)	Vinyl Chloride
MW-23	9/30/14	44.3	13.3	<1.0
	11/25/14	45.7	11.6	<1.0
	12/18/14	41.4	13.2	<1.0
	3/10/15	41.8	10.0	<1.0
	4/19/16	<1.0	<1.0	<1.0
10/25/16	<1.0	<1.0	<1.0	
MW-24	11/25/14	<1.0	<1.0	<1.0
	12/18/14	<10.0	<10.0	<10.0
	3/10/15	<1.0	<1.0	<1.0
	4/19/16	<1.0	<1.0	<1.0
10/25/16	<1.0	<1.0	<1.0	
MW-25	9/30/14	51.6	16.0	<1.0
	11/25/14	40.9	14.9	<1.0
	12/18/14	27.0	10.3	<1.0
	3/10/15	17.4	5.1	<1.0
	04/19/16	36.9	16.5	<1.0
10/25/16	28.3	14.5	<1.0	
DW-3	9/30/14	<1.0	<1.0	<1.0
	11/24/14	<1.0	<1.0	<1.0
	12/17/14	<10.0	<10.0	<10.0
DW-4 (Shallow)	3/9/15	<1.0	<1.0	<1.0
	9/30/14	1.8	<1.0	<1.0
	11/24/14	1.9	<1.0	<1.0
	12/17/14	2.1	<1.0	<1.0
	3/9/15	2.0	<1.0	<1.0
4/19/16	<1.0	<1.0	<1.0	
10/25/16	<1.0	<1.0	<1.0	
2L Standards		3.0	70.00	0.03

**Note:**  
 Measurements in µg/L  
**BOLD** - detected above lab quantitation limit  
**BOLD and SHADED** - detected above 2L Standard

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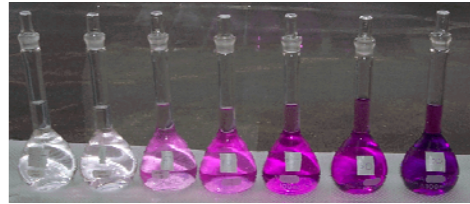
© Amec Foster Wheeler 2016.



## Continued Semi-annual Sampling events



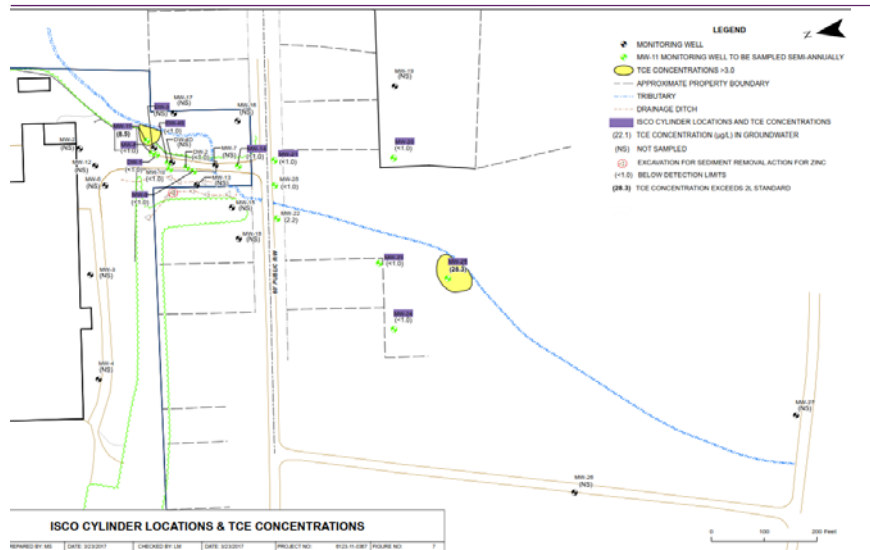
- ▶ TCE was detected in three wells on and off-site. Two wells above 2L Standard
- ▶ Cis-1,2-DCE in four wells, all below 2L Standard
- ▶ Vinyl Chloride below detection limits in all wells
- ▶ Presence of methane indicating dechlorination process is occurring



