BioStryke
Remediation

RemTech Remediation Symposium 2015

On-Site Treatability Evaluation Using Passive In-Situ Biostimulation
Green Remediation Strategy for Chlorinated/Non-Chlorinated GW Contaminants

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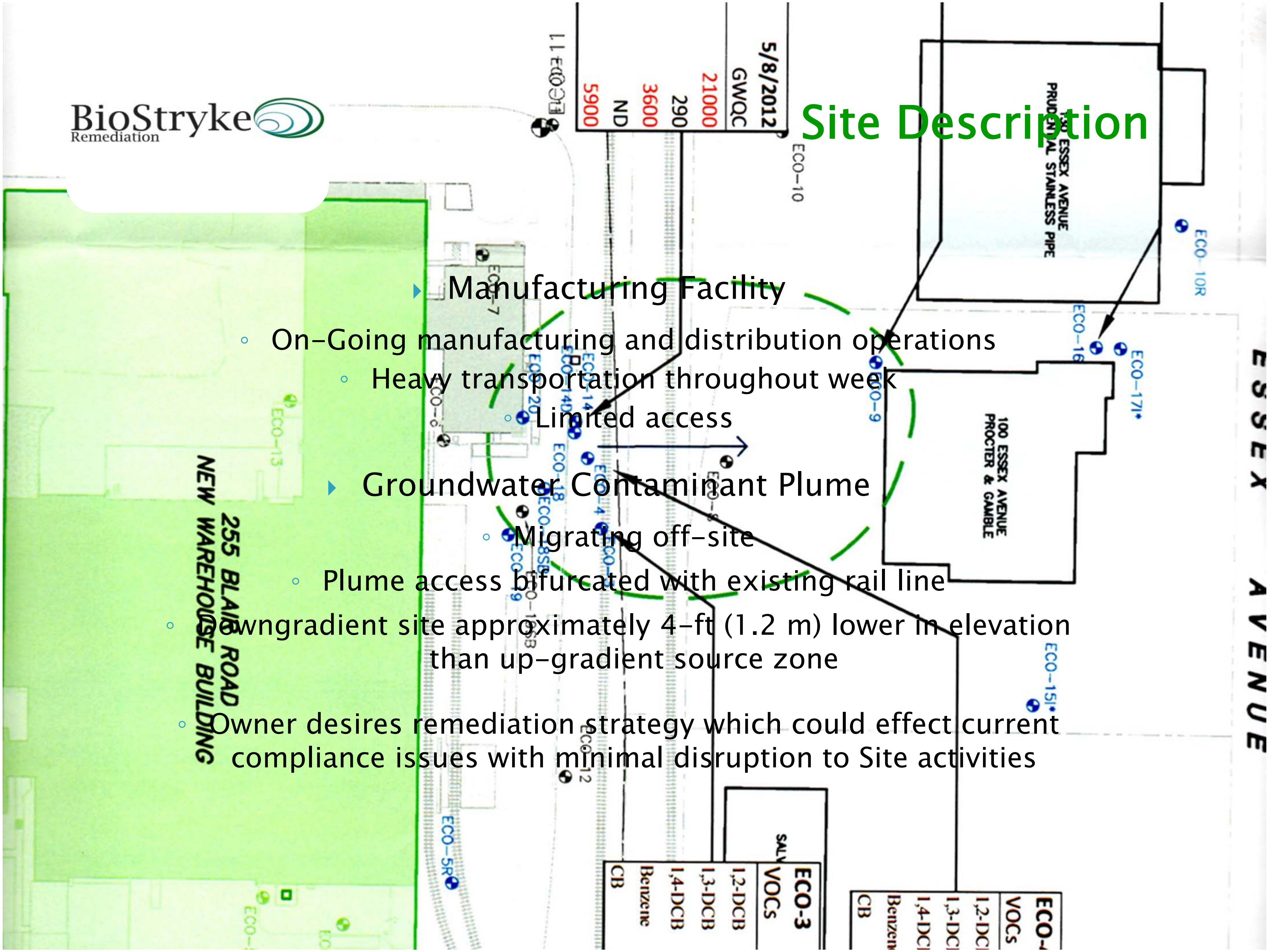
BioStryke Remediation

Site Description



- Manufacturing Facility
  - On-Going manufacturing and distribution operations
    - Heavy transportation throughout week
      - Limited access
- Groundwater Contaminant Plume
  - Migrating off-site
  - Plume access bifurcated with existing rail line
  - Downgradient site approximately 4-ft (1.2 m) lower in elevation than up-gradient source zone
  - Owner desires remediation strategy which could effect current compliance issues with minimal disruption to Site activities

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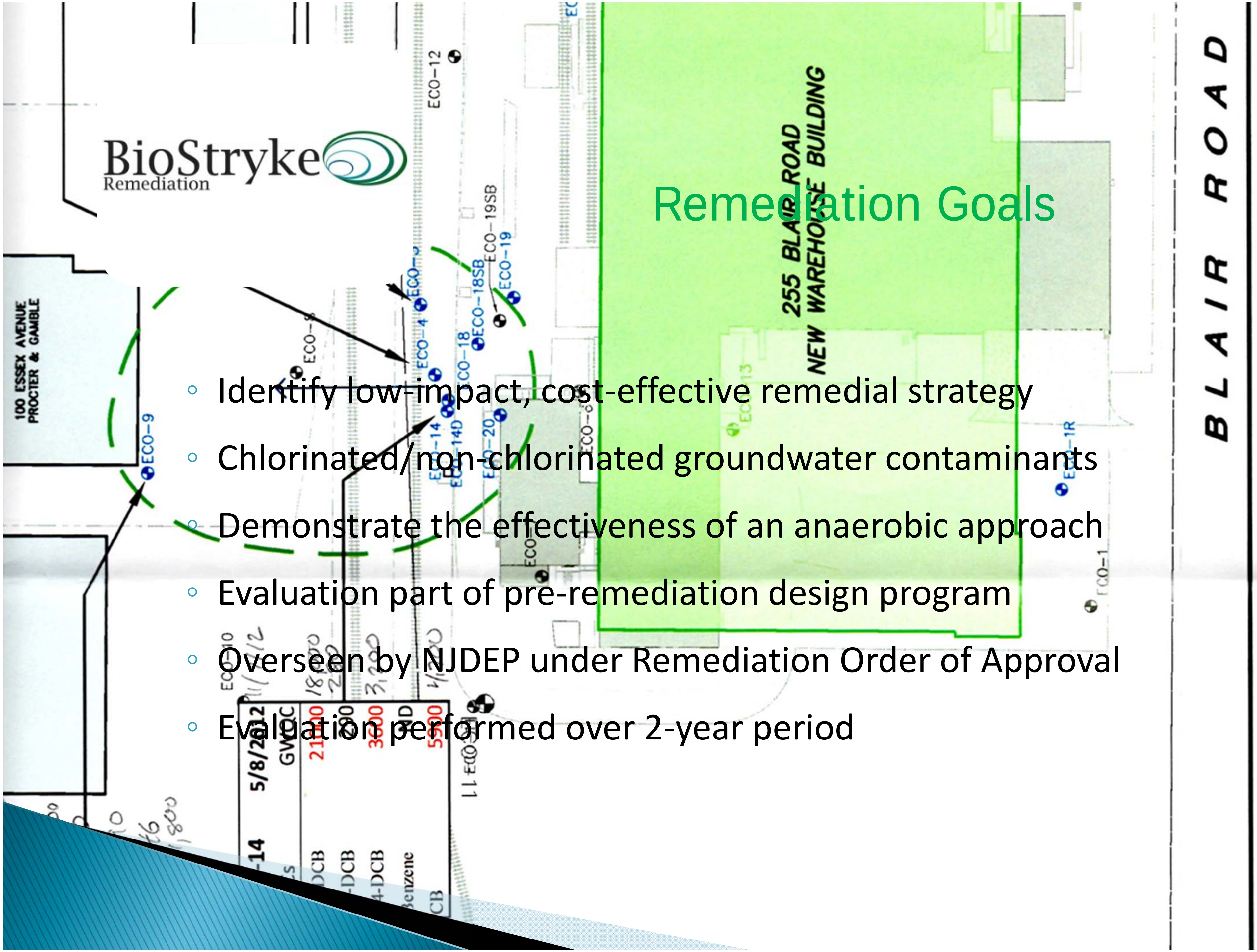

