The Anatomy of a Defensible Case Study

A Turnkey Remediation Contractor's Perspective

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The Big Question

Why is Cascade Talking About Case Studies?

- Injection needs more focus: As the industry leader in injection services and how important “contact” is recognized by all practitioners, case studies contain little or no information on the injection…. And they should contain much more. It’s at least 50% of the battle.

- Lack of peer review: As a new turnkey chemistries provider in the industry, we want to set a standard of a defensible case study, so that consulting customers don’t have to reconcile data gaps to have “confidence” in their vendor designs.

- Reliance on Vendors: In many cases, consultants rely 100% on vendors for chemistry selection and remediation design and often both that don’t have field application experience.

Case Study – Federal Remediation Technologies Roundtable

A case study is undertaken to document the results and lessons learned from technology applications. They will help establish benchmark data on cost and performance which should lead to greater confidence in the selection and use of cleanup technologies.

A case study is meant to serve as a primary reference source and contain information on the site, contaminants and media treated, technology, technology vendor, cost summary, and performance data.

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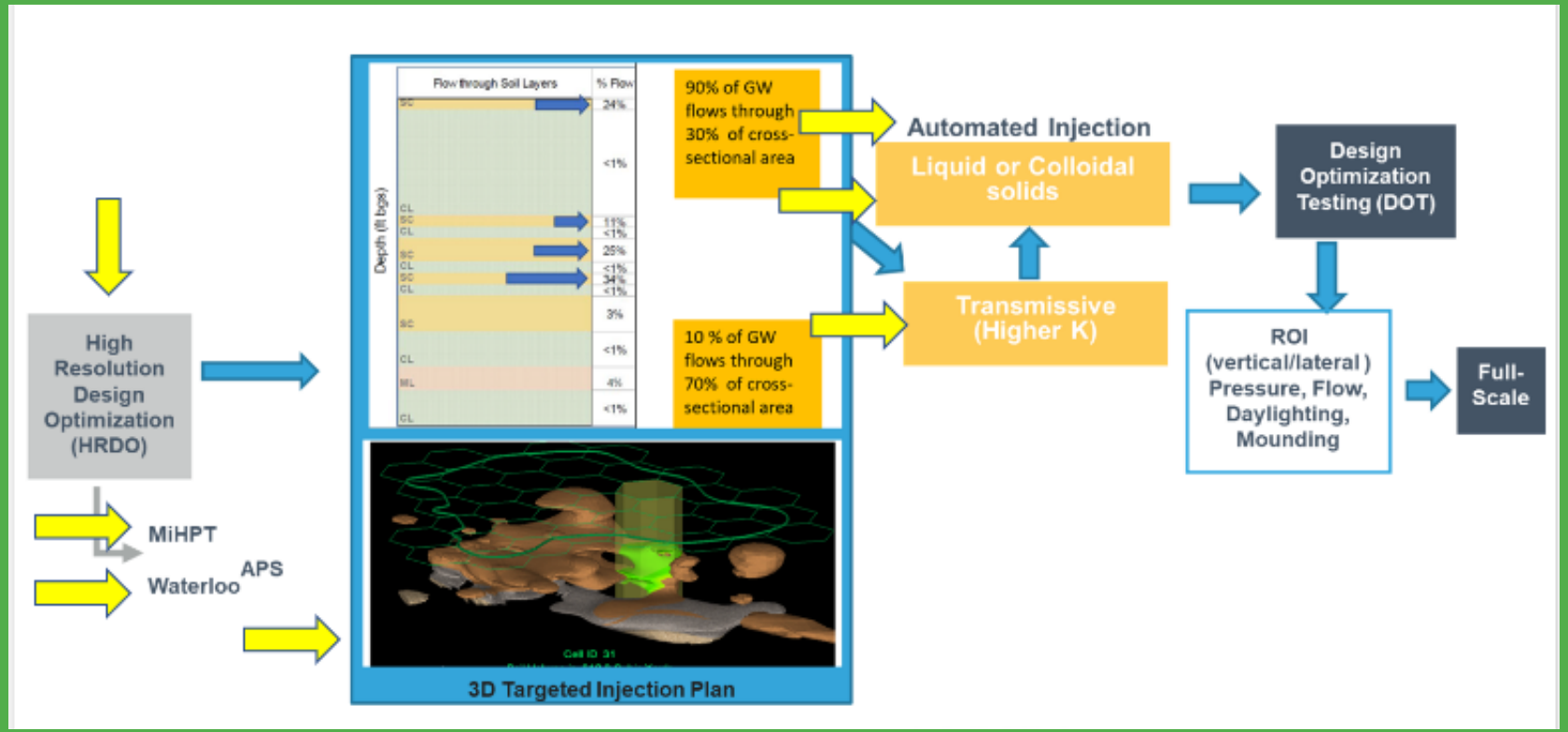
Different Phases Of A Project To Address

