CERCLA Sediment Remediation – Analysis of Project Cost from Completed and Planned Projects

Presented at WODCON XXI

June 15, 2016 | Miami, Florida

Jason Dittman, Ph.D., Meredith Hayes, Dave Profusek, Bob Romagnoli, P.E., Philip Spadaro, R.G.

TheIntelligenceGroup®

RESEARCH ▼ INVESTIGATIONS ▼ FORENSICS

Topics Covered

- **How has the cost of sediment remediation changed over the decades?**
- **How has the movement towards large multi-year cleanups with larger more complex remedies affected cost of alternatives and estimation of costs?**
- **Is the current framework for development of cost estimates sufficient for large scale “mega” sediment remediation projects?**

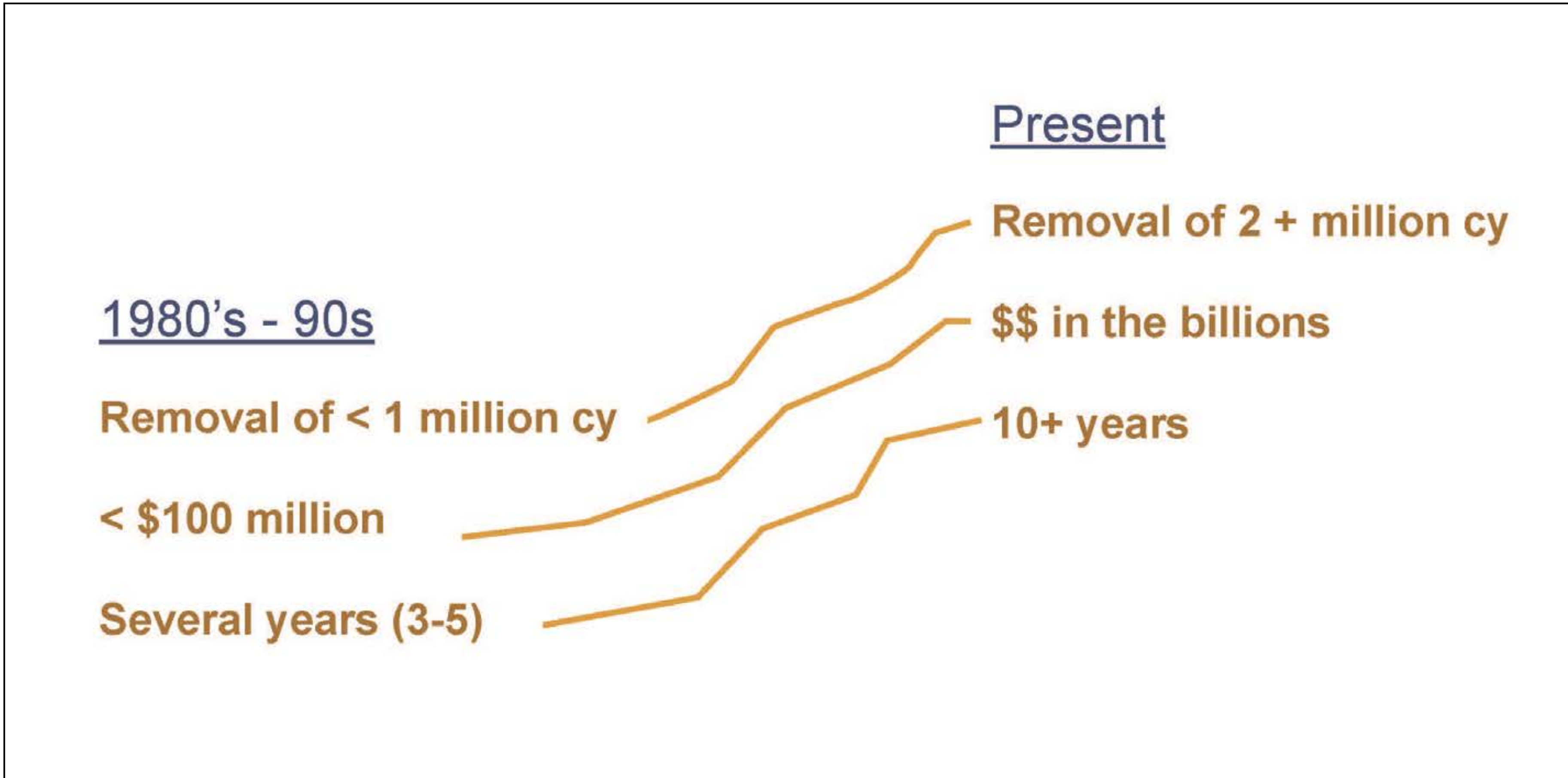
TheIntelligenceGroup®
RESEARCH ▼ INVESTIGATIONS ▼ FORENSICS

Main Messages

- Scale and complexity of sediment remediation projects has dramatically increased over the last few decades.
- All-in unit cost of sediment remediation projects has risen dramatically, although cost of technologies has not. The increase in cost is being driven by larger lengths of river and more complex remedies.
- Cost of alternatives plays an important role in decision making. However, these complex projects are difficult to cost often resulting in inaccurate estimates.
- Probabilistic cost analysis needed to evaluate cost drivers and risk of cost increase to better inform decision making.

