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A Survey of Decision Support Tools for Comparing Cleanup Options and Increasing Decision Making Confidence

April 12, 2018

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Agenda

- The need for more robust analysis
- Multi-Objective Decision Analysis
- Using Microsoft Excel Tools (Goal Seek, Data Table, Solver)
- Decision Tree Management Software
- Monte Carlo Analysis
- Summary

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The Need for More Robust Analysis

- As a whole, the remediation industry under-estimates time and cost of remediation
- There is an inherent optimism in our approaches
- We often have incomplete data sets for developing remedies
- Getting smarter at understanding this, with Adaptive Site Management techniques and “observational approach”
- Another way to be smarter is to consider the uncertainty we have now and make decision with this knowledge

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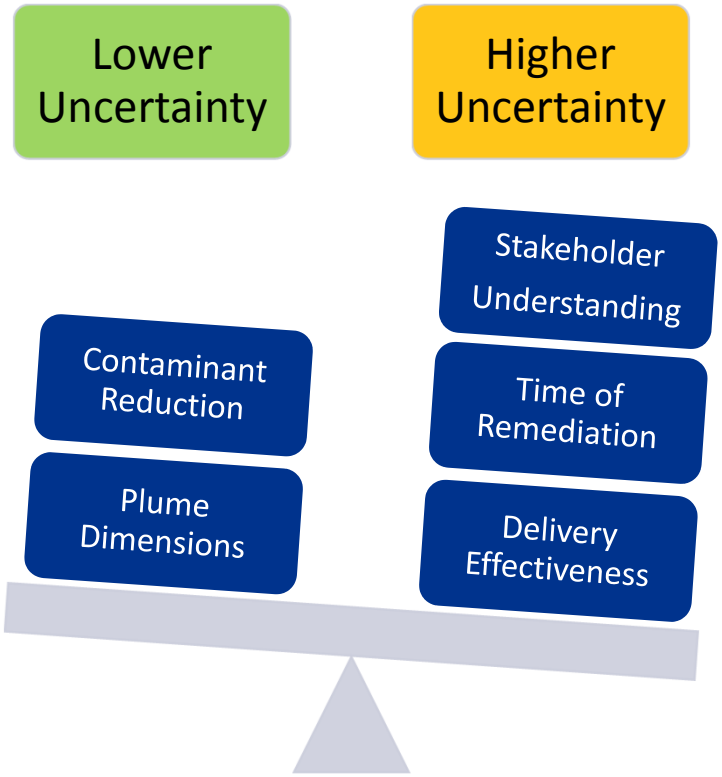
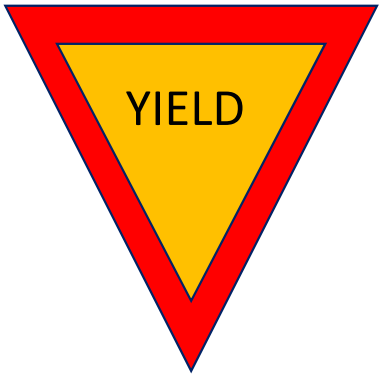
Many parameters have some uncertainty



Are you making your decisions based on a false future?



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Multi-Objective Decision Analysis (MODA) Applications

- Decision requires analysis of competing variables (e.g., CERCLA balancing criteria)
- Stakeholder input and understanding
- Clarify understanding of criteria driving decisions
- Clarifies relative value and benefits

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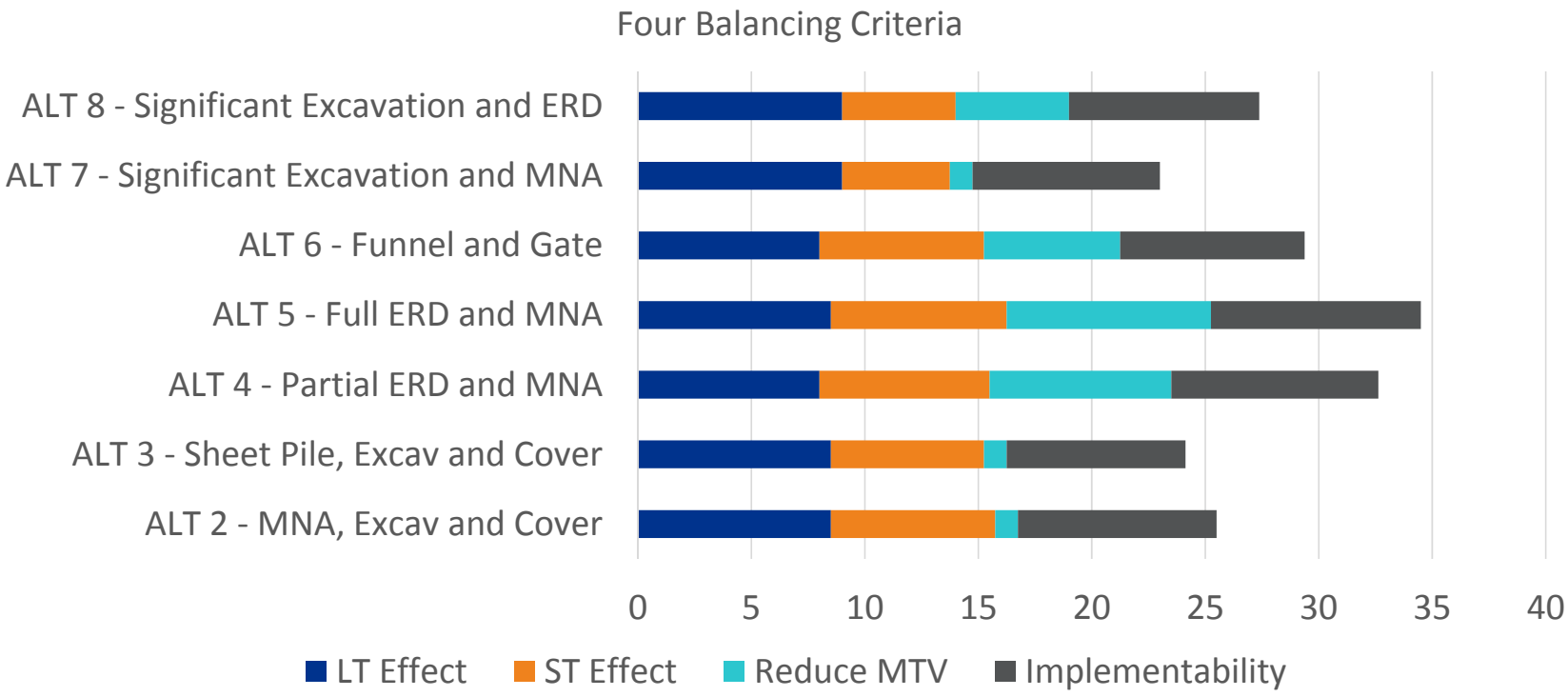
MODA provides semi-quantitative scores to better discern strengths and weaknesses wrt to CERCLA Balancing Criteria