Remediation Goals

- Identify low-impact, cost-effective remedial strategy
- Chlorinated/non-chlorinated groundwater contaminants
- Demonstrate the effectiveness of an anaerobic approach
- Evaluation part of pre-remediation design program
- Overseen by NJDEP under Remediation Order of Approval
- Evaluation performed over 2-year period

Evaluation Purpose

- In-Situ biostimulation approach using DPT chosen by consultant
    - TPHENHANCED™ by *BioStryke®* Remediation Products LLC
    - Biostimulation additive that leverages existing conditions
- Provides analogue to Oxygen (O_2) to support microbial respiration using alternative electron acceptors
- Utilize Benzene (hydrocarbon) as electron donor
- Supports heterotrophic microbial populations, ***not*** just aerobes
- Exhibits ability to expedite residual source mass solubilization
- Eliminates need for long-term above-ground support equipment
- ‘Green” remediation strategy that eliminates nuisance emissions, vapors and noise

Pro’s & Con’s of Bioremediation

- Inappropriate without Physical Removal
  - Pooled DNAPL Source Zone
  - Time is of the essence

- Appropriate with Remedial Design Considerations
  - Heterogeneous matrix, silty/clay soil, fractured bedrock
  - Residual DNAPL
  - cVOC and non-cVOC mixture
  - Highly aerobic overburden or planned future site disturbance

- Ideal Situation
  - Accessible impact zone
  - Time
  - Homogeneous Stratigraphic Conditions

Why is Biostimulation Cost-Effective

- **Biostimulation** is a proven remediation strategy that:
  - Nourishes and stimulates native microbial populations
  - Expedites solubilization of residual source mass contaminants
  - Increases contaminant bioavailability
  - Enhances dissolve phase contaminant destruction to
  - Realize Long-Term Compliance
- **Biostimulation** minimizes the impact of remediation by:
  - Minimizing/Eliminating above ground support equipment
  - Minimizing off-site removal activities, fuel and energy costs
  - Minimizes and eliminates nuisance noise, emissions and vapors

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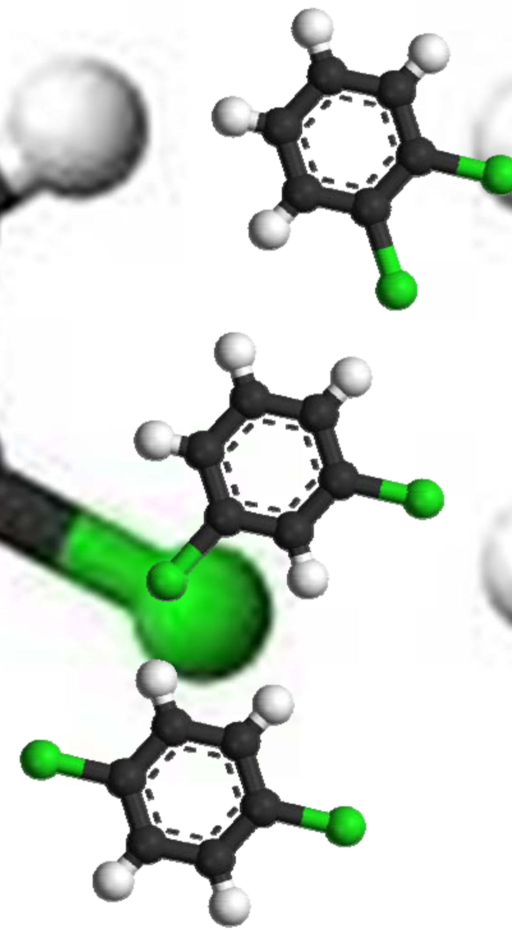
Remediation of DCB using Biostimulation

- Contaminants of Concern
  - Dichlorobenzene
  - Benzene
  - Chlorobenzene

- Three dichlorobenzene compounds:
  - 1,2-Dichlorobenzene or *ortho*-dichlorobenzene;
  - 1,3-Dichlorobenzene or *meta*-dichlorobenzene;
  - 1,4-Dichlorobenzene or *para*-dichlorobenzene.

- Dichlorobenzene does not occur naturally
- Organic compound with the formula $C_6H_4Cl_2$
- Two Chlorine atoms



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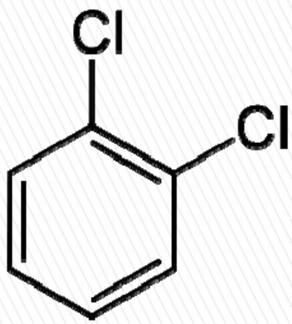
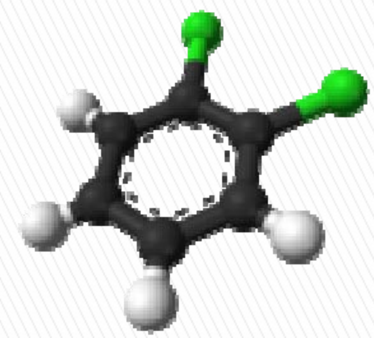
TPHENHANCED®