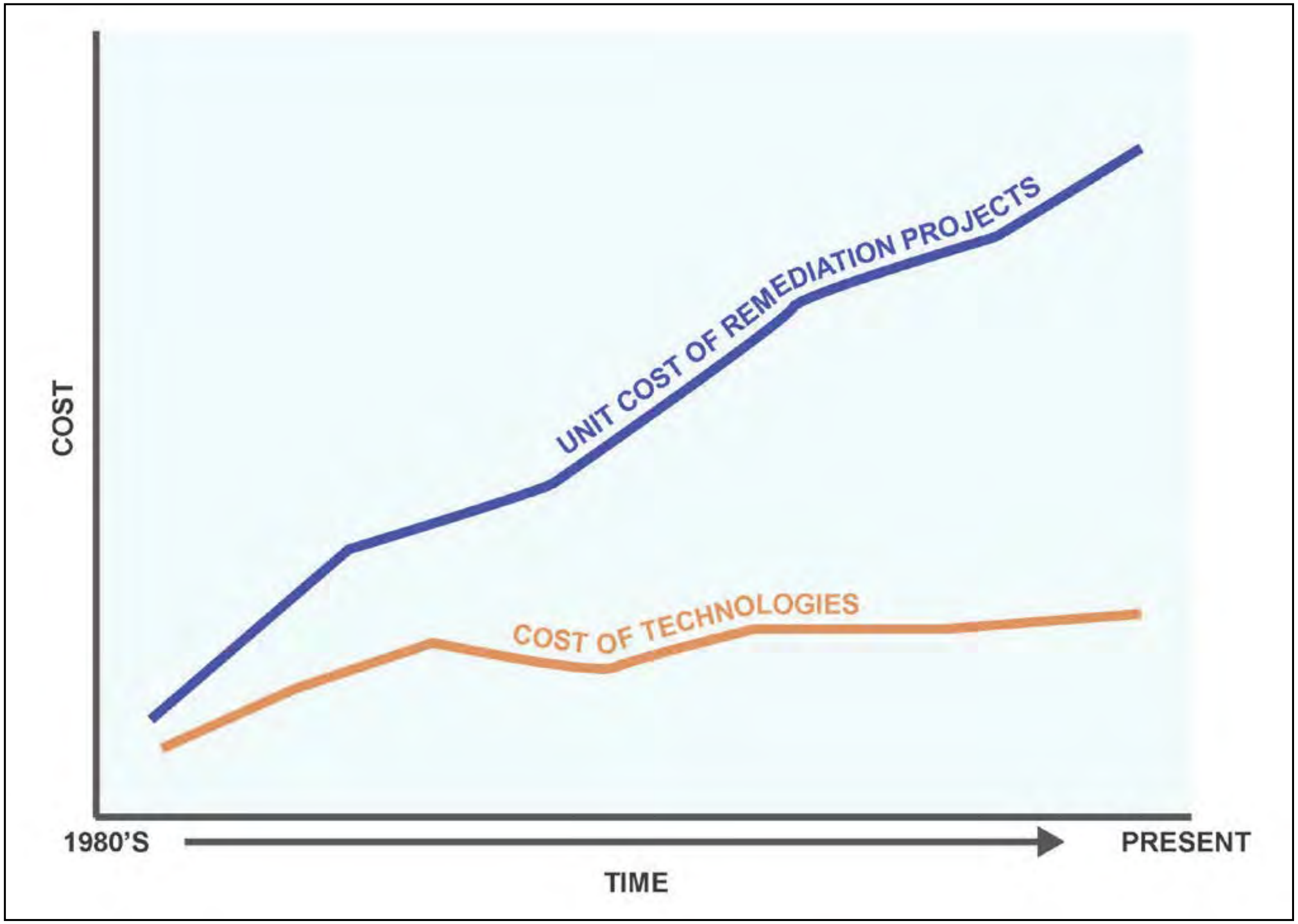
TheIntelligenceGroup®
RESEARCH ▾ INVESTIGATIONS ▾ FORENSICS

Trends in Sediment Remediation Costs



TheIntelligenceGroup®
RESEARCH ▼ INVESTIGATIONS ▼ FORENSICS

Trends in Sediment Remediation Costs



$$\textit{unit cost} = \frac{\textit{total cost of remediation}}{\textit{total volume of sediment managed}}$$

Cost Information for Dredging Projects (1994 to 2012)

Project	Year[1]	Total Cost (million $)	Total Removal Volume (cubic yards)	All-In Cost ($ / cubic yard)	Dredge Unit Cost ($ / cubic yards)
Sitcum Waterway[2]	1994	18.1	2,830,000	6.4	1.25 to 25
Thea Foss[3]	2006	53.8	1,060,000	50.8	3 to 7
Hudson River[4]	2007	*	*	1,900	*
Passaic River Phase I Removal Action[5]	2012	61	41,434	1,460	*

[1]Year indicates year construction was initiated.
[2]Total cost includes construction costs only and excludes design and other costs. Range of dredge unit costs based on dredge and placement of material from waterway and side slopes/under piers. Only 30% of 425,000 cubic yards of sediments from Sitcum Waterway contaminated; combined with navigational dredging project.
[3]Total cost includes construction costs only and excludes design and other costs.
[4]Only all-in unit cost available.
[5]Total costs include all pre- construction, site preparation, construction, transport and disposal, and engineering and monitoring costs.

