Soil Blending

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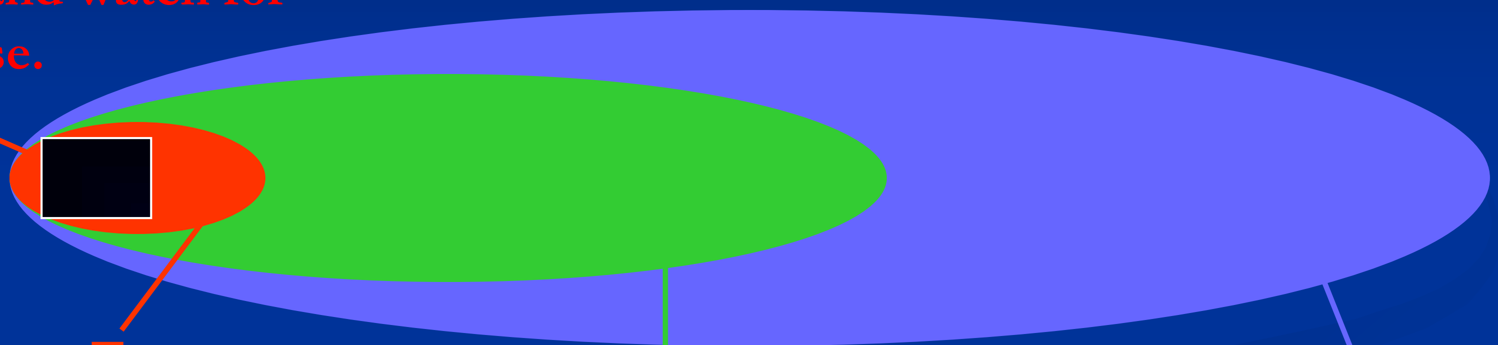
REDOX TECH, LLC

Redox Tech, LLC

- Business founded in 1995
- Headquarters in Cary, NC. Other offices in GA, SC, IL, MA, and CA
- Distributors in Europe
- Turn-Key Provider
- In Situ treatment with biological and chemical manipulation, both reduction and oxidation – over 1400 projects completed
- Hydraulic fracturing with Direct Push
- In Situ Soil Blending

Environmental Remediation Objectives

Do something as soon as possible, but do no harm, and watch for response.



Source Zone

<u>Characteristics:</u>
High Conc./NAPL; Significantly perturbed geochemistry

<u>Need:</u>
Aggressive technologies to limit long term damage

Primary Groundwater/Vadose Zone Plume

<u>Characteristics:</u>
Moderate to high aqueous/vapor phase concentrations

<u>Need:</u> Presumptive baseline or moderately aggressive alternatives

Dilute Plume/Fringe

<u>Characteristics:</u>
Low aqueous/vapor phase concentrations

<u>Need:</u> Innovative technologies - sustainable low energy concepts

Goals

- First Do No Harm
- Reduce Concentration, Flux or Toxicity of contaminants to limit impact on human health and the environment
- Cost of Remediation $<$ Cost to Delay, Property Value

Things we can adjust in subsurface

- Kinetics
  - Move things in or out of volume
  - Prevent things from moving in or out of volume
- Phase Transfer
  - Enhance or limit partitioning within volume
- Chemical Transformation
  - Enhance or limit chemical/bio reactions

Remediation Methods

- Removal Enhancements
  - Permeability e.g., frac, blend
  - Solubility/Mobility e.g., heat, solvents, surfactants
  - Phase Transfer e.g., heat
- Immobilization Methods
  - Barriers/walls e.g., reactive
  - Encapsulation e.g., cement, bentonite, vitrification?
  - Change gradients or flow field
  - Change species/phase to reduce solubility/mobility

Destruction Approach

- **Chemically Transform Contaminant**
  - Chemical Oxidation (e.g., permanganate, persulfate, peroxide, ozone, etc.)
  - Chemical Reduction (e.g. ZVI)

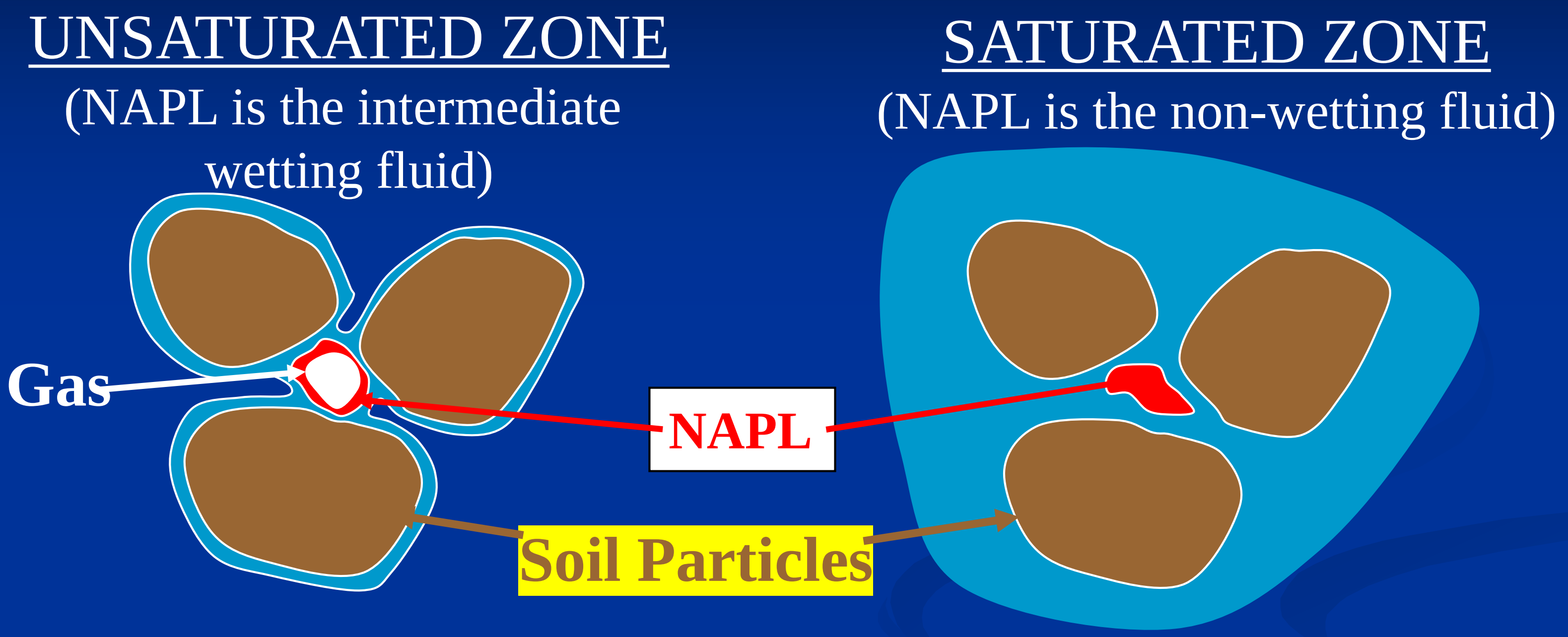
- **Biodegradation**
  - Electron Donor/Acceptor, nutrient addition, and/or bacteria culture
  - Suitable conditions for growth (e.g., proper pH, sufficient moisture, etc.)

…Or a combination

Contaminant Distribution in Subsurface

- Contaminants are heterogeneously distributed in a physically (geologic), chemically, and biologically heterogeneous volume which is also dynamic – makes things easy.
  - Tortuous, preferential pathways control with diffusion playing small role
  - matrix diffusion usually much less of an issue than occlusion or inaccessible pores
  - Usually worse in vadose zone because of gas phase

Residual NAPL



Residual NAPL often occurs as disconnected blobs within the pore spaces.