Allows greater stakeholder engagement and real time "what-if" assessments

All sub-criteria for balancing criteria scored (24 in all)

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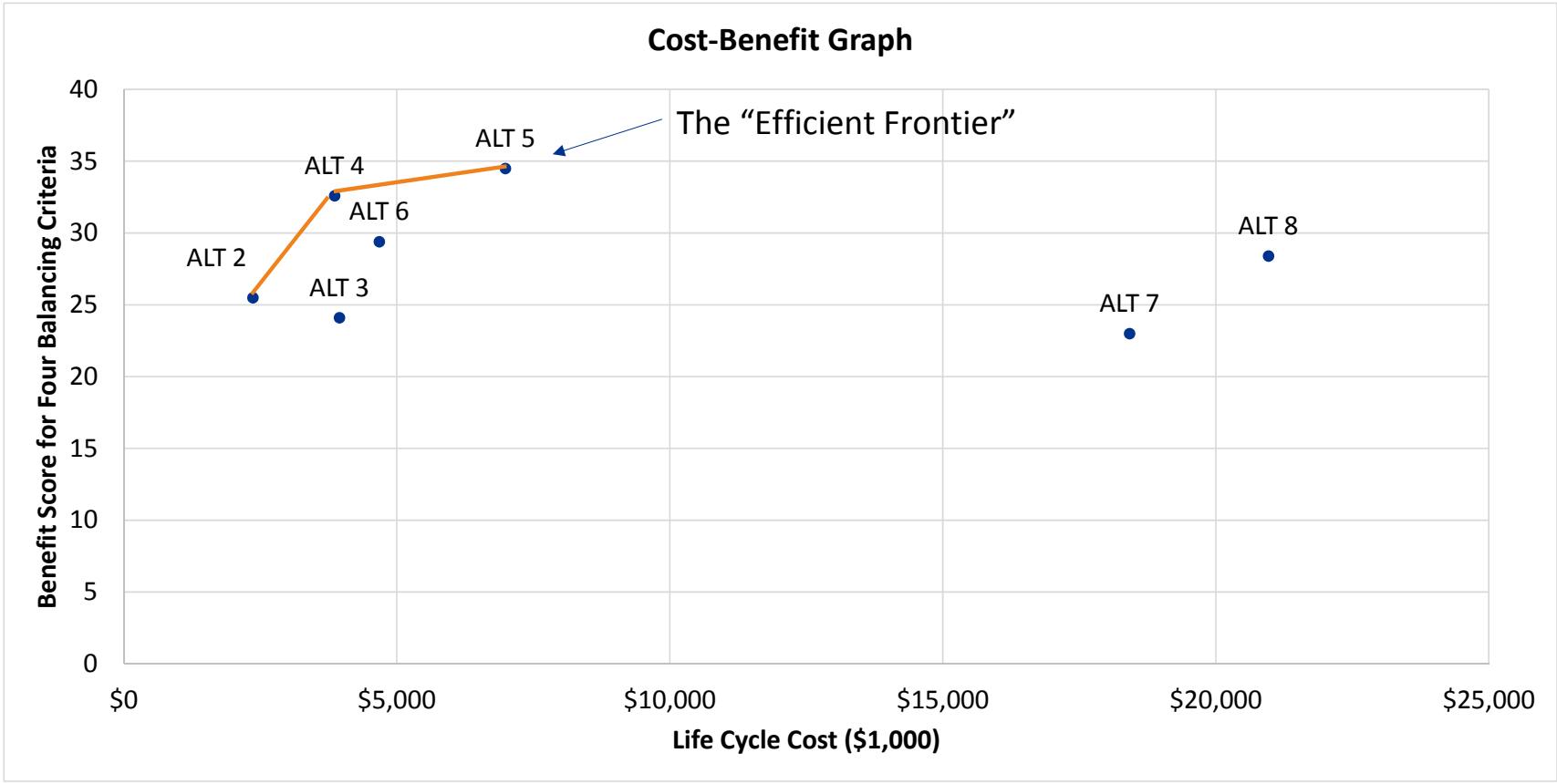
MODA Cost Vs. Benefit and the "Efficient Frontier"