- General Info
- Logistical issues
- Characterization and HRDO Approach
- Chemistry Selection
- Injection Technology Selected and Approach
- Performance Monitoring and representativeness of MWs.
- Did amendments compromise well screens?
- Cost
- Lessons Learned



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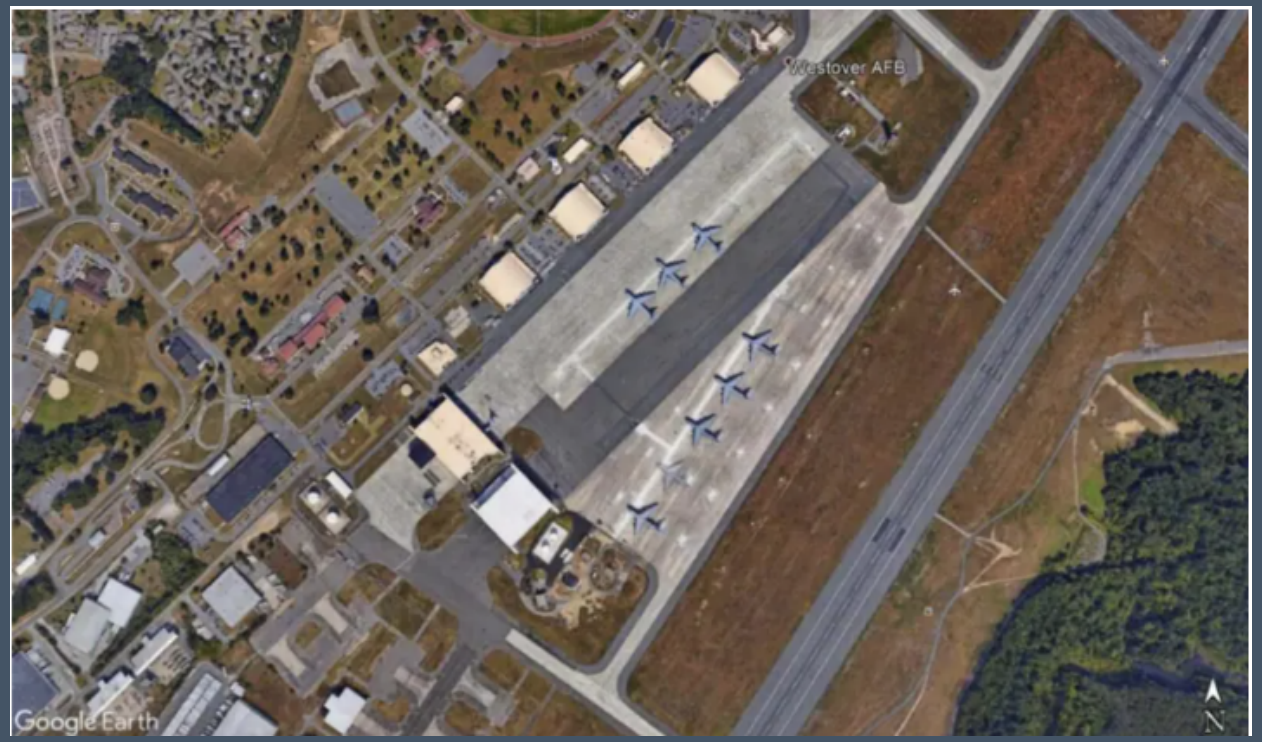
General Info

- Site Location and Client.
- Year(s) performed.
- Summary of chemistry and injection approach used.
- Remediation Goals and Results over time



Soil Saturation (C_{sat}) Limits
4450 West Carroll Avenue
Chicago, Illinois

CONSTITUENT	Sample ID		B-9	B-10B	B-10B	B-19	B-19	B-21	B-22
	Sample Depth		7'	10'	12'	9'	19'	6'	8'
	Outdoor Inhalation	Soil Component of GW Ingestion							
Tetrachloroethene	800	593.31*	1050	1180	892	1460	2110	1940	2480