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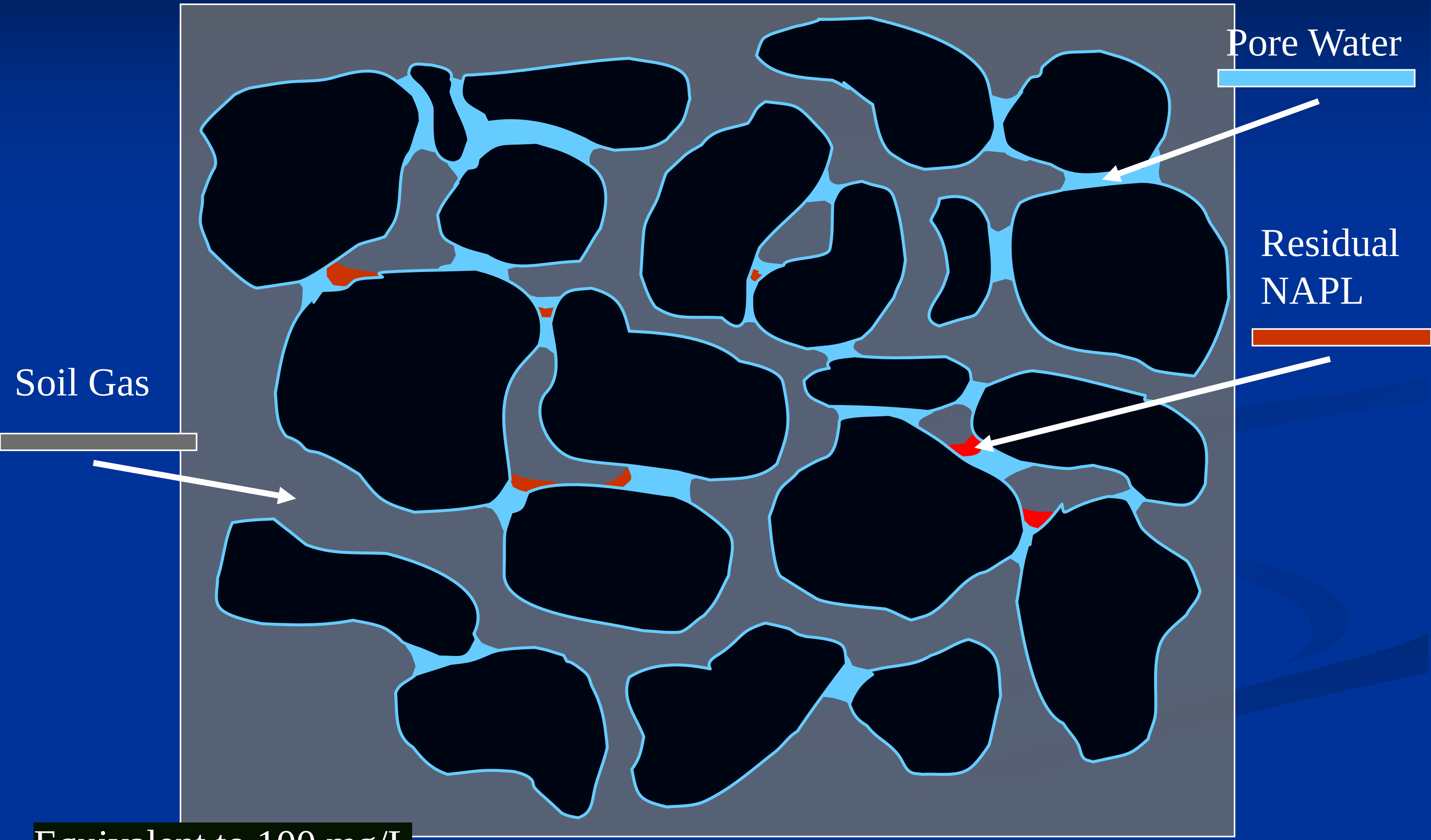
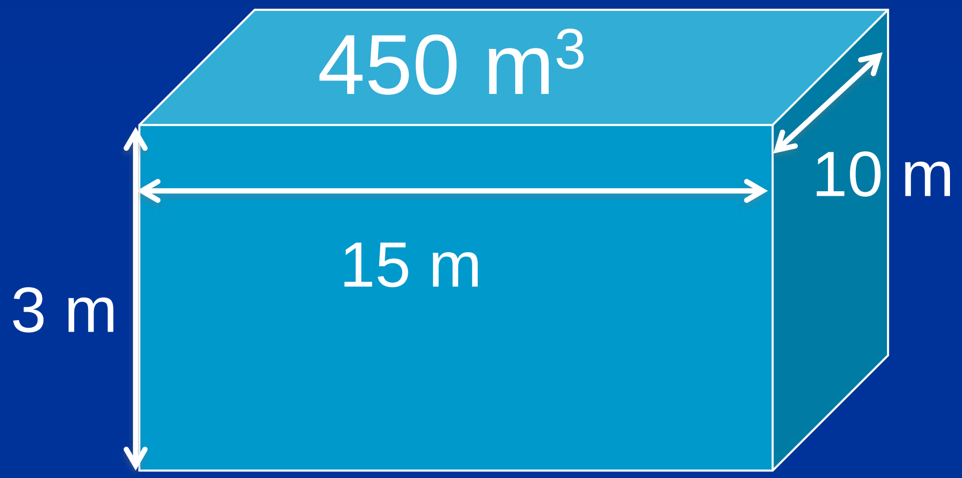
Conceptual Model of Residual NAPL in Vadose Zone