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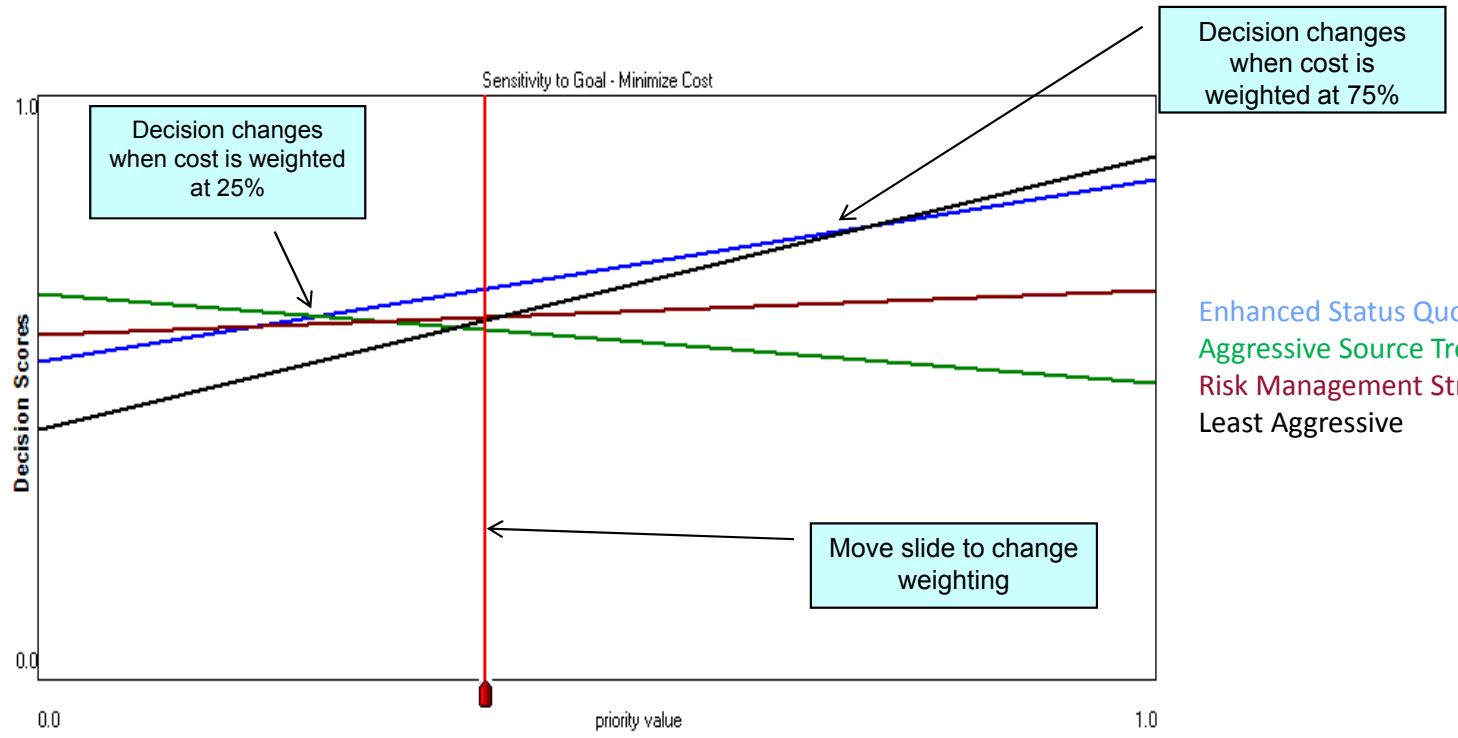
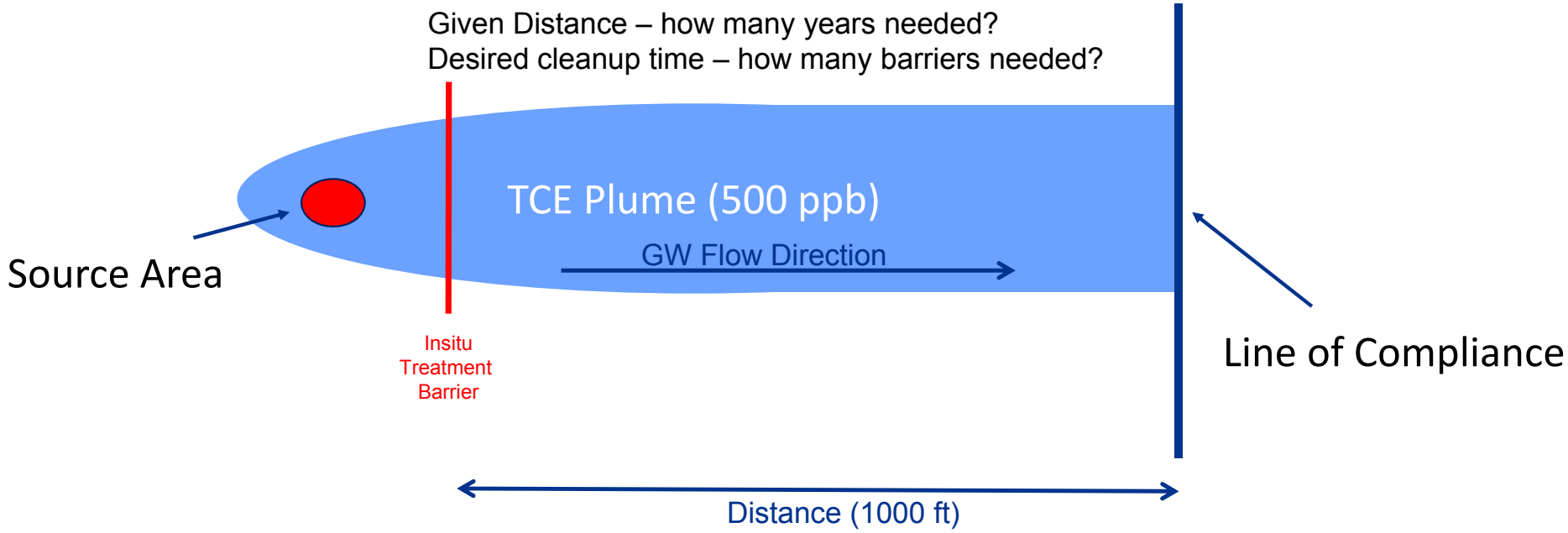
Sensitivity Analysis for Weighting Of *Minimize Cost* Criteria (Can determine how sensitive weights are in decision?)