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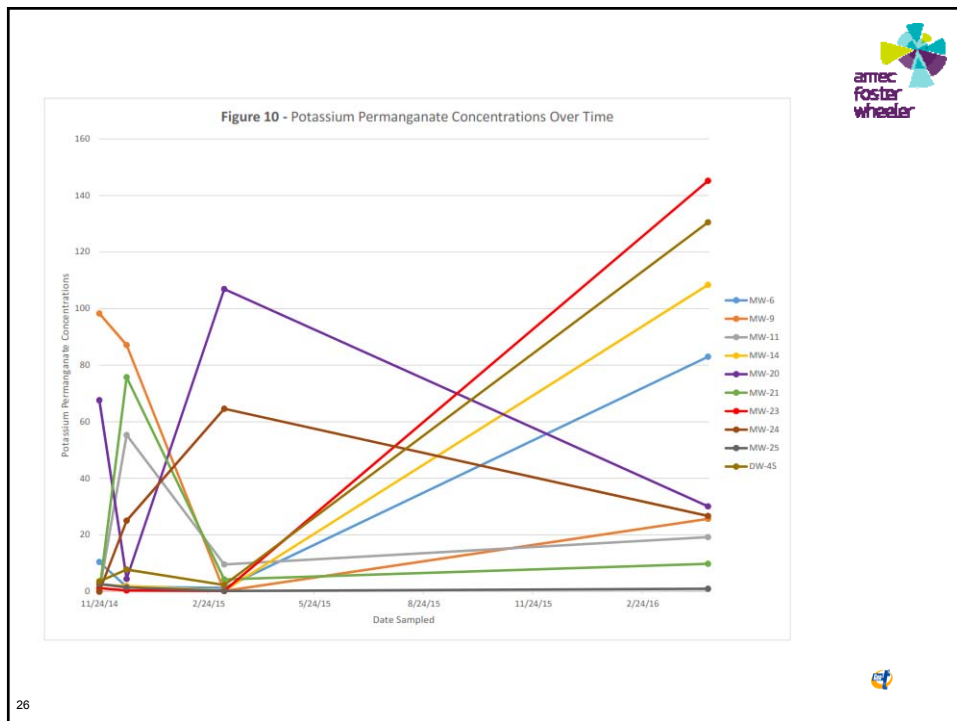
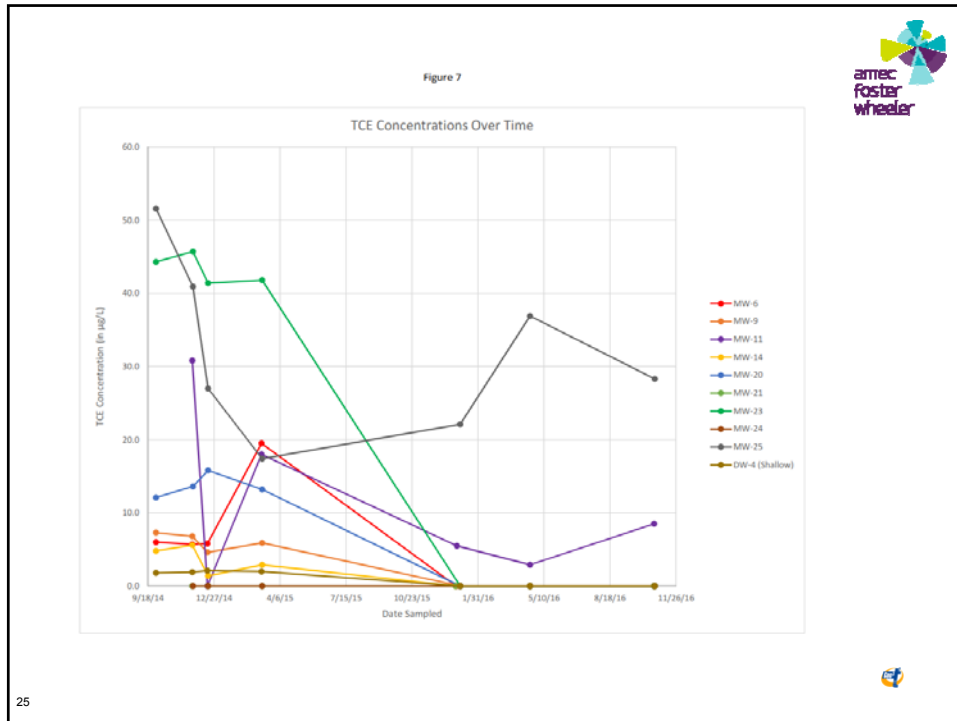


