Modeling Meaningful PFAS Cleanup Costs

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Lloyd S Ross

HALEY ALDRICH

Predicting Future PFAS Response Actions and Costs

Known Knowns Adds Certainty

- Limited number of viable treatment technologies
- Common investigation and remediation methods and system processes apply

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Known Unknowns Adds Uncertainty

- 1,000s of compounds (42 tested in soil and groundwater)
- Evolving regulations, criteria, and standards
- Near ubiquitous and multiple sources

Range of Potential Outcomes

(reasonable story lines)

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Definitions

- **Cost estimates** versus **Probabilistic Cost Model**.
- **Monte Carlo** is a computer method to heuristically solve probabilistic models.
- Types of Probabilistic Cost Models
  - Scenario or **Event Trees** – what may happen.
    - If a groundwater extraction system is ultimately required, If treatment of media would be through resin or carbon, duration horizons
  - **Variable or Distribution Model** – varying how much will happen (quantity, rate and duration).
    - Groundwater extraction system annual costs and duration it would be operated
    - How many gpm will be extracted? How many cubic yards of material to be excavated?

Cost estimating and modeling: well-defined and accepted practices

- **GAAP** (Generally Accepted Accounting Principles)
- **FAS 5** (Statement of Financial Accounting Standards No. 5)
  - Accounting for contingencies
- **ASTM E2137-17** Standard Guide for Estimating Monetary Costs and Liabilities for Environmental Matters
- **FAS 141(R)** Fair Value Accounting
  - Consistent with European Accounting standards (mark-to-market)

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Hierarchy of estimating

Liability estimating

- Quoted price
- Expected value
- Most likely value
- Range of values
- Known minimum

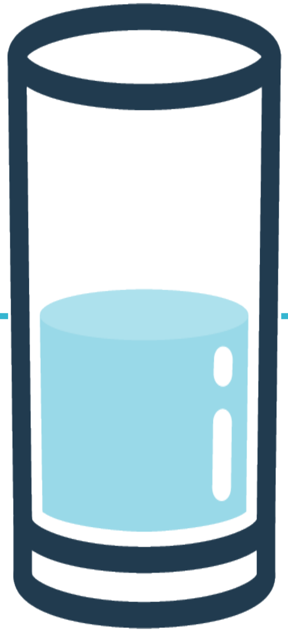
Mark to market (fair value)

- Quotes
- Comparables
- Reference (means, racer)
- Professional judgment

Compounding bias in straight line estimates

Compounding optimism
Pollyanna syndrome

- Every independent event (variable) will be the best possible outcome
- 10% * 10% * 10% * 10% = 0.01% chance



Compounding conservatism
Eeyore syndrome

- Every independent variable be the worst-case outcome
- 90% * 90% * 90% * 90% = 0.01% chance

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The probable answer probably lies somewhere between.