Time to cleanup downgradient of PRB? Goal Seek and Data Table Example

- Pore Volume Related Calculations



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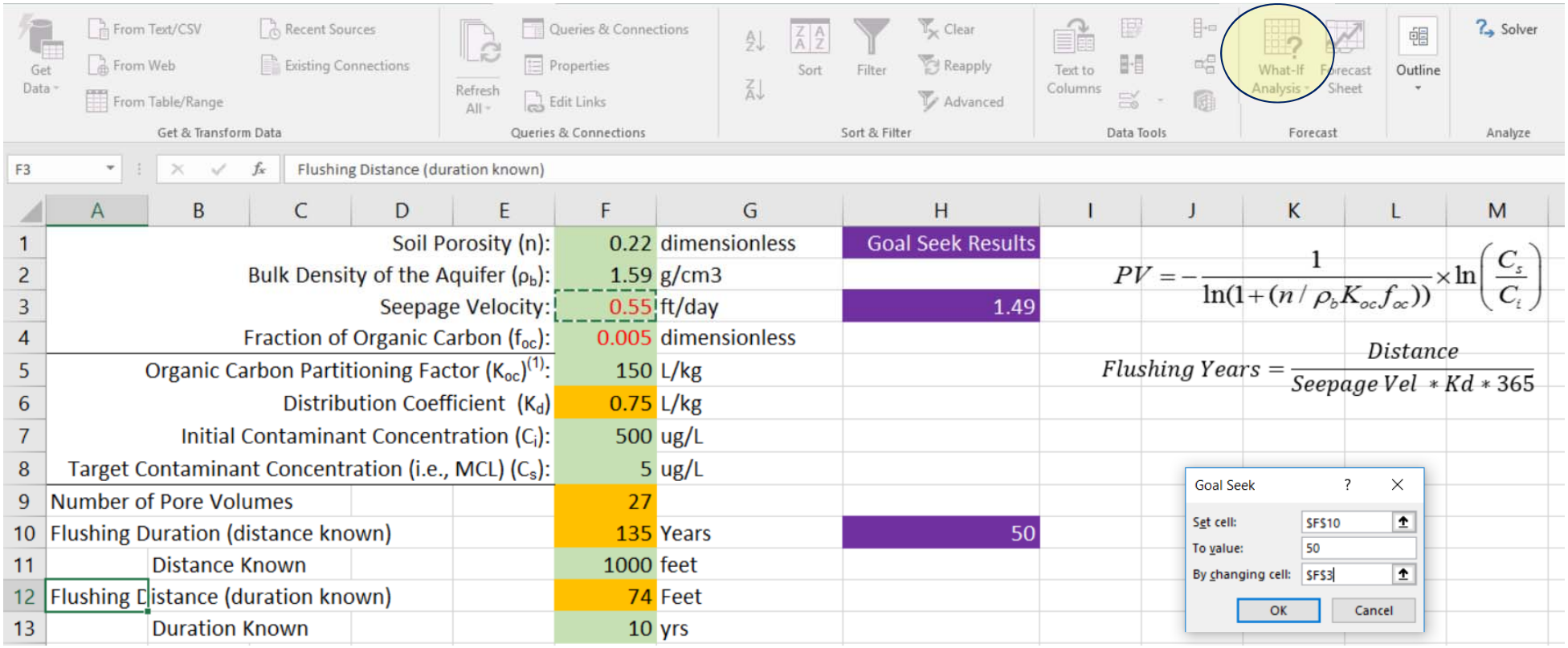
Goal Seek: Find a solution to your problem



