RemTech 2019

Matt Burns, Luc Turbide, David MacGillivray

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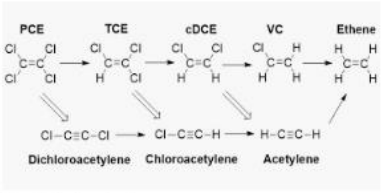
biphenyl | anaerobic | acid | petroleum hydrocarbons | anaerobic biodegradation | benzoate | bioremediation | microorganisms | microbial | microbial degradation | tce | benzene | bacteria | anaerobic degradation | nonylphenol | 8600 dübendorf



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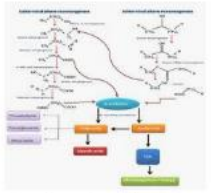
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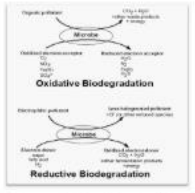

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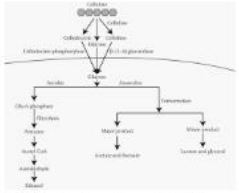
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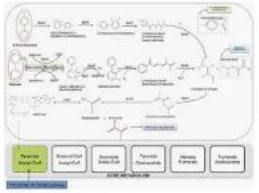
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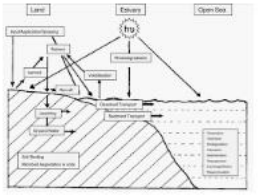
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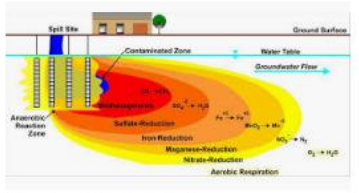

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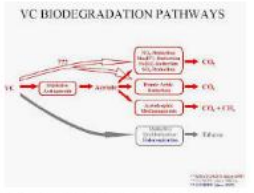

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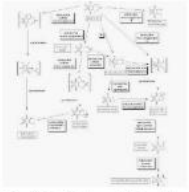
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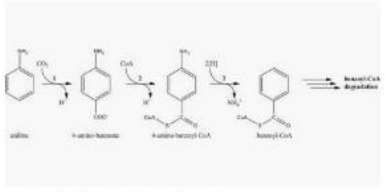
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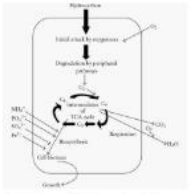
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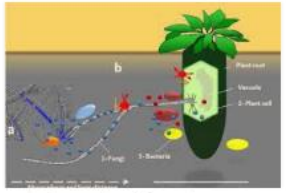
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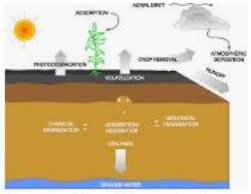

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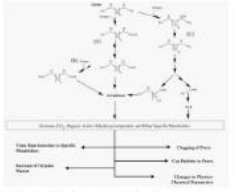
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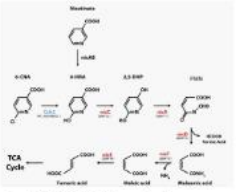

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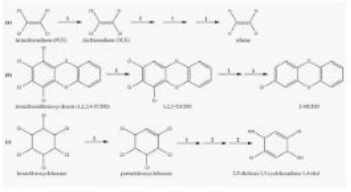
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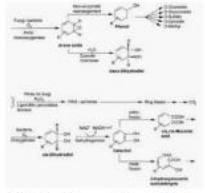
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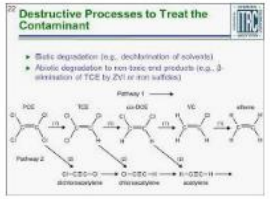

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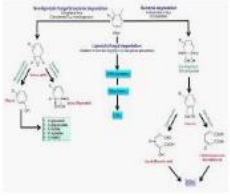
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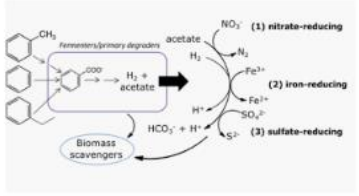

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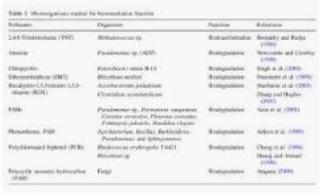
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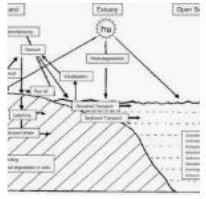
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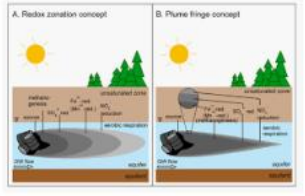

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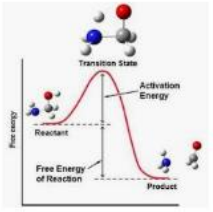

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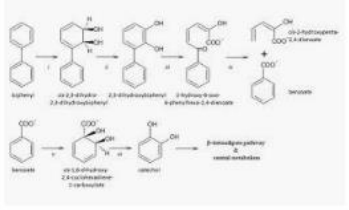
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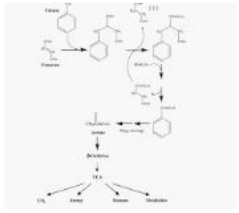
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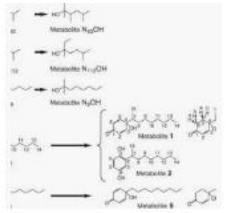
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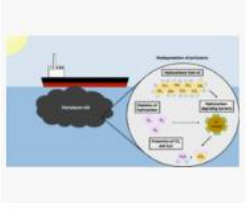
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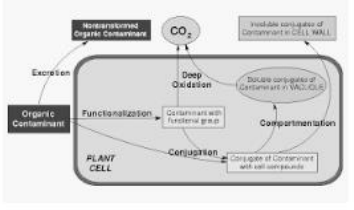

Mechanisms of Organic Contaminants ...
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Evaluating Exposure Pathway...
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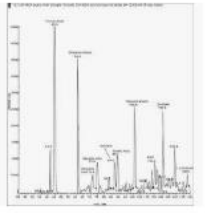
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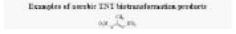

Degradation Pathway

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Reactants + Reactants —(Microbes & Enzymes)→ Products + Products

The degradation equation/pathway is the **remediation roadmap**

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Performance monitoring plans can include **key reactants and products**; anything needed to facilitate the reaction

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Performance monitoring plans can include **key reactants and products**; anything needed to facilitate the reaction

Observing expected trends is evidence of a activity along the targeted degradation pathway and realizing design goals

Risk Mitigation Using Actionable Data

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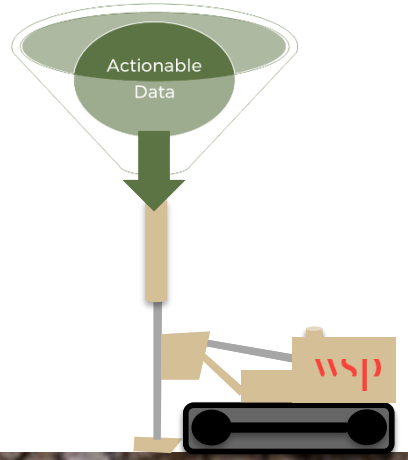