Units in mg/kg

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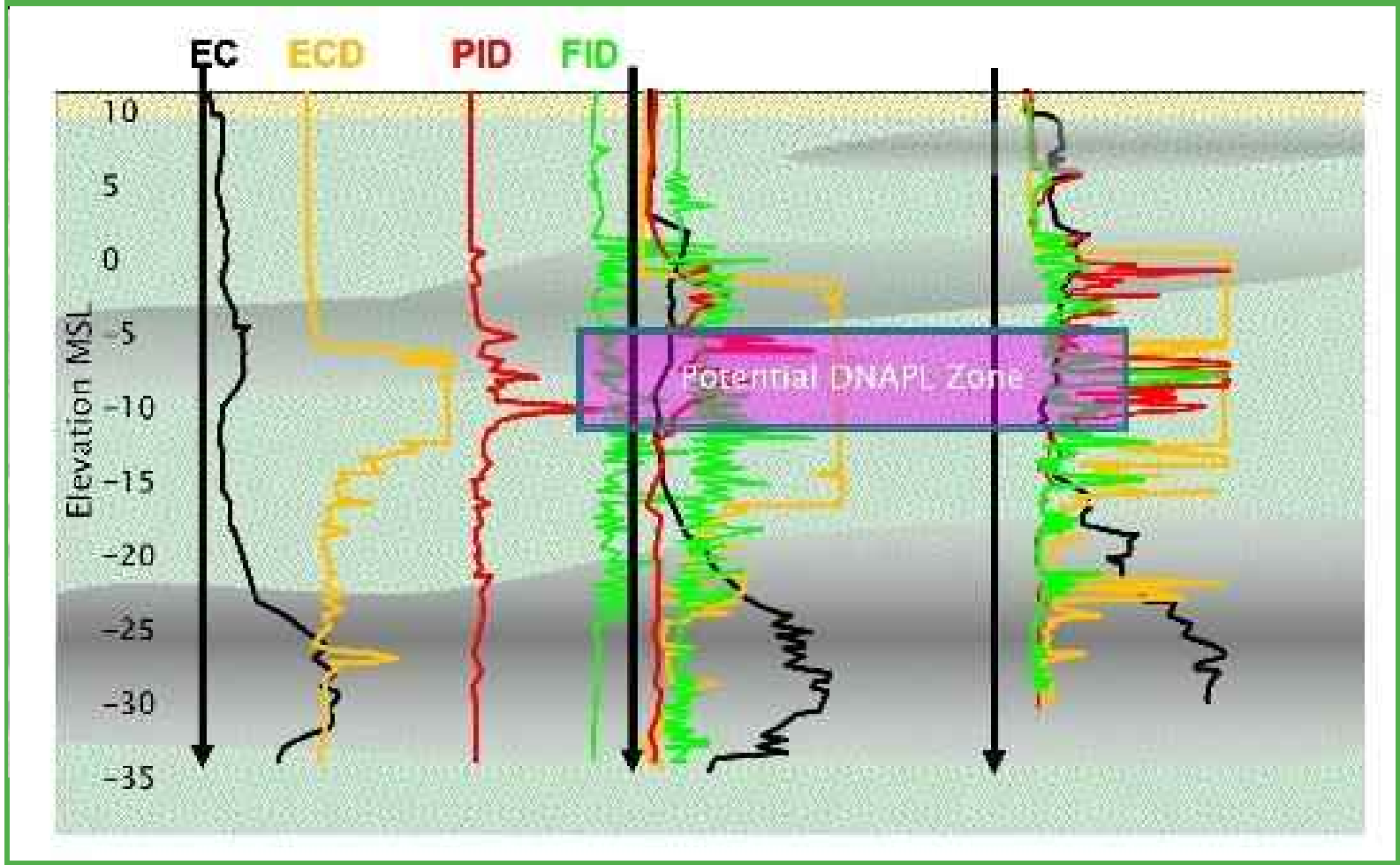
Characterization

- Type of release
- Source, Transition Zone, Plume
- DNAPL or LNAPL
- Saturated, Unsaturated, Smear Zone.
- High Resolution Design Optimization (HRDO) results summary if performed.