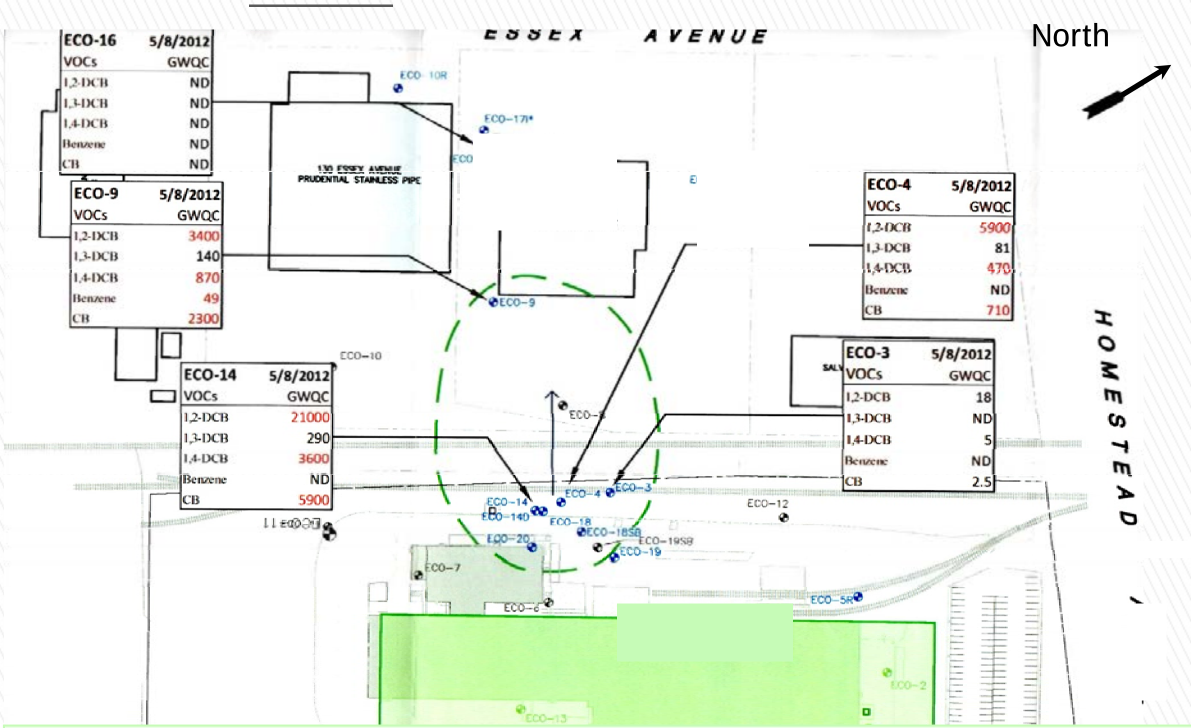
Remediation of DCB using Biostimulation

- 1,4-Dichlorobenzene
  - Colourless solid has a strong odor noticeable at [low]
  - Pesticide, deodorant and commonly as mothball
- 1,3-Dichlorobenzene
  - Colorless to pale yellow liquid
  - Used to make herbicides
- 1,2-Dichlorobenzene
  - Also know an orthodichlorobenzene (ODCB)
  - Colourless liquid
  - Poorly soluble in water but miscible with most organic solvents
  - Used as a solvent

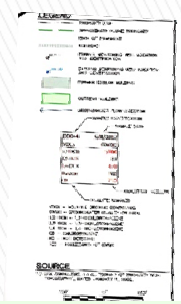




Summary of Baseline Groundwater Conditions



Performance Well ECO-4	
Contaminant	[ug/L]
1,2 Dichlorobenzene	7,600
1,3 Dichlorobenzene	81
1,4 Dichlorobenzene	520
Chlorobenzene	290



Baseline Conditions at performance well indicating main contaminant of concern 1,2-dichlorobenzene; source area near property boundary, offsite concentrations downgradient

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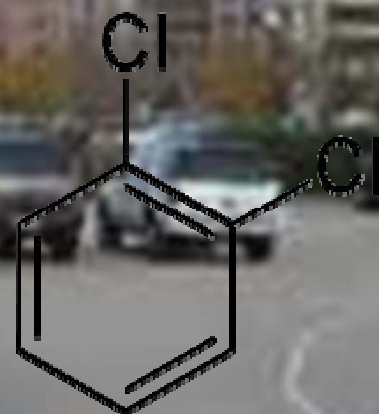
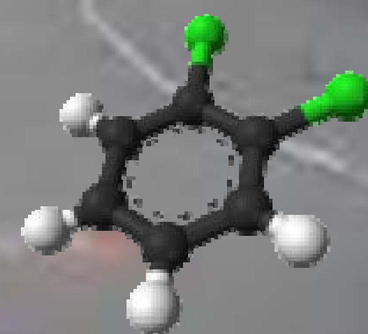
Remediation of DCB using Biostimulation





- 1° Contaminant of Concern
  - 1,2-Dichlorobenzene
- Concentrations of COCs
  - [Benzene] ND to <10 micrograms/Liter (µg/L)
  - [1,2-DCB] 500 µg/L to 10,000 µg/L
  - [total VOCs] between 1,000 µg/L to 12,500 µg/L
- Treatment Zone
  - Contaminants present in smear zone
  - Targeting smear zone proximate to source zone
  - Direct Push Technology chosen for deployment
  - 2 separate injection events over 17-month period

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Summary of Site Subsurface Conditions

- Groundwater monitoring well ECO-4 chosen as performance well
- Groundwater 8.6-ft bgs (≈2.64 m)
- Soil ‘very-tight’ clayey-silt with poorly sorted gravelly sand
- Oxygen Reduction Potential (ORP) -114.5 mV
- pH 6.61 s.u.
- Dissolved Oxygen (DO) 0.22 mg/L
- Saturated zone est. 8-ft to 18-ft bgs
- ECO-4 completed at 16-ft bgs (≈4.88 m)

BORING LOG
Environmental Strategies Corporation
8521 Leesburg Pike
Vienna, Virginia 22182

PROJECT
Ecolab
Avenel, NJ

Boring No. ECO #4
Sheet 1 of 1
Date Drilled 12/8/89

Drilling Co. J.E. Fritts & Assoc.
Driller Jay Bell
ESC Geologist John S. Wyckoff

Boring Location Near Phase II building
Ground Elevation 25.79'
TOC Elevation 27.83'

Boring		Casing/Screen		Sampler	
Method	Auger	Type	PVC/PVC	Method	Split Spoon
Hole Diameter	8"	Diameter	2"	Length (ft.)	2
Inside Diameter	3.375"	Screen Length	10'	Hammer (lbs.)	140
Total Depth	16'	Screen Slot Size	.10	Fall (ins.)	30

Depth	P.I.D. (ppm)	Percent Recovery	Sample Depth	Blows/6''	Well Design	Sample Description
0'	NR	100%	0-2	9,8,8,10		0-6" Top soil and sod. 6"-2' Olive gray 5 Y 4/1 to moderate brown 5 YR 4/4, micaceous, medium sand, moderately well sorted.
2'		100%	2-4	6,6,6,6		2-4' Olive gray, medium sand with organic material. Very small percentage of clay or silt fraction.
4'		100%	4-6	3,3,5,4		4-6' Same as above, slight sulfur odor.
6'	30	100%	6-8	3,5,6,9		6-7' Same as above. 7-8' Tight clayey silt with scattered gravel and pebbles, moderate reddish brown 10 R 4/6. Color transition.
8'	170	100%	8-10	9,8,11,10		8-10' Moderate reddish brown 10 R 4/6 poorly sorted gravelly sand in a clay silt matrix.
10'	5	100%	10-12	3,5,10,9		10-12' Same as above, moist.
12'	8	100%	12-14	29,15,18,17		12-13' Less moisture, tight, same lithology as above. 13-14' Saturated moderate reddish brown poorly sorted clay and silt matrix with gravel and sand.
14'		100%	14-16	[illegible]		14-16' Tight, fine to coarse sand with pebbles in a moderate reddish brown clay silt matrix.

*Contamination-odor noted at 8'.