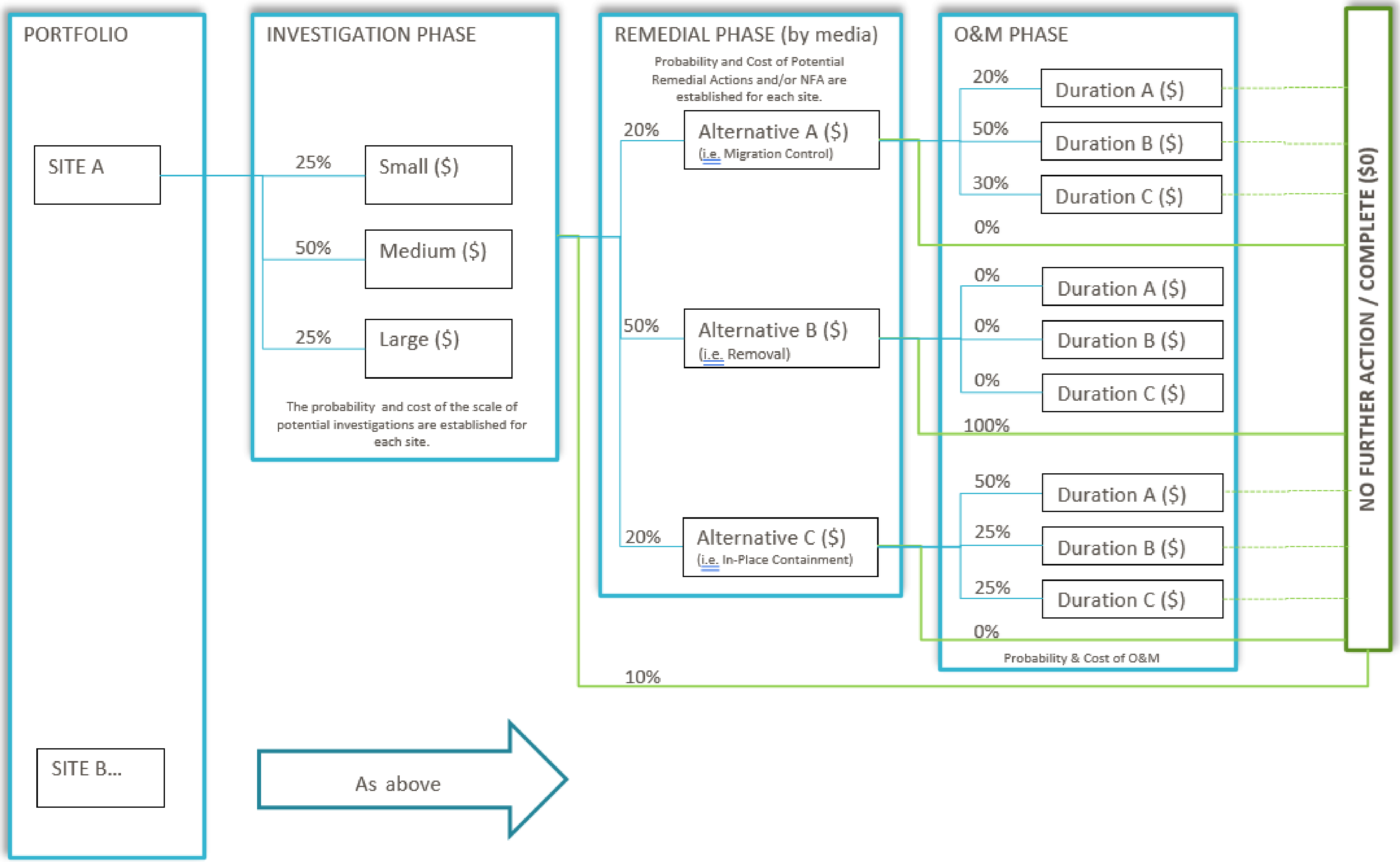
Properly constructed probabilistic models can acknowledge both perspectives.