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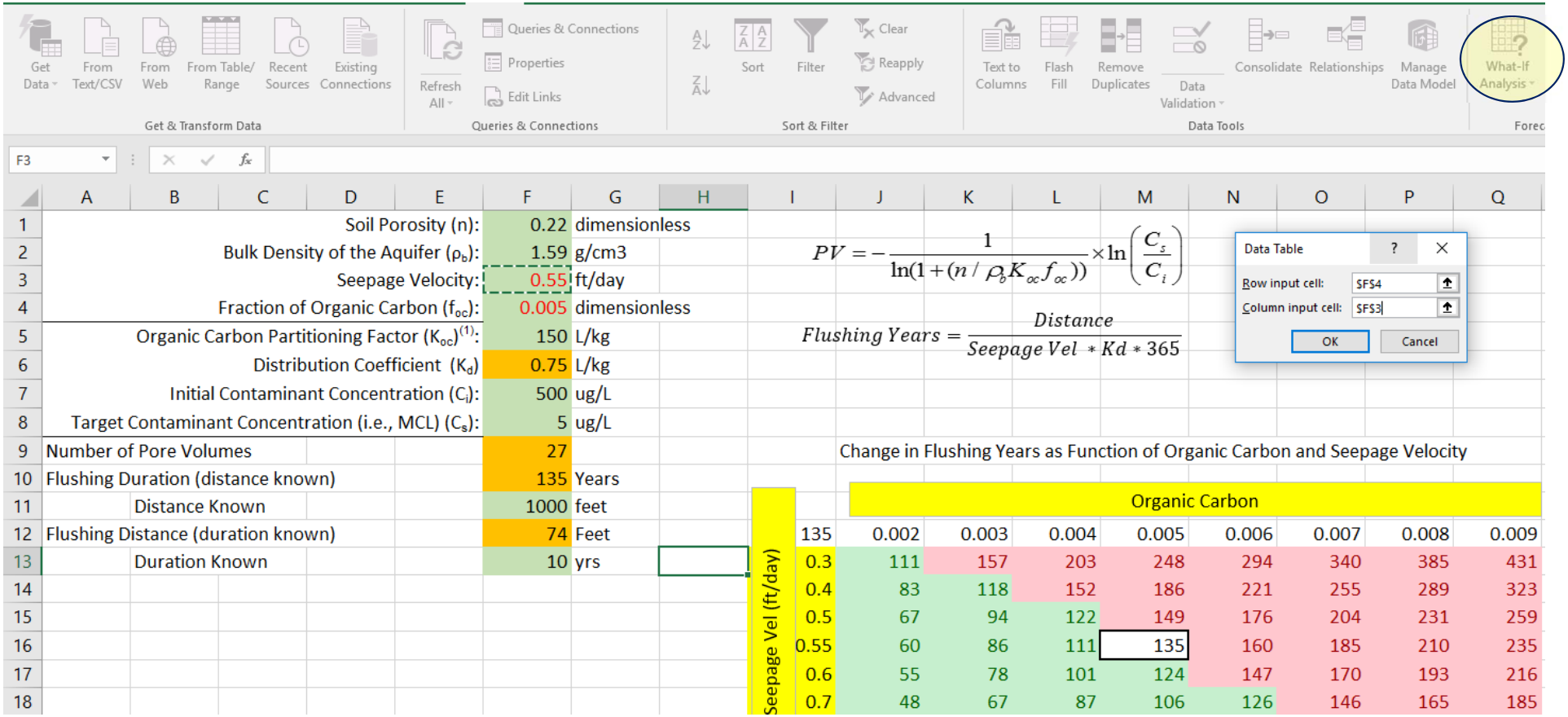
Two-Way Data: Shows how results vary with input parameters



Soil Porosity (n):	0.22	dimensionless
Bulk Density of the Aquifer (ρ_b):	1.59	g/cm3
Seepage Velocity:	0.55	ft/day
Fraction of Organic Carbon (f_{oc}):	0.005	dimensionless
Organic Carbon Partitioning Factor (K_{oc})(1):	150	L/kg
Distribution Coefficient (K_d)	0.75	L/kg
Initial Contaminant Concentration (C_i):	500	ug/L
Target Contaminant Concentration (i.e., MCL) (C_s):	5	ug/L
Number of Pore Volumes	27	
Flushing Duration (distance known)	135	Years
Distance Known	1000	feet
Flushing Distance (duration known)	74	Feet
Duration Known	10	yrs

$$PV = -\frac{1}{\ln(1+(n/\rho_b K_{oc} f_{oc}))} \times \ln\left(\frac{C_s}{C_i}\right)$$

$$Flushing\ Years = \frac{Distance}{Seepage\ Vel * Kd * 365}$$

Change in Flushing Years as Function of Organic Carbon and Seepage Velocity

Seepage Vel (ft/day) \ Organic Carbon	135	0.002	0.003	0.004	0.005	0.006	0.007	0.008	0.009
0.3	111	157	203	248	294	340	385	431	
0.4	83	118	152	186	221	255	289	323	
0.5	67	94	122	149	176	204	231	259	
0.55	60	86	111	135	160	185	210	235	
0.6	55	78	101	124	147	170	193	216	
0.7	48	67	87	106	126	146	165	185	

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Decision Tree Management Example
Additional EVO? Hot-Spot Treatment? Broader Treatment?

- 8-acre plume was treated with EVO and ZVI in 2010
- Effective reduction of TCE
- c12DCE and VC persist (plume approx. 3 acres)
- c12DCE projected to be below cleanup levels in 25 years
  - Some well trends still increasing
- Most wells show no decreasing VC trend
- Options Considered – Which one has the best probable outcome?
  - Continue long-term semi-annual monitoring
  - Reduce monitoring to annual
  - Hot-spot treatment
  - Transect treatment through plume