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Characterization

- How were target remediation intervals selected.
- Hydraulic conductivity and seepage velocity of target intervals.
- Representative MW well logs with target interval highlighted.
- Avg/Max Target/Non-Target Contaminant concentration/lbs in soil, water, soil gas, NAPL (suspected or present) phase.

SITE EVALUATION — Injection and/or Design Support for Chlorinated Solvents

Please add total target and non-target COC mass (if known) within the appropriate compartments [5]

	Source Zone Average (lbs.)		Plume Average (lbs.)	
Phase/Zone	Low Permeability	Transmissive	Transmissive	Low Permeability
Vapor				
DNAPL			Not Applicable	
Aqueous				
Sorbed to Soil [5]				

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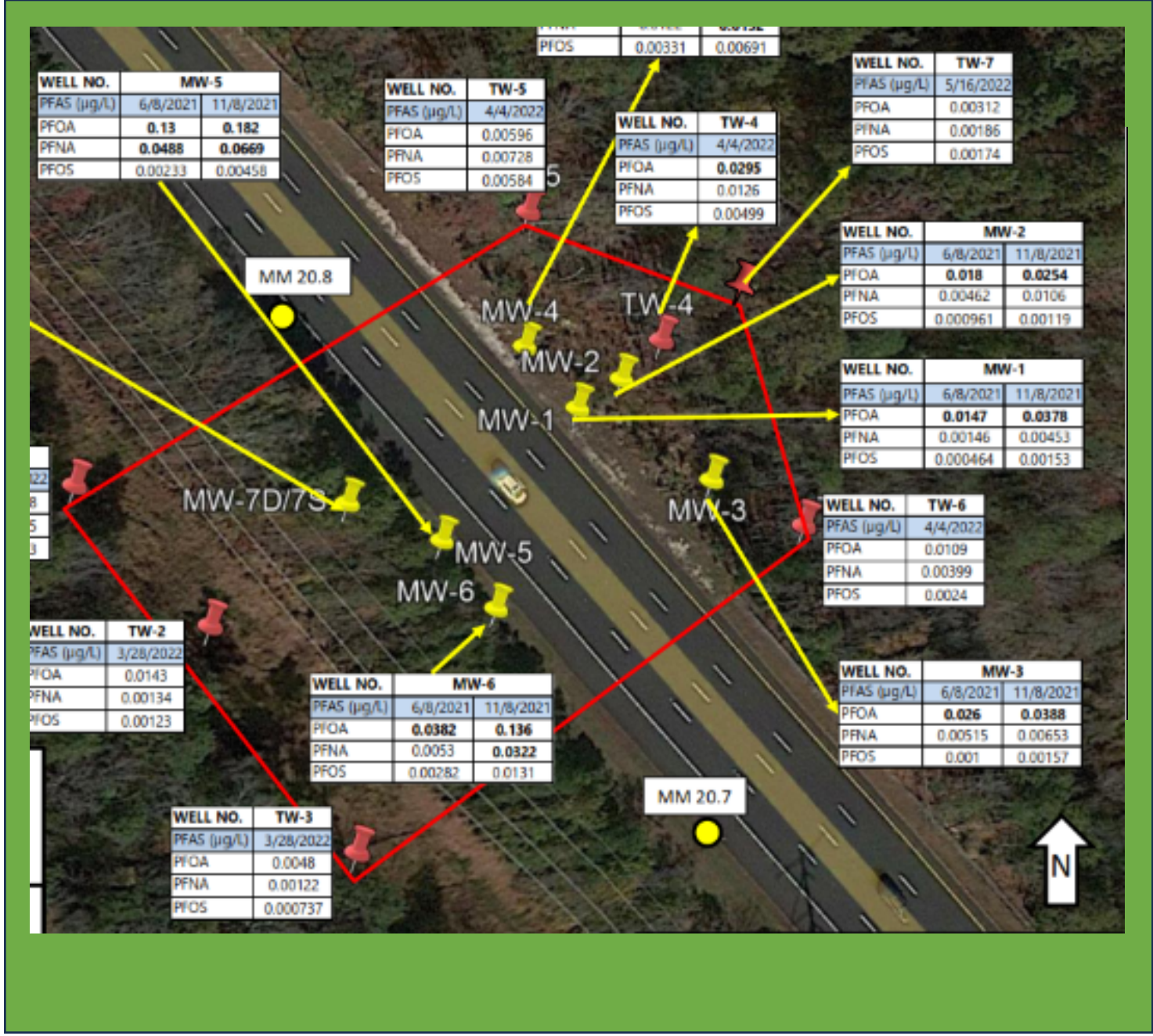
Logistics

Sources of contamination not accessible that could impact on performance.