Considerations for constructing model framework

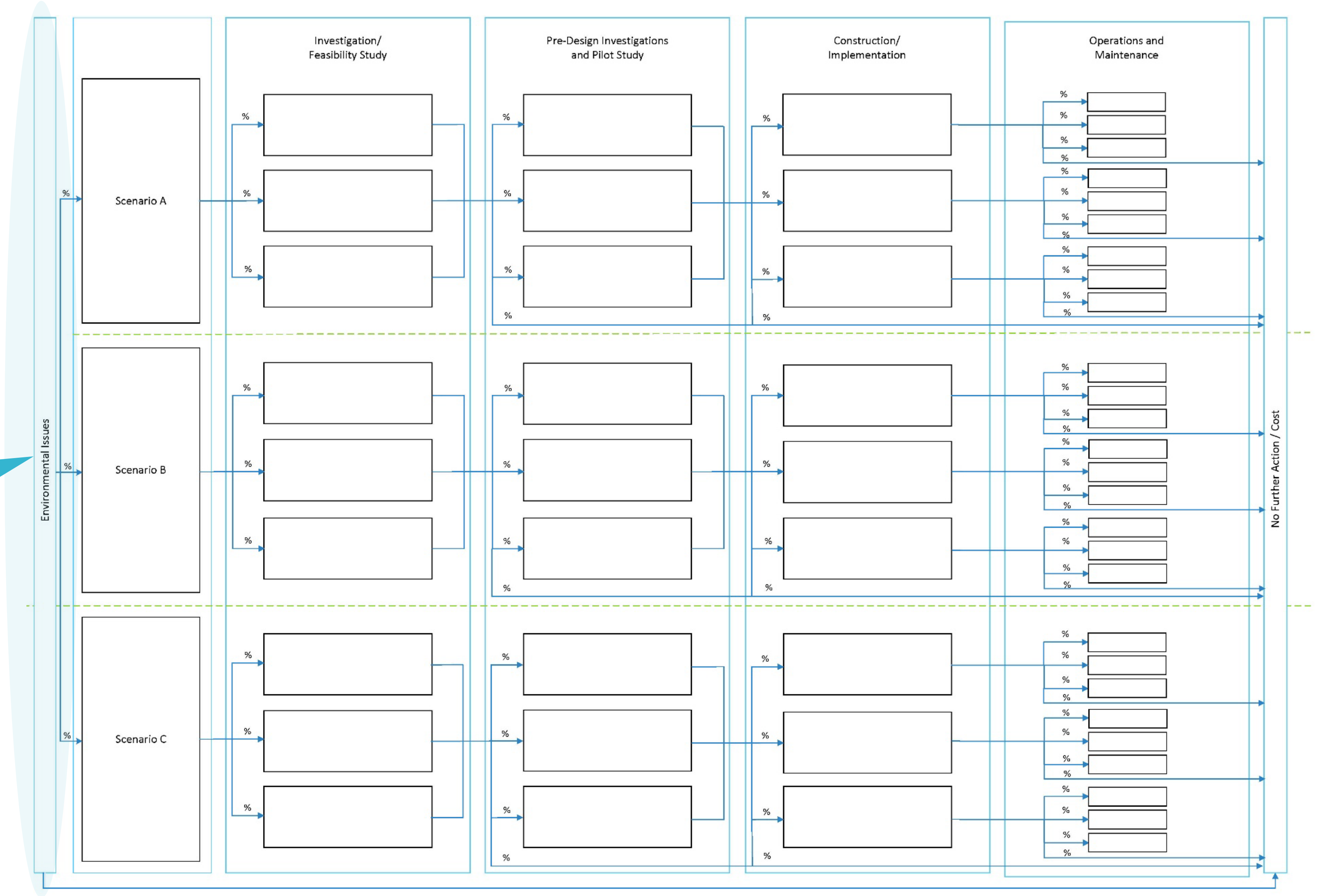
- Lifecycle costs usually developed by phases related to the program but can be refined to account for other buckets:
  - Allocation among parties
  - Accounting or tax purposes (capital versus non-capital investments)
  - Insurance or regulatory applicability (defense and construction costs)

- Is cash flow for Net Present Value analysis applicable?
- Minimum number of scenarios and estimates needed to develop reasonable ranges and capture sensitive variables
  – Generally, we model with 3 primary scenarios per ‘issue’ with 3 branches into each subsequent phase
  – A story line or narrative is developed for each of the potential outcomes.