Initiate

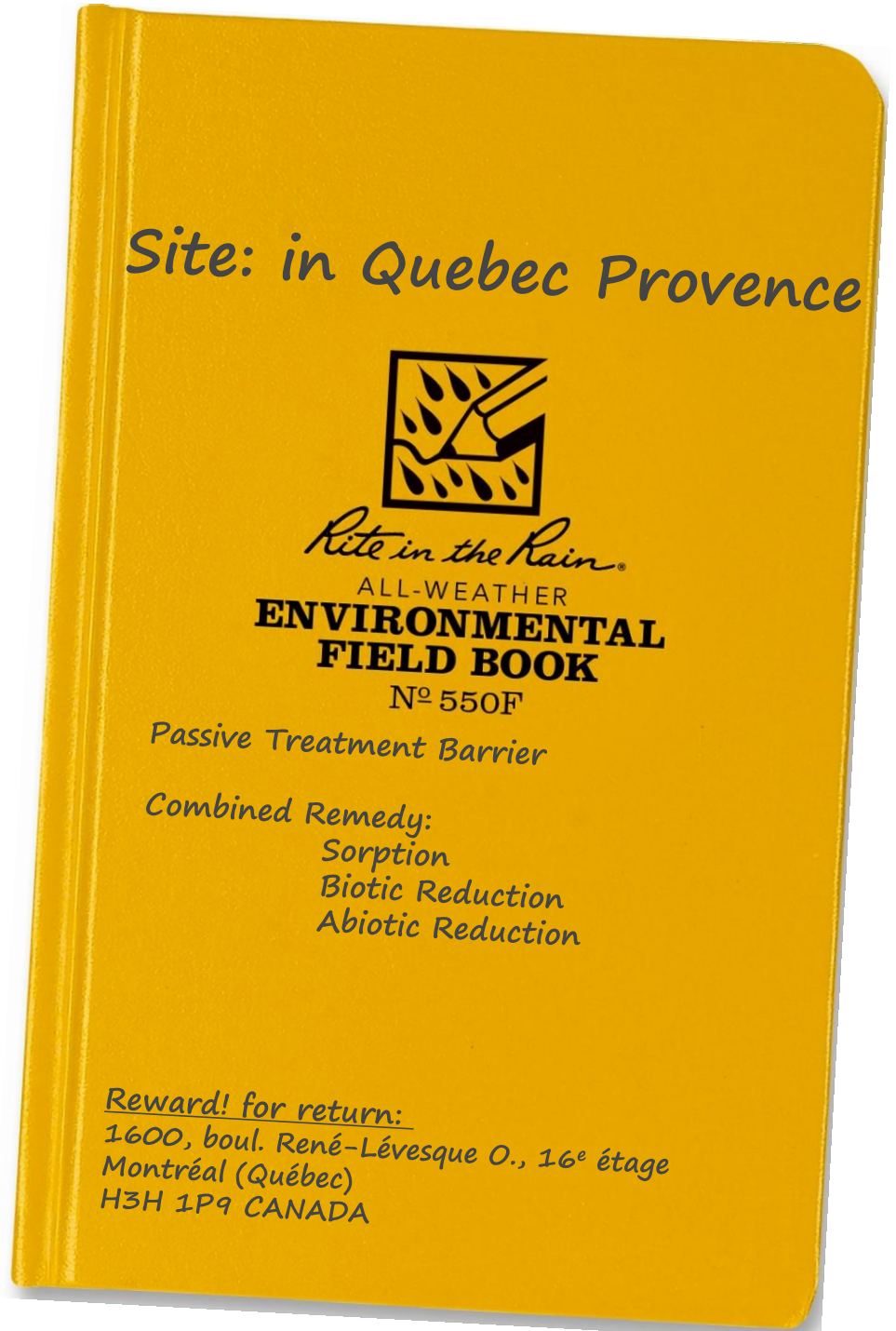
Plan & Design

Execute

Monitor & Control

Close

Case Study


Site: in Quebec Provence
Rite in the Rain
ALL-WEATHER
ENVIRONMENTAL
FIELD BOOK
№ 550F
Passive Treatment Barrier
Combined Remedy:
Sorption
Biotic Reduction
Abiotic Reduction
Reward! for return:
1600, boul. René-Lévesque O., 16e étage
Montréal (Québec)
H3H 1P9 CANADA

Background

Railyard Site
- Typical rail yard activities
- Chlorinated solvents used as cleaner/degreaser in 70's & 80's

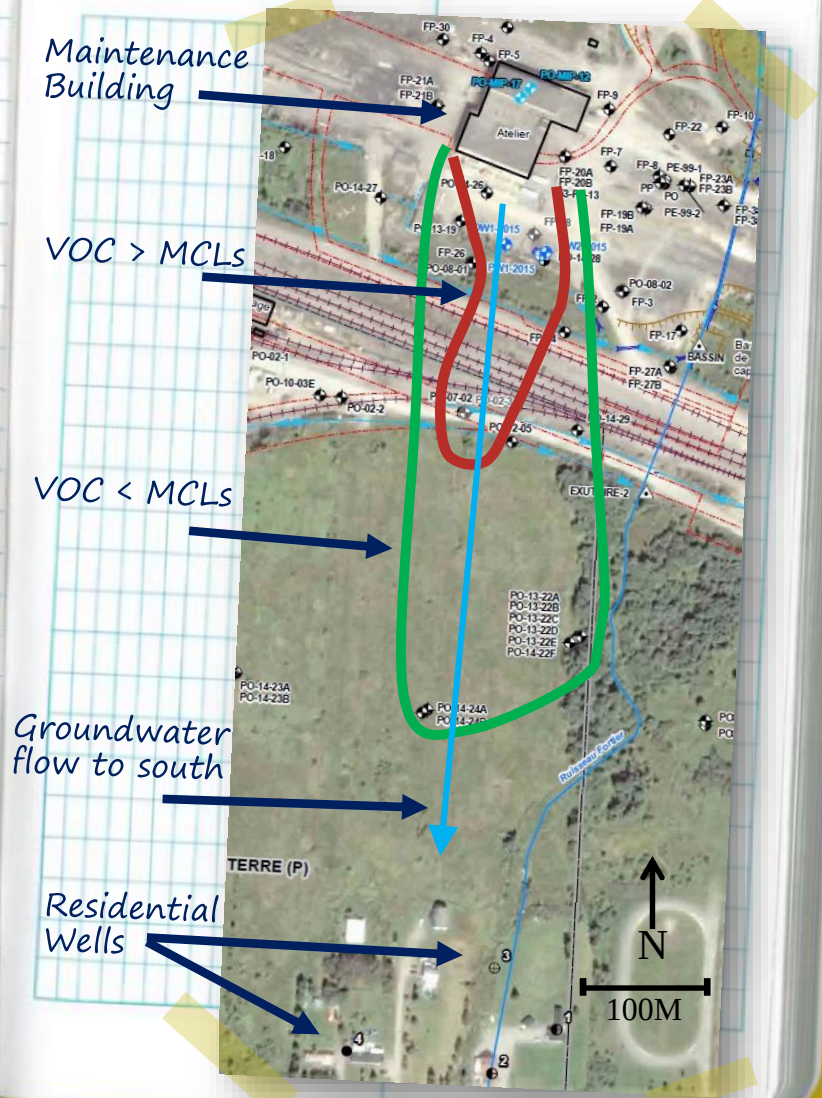
Onsite Contaminants
- Petroleum
- TCE & 1,1,1-TCA and reductive daughter products
- Present in soil and shallow groundwater
- Chlorinated solvents also present in deeper overburden groundwater