Geochemistry

Boring Log

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Remediation of DCB using Biostimulation

- Treatment Zone consisted of limited area
- Existing monitoring well ECO-4 located proximate to center of AOI
- Assumed 15-ft radial Area of Influence (AOI)
- Additive deployed using a direct push GeoProbe rig
- Additive injected between elevations 9-ft and 15-ft within each of the 5-deployment nodes about well

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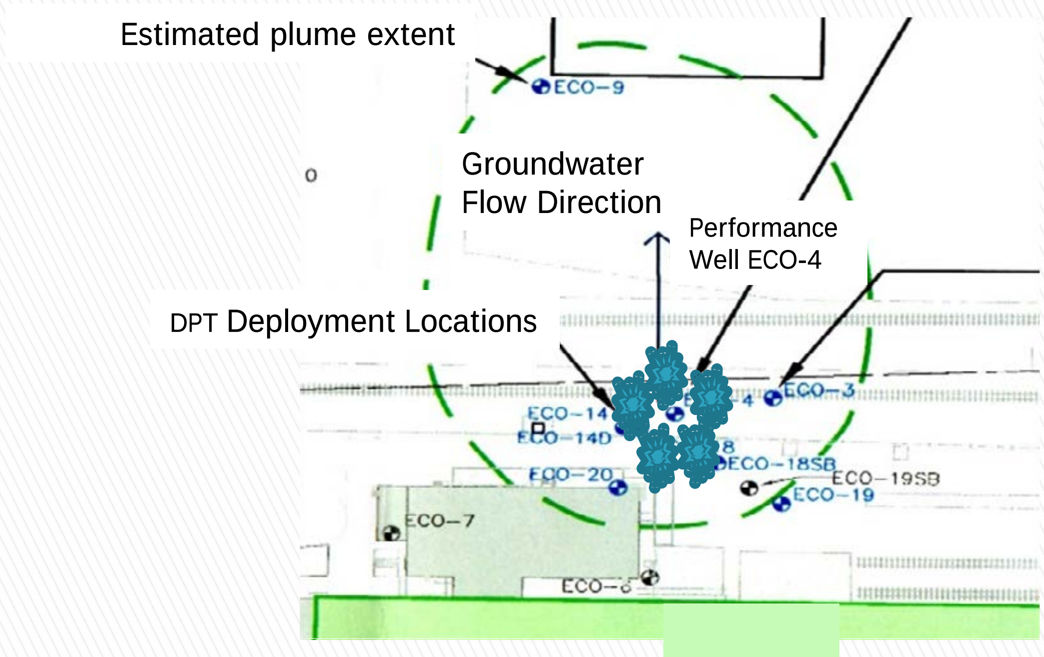
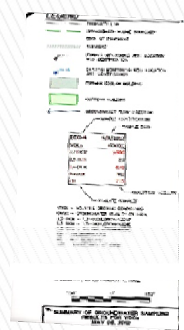
Deployment Locations for Pilot Evaluation





Performance Well ECO-4	
Contaminant	[ug/L]
1,2 Dichlorobenzene	7,600
1,3 Dichlorobenzene	81
1,4 Dichlorobenzene	520
Chlorobenzene	290

Five (5) deployment nodes chosen. Performance well ECO-4 located proximate to the center of the treatment zone created

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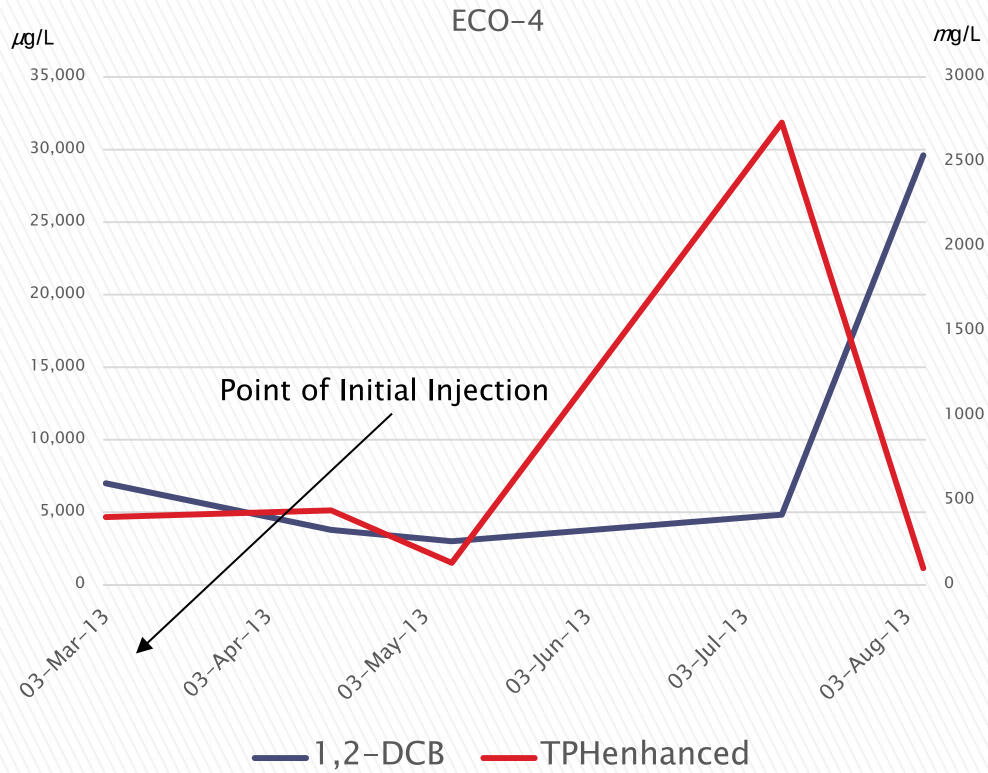
Remediation of DCB using Biostimulation

- Pilot Injection Event 1
  - March 20, 2013
  - 165 pounds TPHENHANCED™
  - 60 gallons chase water per node

- Pilot Injection Event 2
  - August 15, 2014
  - 792 pounds TPHenhanced
  - 230 gallons of chase water

Results Injection One

- Initial deployment of additive results in slow decrease in [DCB]
- ≈2-month delay in additive beginning to reach ECO-4
- By month 3 realize ≈620% increase in additive availability
- By month 5, >96% additive depleted
- Slow degradation of [DCB] in first 3-4 months (31% decrease)
- By month 5 realized massive solubilization of residual source mass with approximate 1,000% increase in [DCB]



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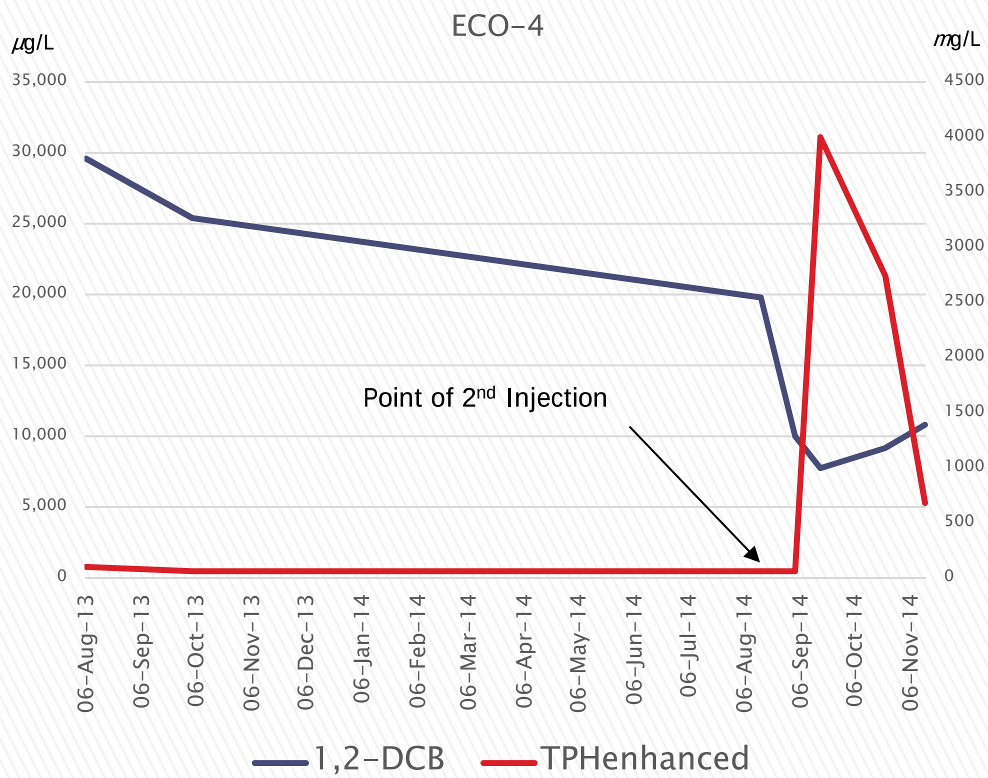
Results Injection Two

