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Optimizing Remedial Strategies in Brazil:

An Evaluation of Dual Thermal Treatment Technologies Using Dynamic Cost Modeling

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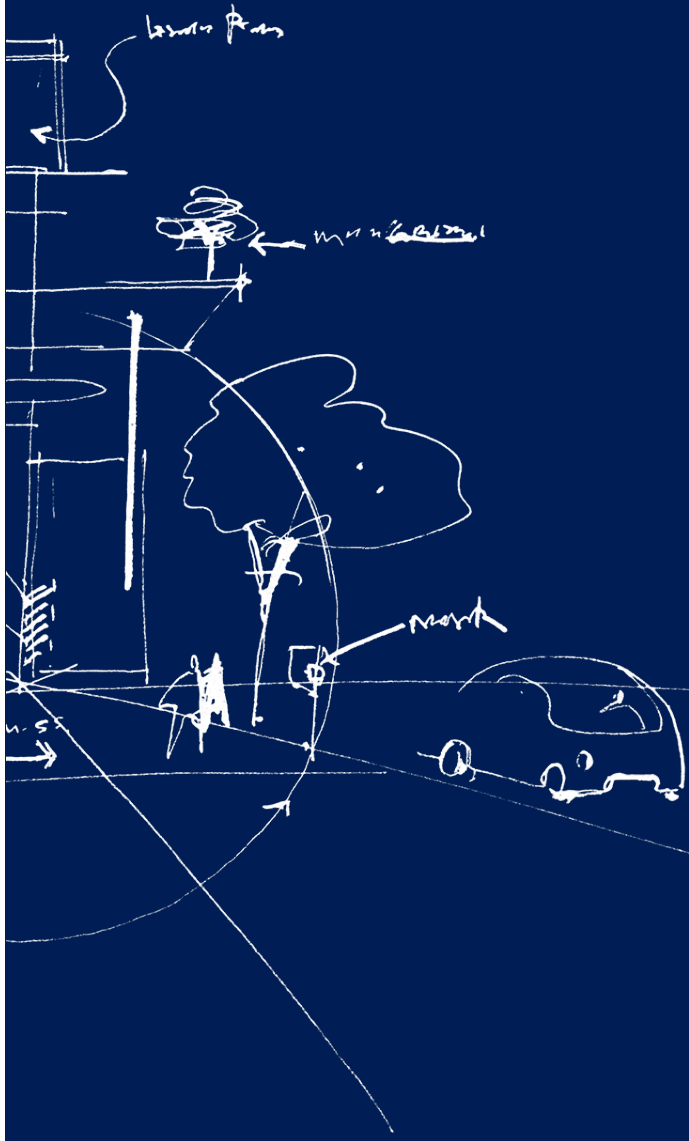
Agenda

- Site Overview and Remedial Strategy
- Cost Estimation: 101
- Multi-Variate Cost Estimation
  - Secondary Source Determination and Remedial Targets
  - Technical Considerations for Dual Thermal Technologies
  - Dynamic Cost Modeling Using Multi-Variate Cost Estimation
- Key takeaways