Offsite Contaminants
- Chlorinated solvents and reductive daughter products in deeper overburden groundwater

Primary Goal
- Protect residential wells

MNA - Occuring
- Not just sequential reduction as DCE fractionated without daughter accumulation (no VCl)

Groundwater VOC Distribution



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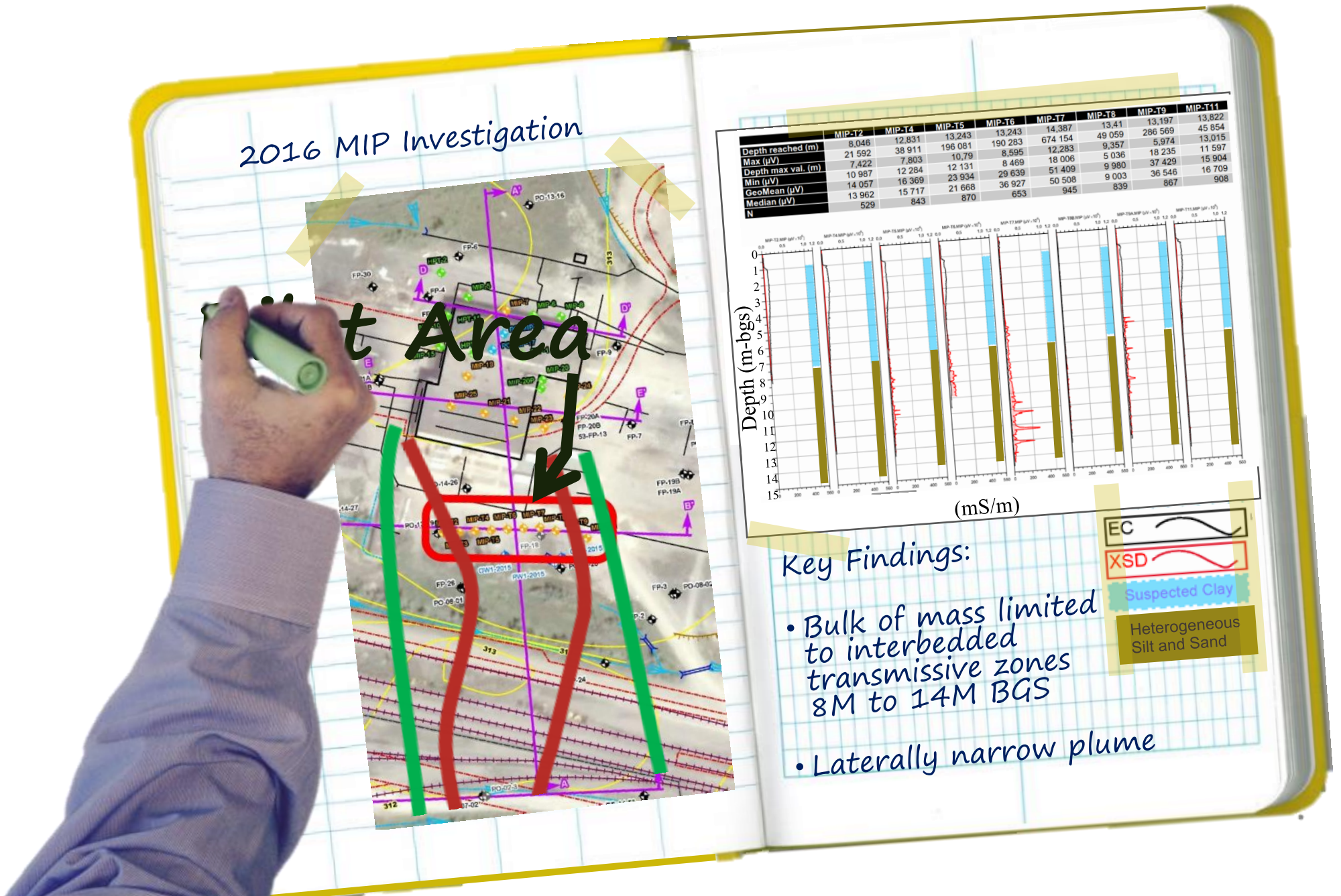

2016 MIP Investigation
t Area
Depth reached (m)
Max (µV)
Depth max val. (m)
Min (µV)
GeoMean (µV)
Median (µV)
N
MIP-T2 8,046 21 592 7,422 10 987 14 057 13 962 529
MIP-T4 12,831 38 911 7,803 12 284 16 369 15 717 843
MIP-T5 13,243 196 081 10,79 12 131 23 934 21 668 870
MIP-T6 13,243 190 283 8,595 29 639 36 927 653
MIP-T7 14,387 674 154 12,283 51 409 50 508 945
MIP-T8 13,41 49 059 9,357 5 036 9 980 9 003 839
MIP-T9 13,197 286 569 5,974 18 235 37 429 36 546 867
MIP-T11 13,822 45 854 13,015 11 597 15 904 16 709 908
Depth (m-bgs)
(mS/m)
EC
XSD
Suspected Clay
Heterogeneous Silt and Sand
Key Findings:
• Bulk of mass limited to interbedded transmissive zones 8M to 14M BGS
• Laterally narrow plume