- **Increase of total remediation costs and all-in unit costs from the 1990s to present day.**
- **Dredge costs in 1994 and 2006 were similar.**
- **What is driving costs so high?**

TheIntelligenceGroup®
RESEARCH ▾ INVESTIGATIONS ▾ FORENSICS

Factors Impacting Cost of Alternative

- **Partly due to a more sophisticated approach**
  - **Advanced site investigation techniques**
  - **More detailed analysis of source control, recontamination, and bioavailability, etc.**

- **Off-site disposal of moderately contaminated sediments**

- **Movement towards "mega" scale projects, essentially a series of smaller construction projects which reduces efficiencies**
  - **Hudson River: 2.75 M cy dredged over 6 years**
  - **Fox River: 3.8 M cy dredged and 446 acres capped over 6 years**
  - **Lower Passaic River: proposed 3.5 M cy to be dredged and ~1,000 acres to be capped**

Factors Impacting Cost of Alternative

- **Regulatory requirements can increase effort, constrain production and flow of work**
  - **Monitoring activities and associated analytical needs**
  - **Underwater sound recently become a topic of interest of the regulatory community**

So what does all of this mean in terms of developing accurate estimates for purposes of decision-making?

Factors Impacting Estimation of Costs

- **Current RI/FS paradigm to generate more detailed and accurate costs during later project stages (design phase).**

- **EPA's guide to developing cost estimates for feasibility studies has an allowable cost range in earlier project stages (feasibility study) -30% to +50%.**

- **Deterministic approach used: hard numbers along with contingency percentages. Contingency is emphasized over accuracy.**

- **The approach generally worked when project were smaller but for mega projects more accurate cost estimates are needed earlier in the process.**

Factors Impacting Estimation of Costs

- **A more robust and accurate costing process is needed.**
  - Technical analyses of critical operational elements should not be deferred until the design stage, but completed during the earlier evaluation stages.
  - While cost guides/databases can be useful, contractor quotes are much more precise.
  - Sensitivity analysis is needed, but typically not performed, especially for larger projects where multiple variables of great significance can often conflict.
  - Probabilistic costs should be developed, providing a much more realistic estimate of overall costs.

TheIntelligenceGroup®
RESEARCH ▾ INVESTIGATIONS ▾ FORENSICS

Managing Cost Risk and Uncertainty

Probabilistic Cost Analysis:

- Manage cost risk and uncertainty.
- Answers the “what if question” typically not included in cost estimation.
  - *What if the time scale of the remediation increases?*
  - *What if the volume of dredge material increases?*

TheIntelligenceGroup®
RESEARCH ▼ INVESTIGATIONS ▼ FORENSICS

Managing Cost Risk and Uncertainty

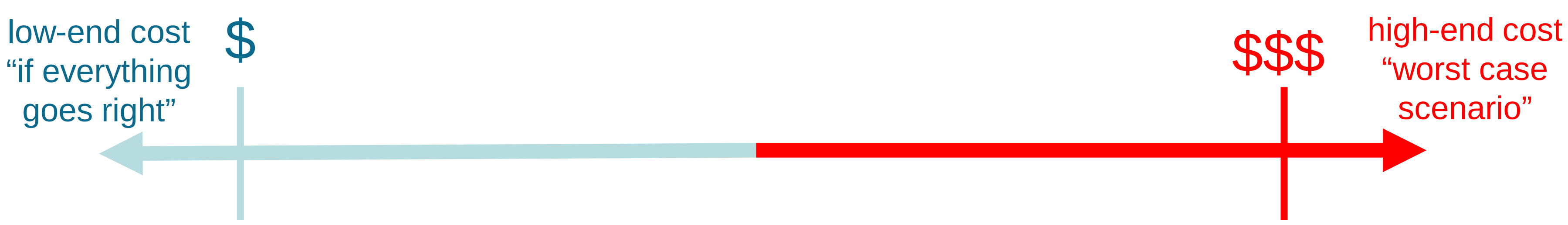
Probabilistic Cost Analysis:

- Useful for remediation approach decision making
- Allows uncertainty to be incorporated into the cost estimate

What is the risk of cost increase?