Site Overview

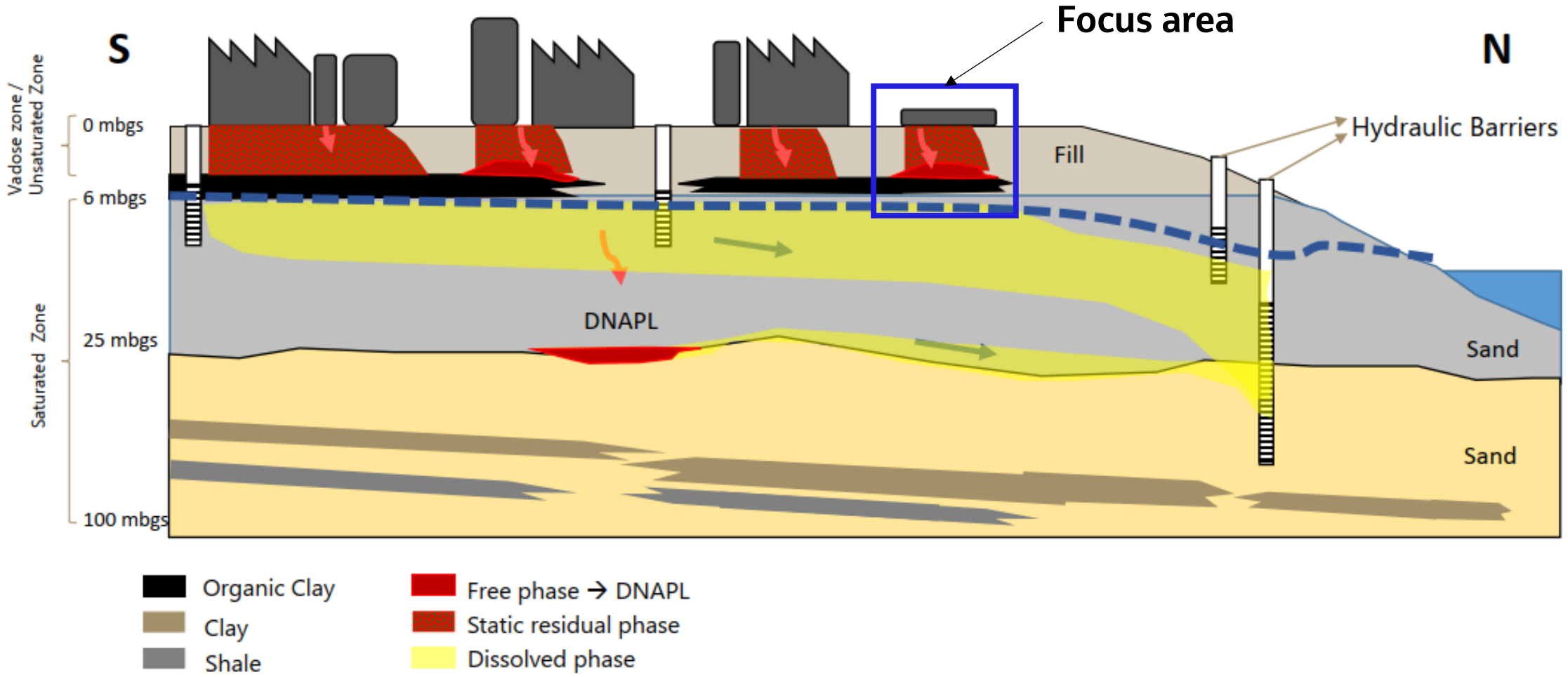
- Inactive site located in **northeastern Brazil**
- Solid and liquid wastes composed of **chlorobenzenes, chloronitrobenzenes, chloroanilines, and BTEX**
- Vadose zone and saturated zones to be remediated sequentially to **address secondary sources**

Remedial Strategy

- Seven former units being investigated, **two are fully investigated and ready for remediation**
- Remedy technologies split into **vadose and saturated zones**
- Need to understand cost of vadose zone remediation to aid in **technology selection, optimize cost-performance outcomes, and book reserve**
- Remediation goals include cleanup, but also use of **sustainable and novel technologies (i.e., limit or eliminate offsite disposal)**

CSM Overview

- Complex mixture of organochlorinated compounds
- Residual free phase product present