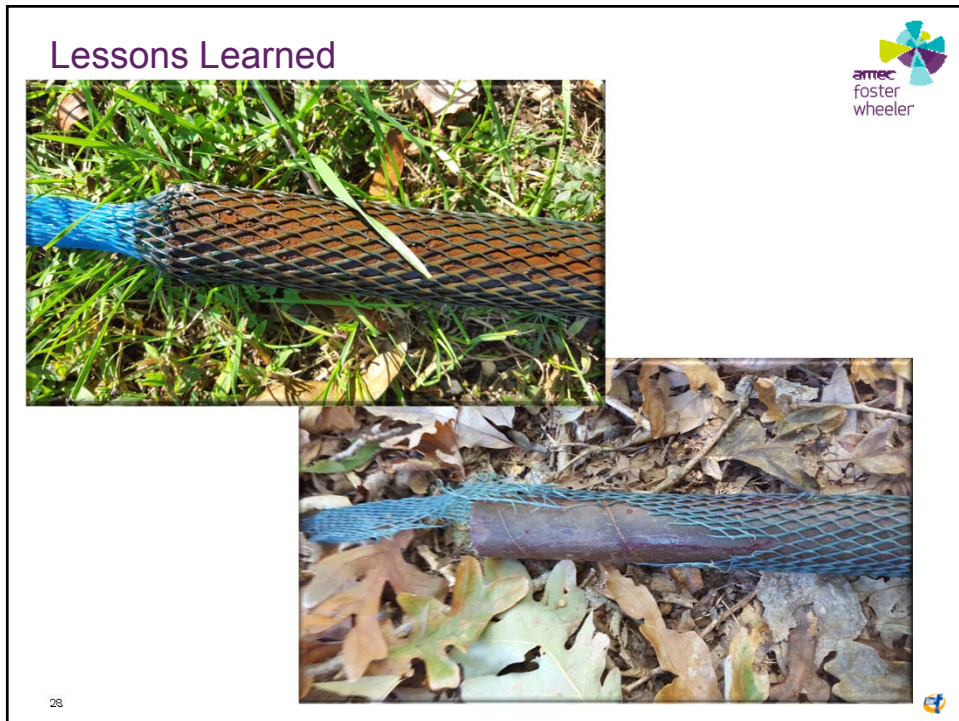
## October 2016 - Most Recent Sampling Results