Probabilistic Cost Analysis

- **Provides a range of costs.**
- **Informs cost drivers and risks of cost increase.**
- **Helps inform contingencies.**
- **Identifies high impact factors to refine overall costs and manage sources of cost creep.**
- **Allows for transparent evaluation of the actual costs for decision making.**

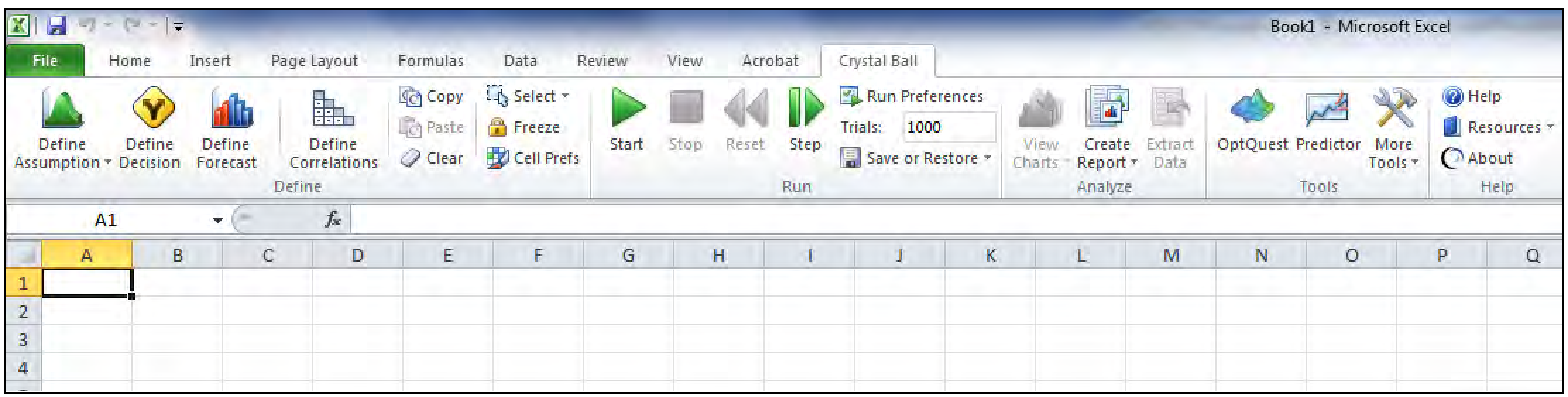


Probabilistic Cost Modeling – Monte Carlo Simulation

- **Computational algorithm designed to evaluate a large number of unknown parameters to explore the behavior of a complex system or process.**
- **Invented by scientists working on the atomic bomb in the 1940s.**
- **Monte Carlo methods are applied to a range of problems in science, engineering, and finance.**

Probabilistic Cost Modeling – Monte Carlo Simulation

- Spreadsheet-based software
- Uses a Monte Carlo simulation to randomly generate a range of values for defined assumptions (i.e., estimated values or inputs into the spreadsheet model).
- Within the model framework there are assumption cells and forecast cells.
- Assumption cells contain estimated values or inputs
- Forecast cells contain formulas that refer to one or more assumption cells and combine the values in the assumption cells to calculate a results.
- Allows the user to explore a range of outcomes based on "what ifs"



Probabilistic Cost Modeling – Monte Carlo Simulation

Description	Estimate	Min	Max	Simulated
Big Co. PROJECT MANAGEMENT	$ 4,719,278			
PROJECT MANAGEMENT	**$ 4,719,278**	**$ 4,500,000**	**$ 5,500,000**	$ 4,719,278
ENGINEERING MANAGEMENT	$ 1,344,586			
TECHNICAL STUDIES	$ 479,725			
DEFINITIVE DESIGN	$ 10,575,071			
ENGINEERING INSPECTION	$ 5,007,916			
EQUIPMENT REMOVAL DESIGN	$ 2,561,272			
ENGINEERING	**$ 19,968,570**	**$ 19,000,000**	**$ 22,000,000**	$ 19,968,570
CENRTC DEFINITIVE DESIGN	$ 668,990			
CENRTC PROCUREMENT	$ 632,731			
CENRTC FABRICATION	$ 902,498			
CENRTC	**$ 2,204,219**	**$ 2,000,000**	**$ 2,500,000**	$ 2,204,219
WHC CONSTRUCTION MANAGEMENT	$ 4,976,687			
INTER-FARM MODIFICATIONS	$ 1,307,065			
C-FARM MODIFICATIONS	$ 6,602,884			
AY-FARM MODIFICATIONS	$ 1,636,429			
EXPENSE PROCUREMENT	$ 4,054,629			
FACILITY PREP	$ 9,536,166			
CONSTRUCTION SERVICES	$ 7,041,973			
CONSTRUCTION	**$ 35,155,833**	**$ 34,000,000**	**$ 45,000,000**	$ 35,155,833
STARTUP ADMINISTRATION	$ 1,676,355			
STARTUP SUPPORT	$ 1,944,661			
STARTUP READINESS REVIEW	$ 1,042,521			
OTHER PROJECT COST	**$ 4,663,537**	**$ 4,000,000**	**$ 5,500,000**	$ 4,663,537
ENVIRONMENTAL MANAGEMENT	$ 424,013			
SAFETY	$ 3,579,477			
NEPA	$ 64,106			
RCRA	$ 11,474			
CAA	$ 176,869			
SAFETY & ENVIRONMENTAL	**$ 4,255,939**	**$ 4,000,000**	**$ 5,000,000**	$ 4,255,939
PROJECT TOTAL	**$ 70,967,376**	**$ 67,500,000**	**$ 85,500,000**	$ 70,967,376
CONTINGENCY	20%			
PROJECT TOTAL WITH CONTINGENCY	**$ 85,160,851**			

Example model provided in Oracle Crystal Ball ® software

95% confident that the project will not exceed this cost.