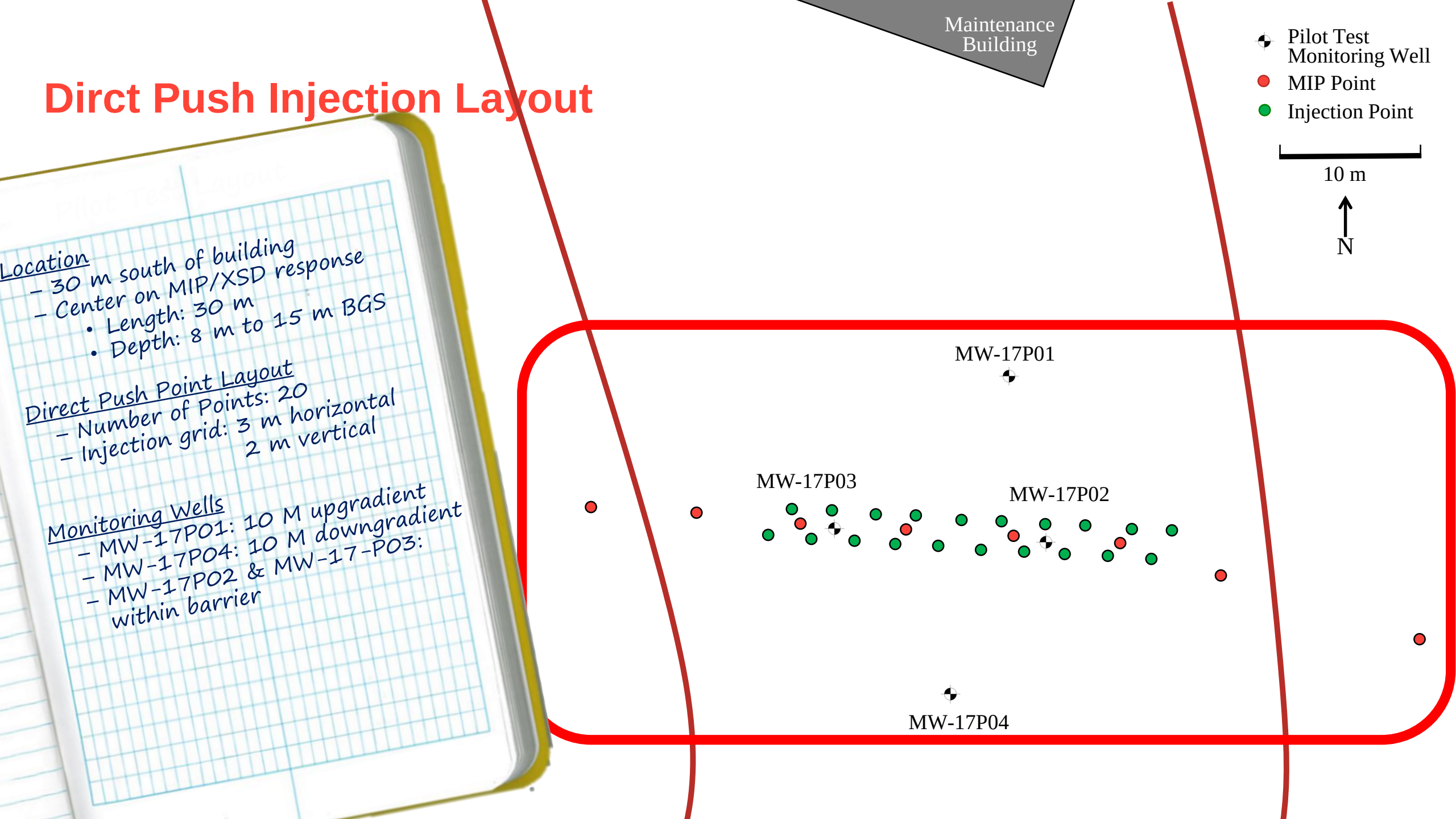
Dirct Push Injection Layout

Pilot Test Layout

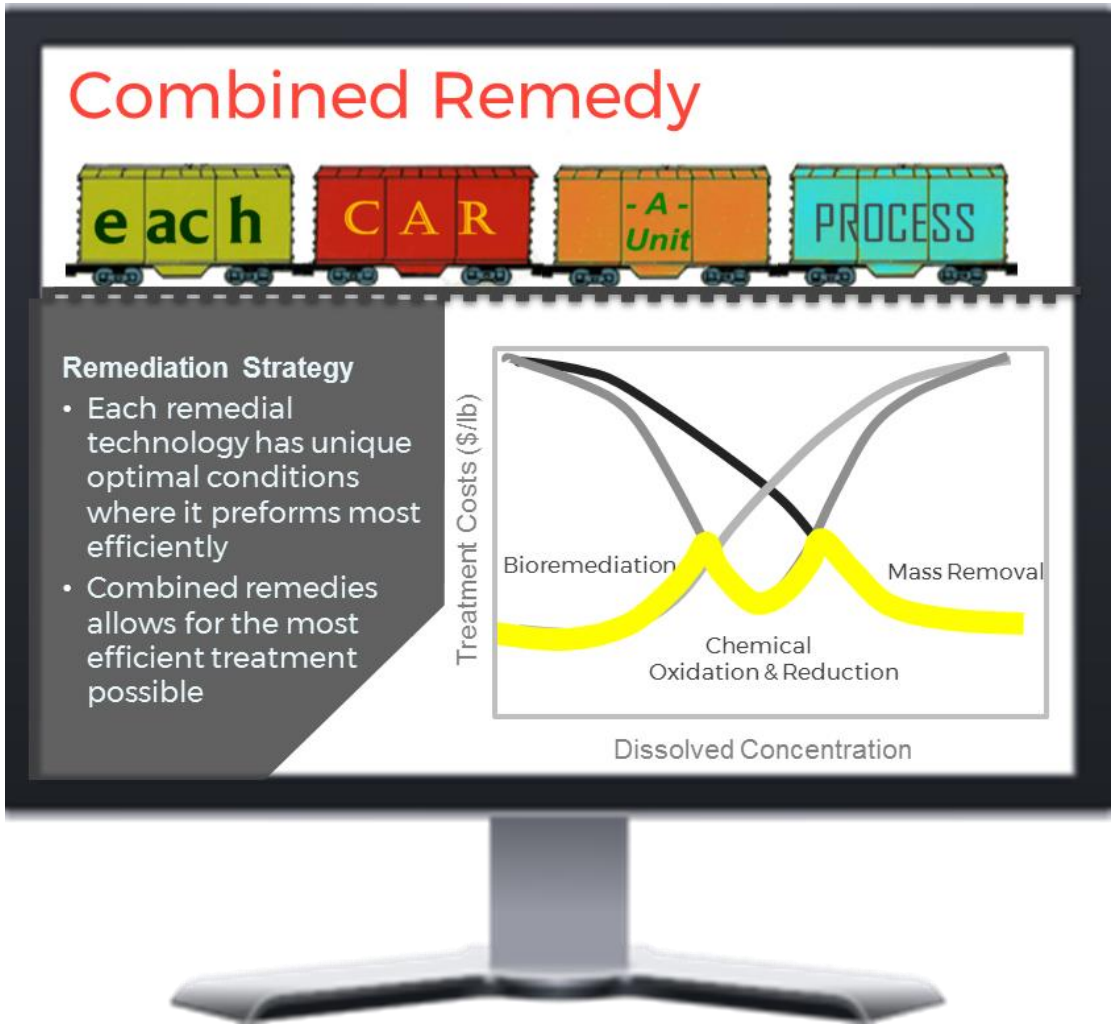
Location
- 30 m south of building
- Center on MIP/XSD response
  - Length: 30 m
  - Depth: 8 m to 15 m BGS

Direct Push Point Layout
- Number of Points: 20
- Injection grid: 3 m horizontal
  2 m vertical

Monitoring Wells
- MW-17P01: 10 M upgradient
- MW-17P04: 10 M downgradient
- MW-17P02 & MW-17-P03:
  within barrier



Amendment Selection



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- Activated Carbon (PlumeStop®)
- Fermentable Electron Donor
- Microbial Augment
- S-MicroZVI (sterically stabilized ZVI)

Amendment Selection

Site Specific Degradation

Natural Attenuation:

- Appears to be some natural attenuation based on VOC distribution
- Isotopic data indicates degradation but minimal accumulation of VCl or ethene or ethane (not hydrogenolysis)
- Mineralogical evaluation identified naturally occurring ferrous iron minerals (abiotic elimination pathways)

Stimulated Degradation:

- In Situ Microcosms demonstrated the ability to stimulate hydrogenolysis pathway

InfraSUR Environment & Infrastructure

Transmitted by Email

To: Messrs. Luc Turbide and Matthew Burns, WSP
From: Jim Studer, InfraSUR
Date: December 30, 2015
Subject: Baseline Elemental-Mineralogical-Morphological-Microbial (EM3) E

Table 3. Weakly Bound Ferrous-Ferric-Total Iron (InfraSUR Method WBI-2015-B)

Sample	Ferrous (mg/kg)	Ferric (mg/kg)	Total (mg/kg)
OW1-2015	920	209	1,129
PW1-2015	1,925	381	2,307

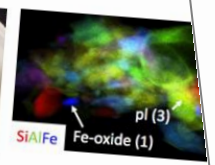

Table 6. Summary of selected elemental/mineralogical information for OW1 and PW1 (2015).

Sample ID	Weakly Bound Iron, mg/kg	Ferro-Magnetic Particles Y/N	Total Iron mg/kg	Identified Minerals: XRD (random orientation)	Identified Minerals: SEM-EDS (focus on fine fraction)	Identified Minerals: TEM-EDS (focus on fine fraction)
OW1-2015	1,129	Y	4,850	Alkali Feldspar (albite) Amphibole (ferro-actinolite) Mica (muscovite), Chlorite (chinoclore) Alkali Feldspar (microcline), Quartz	Alkali Feldspar (see below) (albite, K-rich, plagioclase, oligoclase) Quartz, Amphibole (actinolite), Chlorite Mica (muscovite)	Feldspar (K-rich, plagioclase, others), Quartz Mixed Chlorite/Vermiculite (corrensite) Chlorite, Mica (muscovite) Amphibole (Ca-rich) Ca Phosphates, Titanium Oxide, Iron Oxide
PW1-2015	2,307	Y	5,000	Alkali Feldspar (albite) Amphibole (ferro-actinolite) Mica (muscovite), Chlorite (chinoclore) Alkali Feldspar (microcline), Quartz	Alkali Feldspar (see below) (albite, K-rich, plagioclase, oligoclase) Quartz, Amphibole (actinolite, hornblende) Chlorite, Epidote	Not Performed

microbialinsights

Results

Table 1. Summary of the results obtained for *In Situ* Microcosm Units deployed in PO14-26 and PO14-28.

Sample Information Treatment	PO14-26 MNA	PO14-26 BioStim	PO14-28 BioAug
Microbial Populations (cells/bead)			
Dehalococcoides sp. (DHC)	6.62E+02	1.18E+03	1.04E+07
tceA Reductase (TCE)	2.11E+01 (J)	<2.50E+01	5.10E+05
bvcA Reductase (BVC)	1.18E+02	5.57E+02	<2.50E+01
vcrA Reductase (VCR)	<2.50E+01	<2.50E+01	9.99E+05
Dehalogenimonas spp. (DHG)	4.98E+01 (J)	4.05E+01 (J)	4.41E+05
Geobacter spp. (GEO)	1.55E+05	2.23E+06	5.60E+05
Sulfate Reducing Bacteria (APS)	1.53E+05	8.47E+05	3.80E+05
Methanogen (MGN)	1.31E+02 (J)	1.16E+03	1.65E+05
Total Eubacteria (EBAC)	3.13E+07	3.56E+07	1.55E+08
Contaminant of Concern (µg/L)			
Tetrachloroethene	<10	<10	<10
Trichloroethene	<10	<10	<10
1,1-Dichloroethene	<10	16.6	180
cis-1,2-Dichloroethene	4.4	<10	1170
Vinyl chloride	<10	11.7	81
1,1-Dichloroethane	3.1		548
Dissolved Gases (µg/L)			
Ethene	0.52	0.71	10
Ethane	<0.10	0.36	2.6
Acetylene	<0.50	<0.50	<0.50
Geochemistry			
Ferrous Iron (mg/L)	<0.50	<0.50	<0.50
Sulfate (mg/L)	110	36	<1.0
pH	7.71	7.26	6.89
CSIA (‰)			
Trichloroethene	NA	NA	NA
cis-1,2-Dichloroethene	-17.05	-17.08	-18.11
Vinyl Chloride	NA	NA	-28.57
1,1-Dichloroethene	NA	-28.36	-31.68
1,1-Dichloroethane	-27.93		-27.92

Legend: J = estimated concentration below PQL but above LQL < = Result not detected NA = Not Analyzed

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Pre-Injection ISM Deployment

collect and dry saturated soils

place soil into screened housings

deploy before amendment application

Implementation

November 2017

Amendments
- PlumeStop: 1,900 L
- AquaZVI: 800 L
- HRC Pimer: 250 L
- HRC: 250 L
- Augment: 18 L

Dilution/Chase Water
- Potable Water: 25,000L

Total Fluids:
- Wast + Amendment: 28,000
- Aproximately 10% of mobile porosity within treatment zone

Observations
- Pressure: 20 to 40 psi
- Some back pressure
- Amendment observed and some geochemical shifts in wells within treatment area

Results - Delivery

Legend

	17PO-03	
Parameter	D	R1
PS Visual		
Specific Conductance		
ORP		
DOC		
BOD		
Iron		-
Sulfide		

← Sampling Period
D = 11/17
R1 = 9/18

Evidence of Geochemical Shift

- Strong
- Limited
- None

Pilot Test Monitoring Well

Injection Point

	17PO-01	
Parameter	D	R1
PS Visual		
Specific Conductance		
ORP		
DOC		
BOD		
Iron		
Sulfide		

MW-17P01

	17PO-03	
Parameter	D	R1
PS Visual		
Specific Conductance		
ORP		
DOC		
BOD		
Iron		-
Sulfide		

MW-17P03

	17PO-02	
Parameter	D	R1
PS Visual		
Specific Conductance		
ORP		
DOC		
BOD		
Iron		
Sulfide		

MW-17P02

	17PO-04	
Parameter	D	R1
PS Visual		
Specific Conductance		
ORP		
DOC		
BOD		
Iron		
Sulfide		