- Under Building
- Public Roads
- Utilities



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Chemistry Selection

- Remediation goals
- Previous remediation approaches at the site and results
- Injectability of chemistry into target interval considerations
- Bench scale test results used to select chemistry
- Design Optimization Testing (DOT) to confirm design assumption
- “Transparent” Dosing calculations

Reagent Dosing (Treatment Area)

Contaminant	Total Mass		Stoichiometry	Iron Dose	
PCE	-	kg	1.35	-	kg
TCE	-	kg	1.28	-	kg
1,2-DCE	39.57	kg	1.15	46	kg
1,1-DCE	-	kg	1.15	-	kg
VC	39.70	kg	0.89	35	kg
1,1,1 TCA	-	kg	1.26	-	kg
1,2 DCA	-	kg	1.13	-	kg
Other 1 - enter name	-		1.12	-	kg
Other 2 - enter name	-		1.12	-	kg

Product Concentration	40%	w/w	TOTALS	81	kg Fe (stoichiometry contaminant only)
Product Density	1.8	g/mL		203	kg product 364.83 L
Fe concentration (m/v)	720	g/L		**446**	lb product (stoichiometry)
				352.0	lb product (CEAs)
Fixed Dose	0.20%	w/w vs soil		**798**	lb product (TOTAL stoichiometry, incl. CEA)
Optional Safety Factor	2	x (stoichiometry + CEA)		145.1	kg Fe (TOTAL stoichiometry incl. CEA)
				1,596	lb product (Safety factor method)
Notes				290	kg Fe (Safety factor method)
Fixed Dose default = 0.1%				**7,774**	lb product (Fixed dose method)
Longest dimension of barrier is considered "Length"				1,413.48	kg Fe (fixed dose method)

DILUTION CALCULATIONS

Design Method	Total Injection Volume (gal)	Product QTY(lb)	Product (gal)	Dilution water (gal)	Dilution Factor	Inj. Concentration Fe (mg/L)	Conc in aquifer (mg/L)
Stoichiometric - cont	11,670	446	**30**	**11,641**	**393.1**	**1,831**	610
TOTAL Stoichiometr	11,670	798	**53**	**11,617**	**219.7**	**3,277**	1,092
TOTAL Stoichiometr	11,670	1,596	**106**	**11,564**	**109.8**	**6,555**	2,185
Fixed Dose	11,670	7,774	**518**	**11,153**	**22.5**	**31,930**	10,643