Project cost example

- Traditional contingency analysis can lead to overestimating costs if individual elements are summed as a worst case scenario
- The model creates a probability distribution based on the uncertainty surrounding specific input variables

TheIntelligenceGroup®
RESEARCH ▾ INVESTIGATIONS ▾ FORENSICS

Example - Portland Harbor Superfund Site

PORTLAND HARBOR SUPERFUND SITE

LWG Lower Willamette Group

Home | Overview | Harbor Information | Remedial Investigation | Feasibility Study | Library

Feasibility Study

- Remedial Action Objectives
- Remedial Goals/Remedial Action Levels
- Cleanup Methods
- Alternatives Analysis

Click Here to View the **Portland Harbor Superfund Site Draft Feasibility Study Report**

Feasibility Study

• The LWG's Draft Feasibility Study (FS) was submitted to EPA on March 30, 2012. It represents one of the most comprehensive scientific studies and analysis of sediment contamination, and risks from the contamination, in any U.S. major urban waterway. EPA will finalize its FS report in 2015.

• The FS is the "toolbox" from which EPA will select the remedies for the cleanup of the Portland Harbor Site. It is the mechanism for the development, screening, and detailed evaluation of alternative remedial actions.

• The report does not determine who is responsible for the costs of cleanup, define precise cleanup boundaries, select the cleanup methods or sediment disposal sites. Those decisions will take place after EPA has prepared a Proposed Plan for public review and issues a Record of Decision that describes the cleanup in greater detail. Responsibility for funding and implementing EPA's selected cleanup will be determined in a separate process.

• EPA will use the FS to create a Proposed Plan for public review and then issue a Record of Decision that describes the cleanup.

TheIntelligenceGroup®
RESEARCH ▼ INVESTIGATIONS ▼ FORENSICS

Example - Portland Harbor Superfund Site

Modeling Approach:

- Evaluate Alternatives E, F, and G of the Portland Harbor Feasibility Study (FS).
- Cost estimate associated with capital costs was used from Appendix G of the FS.
- A lower-end and higher-end cost estimate was developed based on professional experience and precedents at other large-scale sediment remediation sites.
- Model output provides a probability distribution for the cost along with the expected or most likely cost based on the variability associated with the input parameters
- A sensitivity analysis was also performed to inform which variable(s) has the greatest influence on cost in the model

Example - Portland Harbor Superfund Site

TABLE CS-E

Alternative E

DETAILED COST ESTIMATE SUMMARY

Site: Portland Harbor Superfund Site
Location: Portland, Oregon
Phase: Draft Feasibility Study (-30% to +50%)
Base Year: 2015
Date: 8/12/2015

Description: This alternative evaluates a remedy that would involve dredging of contaminated sediments, disposal of contaminated sediment at offsite facilities (Subtitle D and Subtitle C/TSCA), capping, enhanced monitored natural recovery (EMNR), in-situ treatment, and monitored natural recovery (MNR). Capital costs are based on Disposed Material Management (DMM) Scenario 2.

TECHNOLOGY ASSIGNMENTS MEASURES CAPITAL CONSTRUCTION COSTS: (Assumed to be Incurred During Years 0 through 6)