- Second Deployment performed on August 15, 2014
- 10-12 months following first injection [DCB] decreased >74% from peak bioavailability
- Equals destruction of previously unavailable residual source mass
- Without such solubilization and destruction one will experience rebound
- Additive unavailable until 2nd injection increasing >650%
- Over next 2-months additive depleted by >83%
- Overall reduction [DCB] between March 2013 and September 2014 approximates 63.5%



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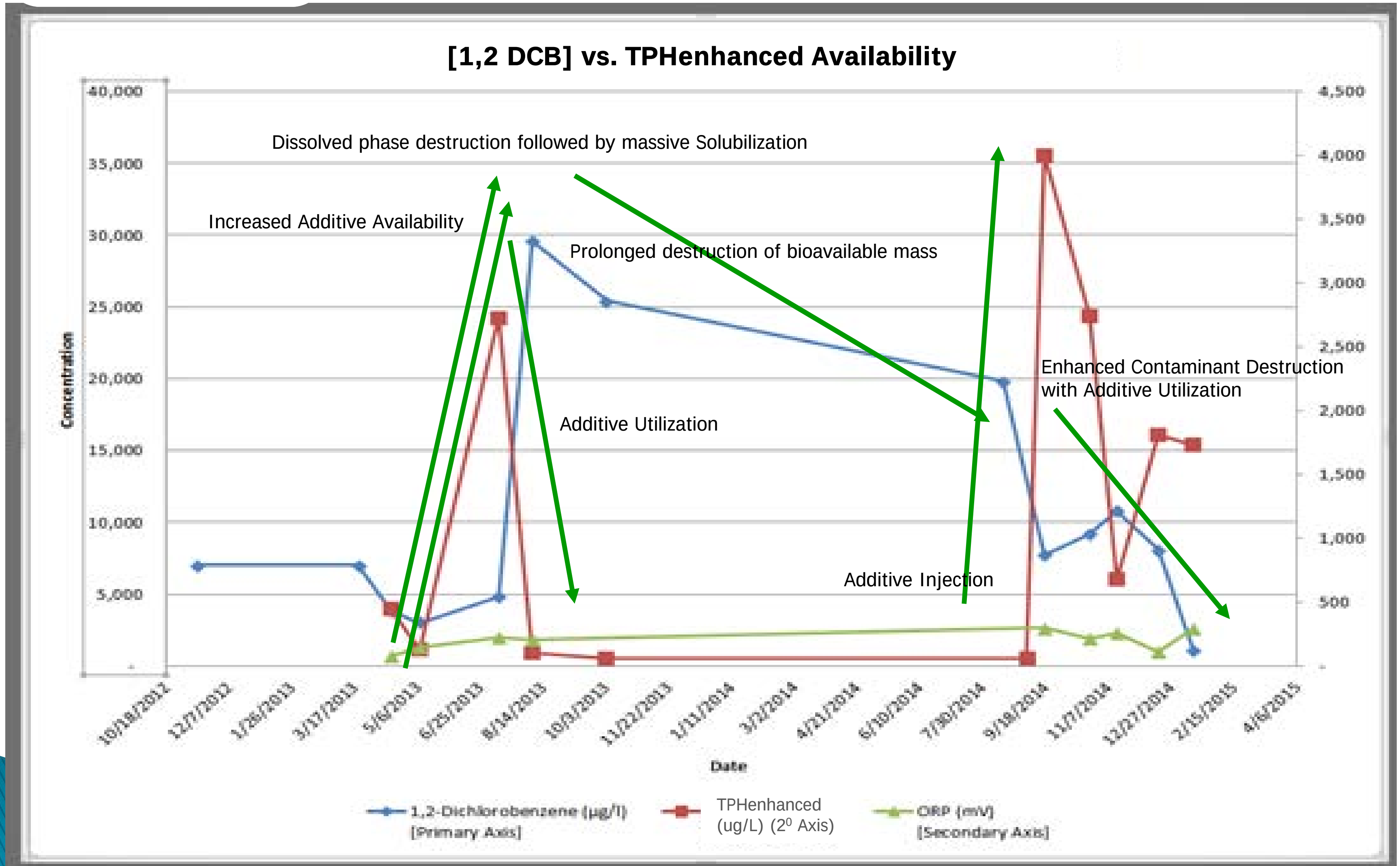
Remediation

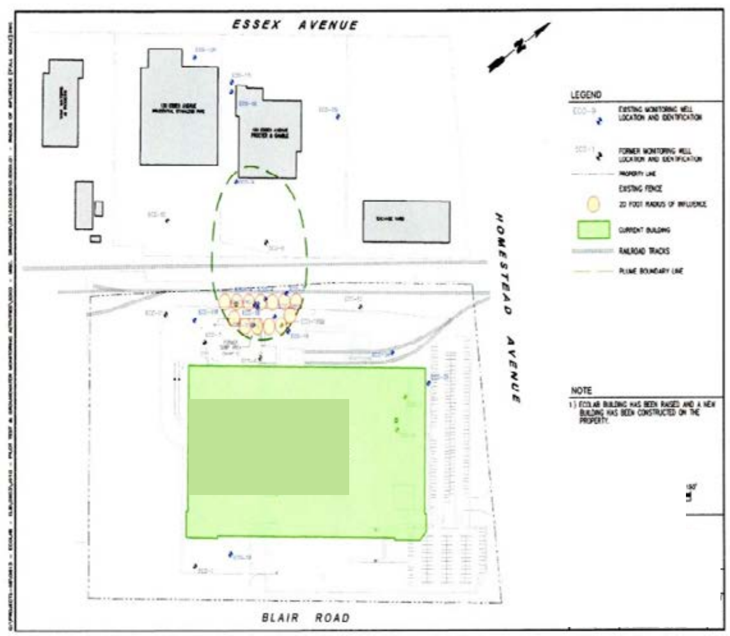
TPHENHANCED™



TPHENHANCED™
PERFORMANCE SUMMARY

- Results of approximate 2-year evaluation
- Documented overall 63.5% reduction in [DCB]
- Ist Injection March 2013
  - >97% utilization of additive in weeks
  - >887% increase in COC bioavailability from lowest [DCB]
  - Followed by 73.9% reduction in [1,2-DCB]
  - = residual source mass destruction