Frameworks Illustrated



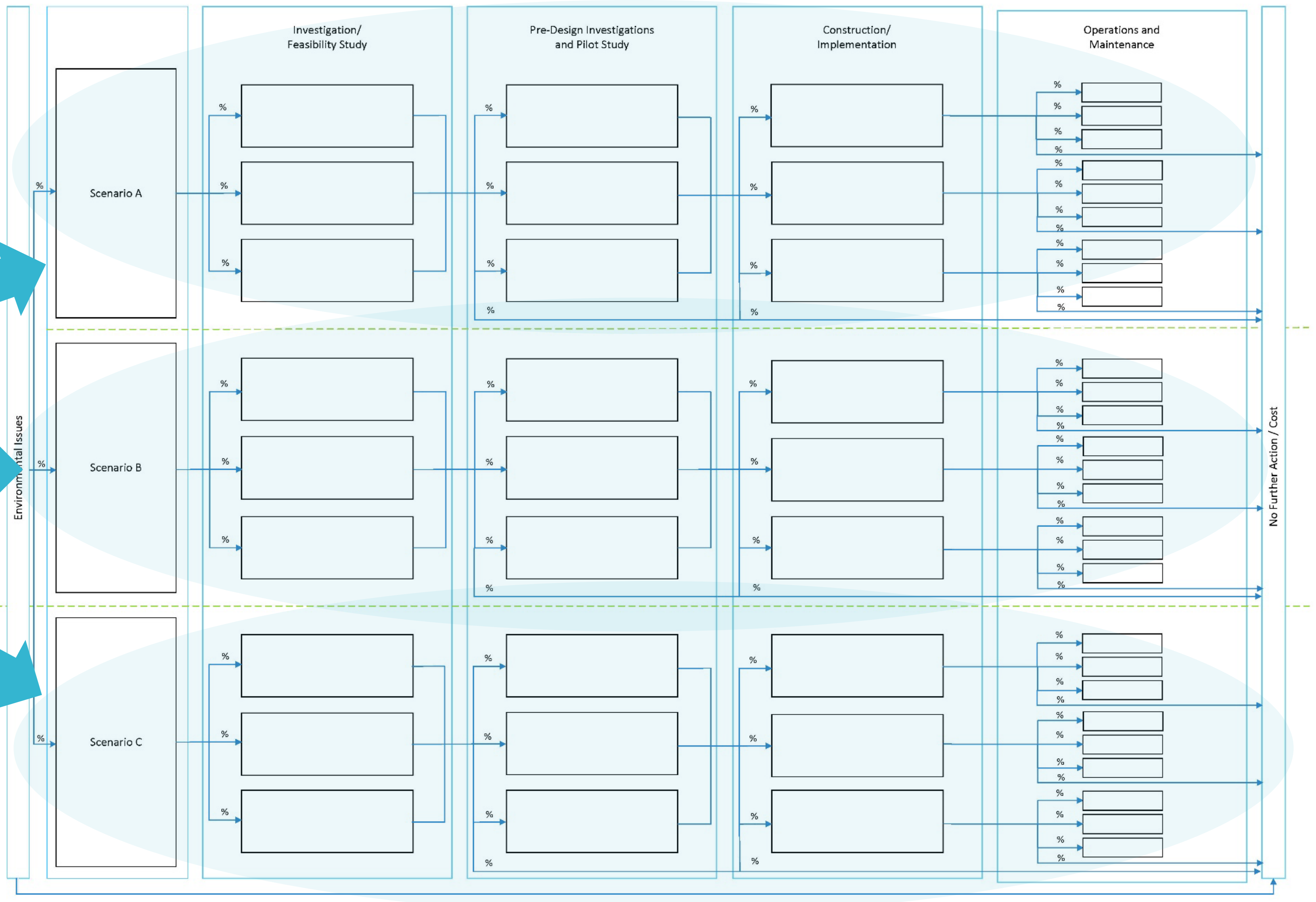
Cost model event