DESCRIPTION	WORKSHEET	QTY	UNIT(S)	UNIT COST	TOTAL	NOTES
Mobilization / Demobilization	CW-E1	1	LS	$17,645,000	$17,645,000	
Transload Facility Development	CW-E21	1	LS	$14,447,813	$14,447,813	
Debris Removal and Disposal	CW-E5	329	AC	$13,084	$4,305,653	
Obstruction Removal and Relocation	CW-E6	1	LS	$15,790,250	$15,790,250	
Erosion/Residual Control Measures	CW-E7	1	LS	$24,941,250	$24,941,250	
Dredging of Contaminated Sediments (Open Water)	CW-E8	2,050,277	CY	$38	$77,961,783	
Dredging of Contaminated Sediments (Confined)	CW-E9	354,680	CY	$54	$19,033,016	
Excavation of Contaminated Sediments (From Shore for Riverbanks)	CW-E10	89,212	CY	$47	$4,175,122	
Hydraulic Offloading of the Contaminated Sediments	CW-E11	2,494,169	CY	$6	$15,713,265	Includes offloading contaminated sediments the transload facility (for Subtitle C/TSCA or Subtitle D disposal).
Subtitle C/TSCA Disposal (Handling, Transportation, Treatment of Select PTW Materials, and Disposal)	CW-E12	387,584	CY	$949	$367,668,307	Includes waste going to offsite Subtitle C/TSCA facility for disposal, including the volume of NRC/NAPL PTW that would require treatment.
Subtitle D Disposal (Handling, Transportation, and Disposal)	CW-E13	2,106,585	CY	$127	$266,724,501	Includes waste going to offsite Subtitle D facility for disposal without treatment, including the volume of "concentration"-based PTW (such as DDx and non-TSCA PCBs).
Mitigation	CW-E14	42	AC	$2,369,484	$99,518,323	
Sand Placement for Technology Assignments	CW-E15	762,409	CY	$48	$36,697,298	
Beach Mix Placement for Technology Assignments	CW-E16	35,348	CY	$96	$3,400,581	
Armor Placement for Technology Assignments	CW-E17	68,386	CY	$98	$6,730,702	
Reactive/GAC Placement for Technology Assignments	CW-E18	15,410	TON	$8,861	$136,542,696	
Geofabric for Riverbanks	CW-E19	18	AC	$14,124	$254,238	
Organoclay Mat Placement for Technology Assignments	CW-E20	19	AC	$465,805	$8,850,304	
SUBTOTAL					$1,120,420,102	
Contingency (Scope and Bid)		20%			$224,084,020	10% Scope, 10% Bid (Low end of the recommended range in EPA 540-R-00-002).
SUBTOTAL					$1,344,504,122	
Project Management		2%			$26,890,082	Percentage modified as documented in Attachment A.
Remedial Design		2%			$26,890,082	Percentage modified as documented in Attachment A.
Construction Management		3%			$40,335,124	Percentage modified as documented in Attachment A.
TOTAL					$1,438,619,410	
TOTAL CAPITAL COST					**$1,438,619,000**	Total capital cost is rounded to the nearest $1,000.

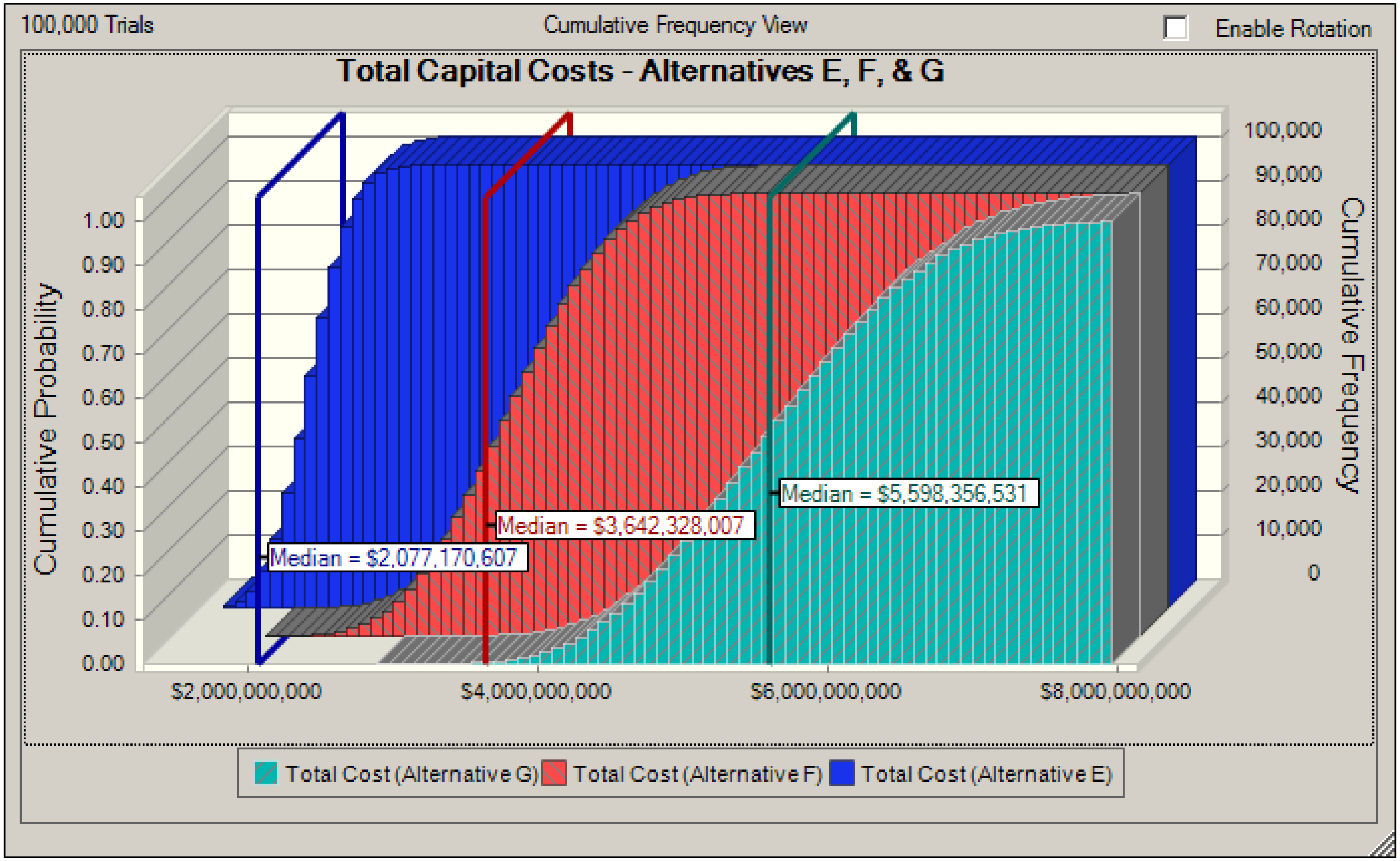
TheIntelligenceGroup®
RESEARCH ▼ INVESTIGATIONS ▼ FORENSICS