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Decision Tree Model

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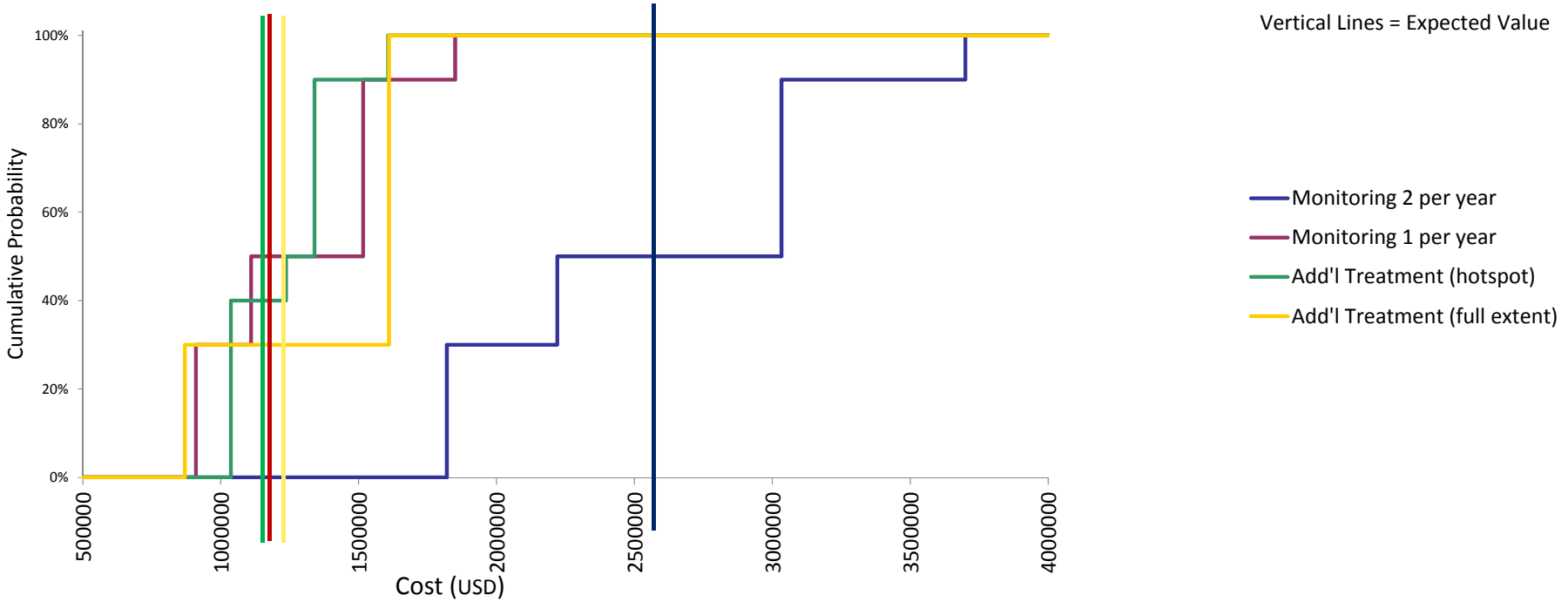
Probable Costs

Semi-Annual costs most expensive; other three options in same cost range and each provides significantly different time to reach cleanup objectives



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Is there a benefit to using both injection wells and direct push points? (Excel Solver)

- 20,000 sf cVOC plume – planning EVO delivery
- Target treatment depth 5-15 ft-bgs
- Initially considered direct push delivery only
- Considering some permanent injection (near likely hotspots) to facilitate future injections
- Is there a “sweet-spot” for the two different delivery technologies?
- DPT: lower cost for delivery point versus higher labor for delivery
- Injection Well: higher capital cost, fewer points, lower delivery costs

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Cost of using only direct push or injection wells

Work Planning and Pre-Delivery	Direct Push Delivery	Inj. Well Delivery
Work Planning	$5,141	$5,141
Mobe/Demobe Rig	$6,000	$6,000
Security and Barricades	$6,666	$6,666
work plan costs	$10,116	$10,116
Subtotal	$27,922.24	$27,922.24
Delivery Costs		
# of Points	**195.0**	**109.0**
Total EVO per point (lbs)	485.0	867.0
Cost per Point (with abandonment)	$1,858	$4,650
Field Labor per point	$1,214	$800
Total Cost for Delivery (w/EVO)	$833,586	$828,417
Total Cost	**$861,508**	**$856,340**
Total Substrate (lbs)	94575	94503
Total Area (sf)	22054	21916
Cost per Point All In	$4,418	$7,856

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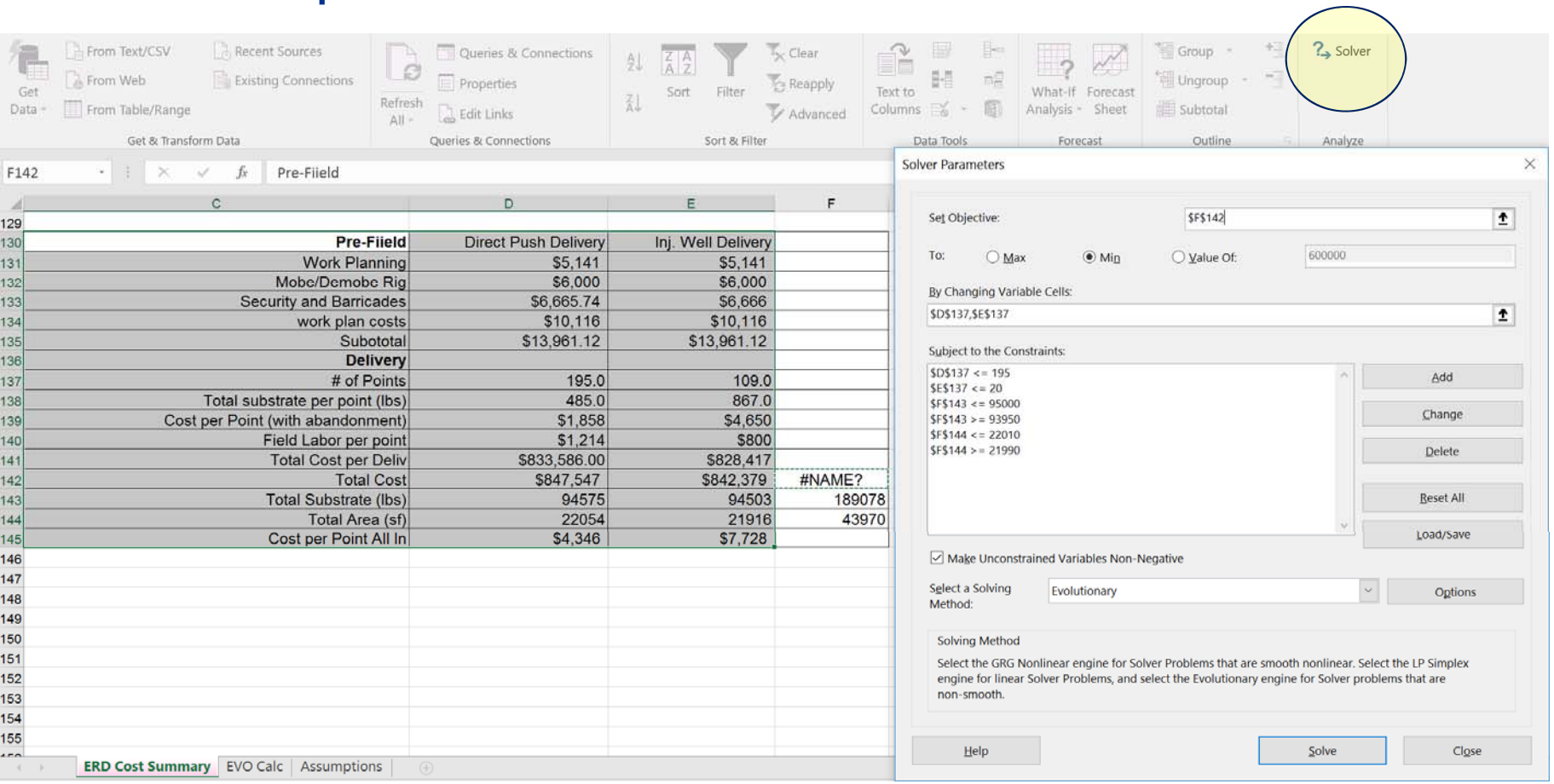
Solver Input Screen