tree example



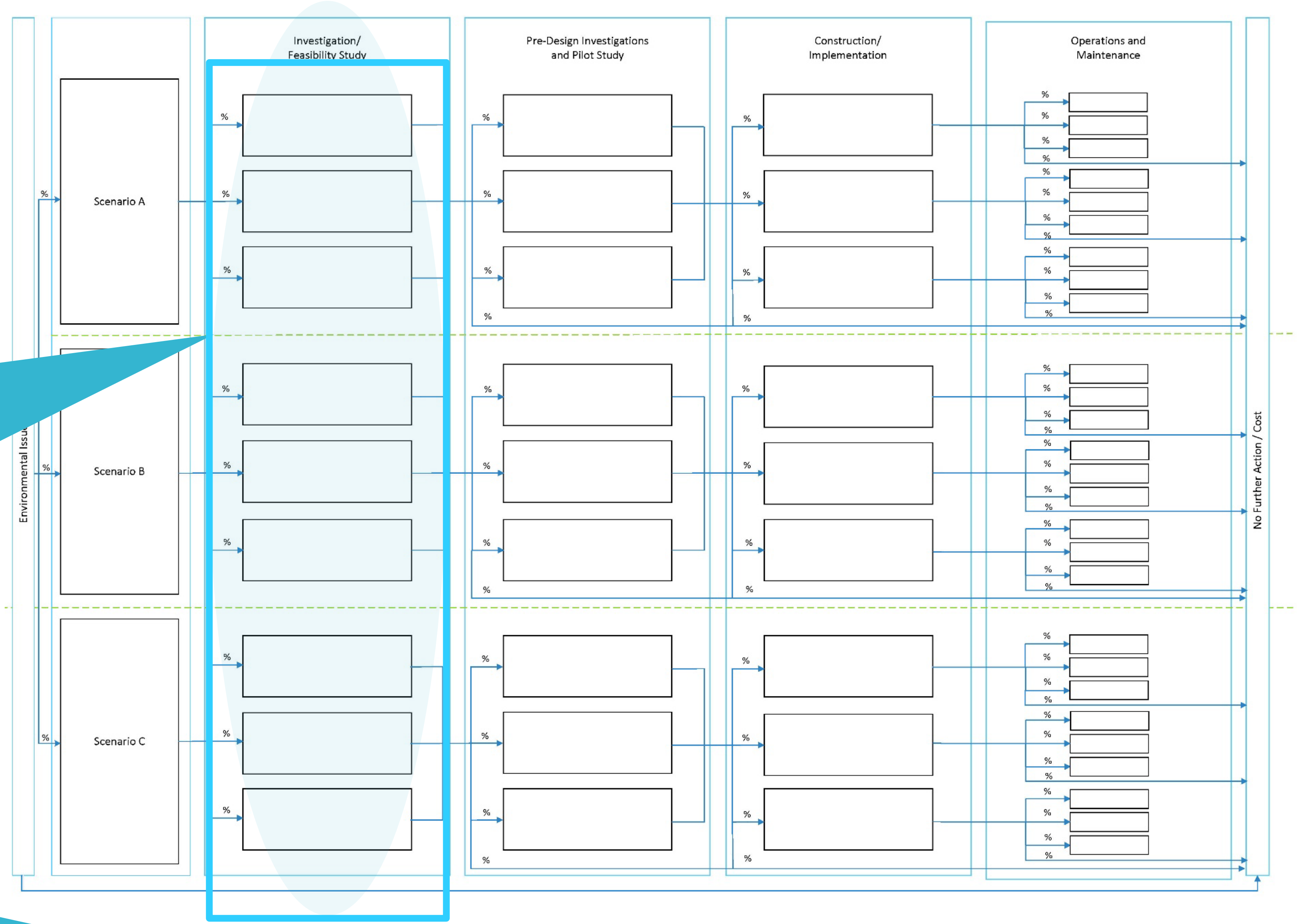
Each issue
(i.e. PFAS)