Equivalent to 100 mg/L

Scale Reality

Very small signal in large noisy system



Mass ~ 720,000 kg

Pore volume ~ 112,500 L

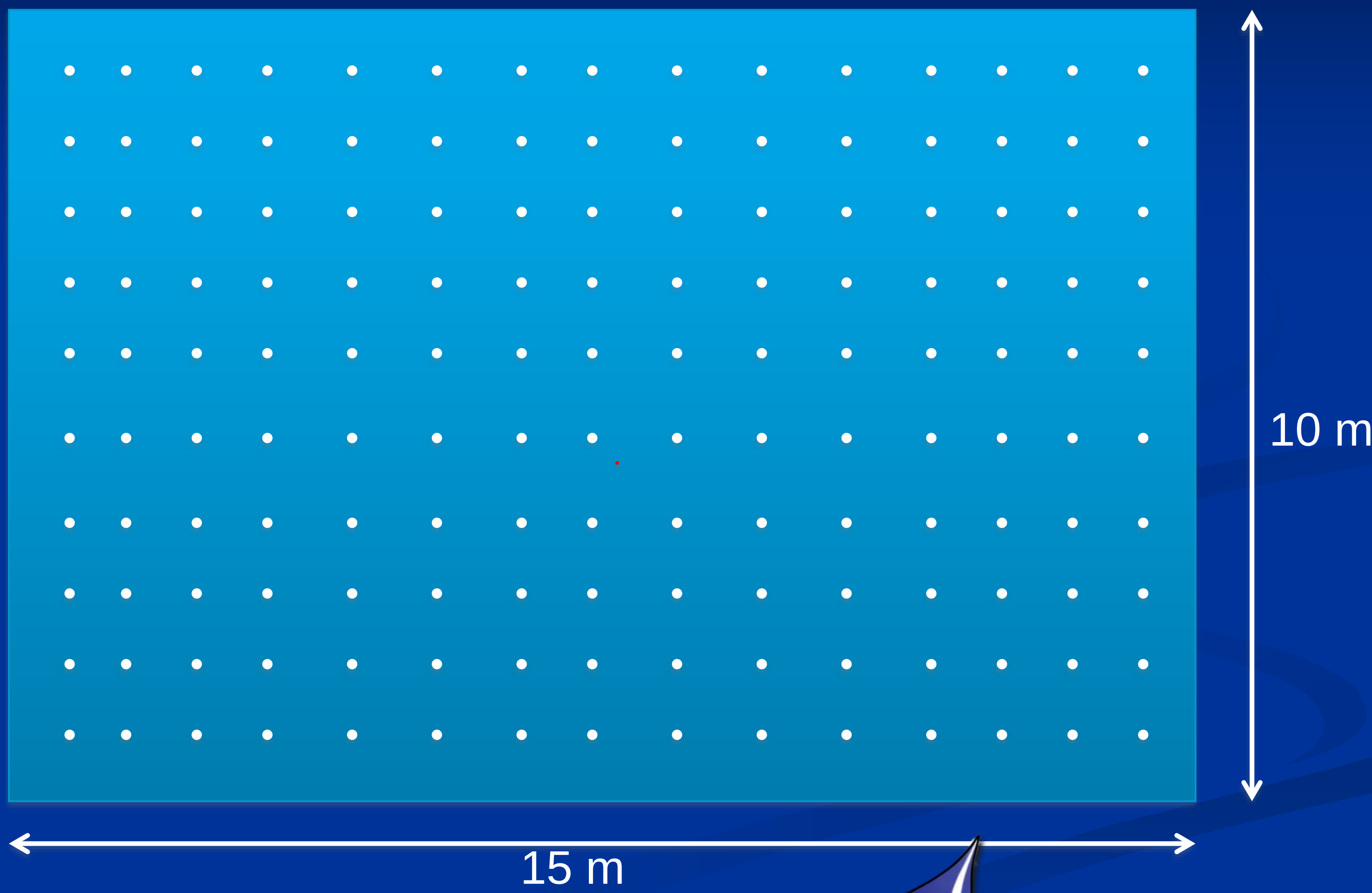
Mass of contaminant for 10 mg/L

= 1.125 kg ~ 700 mL ~ 0.001% of pore volume

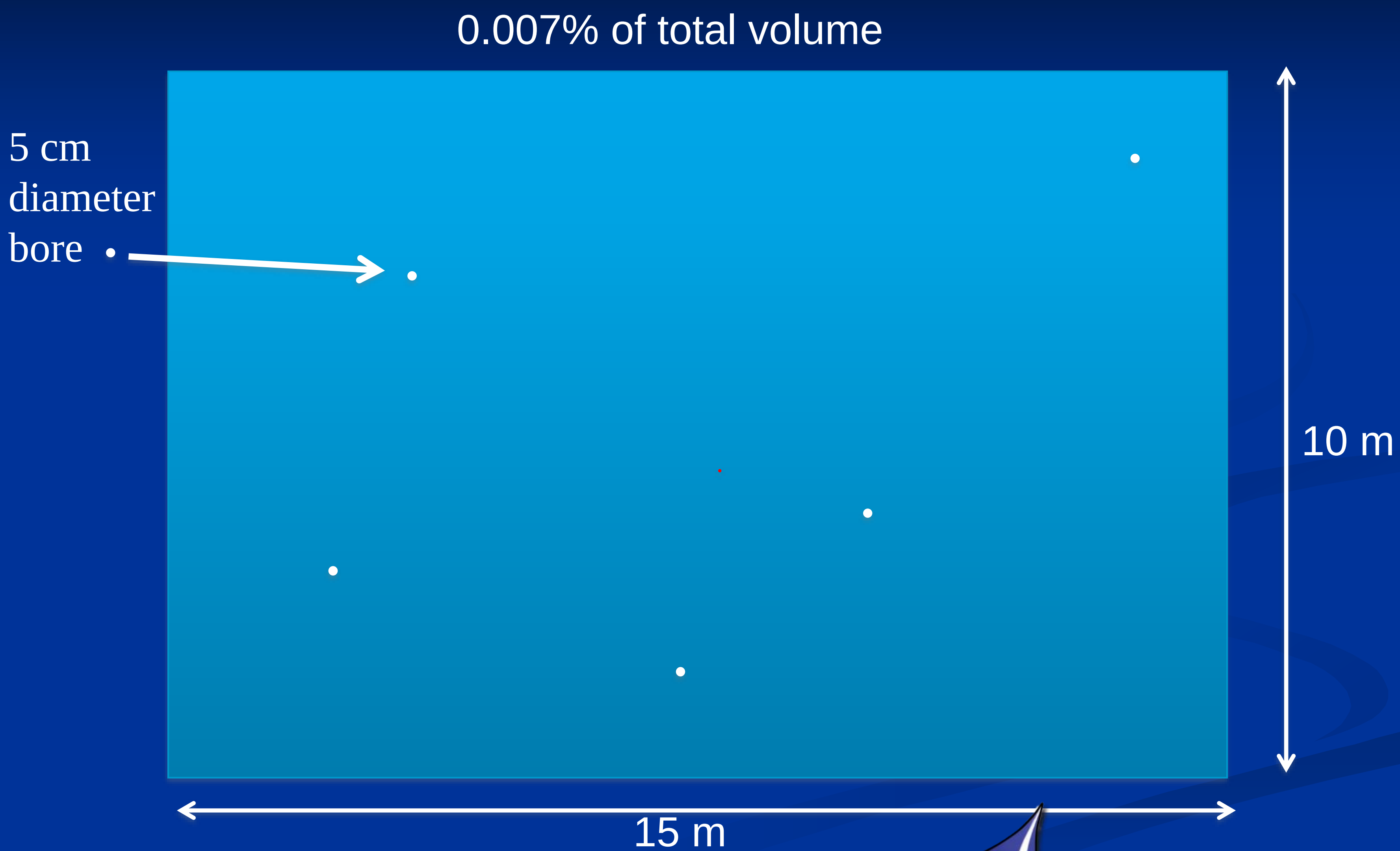
Note: More like 100 mg/L depicted in previous pore scale figure

Characterization Scale: Excessive?

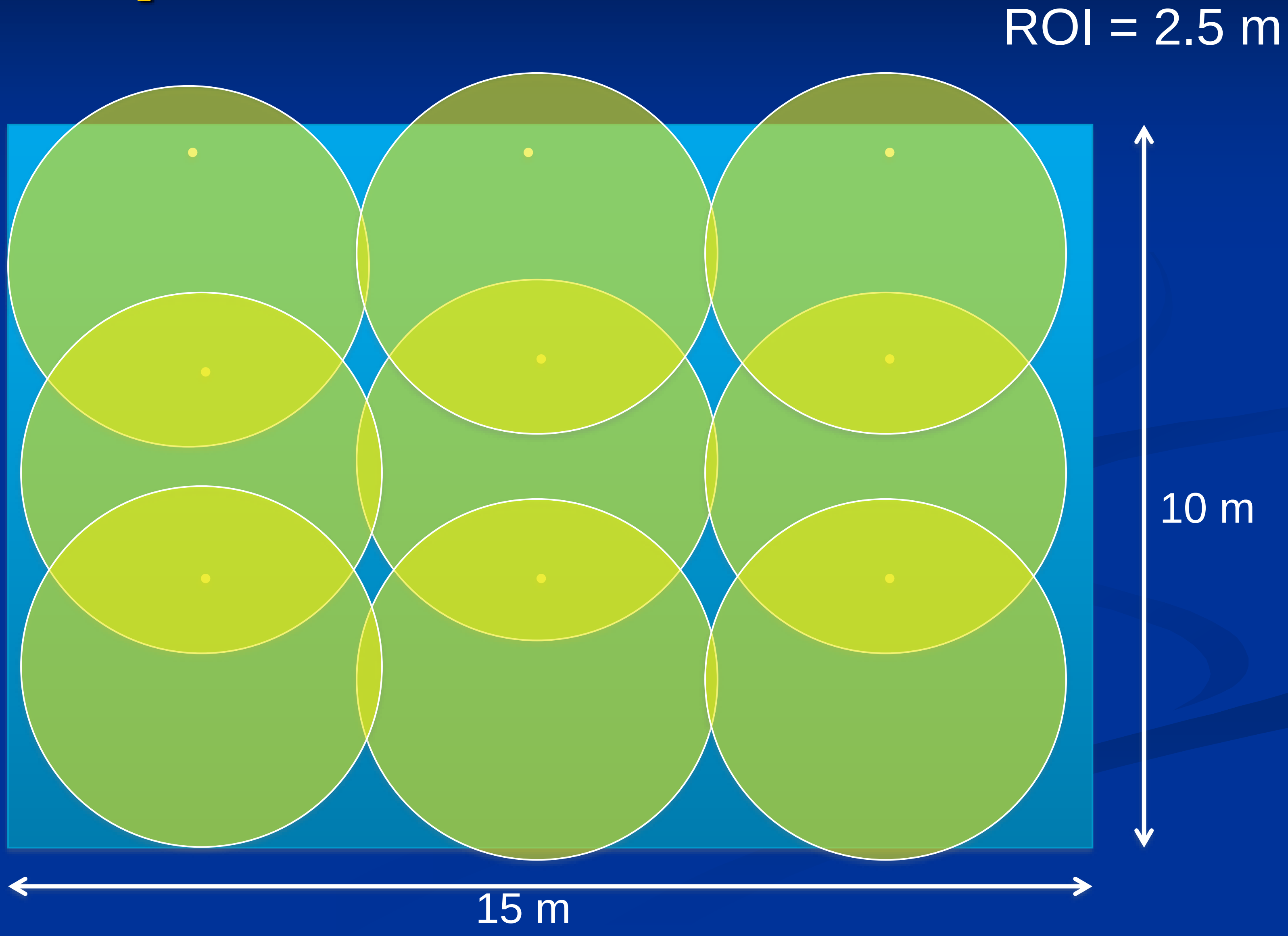
150 soil samples, 5 cm diameter, 3 m long = 0.2% of total volume



Characterization Scale: Reality



Remediation Scale: Injection Optimism in Plan View



Injection Heterogeneity

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Causes of Failure - Contact

- Insufficient contact in active time period
  - Non intersecting pathways (e.g., zvi surface rxn)
  - Insufficient amendment/bacteria
  - Gas occlusion
  - Rebound from transport out of immobile zones

Injection Amendment Distribution

- Amendments typically applied and distributed non-homogeneously
- Often get lucky that amendments follow similar pathways to contaminant
- Enough amendment must be able to <u>contact contaminants before being depleted</u> by non-target compounds and, must remain in contact <u>long enough for reaction to occur</u>
- Injection is actually a non-contact sport for the most part

Injection Facts

- Will not fill the target pore volume, no matter how much you inject.
- Hope that injectate is following approximately the same permeability opportunities that contaminant has (advection and diffusion).
- Increase odds with multiple points

Issues Complicating Injection

- Daylighting increases w/volume and near surface
- Sometimes displace fluids (but rarely add contaminants)
- Permeability issues created by reaction such as heat, gas or precipitated solids
  - Heat can create pressure that will move fluids away
  - Gas (O_2, CO_2, CH_4, H_2, H_2S) can occlude pores, reduce flow
  - Solids (MnO_2 or Fe oxides) can occlude pores, or sorb chemicals

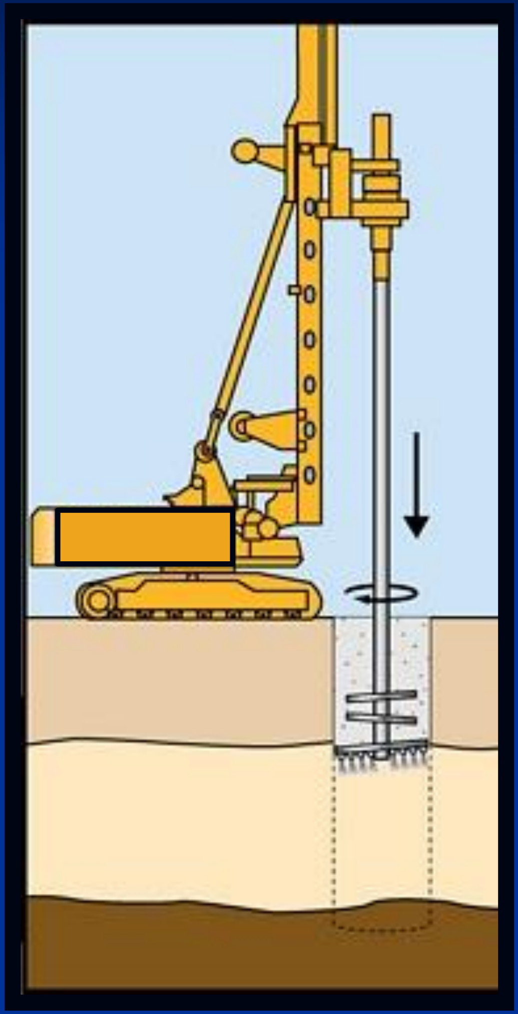
Soil Blending

- Efficient and uniform delivery of remediation amendments
- Production rates comparable to dig, haul and backfill
- No long term liability associated with disposal
- Costs can be 2 to 10 times less expensive than dig and haul, depending upon the extent of contamination
- No RCRA TSD permits are required
- Greener solution that results in treatment, not transfer