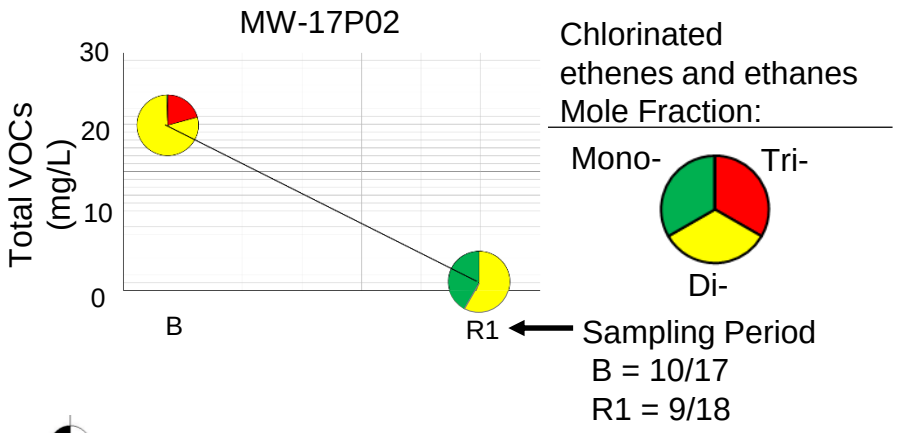
MW-17P04

N

10 m

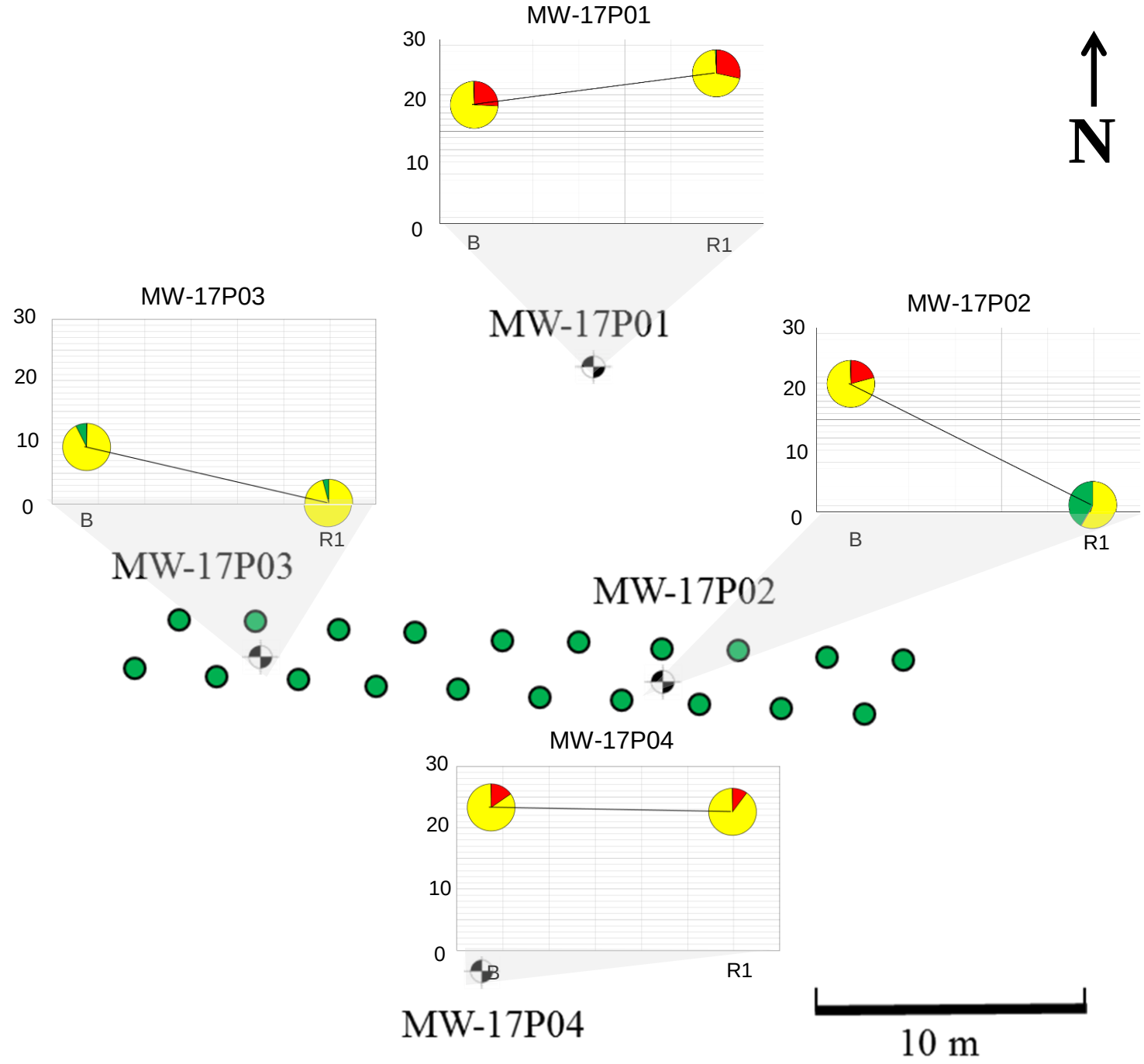
Results - Groundwater

Legend



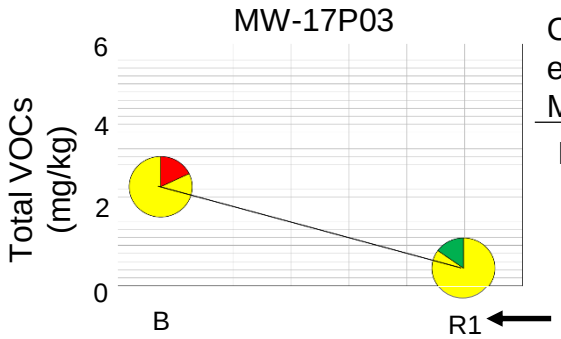
Notes:

- Groundwater flow to south
- Continuous mass loading into treatment zone
- >95% concentration decrease at mid-point of treatment zone
- Daughter product data indicate abiotic primary pathway

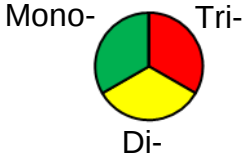


Results – Soil ISMs

Legend



Chlorinated ethenes and ethanes Mole Fraction:



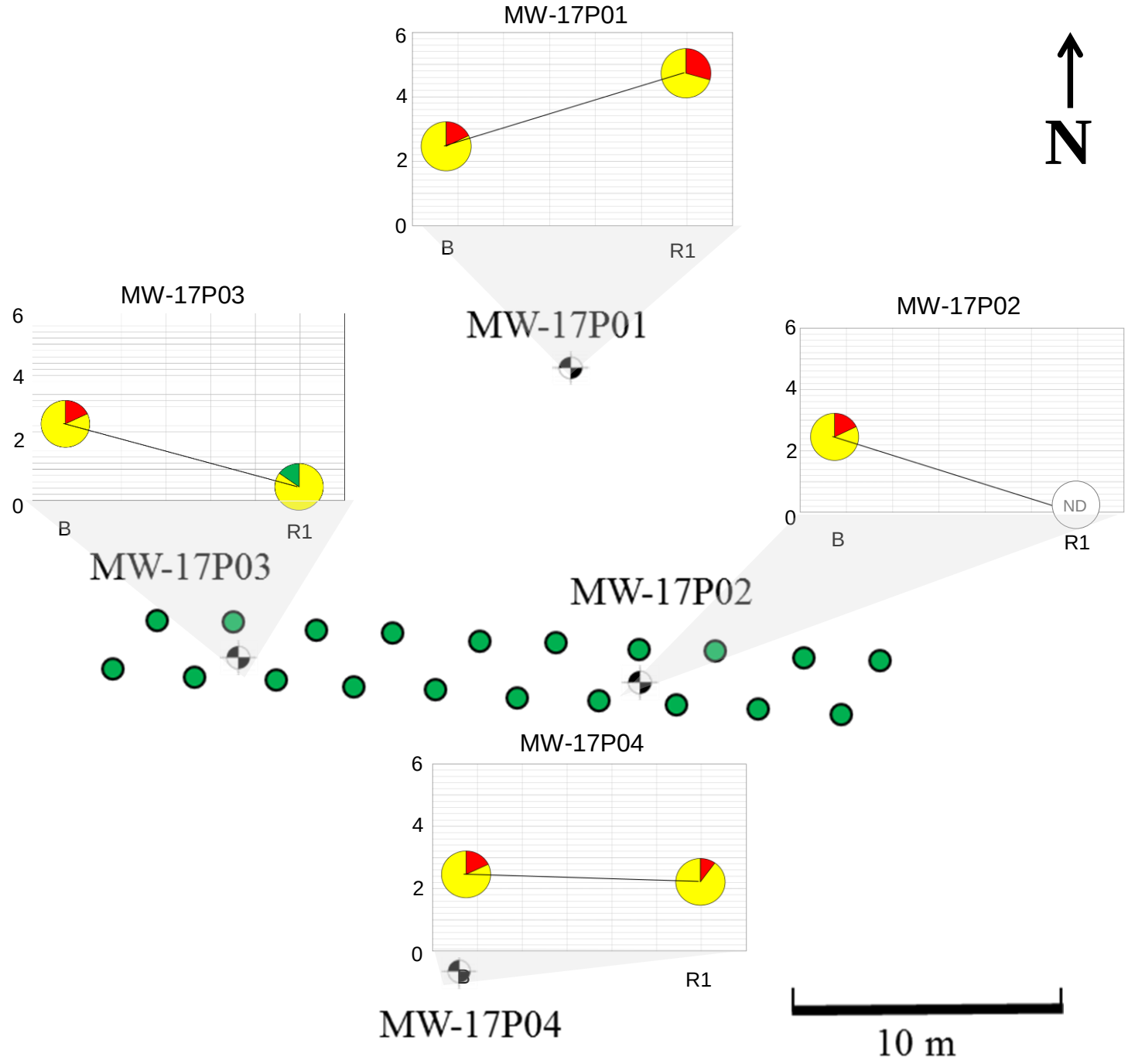
Sampling Period
B = 10/17
R1 = 9/18

Pilot Test Monitoring Well

Injection Point

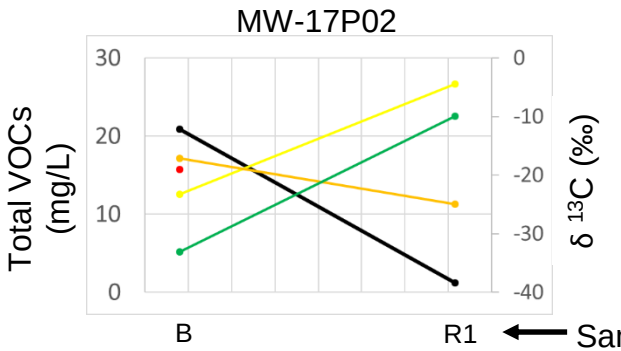
Notes:

- >95% concentration decrease at mid-point of treatment zone
- Demonstrated destruction – not phase transfer to activated carbon



Results - CSIA

Legend

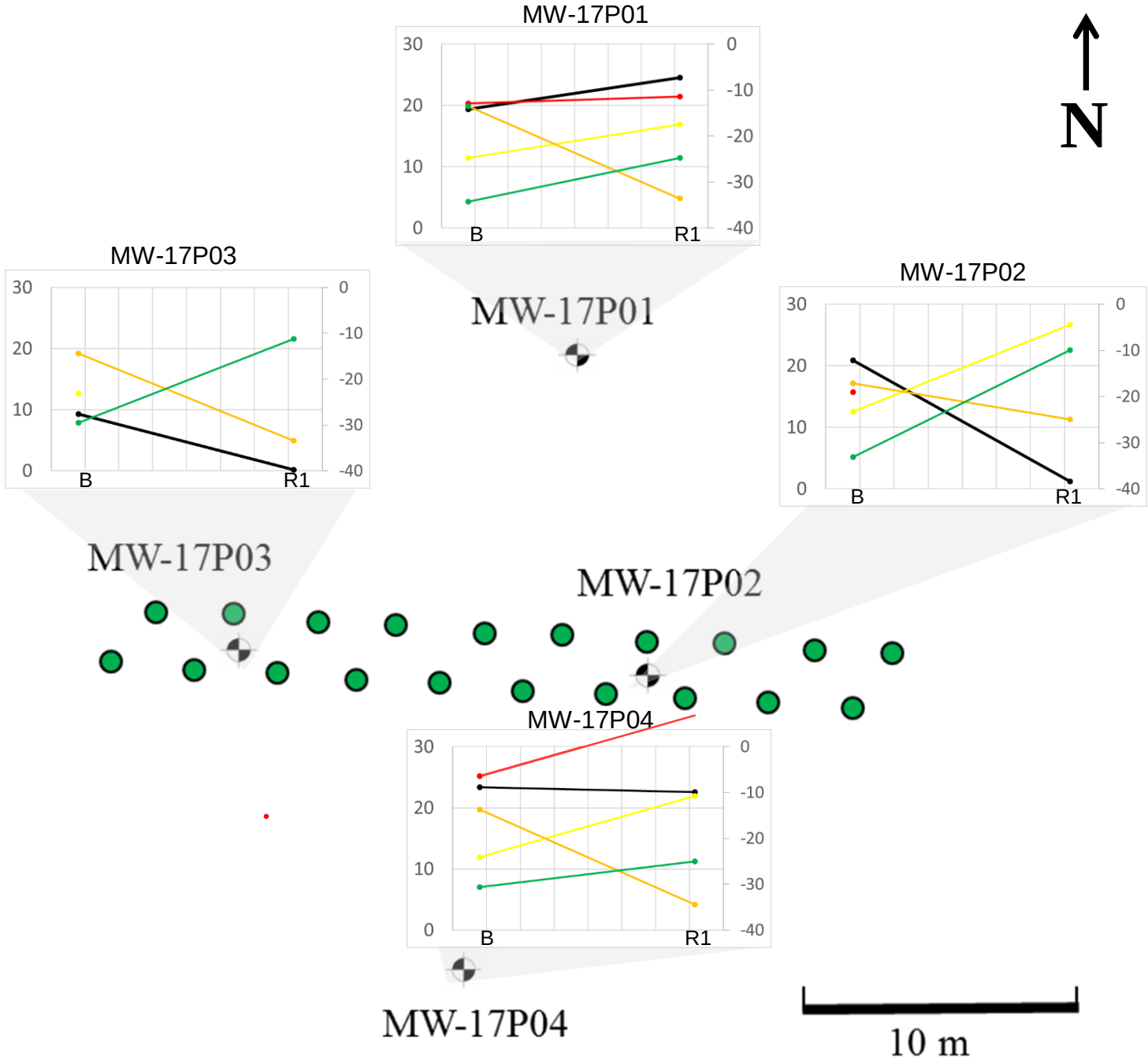


Sampling Period
B = 10/17
R1 = 9/18

- Total VOCs (µg/l)
- TCE δ ^{13}C (‰)
- cis-DCE δ ^{13}C (‰)
- 1,1-DCE δ ^{13}C (‰)
- Vinyl Chloride (‰)