Cost model event tree example

Each issue has multiple scenarios or possible outcomes

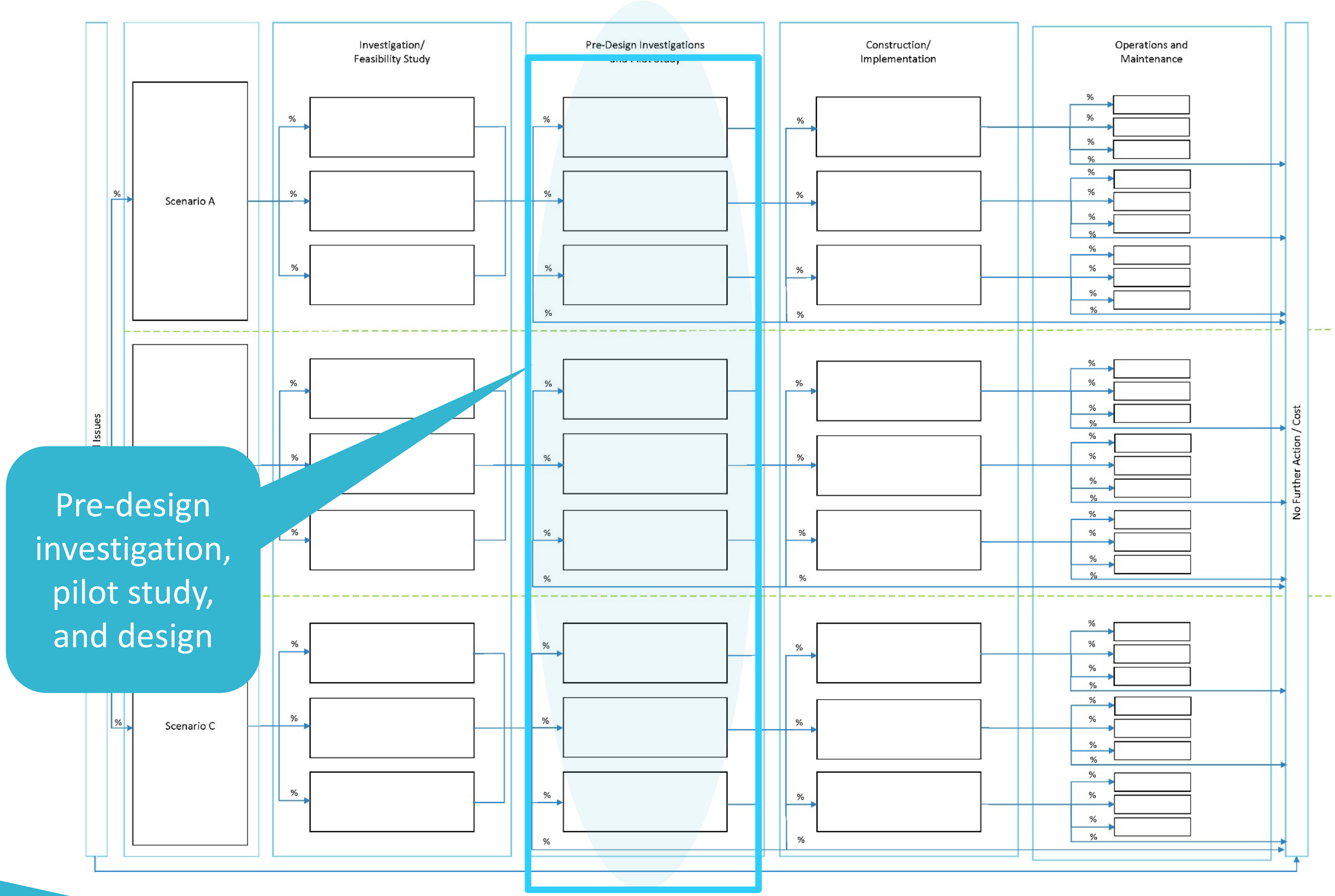