Cost Estimation: 101

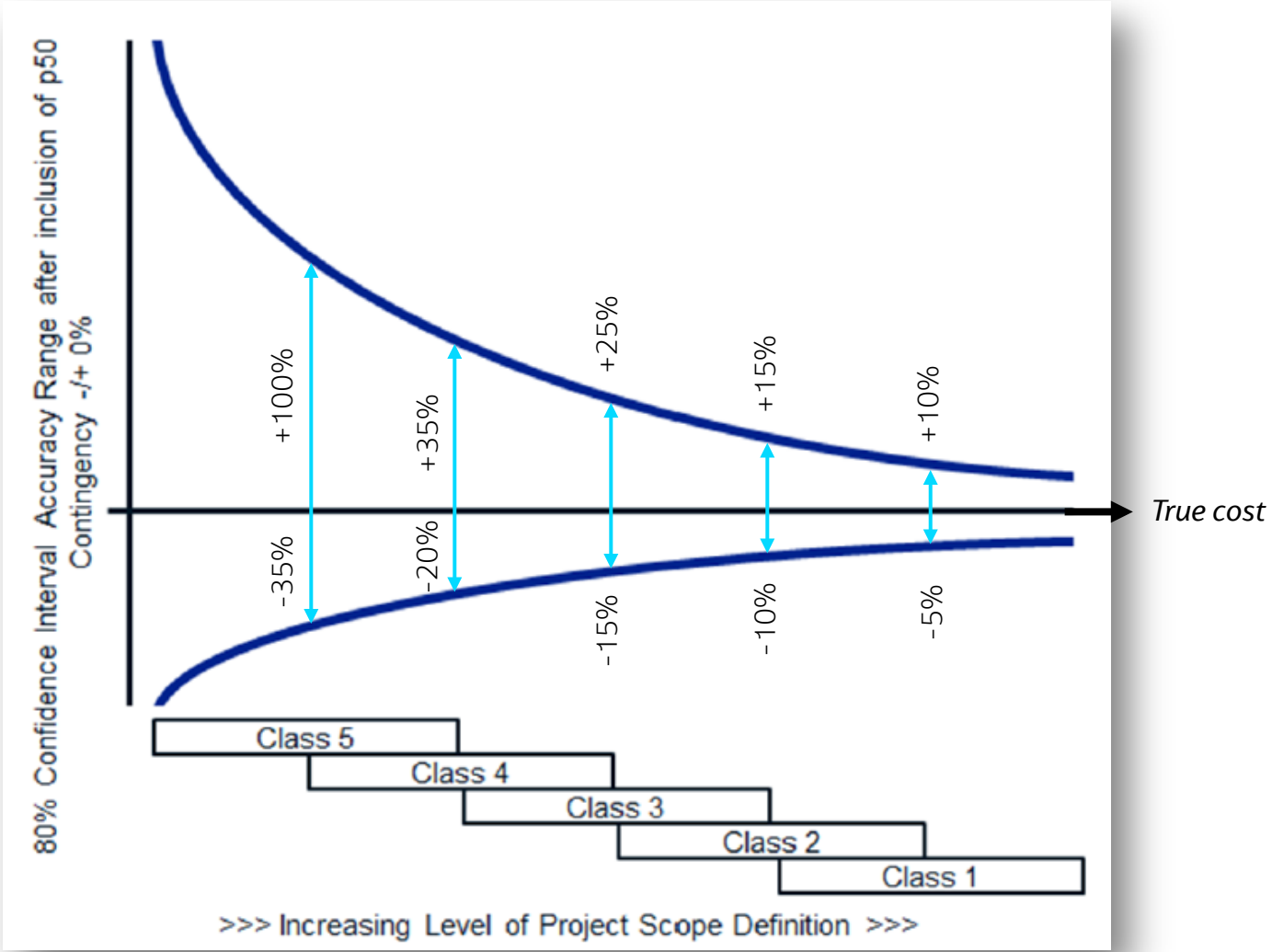
Cost Estimation Basics – Classification Matrix

	Primary Characteristic	*Secondary Characteristic*			
ESTIMATE CLASS	**MATURITY LEVEL OF PROJECT DEFINITION DELIVERABLES** Expressed as % of complete definition	**END USAGE** Typical purpose of estimate	**METHODOLOGY** Typical estimating method	**EXPECTED ACCURACY RANGE** Typical +/- range relative to index of 1 (i.e. Class 1 estimate) [a]	**PREPARATION EFFORT** Typical degree of effort relative to least cost index of 1 [b]
Class 5	0% to 2%	Screening or feasibility	Stochastic (factors and/or models) or judgment	4 to 20	1
Class 4	1% to 15%	Concept study or feasibility	Primarily stochastic	3 to 12	2 to 4
Class 3	10% to 40%	Budget authorization or control	Mixed but primarily stochastic	2 to 6	3 to 10
Class 2	30% to 75%	Control or bid/tender	Primarily deterministic	1 to 3	5 to 20
Class 1	65% to 100%	Check estimate or bid/tender	Deterministic	1	10 to 100

Association for the Advancement of Cost Engineering (AACE). 2020. *Cost Estimation Classification System*. AACE International Recommended Practice No. 17R-97.

Cost Estimation Basics – Accuracy Range

- Important for understanding certainty and potential cost swings
  - Certainty increases as project scope defined
- Estimates tend to skew higher than true end cost



Association for the Advancement of Cost Engineering (AACE). 2020. *Cost Estimate Classification System – As Applied in Engineering, Procurement, and Construction for the Environmental Remediation Industries*. AACE International Recommended Practice No. 107R-19.