Example - Portland Harbor Superfund Site

“What ifs” considered for Portland Harbor example:

- Schedule – mobilization/demobilization over multiple seasons
- Debris removal
- Volume of sediment managed (dredge, removal)
- Transload Facility – size, location, dewatering, etc…

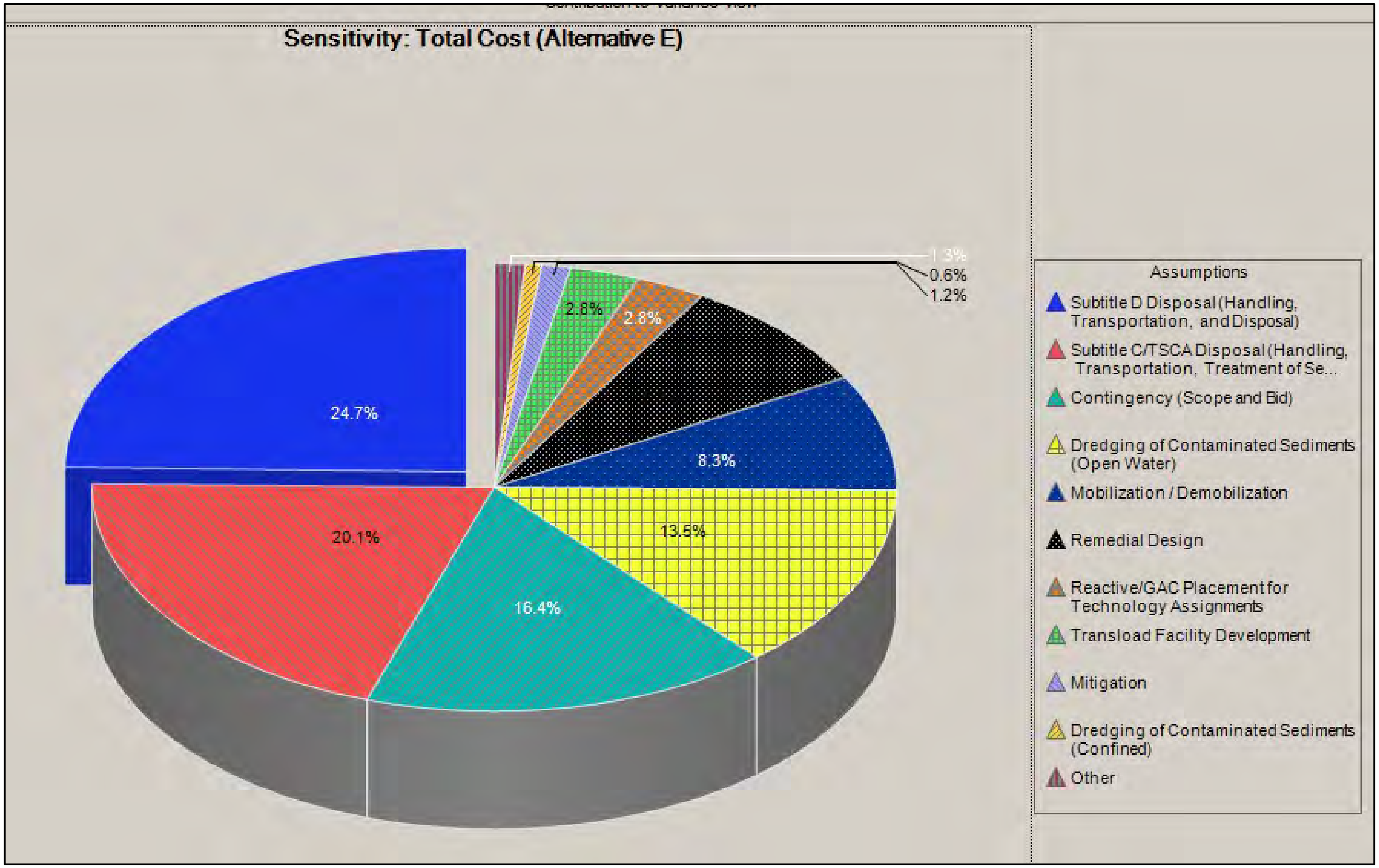
Probabilistic Cost Modeling – Portland Harbor Superfund Site