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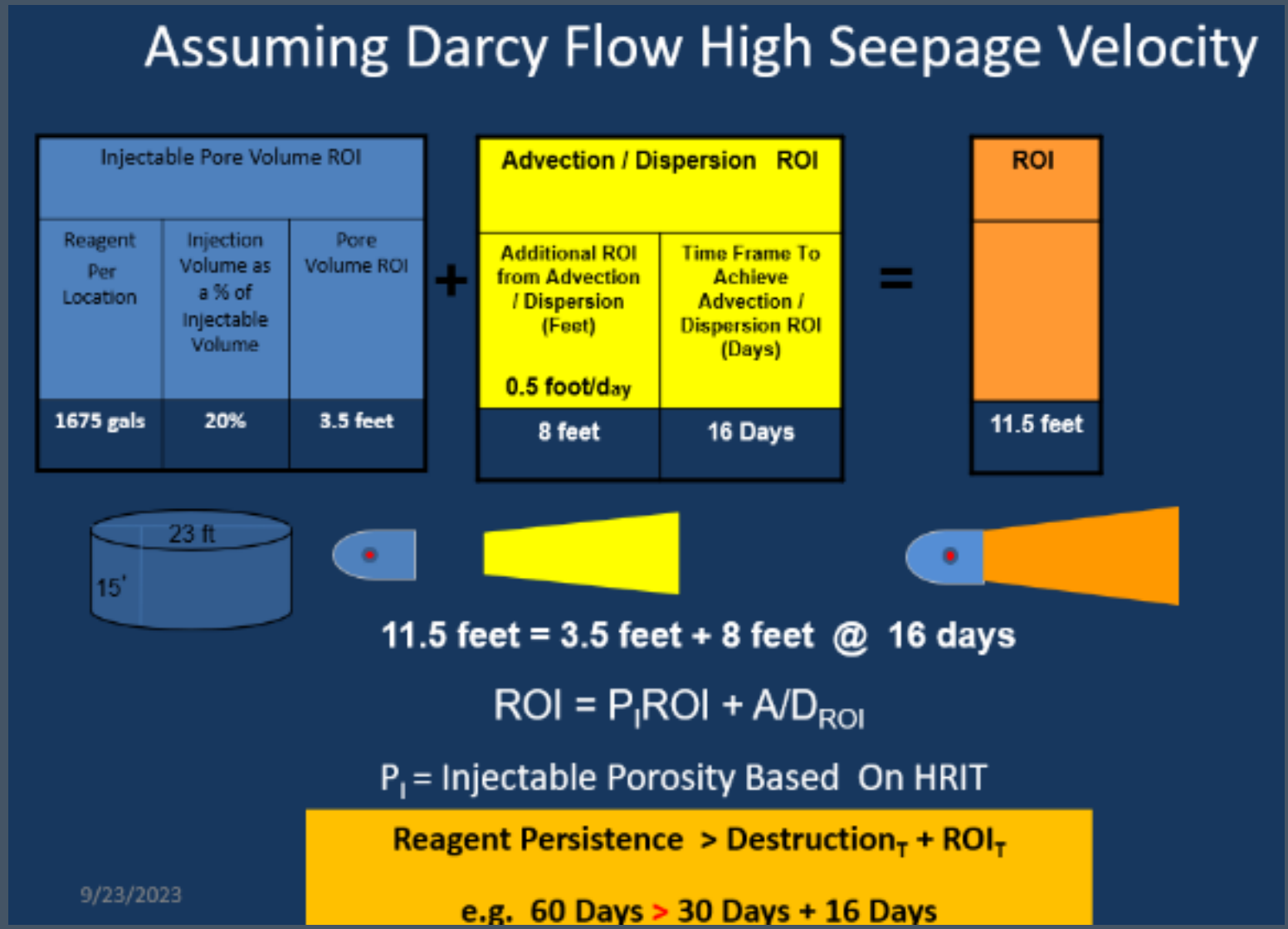
Chemistry Selection

- Were all contaminants, precursors and scavenging/competing reactions considered?
- Projected # of events and basis
- Overall lbs of chemistry used
- Chemistry injection concentrations and volumes

Injection

- Was a design optimization/pilot test performed in advance, if yes summary of results
- DPT, Wells, and or Open Borehole diameters and what size drill rig used.
- What pump and specs were used
- If DPT, injection tooling utilized in relation to target intervals.
- Number of injection locations.
- Radius of Influence and Basis / % pore volume injected



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Injection

- # manifolded injection locations?
- Avg and max injection flow rates and pressures and how and where were they measured.
- Any pressure and flow regulatory limitations?
- Injection Logs
- Mixing approach
- Any unique logistical challenges
- If daylighting occurred, what % of chemistry not injected.
- Site photos (injection and mixing system) Chemistry storage, injection locations.

Performance Monitoring

- Figure of injection locations vs performance monitoring wells and/or soil sampling locations.
- Performance monitoring schedule and required duration once injection complete.
- Status of performance monitoring – Months post injection
- COC and Water Chemistry pre and post injection as compared to remediation goals