Remedial Strategy, Technology Evaluation, & Cost Estimation

Remedial Options Evaluation (Class 5)

Criteria	Alt 1 Containment/ Capping	Alt 2a Excavation, Offsite Disposal Landfill	Alt 2b Excavation, Offsite Disposal Incinerator	Alt 3a Excavation, ESTD	Alt 3b Excavation, ESS	Alt 4 ISTD (Deep), Excavation, ESS (Shallow)
Effectiveness						
Implementability						
Sustainability						
Cost (Class 5)	$	$	$$$$	$$$	$$	$$
Overall Evaluation						


Low - Approach expected to perform poorly against criterion when compared to other approaches
Moderate - Approach is expected to perform moderately well against criterion when compared with other approaches
High - Approach is expected to perform very well against criterion when compared with other approaches

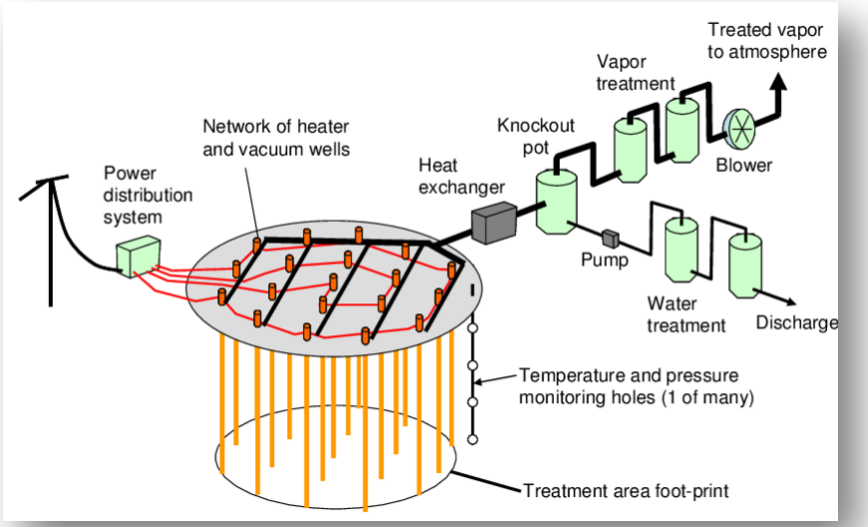
ISTD – *In situ thermal desorption*
ESS – *Ex situ smoldering*

Technology Overview

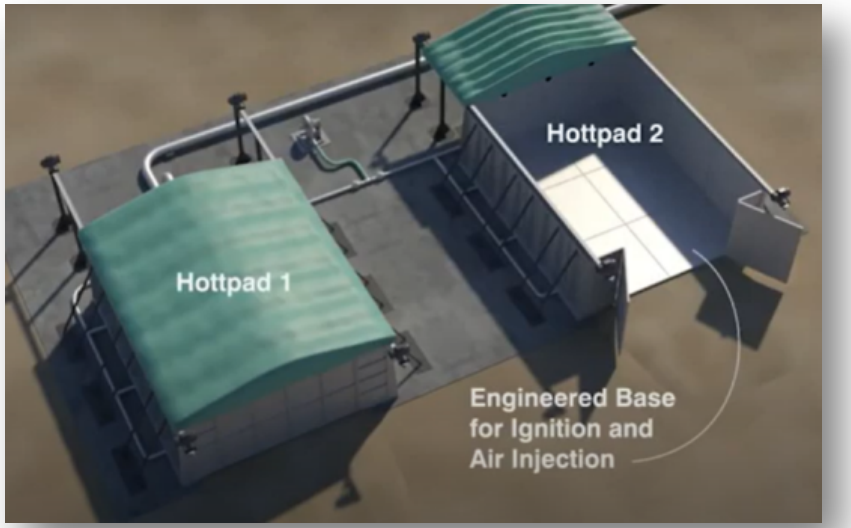
- In situ thermal desorption (ISTD)
  - Install electric heater wells, vapor recovery system, and monitoring network
  - Condense vapors, treat, dispose

- Ex situ smoldering (ESS)
  - Excavate vadose zone soil, stockpile
  - Mix soil with carbon, concrete
  - Load box, treat soil and process vapor
  - Remove treated soil, backfill

ISTD Concept



Smoldering Concept



ISTD Concept: Johnson, et al., *Critical Evaluation of State-of-the-Art In Situ Thermal Treatment Technologies for DNAPL Source Zone Treatment*. 2009.
ESS Concept: https://www.savronsolutions.com/starx/