Pilot Test Monitoring Well

Injection Point



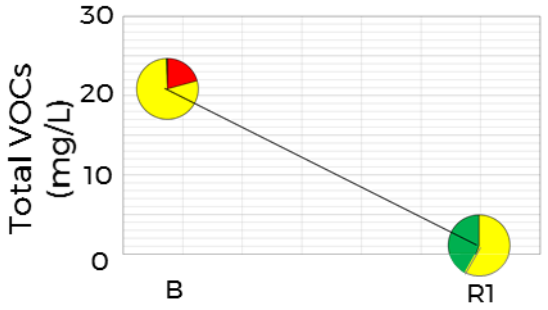
Conclusions

Successful Technology Implementation

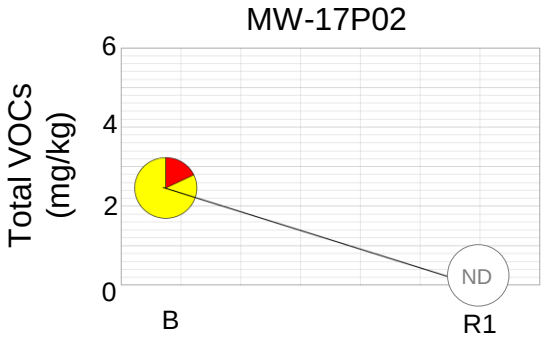
Great Amendment Delivery

	17PO-03	
Parameter	D	R1
PS Visual		
Specific Conductance		
ORP		
DOC		
BOD		
Iron		-
Sulfide		

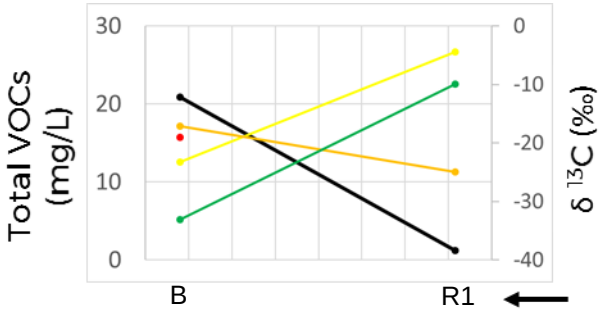
95% + Dissolved VOC Concentration Decrease



Destruction on Activated Carbon



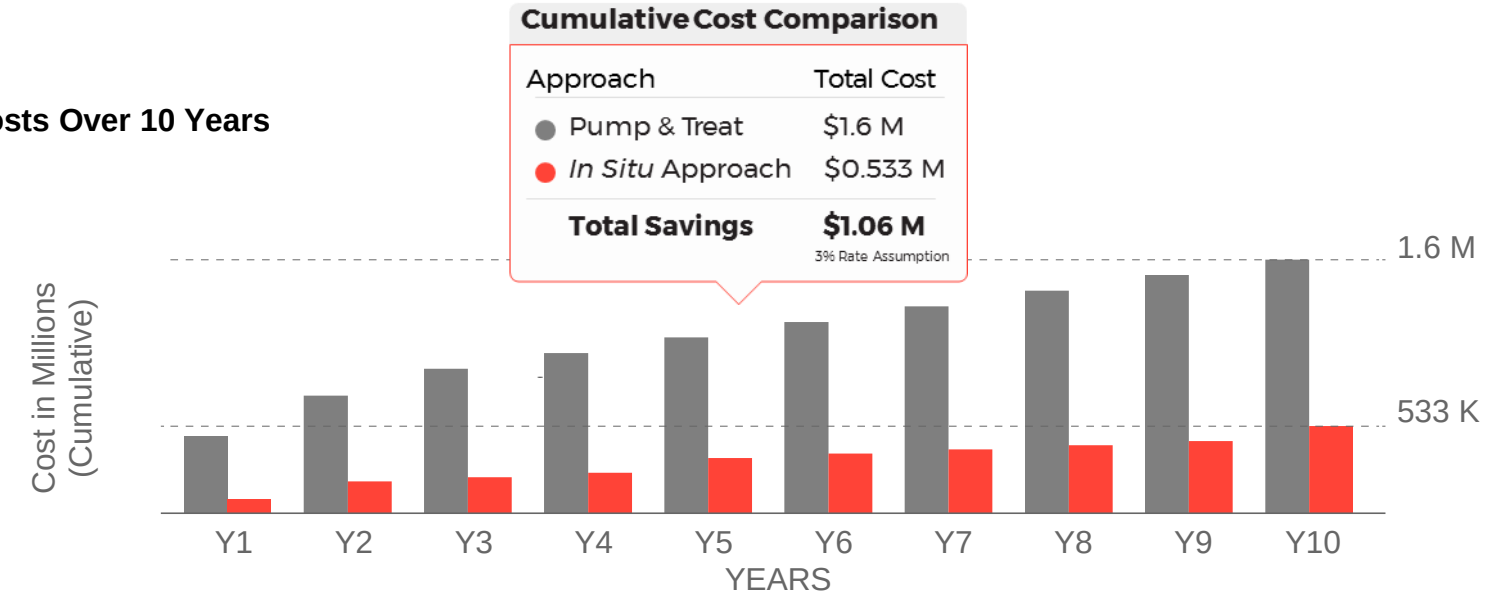
CSIA Definitively Demonstrates Degradation



Background

We've performed similar applications with similar results at many sites including fractured bedrock

Annual Recurring Costs Over 10 Years



Cost Comparison (USD)

Remediation Approach	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Pump & Treat										
Investigation, Design, & Installation	540,000	290,000	190,000	0	0	0	0	0	0	0
O&M	0	0	0	110,000	110,000	110,000	110,000	110,000	110,000	110,000
Total Annual Cost	540,000	290,000	190,000	110,000	110,000	110,000	110,000	110,000	110,000	110,000
Net Present Value	1,598,679									
In Situ										
Investigation, Design & Installation	65,000	100,000	0	0	0	0	0	0	0	0
O&M/	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000
Reapplication	0	0	0	0	75,000	0	0	0		75,000
Total Annual Cost	95,000	130,000	30,000	30,000	105,000	30,000	30,000	30,000	30,000	105,000
Net Present Value	533,775									

Net Present Value of Estimated Cost Savings Over 10 Years: $1,064,901*

*Rate Assumption: 3%

MBTs Critical to Informing Design & Performance

MBT Costs	Cost
Pre-Design	
CSIA	$3,600
PCR (including Biotrap ISMs)	$10,000
Core Studies	$7,000
Performance Monitoring	
CSIA	$5,000
PCR	$2,500
Native Material ISMs	$500
Total:	***$28,600***

Questions

wsp.com/usa