		Date Sampled:	2/11/2021	12/21/2022	5/5/2023	2/9/2021	12/7/2022	5/5/2023
VOCs								
Tetrachloroethene (PCE)	5	ug/l	0.427 J	N/A	<0.300	<0.3	<7.50	<0.3
Trichloroethene (TCE)	5	ug/l	55.7	N/A	0.646 J	<0.190	<4.75	<0.190
cis-1,2-dichloroethene (cis-1,2-DCE)	6	ug/l	1.7	N/A	0.341 J	7.77	<3.15	0.371 J
trans-1,2-Dichloroethene (trans-1,2-DCE)	10	ug/l	<0.149	N/A	<0.149	0.773 J	<3.73	<0.149
1,1-Dichloroethene (1,1-DCE)	6	ug/l	0.833 J	N/A	<0.188	<0.188	<4.70	<0.188
1,1-Dichloroethane (1,1-DCA)	5	ug/l	<0.1	N/A	<0.1	<0.1	<2.50	<0.1
Vinyl Chloride	0.5	ug/l	<0.234	N/A	<0.234	12	<5.85	<0.234
General Chemistry								
Biochemical oxygen demand (BOD)		ug/l	N/A	N/A	N/A	N/A	N/A	N/A
Chloride		ug/l	97700	N/A	N/A	60000	N/A	N/A
Dissolved Organic Carbon (DOC)		ug/l	1620	N/A	N/A	4760	N/A	N/A
Ferrous Iron		ug/l	N/A	N/A	N/A	N/A	N/A	N/A
Nitrate as N		ug/l	10100 J	N/A	N/A	<48.0	N/A	N/A
Sulfate		ug/l	58600	N/A	N/A	672 J	N/A	N/A
Sulfide		ug/l	N/A	N/A	N/A	N/A	N/A	N/A
Total organic carbon (TOC)		ug/l	N/A	N/A	N/A	N/A	N/A	N/A
Dissolved Gases								
Ethane		ug/l	<0.296	N/A	N/A	2530	N/A	N/A
Ethene		ug/l	<0.422	N/A	N/A	<0.422	N/A	N/A
Methane		ug/l	<0.287	N/A	N/A	3650	N/A	N/A
Field Parameters								
Temperature		C	18.5	N/A	20.7	18.2	19.8	20
Conductivity		uS/@ 25C	879	N/A	769	1045	1448	994
pH		SU	6.96	N/A	8.33	6.63	7.1	6.93
Turbidity		NTU	10.86	N/A	33	6.41	121	87.6
Dissolved Oxygen (DO)		mg/l	4.72	N/A	0.95	0.28	5.88	0.83
Oxidation-Reduction Potential (ORP)		mV	59.2	N/A	-395.3	-105.8	120	129

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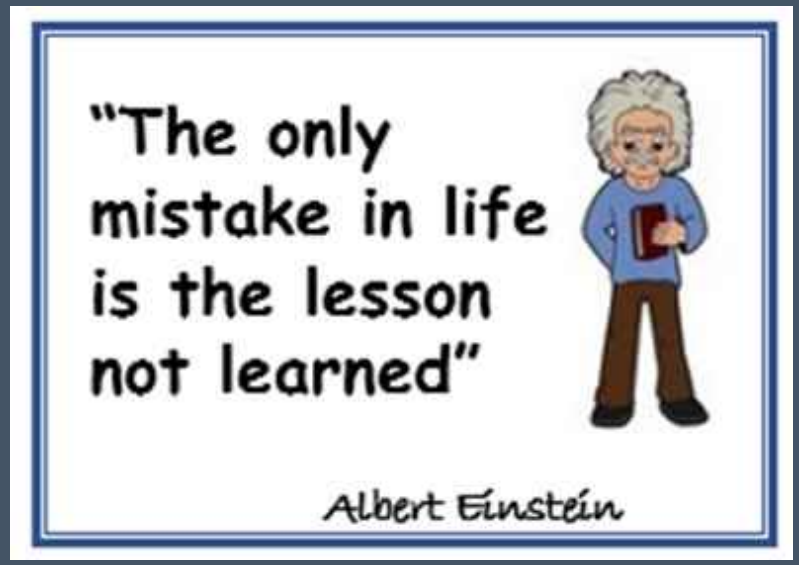
Cost

- Chemistry Cost (without tax and shipping)
- Injection Days and Cost (without mobilization and per diem.
- Other significant cost items
- Cost per cubic yard of soil (saturated and/or unsaturated) treated.
- Cost per lb of contaminants treated.

Chemistry Cost	$120,000
Injection Cost (includes drilling)	$ 63,000
Other Significant Costs (Dilution Water Extraction)	$ 25,000
Total Costs	$208,000
Saturated Soil (yards)	7500
Cost Per Yard	$ 28
Soil/GW Contaminant (Lbs TCE)	100
Cost Per Lb TCE Treated (90%)	$ 2,311

Lessons Learned

- Characterization
  - DNAPL Denial
  - Were 3D model assumptions accurate
- Chemistry Selection
  - Scaling Up Bench Testing not considering lithology
  - Liquid injection into clays
- Injection
  - Inaccurate well logs
  - Injection into silt clays supports low pressure and flow rates, it just takes longer
  - Unexpected field conditions without DOT
- Performance
  - Rebound at 6 months
- Cost vs # of unanticipated events