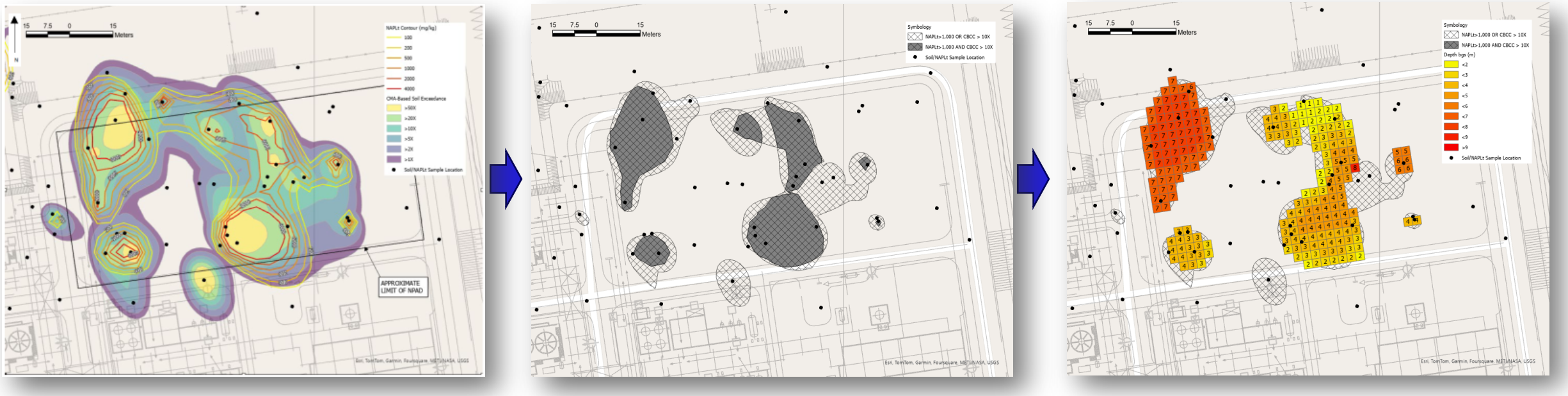
Establishing the Remedial Targets

- Cleanup levels for most site COIs not established
  - Rather, legislation calls for “addressing secondary sources”
  - Secondary source = mass contributing to secondary media

So what are we targeting?