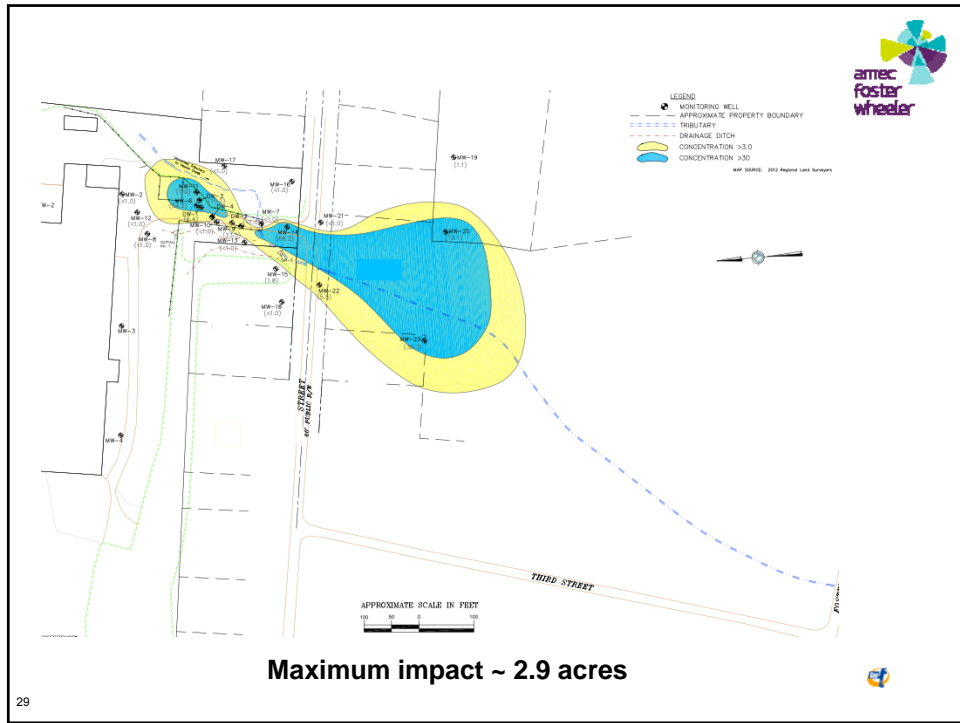


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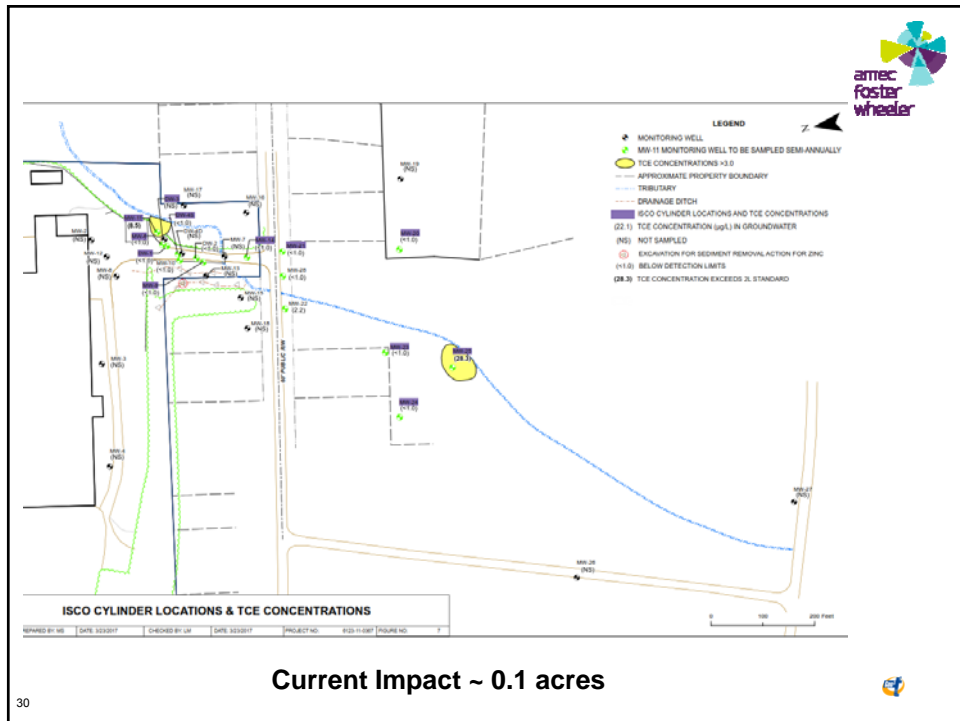








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## Questions?

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