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Can AI Help Develop Remediation Approaches and Develop Defensible Case Studies

Injection		ROI
		Target Interval
		below or above fracture pressures
		injection volumes
		Wells or DPT
		DPT and Screen lengths
		Wells and screen lengths
		fracturing versus contact efficiency
Chemistries		
Remediation Cost and time to reach goals		
		100% remediation Approach and Costs
		Partial remediation based on practicality and cost.
		Potential liability risks
		Remediation Return on Investment
		Go no go on real estate development (including brownfields)
Regulatory Prioritization		
	State and Federal Scoring Inputs	State and Federal Ranking for enforcement or funding.
		Disadvantaged communities
		3D extrapolation to entire site.
		Residence time
		Non contaminant demands
		Retardation by soils or competing reactions
		dosing, % pore volume, # events, time between ever
	HRSC output	extrapolation to entire site
	PFAS Specific considerations (TBD)	Back diffusion rates to dissolved phase
	Stratigraphy	3D extrapolation to entire site.
	NMR	Above gound VI impacts

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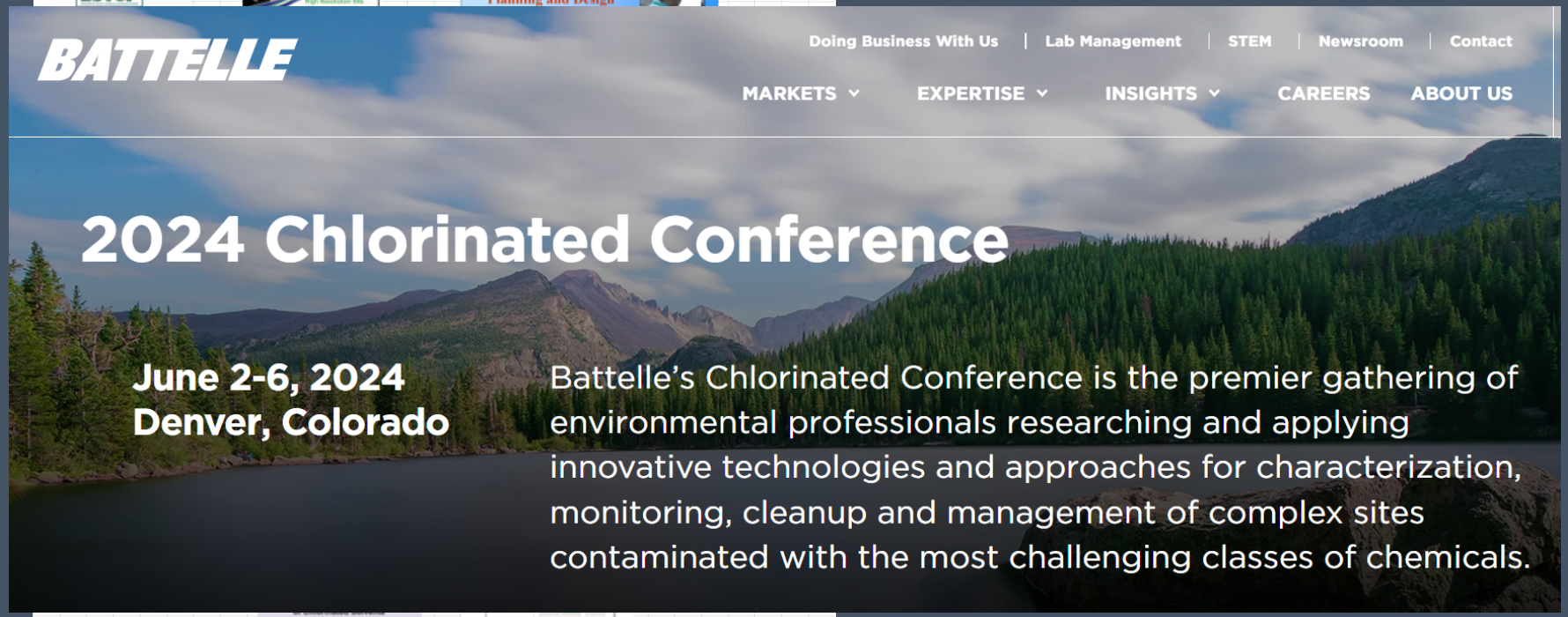
Example AI Resources



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