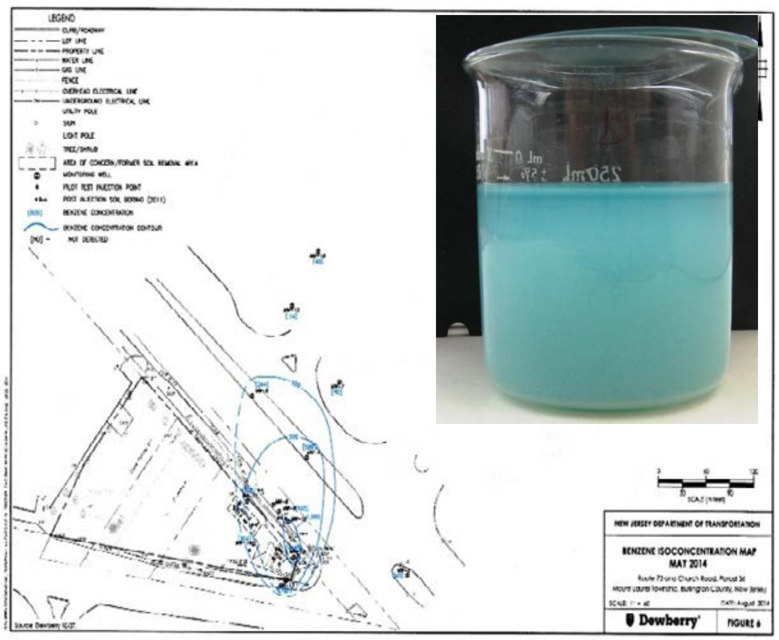
- 2nd Injection August 2014
  - >83% utilization of additive in weeks time
  - 97.8% reduction in [1,2-DCB] from peak bioavailability



TPHENHANCED™

Benefits and Limitations

- Enhances heterotrophic microbial populations creating greater ‘operating’ biomass
- Typically slower than aerobic destruction; along with, lag periods
- TPHENHANCED® additives’ solubility orders-of-magnitude > than O_2 based
  - Decreased risk of biofouling
  - Expedites contaminant solubilization
  - Enhances long-term compliance
- Enhanced additive solubility increases deployment options
- ncreases distribution capabilities in subsurface



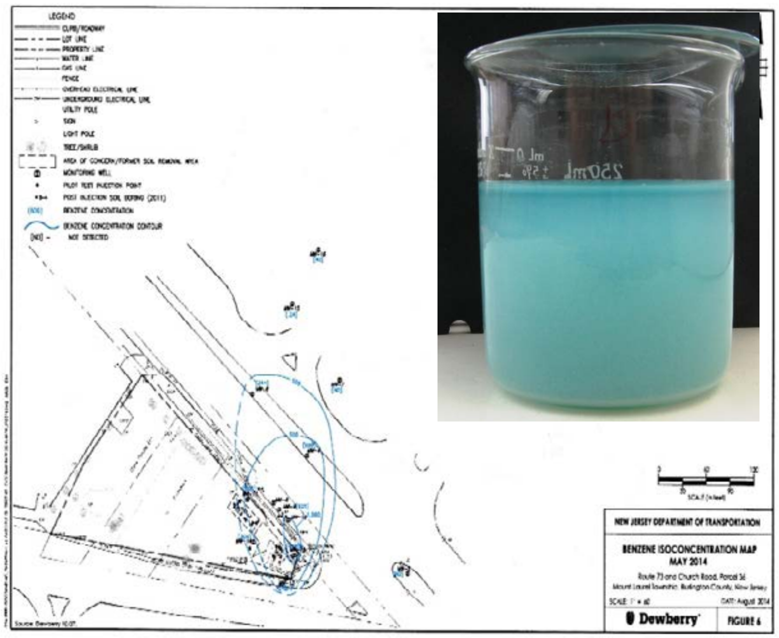
Maximize Compliance Objectives while Minimizing the impact and costs of remediation

BioStryke Remediation

TPHENHANCED™

Benefits and Limitations

- Secondary geochemical indicators support additive induced anaerobic contaminant degradation
  - Increased additive availability post inj.
  - Dramatic decreases of same thereafter
  - Concurrent decreases in COD
  - Increases in both ORP and pH recorded
- Evaluation demonstrates cost-effectiveness of a non-assimilatory remediation program
- Appropriate for dissolve phase and specifically, residual source mass contaminants
- Realizing >98% reduction in [contaminant] post residual source mass solubilization



Maximize Compliance Objectives while Minimizing the impact and costs of remediation

Full-Scale Remediation of DCB using Biostimulation Scheduled Fall 2015

Proposed injection plan for full-scale remediation using direct push
Anticipate full-scale deployment early November 2015
Estimated cost approximately $8.50 per ton treated soil (saturated)