When to Consider Using Soil Blending

- Cohesive or low permeable soils
- High mass/volume of amendment
- Timeframe for cleanup is short
- Shallow water table
- High disposal costs

Deep Soil Augers/Mixers



Source: www.haywardbaker.com

- Great for deep applications at well characterized sites
- Not as efficient for large areas.
- High mob/demob costs

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Excavator Style Soil Blenders

- **Soil Blenders** are limited in depth (~ 22’) without benching but:
  - Can efficiently blend large areas
  - Production rates 200 to 600 tons per day
  - Fit on standard size equipment so smaller equipment footprint
  - Lower mob/demob costs

Soil Blenders

ALLU

PMX-500
Working Depth: 16.4 feet
Constant Power: 90 HP
Dual Motors: Yes
Automatic Power Control: No
Reach Working Depth in Clay: No
Blend Weathered Rock: No

REDOX - LANG

Modified Lang
Working Depth: 22 feet (with extension)
Constant Power: 200 HP
Dual Motors: No
Automatic Power Control: No
Reach Depth in Clay: Sometimes
Blend Weathered Rock: Maybe

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Redox Tech Custom
Working Depth: 22 feet
Constant Power: 295 HP
Dual Motors: Yes
Automatic Power Control: Yes
Reach Working Depth in Clay: Yes
Blend Weathered Rock: Yes

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Soil Blending

- Improves distribution by diminishing constraints of permeable pathways
- Increases homogeneity of heterogeneous system
- Better distribution of amendment
- Never 100% homogenized, but much better than 2D injections (really 1D*X)
- May need to re-establish soil cohesive strength

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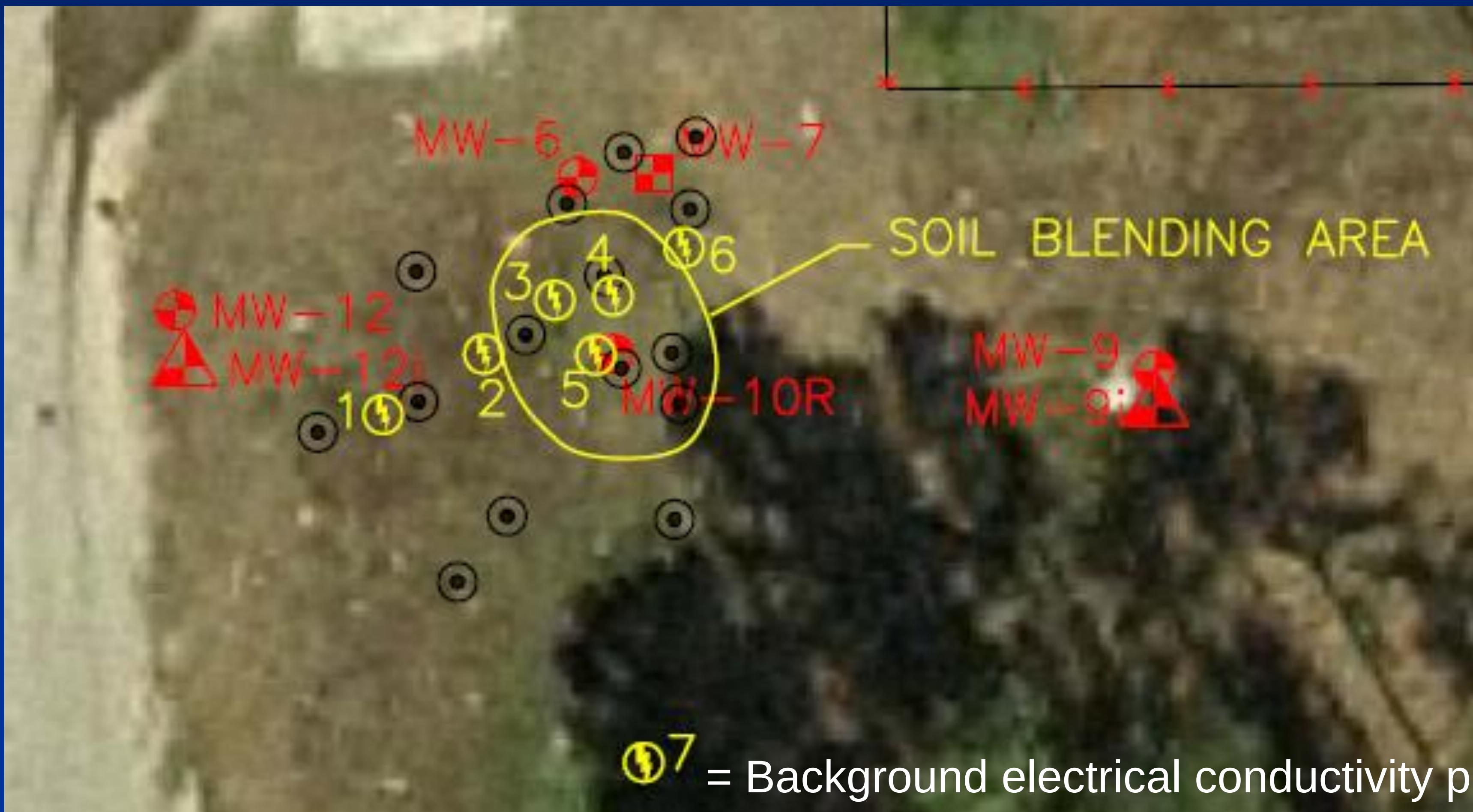
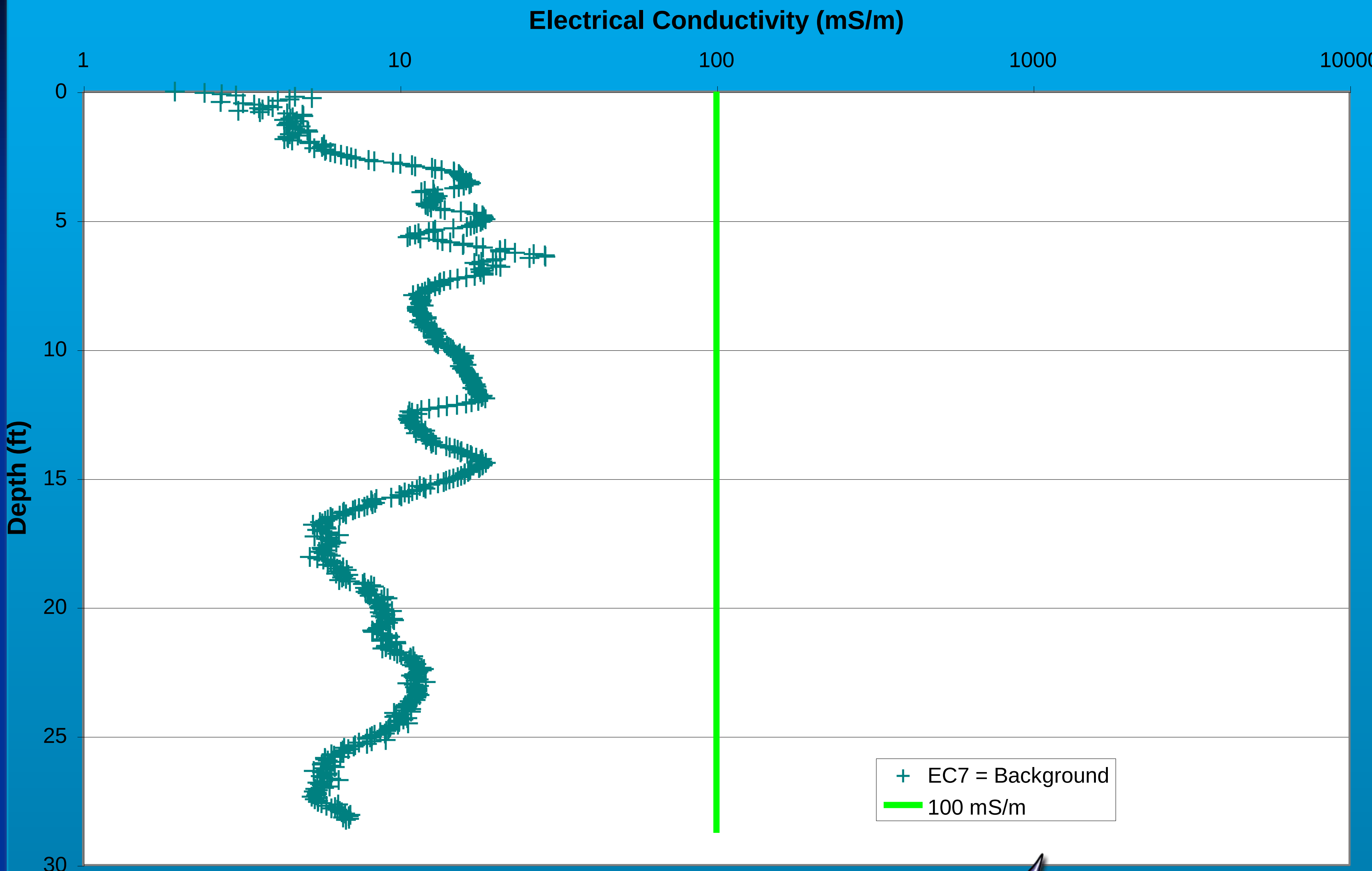
Distribution: Inj vs Soil Blend