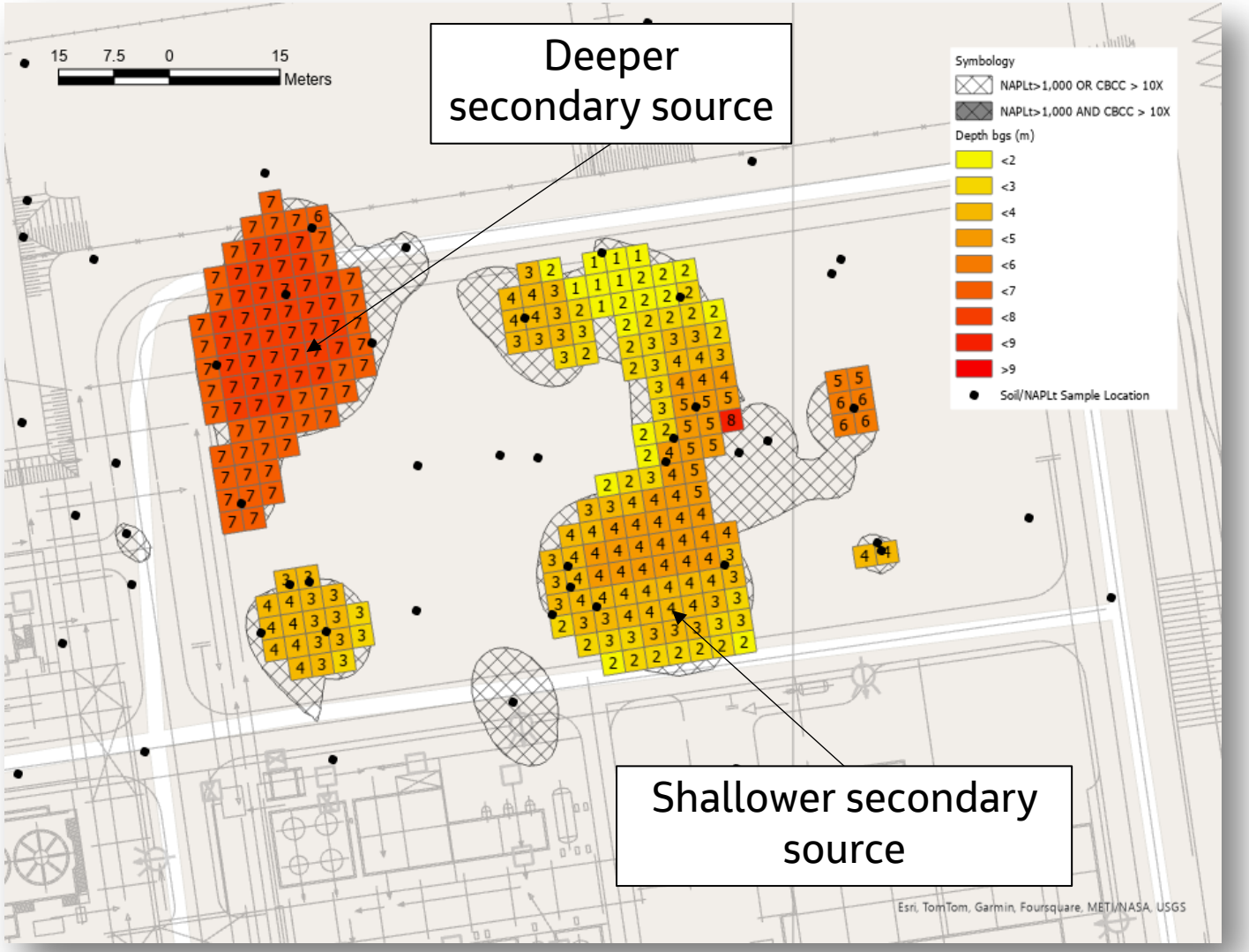
Establishing the Remedial Targets

- ✓ Step 1 – Assess NAPL saturation (NAPLt) for each sample
- ✓ Step 2 – Assess leachability of COIs from subset of samples
- ✓ Step 3 – Perform multi-variate statistical analysis correlating NAPL saturation and leachability
- ✓ Step 4 – Reference leachability to site risk values (CMAs) and screen exceedances