	C	D	E	F
129				
130	**Pre-Fiield**	Direct Push Delivery	Inj. Well Delivery	
131	Work Planning	$5,141	$5,141	
132	Mobc/Dcmobc Rig	$6,000	$6,000	
133	Security and Barricades	$6,665.74	$6,666	
134	work plan costs	$10,116	$10,116	
135	Subototal	$13,961.12	$13,961.12	
136	**Delivery**			
137	# of Points	195.0	109.0	
138	Total substrate per point (lbs)	485.0	867.0	
139	Cost per Point (with abandonment)	$1,858	$4,650	
140	Field Labor per point	$1,214	$800	
141	Total Cost per Deliv	$833,586.00	$828,417	
142	Total Cost	$847,547	$842,379	#NAME?
143	Total Substrate (lbs)	94575	94503	189078
144	Total Area (sf)	22054	21916	43970
145	Cost per Point All In	$4,346	$7,728	
146				
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Microsoft Excel Solver used to assess

Constraints:

Minimize cost

93,950 < EVO lbs < 95,000

21,950 < sq. ft. < 22,050

Adjust number of points with < 20 Injection Wells

	Direct Push Delivery	Inj. Well Delivery	
Work Planning	$5,141	$5,141	
Mobe/Demobe Rig	$6,000	$6,000	
Security and Barricades	$6,665.74	$6,666	
work plan costs	$10,116	$10,116	
Subtotal	$13,961	$13,961	
# of Points	167.6	15.1	
Total substrate per point (lbs)	485.0	867.0	
Cost per Point (with abandonment)	$1,858	$4,650	
Field Labor per point	$1,214	$800	
Total Cost per Deliv	716580	114595	
Total Cost	$730,541	$128,556	$859,098
Total Substrate (lbs)	81300	13073	94373
Total Area	18958	3032	21990
Cost per Point All In	$4,358	$8,526	

Solution not found, but criteria met

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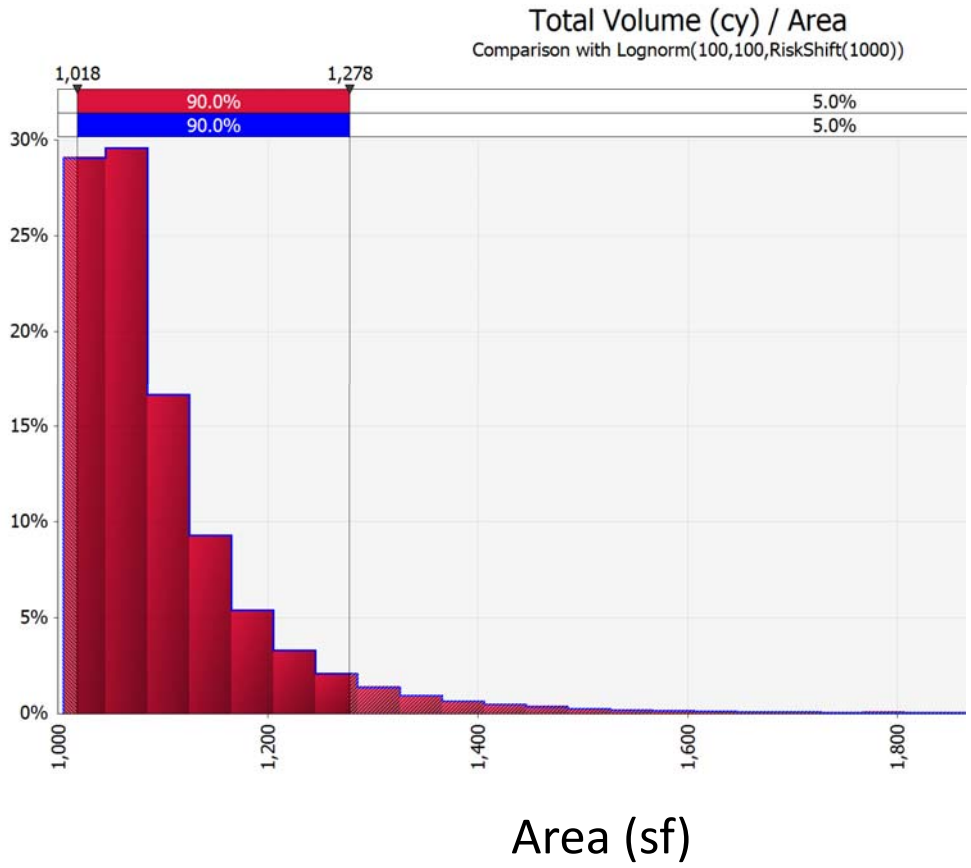
How can we address uncertainty in area of soil contamination based on investigation data