Cost model event tree example

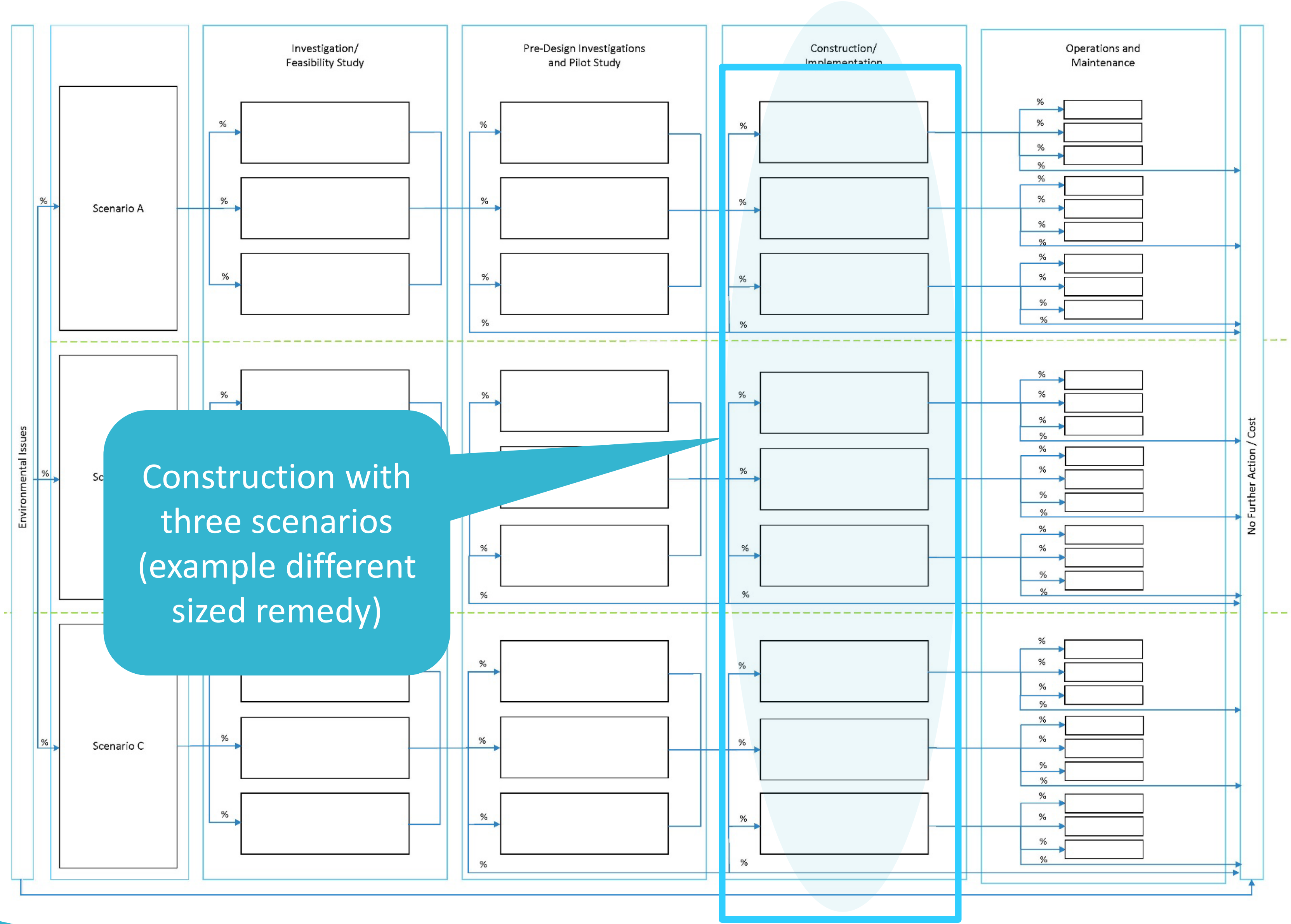


Investigation / Feasibility Study