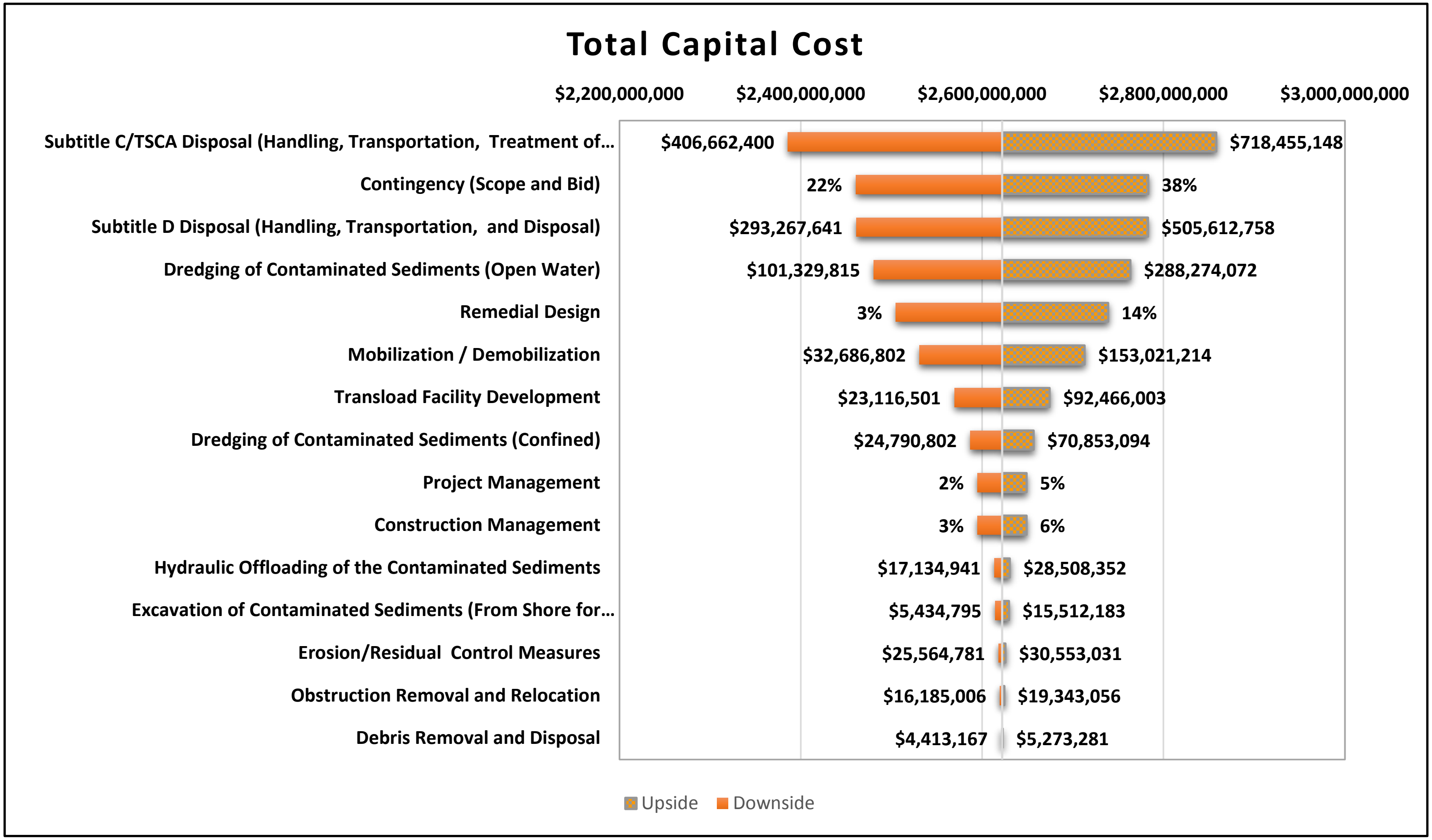
Cumulative Probability for Alternative E, F, and G's Capital Costs

TheIntelligenceGroup®
RESEARCH ▼ INVESTIGATIONS ▼ FORENSICS

Sensitivity Analysis – Portland Harbor Superfund Site



Sensitivity Analysis – Portland Harbor Superfund Site



TheIntelligenceGroup®
RESEARCH ▼ INVESTIGATIONS ▼ FORENSICS

Conclusions

- The scale and complexity of sediment remediation projects has increased over the last several decades.
- The all-in unit cost of sediment remediation has risen despite that the cost of technologies has not.
- The inherent complexity of “mega” sediment projects makes them difficult to cost, resulting in inaccurate cost estimates which could result in inappropriate remedial decisions and significant cost outlays.
- Probabilistic cost analysis allow for a more transparent evaluation of what the actual costs may be and also allow decision makers to see what variable has the most influence on overall cost.

TheIntelligenceGroup®
RESEARCH ▾ INVESTIGATIONS ▾ FORENSICS

Questions and Comments