- Area = 1,000 sf
- Depth = 3 ft
- Volume = 111 CY
- Assign probability distributions to area and depth
- Depth = uniform +/- 20%
- Area was more uncertain, selected log-normal distribution



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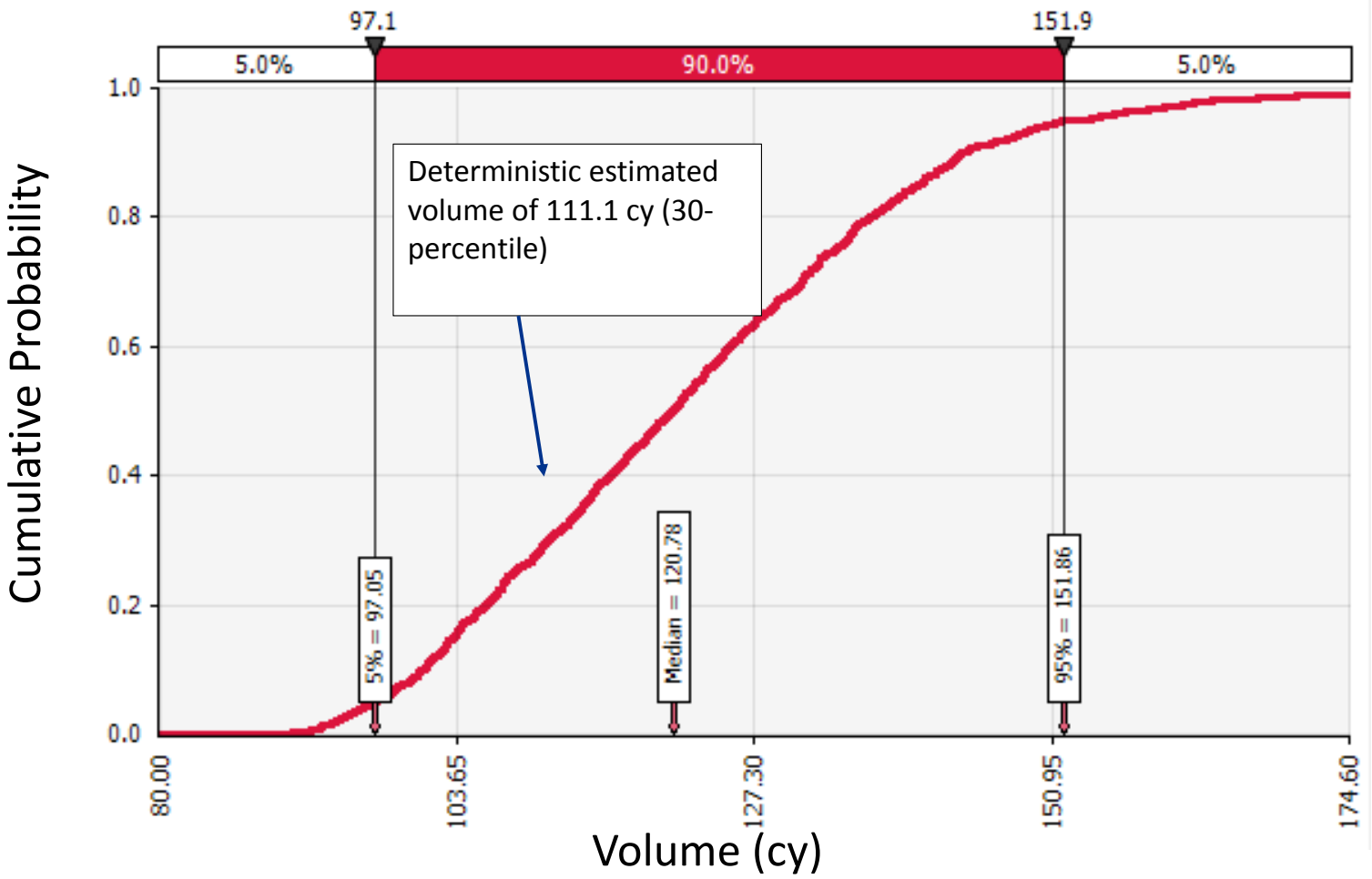
Cumulative probability distribution shows original estimates optimistic



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Summary

- MODA is recommended where there are competing objectives and a range of stakeholder perspectives
- Excel tools can:
  - Solve complex solutions to define key variables,
  - Provide tabular data on how different variables impact results,
- Decision Tree models provide a comparison of different management options and probable outcomes
- Monte Carlo Analysis allows for replacing uncertain variables with probability distributions
  - Allows better understanding of uncertainty and decisions based on probability and risk tolerance
- All of these tools provide a means to “stress-test” your design and cost calculations

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Thank you!

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May 8, 2018

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