Coastal Plain – homogeneous sand



= Background electrical conductivity probe

Background Electrical Conductivity



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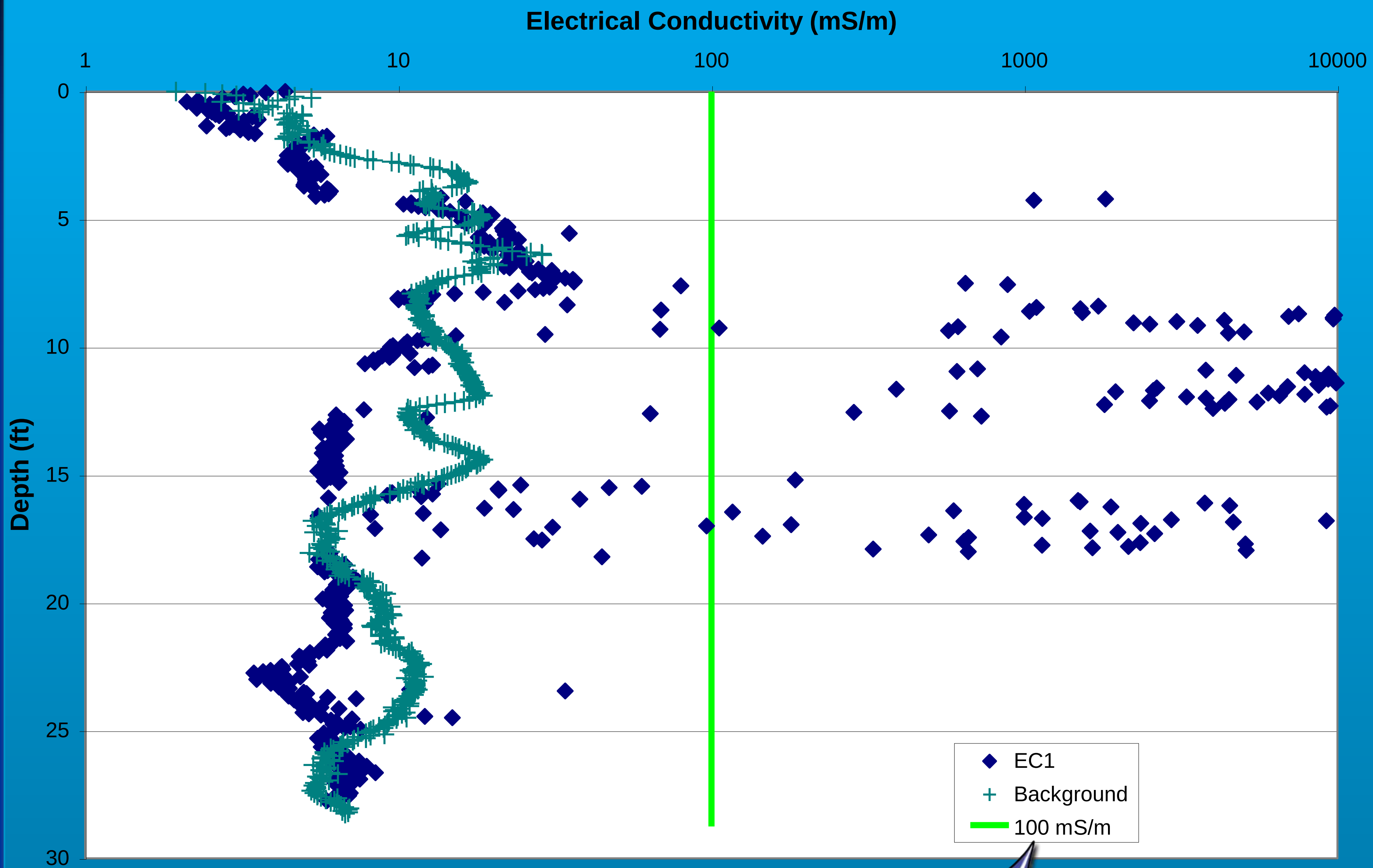
Background Electrical Conductivity and Near Injection Point



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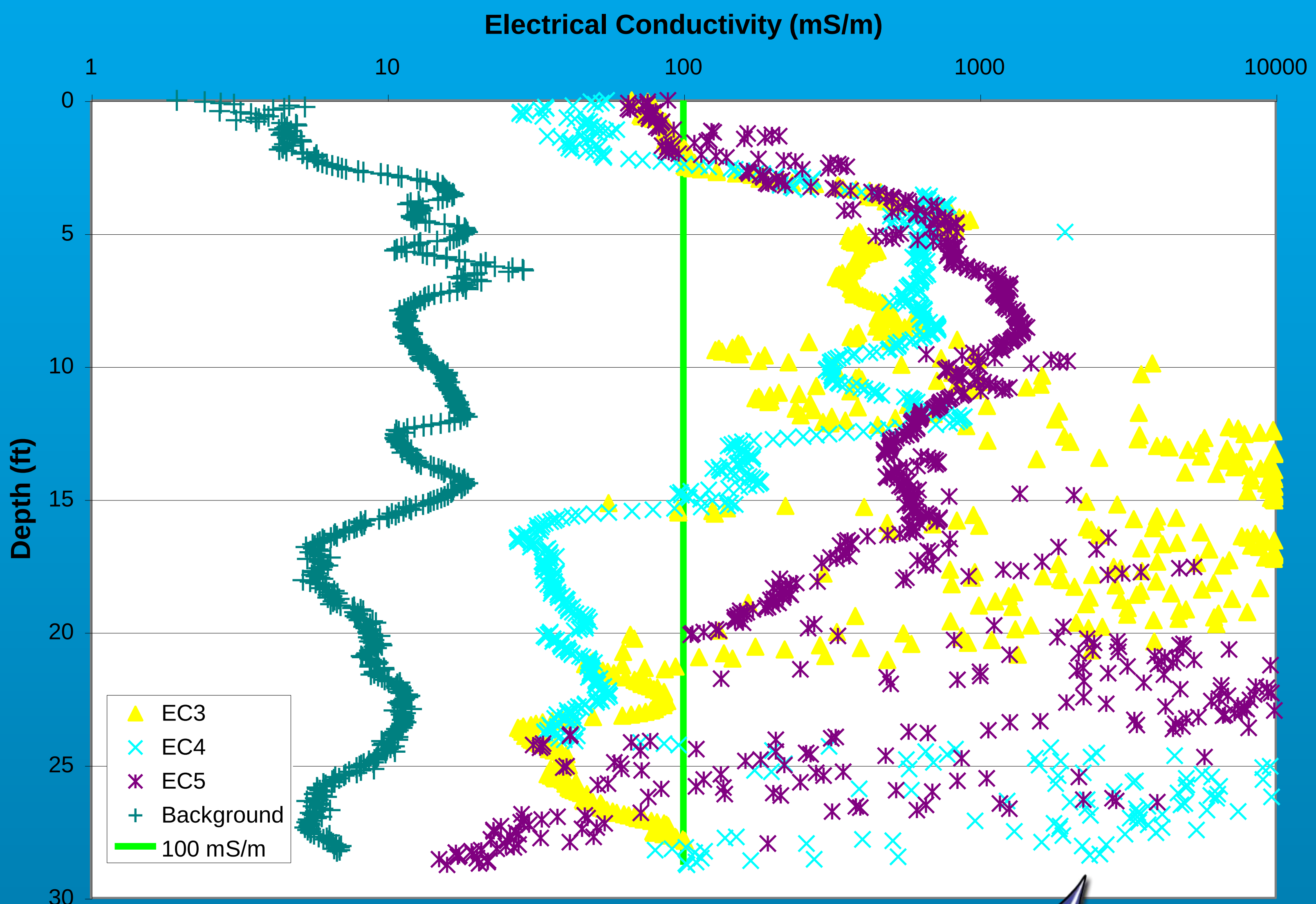
Electrical Conductivity in the Blending Area



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Remediation Cost

- Excavation and removal can be expensive
  - Tipping cost can range from $10 to > $100 per ton
  - Transportation cost > $0.05/ton x number miles
- Extraction is inexpensive but takes a while
- Air/Steam addition $300 to $2000 per day
- Injection is inexpensive but limited distribution
  - Typically $10 to $50 per ton (min $250,000 per acre)

Remediation Cost Blending

- Blending is relatively inexpensive ($15 - $20 per ton bulk soil)
- Amendments range from inexpensive ($5 per ton bulk soil) to expensive (> $60 per ton bulk soil)

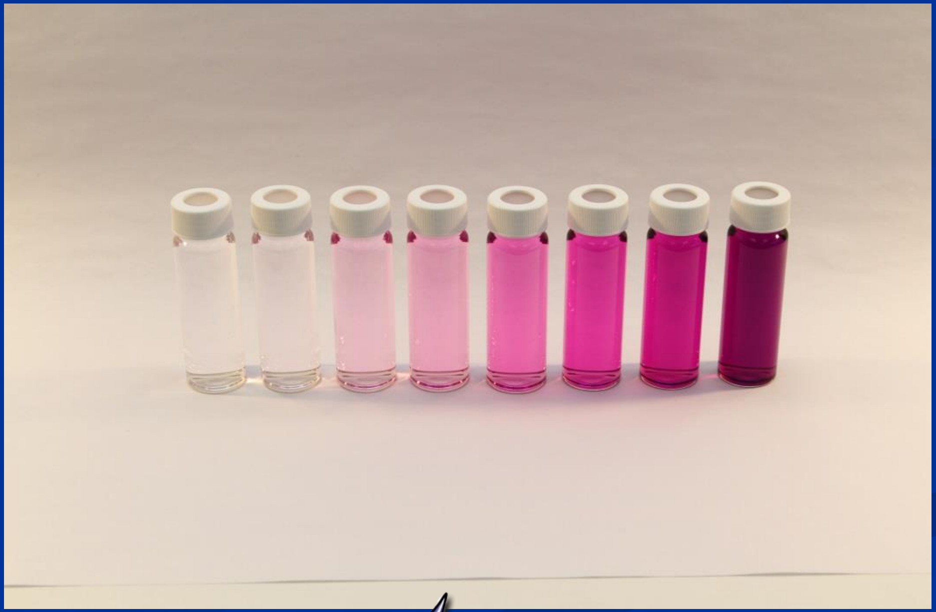
Significant Advantage:

No long term liability with waste stream

The Keys to Success with ISCO are:

- Choosing the correct oxidant
- Choosing the correct delivery mechanism
- Understanding the site specific oxidant demand
- Providing enough oxidant
- Creating contact

Not a factor when soil blending



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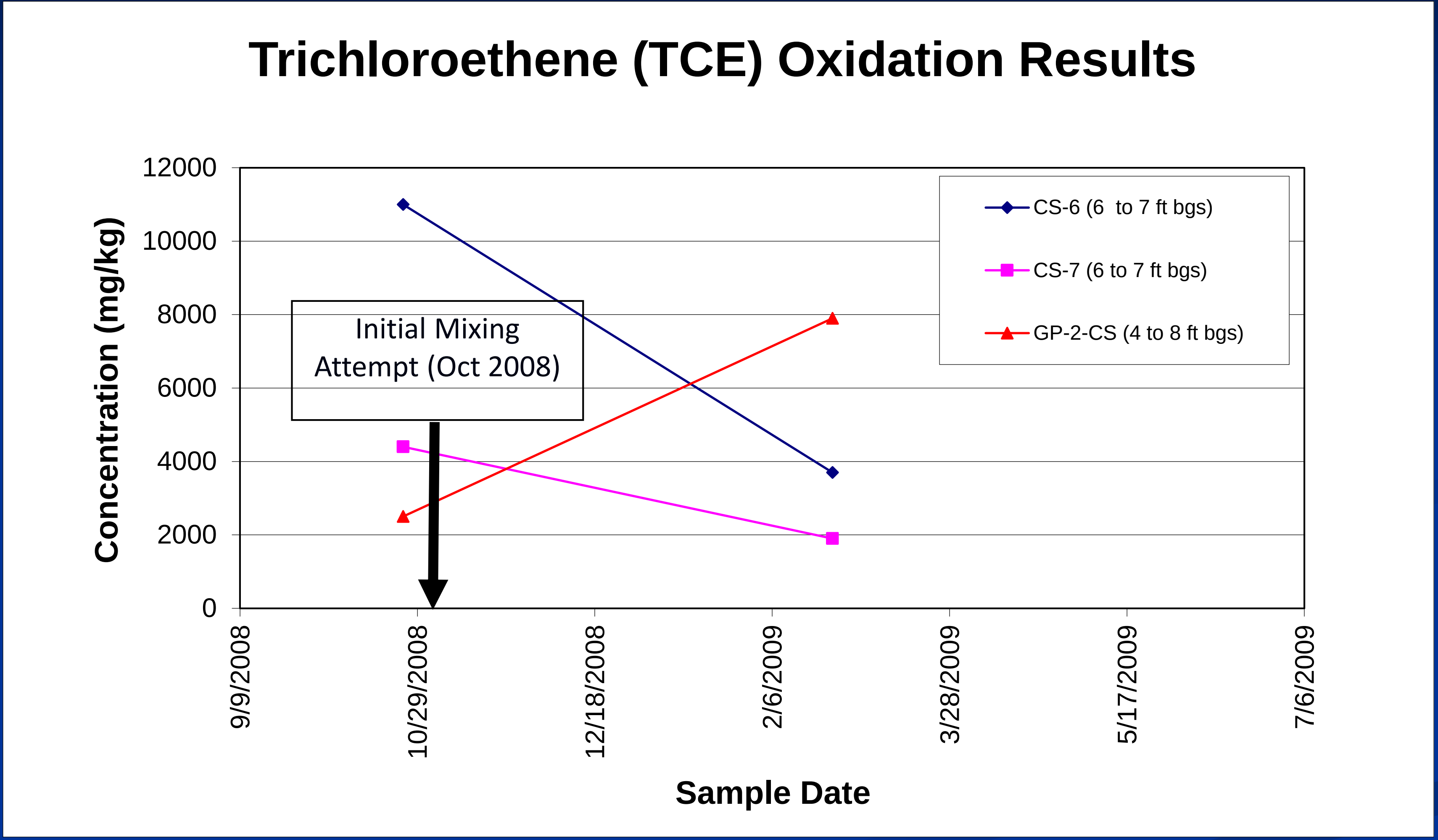
Amendments Blended

- Oxidants (permanganate, persulfate, peroxide)
- Zero Valent Iron (with clay or substrate)
- Carbon substrate (mulch, ABC, etc)
- Portland cement, lime (stabilization or geotechnical)

Case Study #1

- Industrial Site in Illinois
- Vadose Zone application in clays and silts from 4 to 8 feet bgs (500 square ft).
- TCE in Soil as high as 10,000 mg/kg (ppm)
- Prior mixing using a conventional backhoe with permanganate ineffective at achieving target (1,300 mg/kg = soil saturation limit).
- Soil concentrations remained at 7,000 mg/kg

Case Study #1



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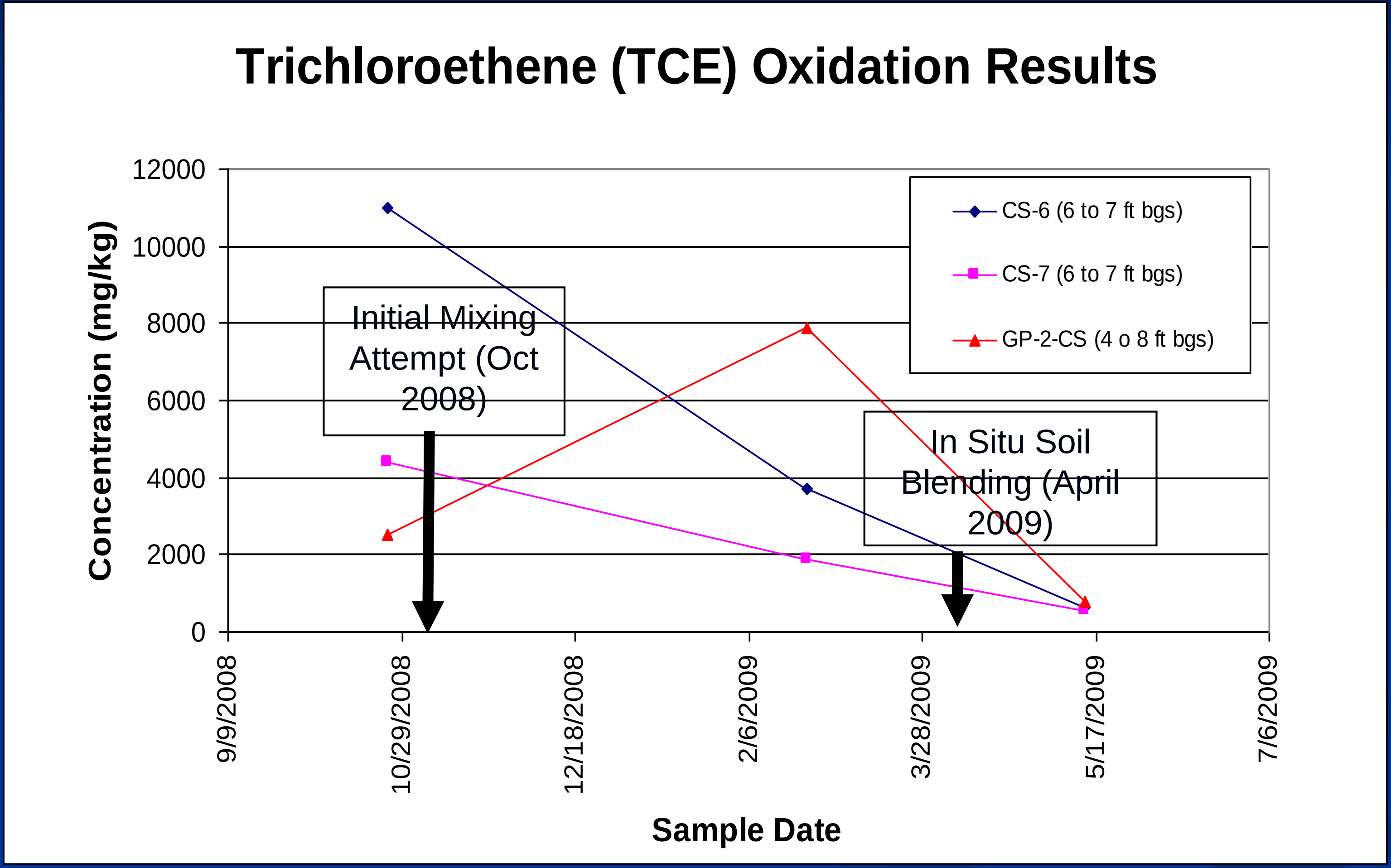
Case Study #1

- In Situ Soil Blending with Potassium Permanganate selected
- Applied 2,670 lbs of Potassium Permanganate
- Work completed in one day for $17,500 (~233 cubic yard) or $50/ton