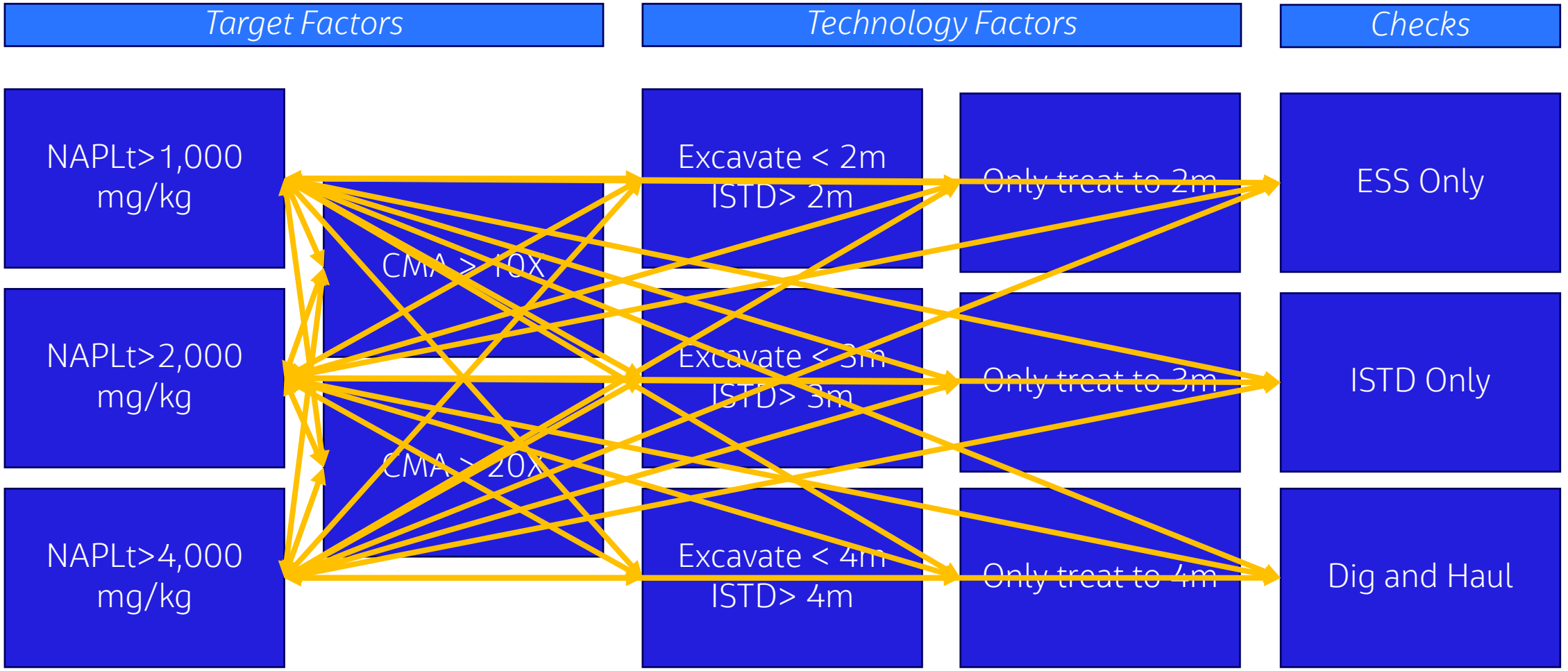


NAPLt calculated from NAPL Calculator Software by Savannah River Nuclear Solutions, LLC (i.e., NAPLator)