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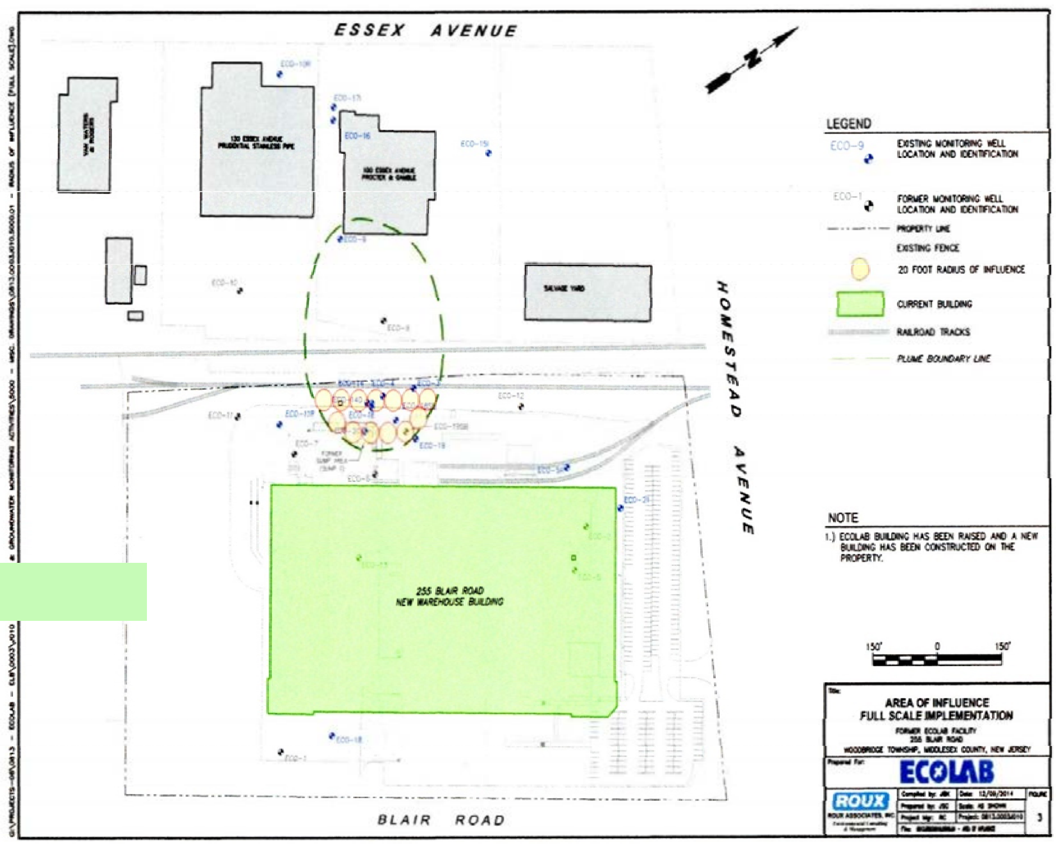
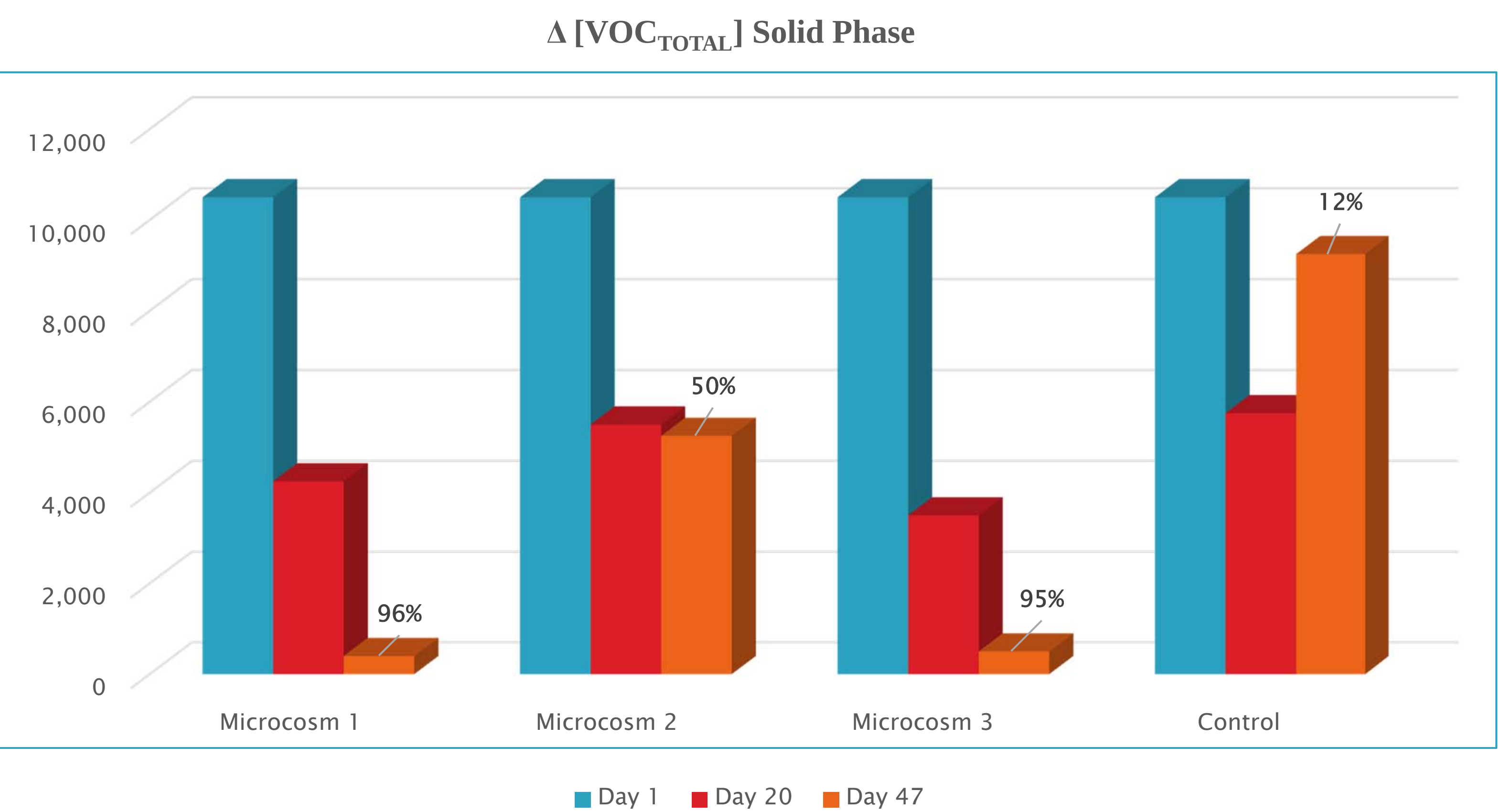
Full-Scale Remediation of DCB using Biostimulation Scheduled Fall 2015

- eatment Zone estimated at
)0-ft x 75-ft
-)-ft thick impact zone
- timate 50,000 pounds
  'Henhanced required
- timated additive cost $220-
  240K (<$5 per ton)
- timate 100+ nodes assuming
)-ft spacing
- otal project cost <$450,000
  $10/treated ton)



TPHENHANCED®
vs. Aerobic PHC Degradation

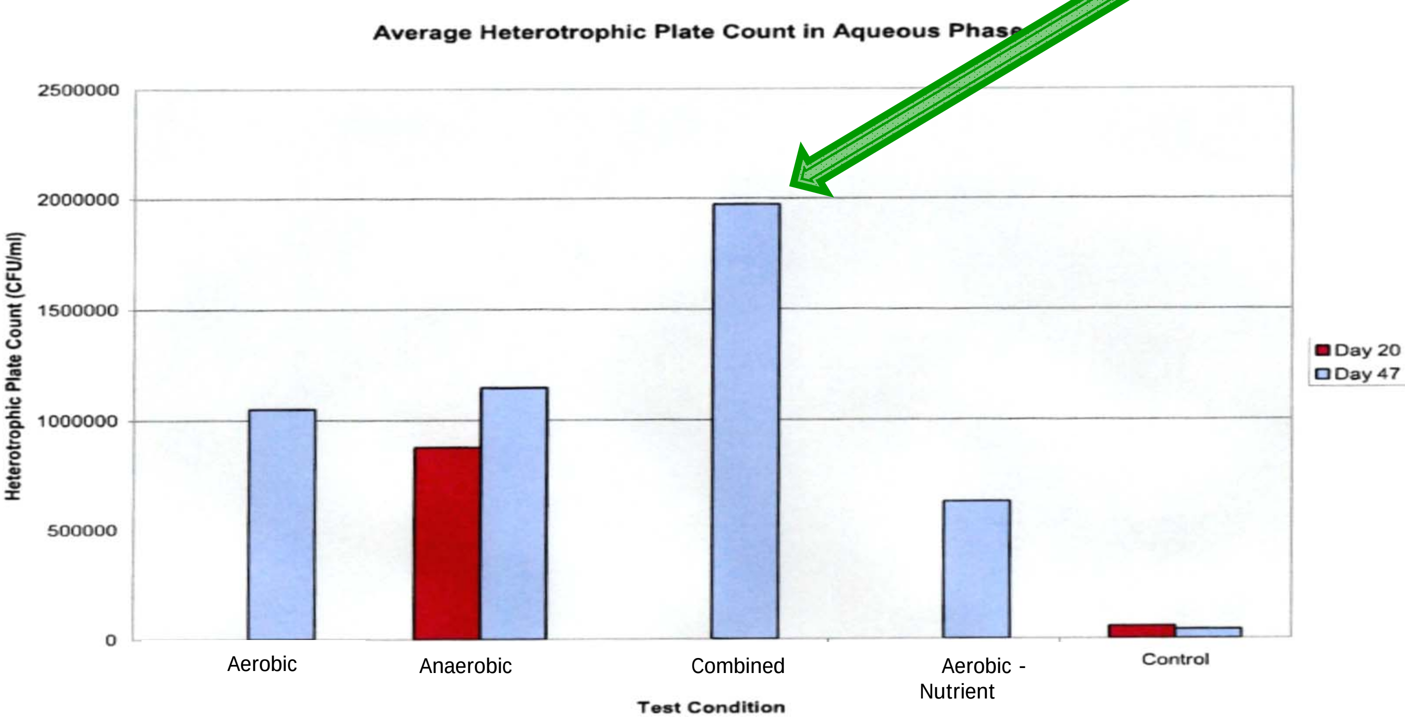


Aerobic Anaerobic TPHenhanced Control

TPHENHANCED–IIO®

Comparison Aerobic PHC Degradation vs. Combined Approach

Realize twice the microbial growth



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Drum Study – Results
Former Chanute USAFB Fire Training Area