Case Study #1



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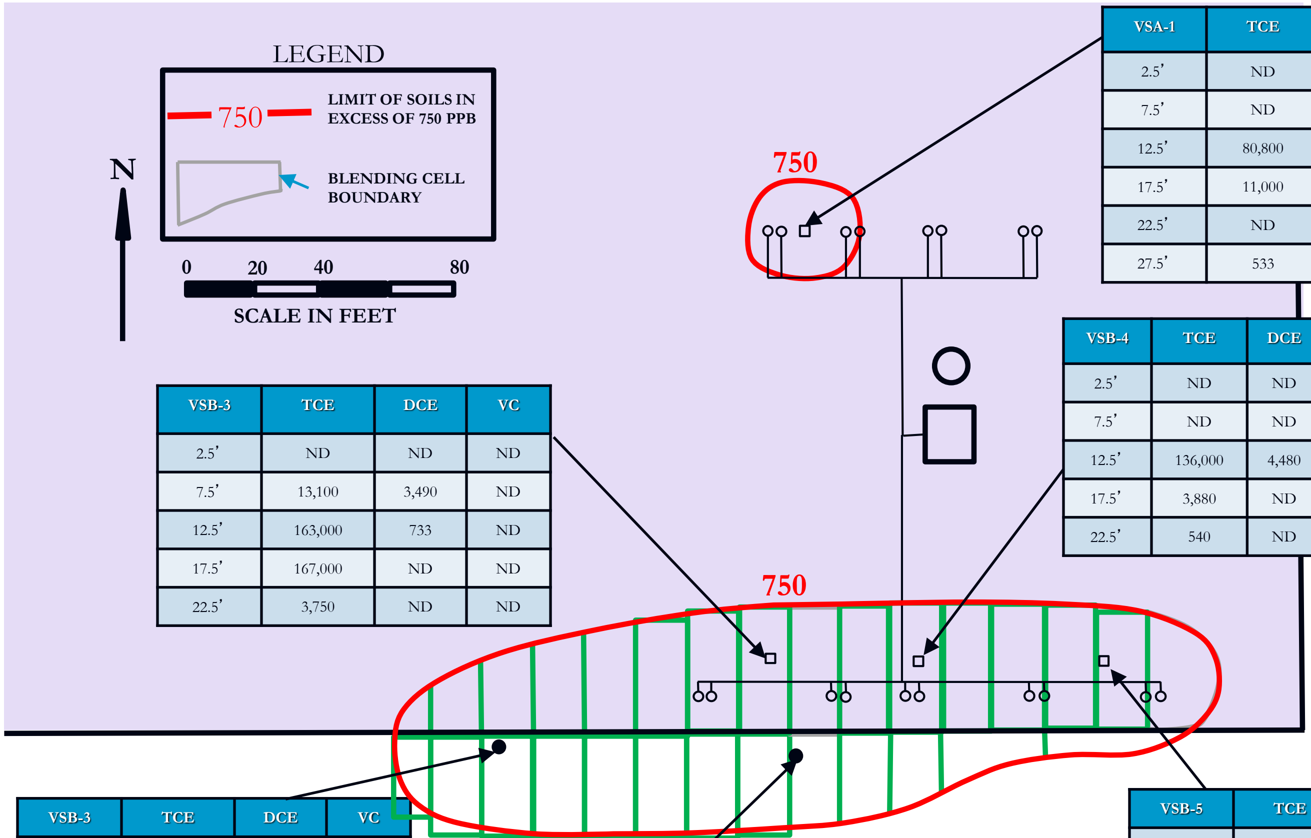
Case Study #2

- Former Industrial Site in Midwest
- TCE and DCE in soil and groundwater
- Glacial till with interbedded sand layers
- TCE in Soil as high as 1,200 mg/kg pre-treatment
- Prior treatment included dig and haul to remove small amount of source area
- SVE also attempted but unable to remove source

Case Study #2

- Two areas:
  - One inside footprint of building (420 tons)
  - One along edge of building (16,250 tons)
- Treatment targeted 2 to 25 ft bgs
- Potassium Permanganate with soil blending selected over soil stabilization and dig and haul because less expensive and provides permanent treatment (COST = $50 per ton)

Case Study #2



VSA-1	TCE	DCE	VC
2.5'	ND	ND	ND
7.5'	ND	ND	ND
12.5'	80,800	4,480	ND
17.5'	11,000	ND	ND
22.5'	ND	ND	ND
27.5'	533	ND	ND

VSB-4	TCE	DCE	VC
2.5'	ND	ND	ND
7.5'	ND	ND	ND
12.5'	136,000	4,480	ND
17.5'	3,880	ND	ND
22.5'	540	ND	ND

VSB-3	TCE	DCE	VC
2.5'	ND	ND	ND
7.5'	13,100	3,490	ND
12.5'	163,000	733	ND
17.5'	167,000	ND	ND
22.5'	3,750	ND	ND

VSB-3	TCE	DCE	VC
2.5'	ND	ND	ND
7.5'	7,280	4,050	ND
12.5'	68,200	4,650	ND

GP-15	TCE	DCE	VC
2.5'	ND	17,500	5,500
7.5'	85,600	35,200	1,610
12.5'	1,290,000	9,570	ND

VSB-5	TCE	DCE	VC
2.5'	ND	ND	ND
7.5'	264,000	22,300	1,010
12.5'	155,000	1,080	ND
17.5'	7,170	ND	ND
22.5'	1,300	ND	ND

Case Study #2

- 167,800 lbs of potassium permanganate used (average dosing = 5 g/kg)
- Dosing varied per cell to account for contaminant load
- Entire project took 49 days to complete (340 tons per day)
- Post blend samples collected in each cell
- All samples reported Non-Detect after treatment

Case Study #2

Case Study #2

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Case Study #3

- USEPA Site; Rhode Island
- Former Drum Storage Area
- Excavate upper 10-12 feet bgs of clean overburden and stockpile
- Blended $KMnO_4$ from 10-12 ft bgs to top of bedrock (~18 ft bgs).
- Loading based on TOD analysis of soil
- Work was completed for ~$70 per ton

Case Study #3: Location

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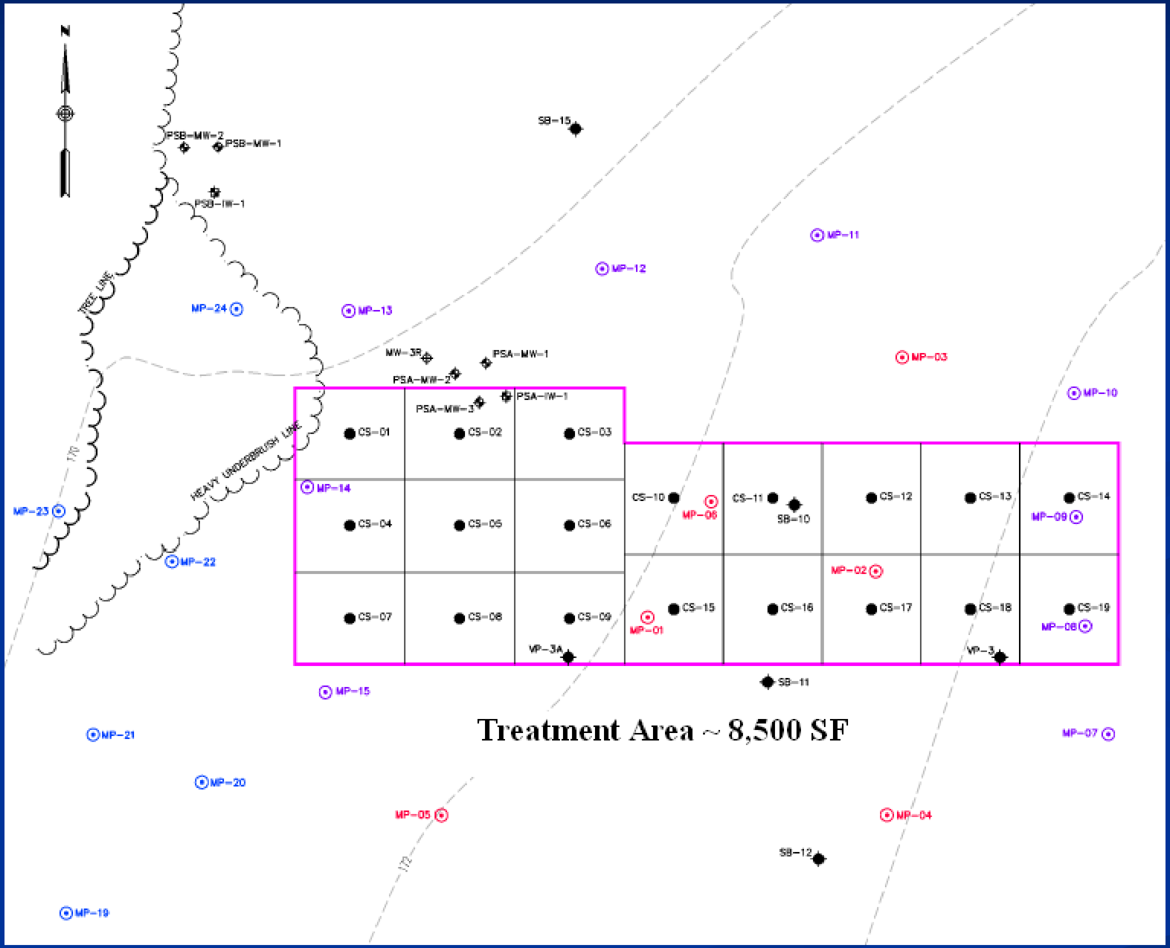
Case Study #3: Treatment Area



Case Study #3:
Blending Activity – Day 1

- Top Photo – A view of the excavation prior to blending activity

- Bottom Photo – A view of the application of the first 1000 pounds of $KMnO_4$

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Case Study #3:
Blending Activity – Day 1 (Continued)

- Top Photo – A view of the initial mixing with an excavator.