Establishing the Remedial Targets

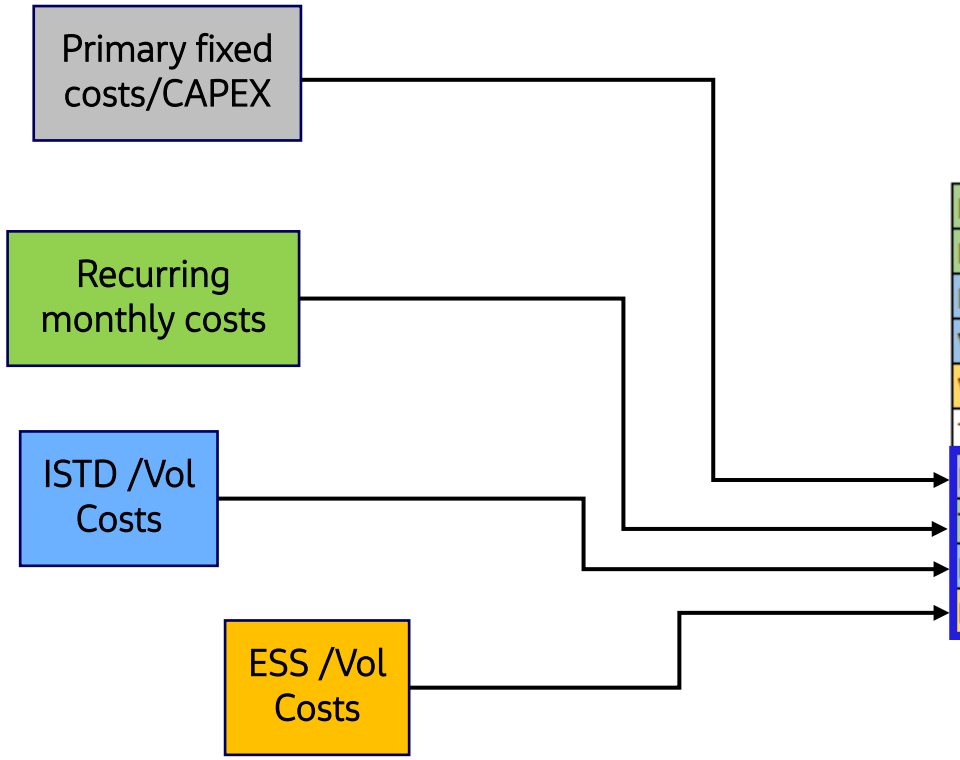


Dynamic Cost Model - Multivariate Cost Estimate



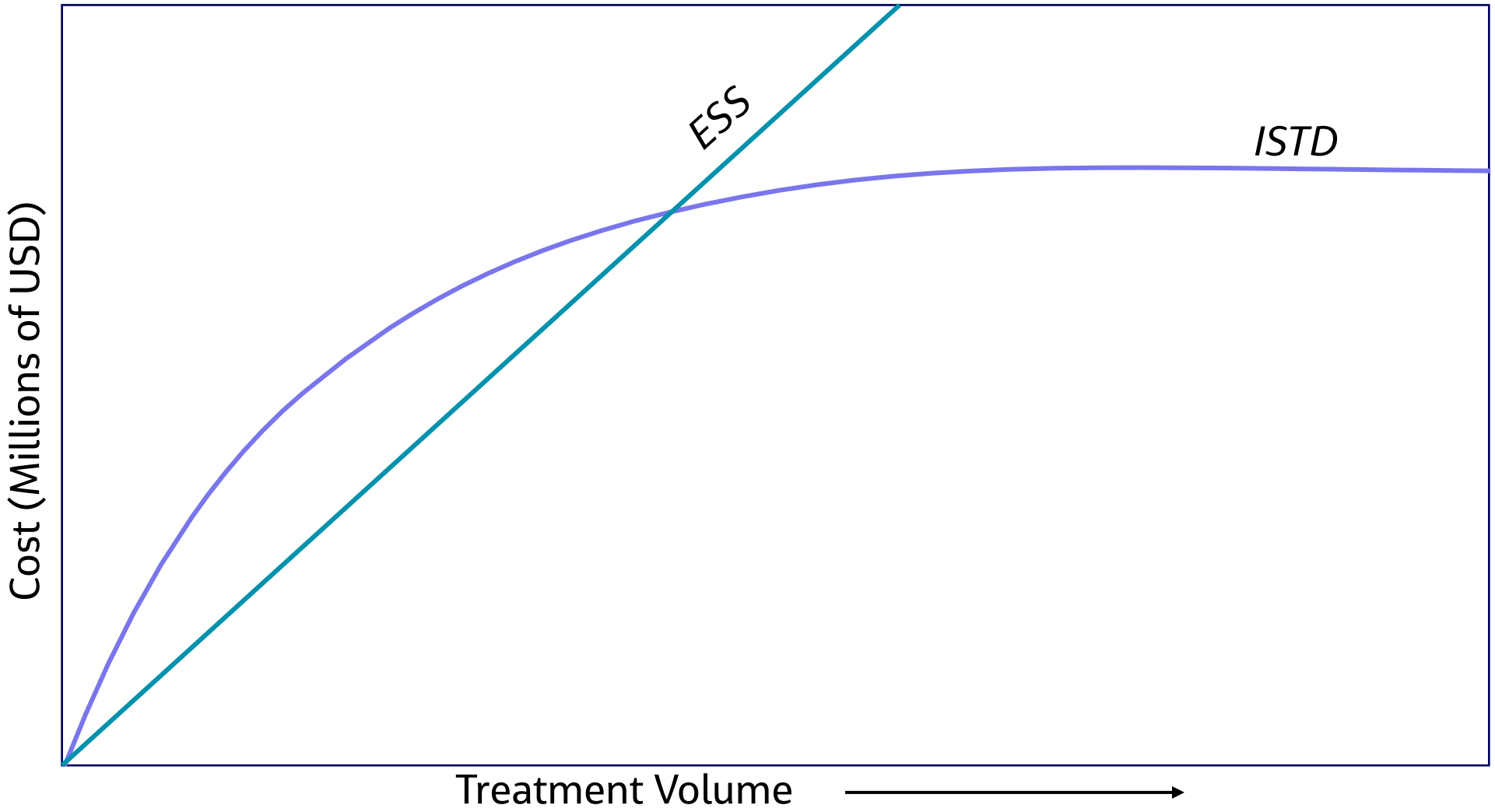
- Over 30 estimates in total

Example Estimate Output



Vadose Zone	Scenario 1 NAPLt>1,000 mg/kg AND Leaching 10X CMA, ESS to 3 mbgs, ISTD to ~7 mbgs	Scenario 2 NAPLt>2,000 mg/kg AND Leaching 10X CMA, ESS to 3 mbgs, ISTD to ~7 mbgs	Scenario 3 NAPLt>4,000 mg/kg AND Leaching 10X CMA, ESS to 3 mbgs, ISTD to ~7 mbgs
Percent of Secondary Source Mass	100%	84%	67%
Duration ISTD (Months):	20	20	20
Duration ESS (Months):	18	11	7
Depth ISTD (M)	8	8	8
Volume ISTD (CM)	5,200	3,900	2,400
Volume ESS (CM)	3,000	1,900	1,100
Total Volume (CM)	8,200	5,800	3,500
Fixed Costs	$1,395,000	$1,395,000	$1,395,000
Time Variable Costs	$5,393,023	$4,657,083	$4,323,153
ISTD Volume Variable Costs	$1,581,000	$1,185,750	$740,500
ESS Volume Variable Costs	$2,976,200	$2,667,760	$2,443,440
Total	$ 11,345,223	$ 9,905,593	$ 8,902,093

Remedial Technology Cost Functions



- *Not including capital costs

Key Takeaways

- Dynamic cost modeling can help decision making when multiple technical options available
  - Can even steer specific ways in which technology is applied
- Sometimes additional data and analysis are warranted, even after Class 5 estimate
  - Conclusions under Class 5 can differentiate from Class 3
- Remediation technologies not always “$/volume”, but scale differently

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