enhanced®	April 4 (µg/L)	April 18 (µg/L)	May 2 (µg/L)	May 21 (µg/L)	%Reduction
ene	606	1,780	8,350	24.6	99.7%
thalene	197	178	302	2.02	99.3%
ene	2,360	3,620	8,370	13.4	99.8%
-TMB	282	224	843	4.13	99.5%
	NT	5.7	5.3	6.1	NA

-Advanced	April 4 (µg/L)	April 18 (µg/L)	May 2 (µg/L)	May 21 (µg/L)	%Reduction
ene	1,970	471	362	241	87.8%
thalene	213	76.7	34.1	8.36	96.1%
ene	6,320	1,130	651	385	93.9%
-TMB	349	80.7	37.8	17.1	95.1%
	NT	9.4	9.8	10.3	11.0

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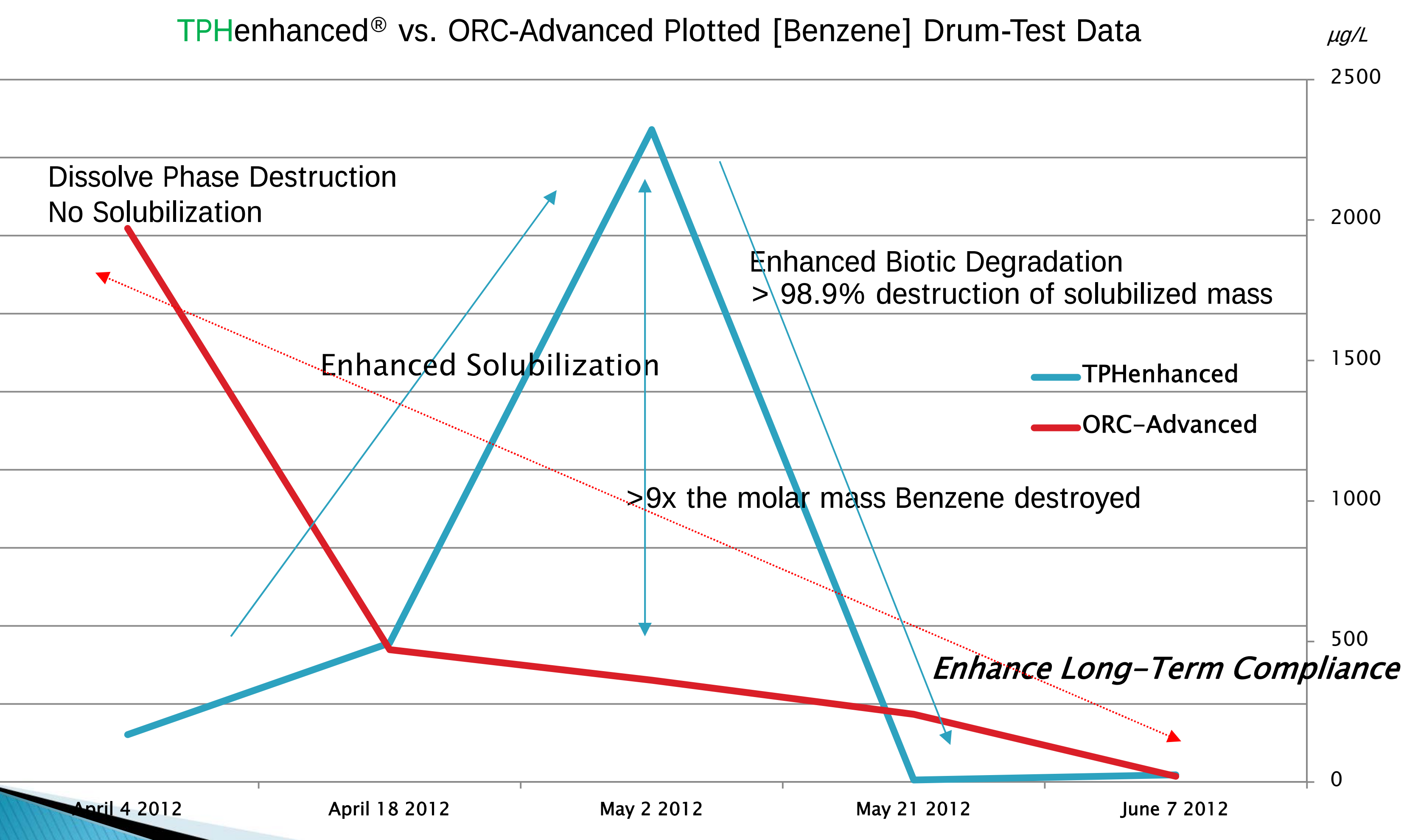
Speed?, or Solubilization
Work to realize long-term compliance



Low-Impact Chlorinated and Non-Chlorinated VOC Remediation

Leveraging Existing Anaerobic Site Conditions

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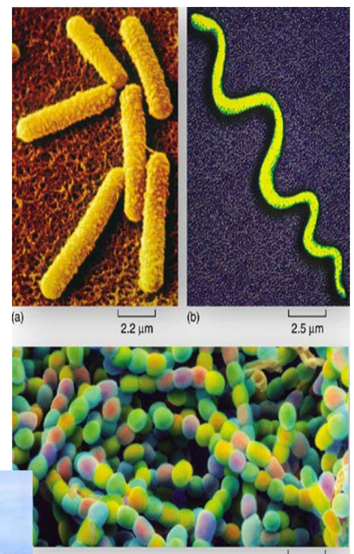

enefits to Leveraging Anaerobic Site Conditions

- Utilize geochemistry created by contaminant
- Eliminate aboveground support equipment
  - costs, nuisance noise, vapors, emissions

rovides Respiratory Analog to O_2

- Enhance same microbial populations
- Create greater electron availability

PHenhanced

- Low-Cost biostimulation additive
  - Low-Impact
  - Minimal support energy required
  - Get rebound out upfront
  - Achieve long-term site compliance cost-ef**fectively**

TPHENHANCED™

Summary Conclusions

- Cost-Effective Strategy to Passive-Aggressively Destroy Contaminants
    - Dissolved Phase and Residual Source Mass Contaminants
        - Minimize the Environmental Impact of Remediation
    - Leverage Existing Site Conditions to Maximize Project Effectiveness while Lowering Costs and Impacts
    - Save Remedial Dollars, Lower Client Costs, Increase Margins
        - Maximize Project Performance and Client Satisfaction

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Thank You ?? Questions ??

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