- Bottom Photo – A view of the soil blending thoroughly mixing the $KMnO_4$ with the contaminated soil.

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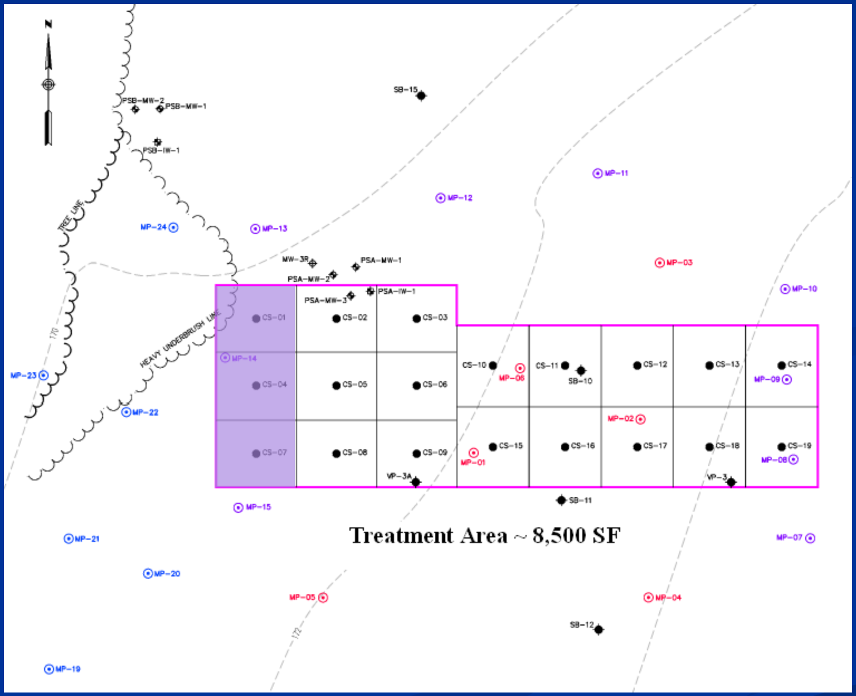
Case Study #3:
Day 1 – Area Completed

- 2,000 pounds of $KMnO_4$ blended with ~ 300 cy of contaminated soil (Area shaded in purple).
- $KMnO_4$ <u>not</u> observed in down gradient monitoring wells.



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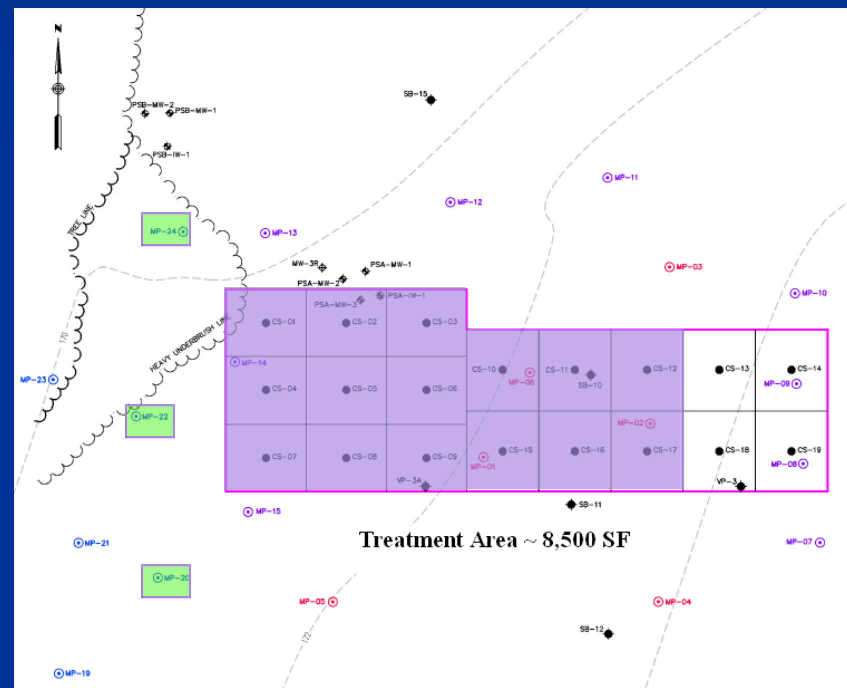
Case Study #3
Day 5 – Area Completed

- 7,000 pounds of $KMnO_4$ blended with ~ 1,500 cy of contaminated soil (Area shaded in purple).
- Approximately 8,500 gallons of water was used to blend the $KMnO_4$ with the soil.
- $KMnO_4$ observed in 3 down gradient monitoring wells ( ).



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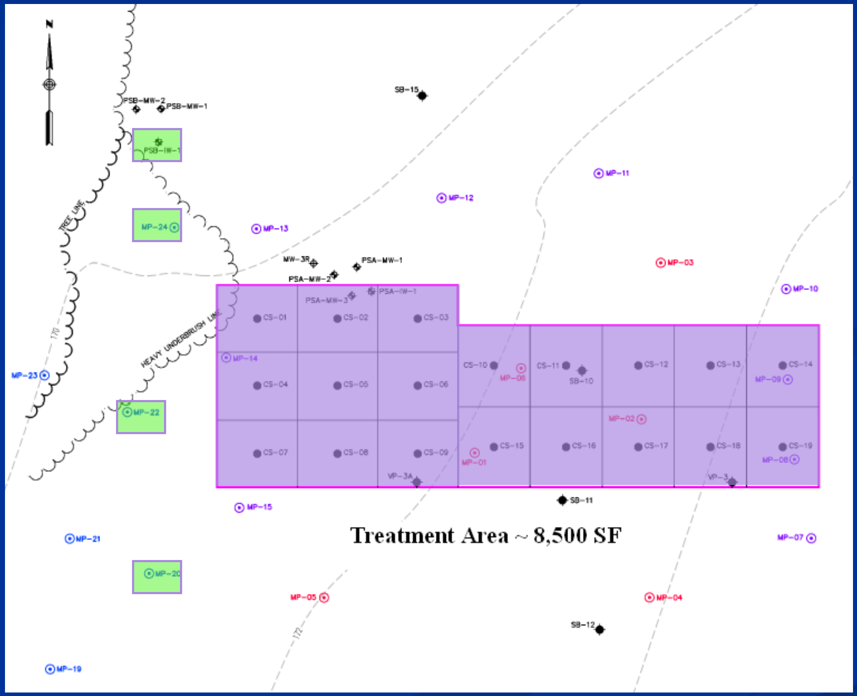
Case Study #3:
Day 7 – Soil Blending Completed

- 10,000 pounds of $KMnO_4$ blended with ~ 2,100 cy of contaminated soil (Area shaded in purple).
- Approximately 10,500 gallons of water was used to blend the $KMnO_4$ with the soil.
- $KMnO_4$ observed in 4 down gradient monitoring wells (▬).



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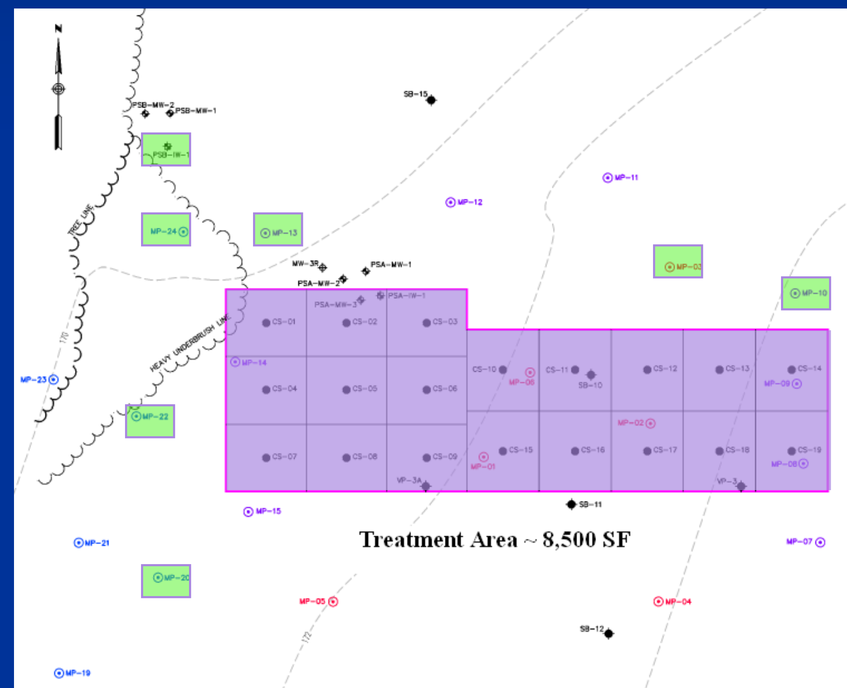
Case Study #3:

Day 12 – Post Blending Monitoring

- $KMnO_4$ observed in 7 monitoring wells ( ).



Summary

- Heterogeneity of subsurface and contaminant disposition makes contact difficult
- Soil Blending improves distribution of amendment by diminishing constraints of permeable pathways- makes a heterogeneous system more homogeneous
- Never 100% homogenized, but much better than injections
- Cost Effective
- May need to re-establish soil cohesive strength

Thank You

Questions?

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