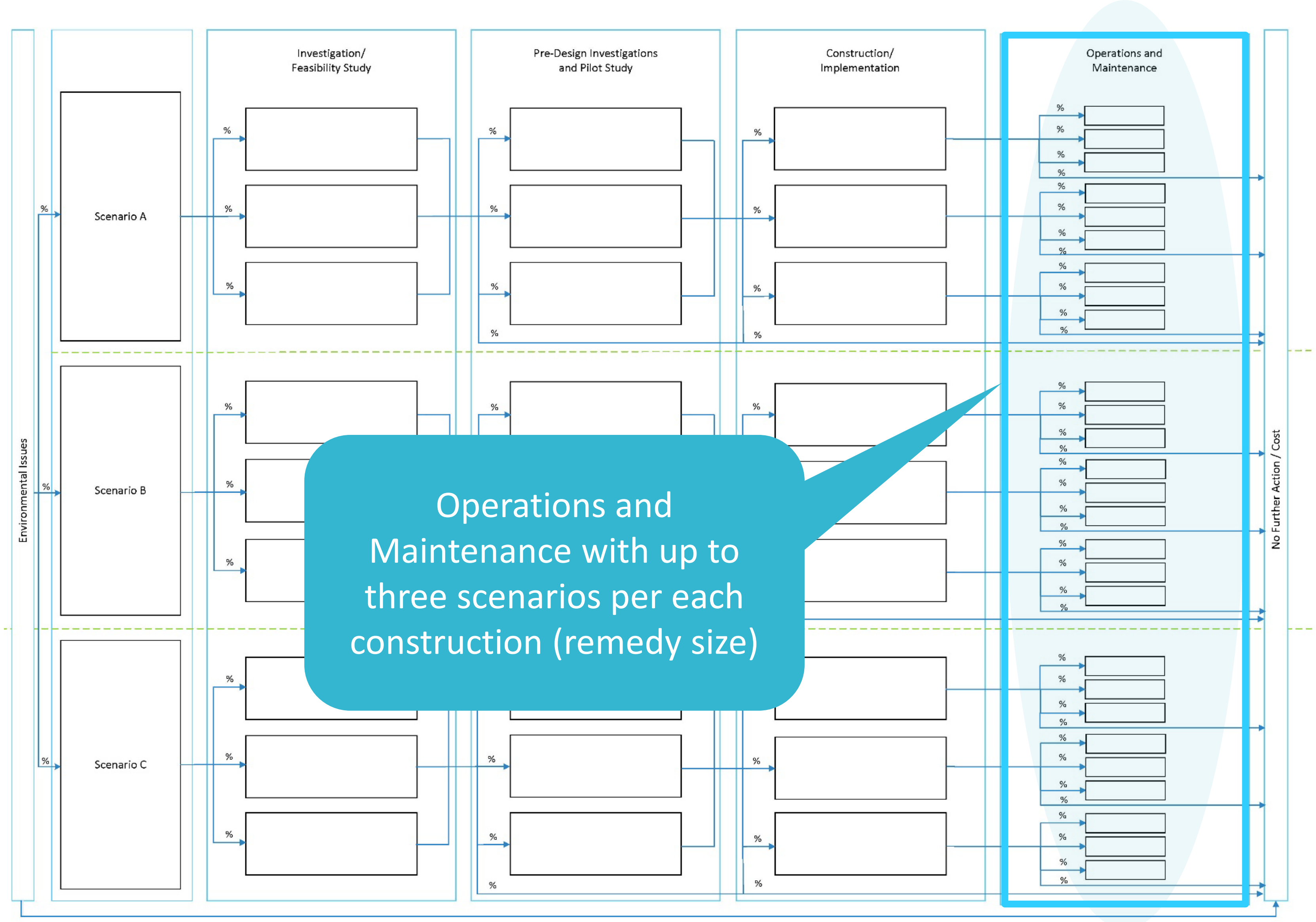
Cost model event tree example



Cost model event tree example

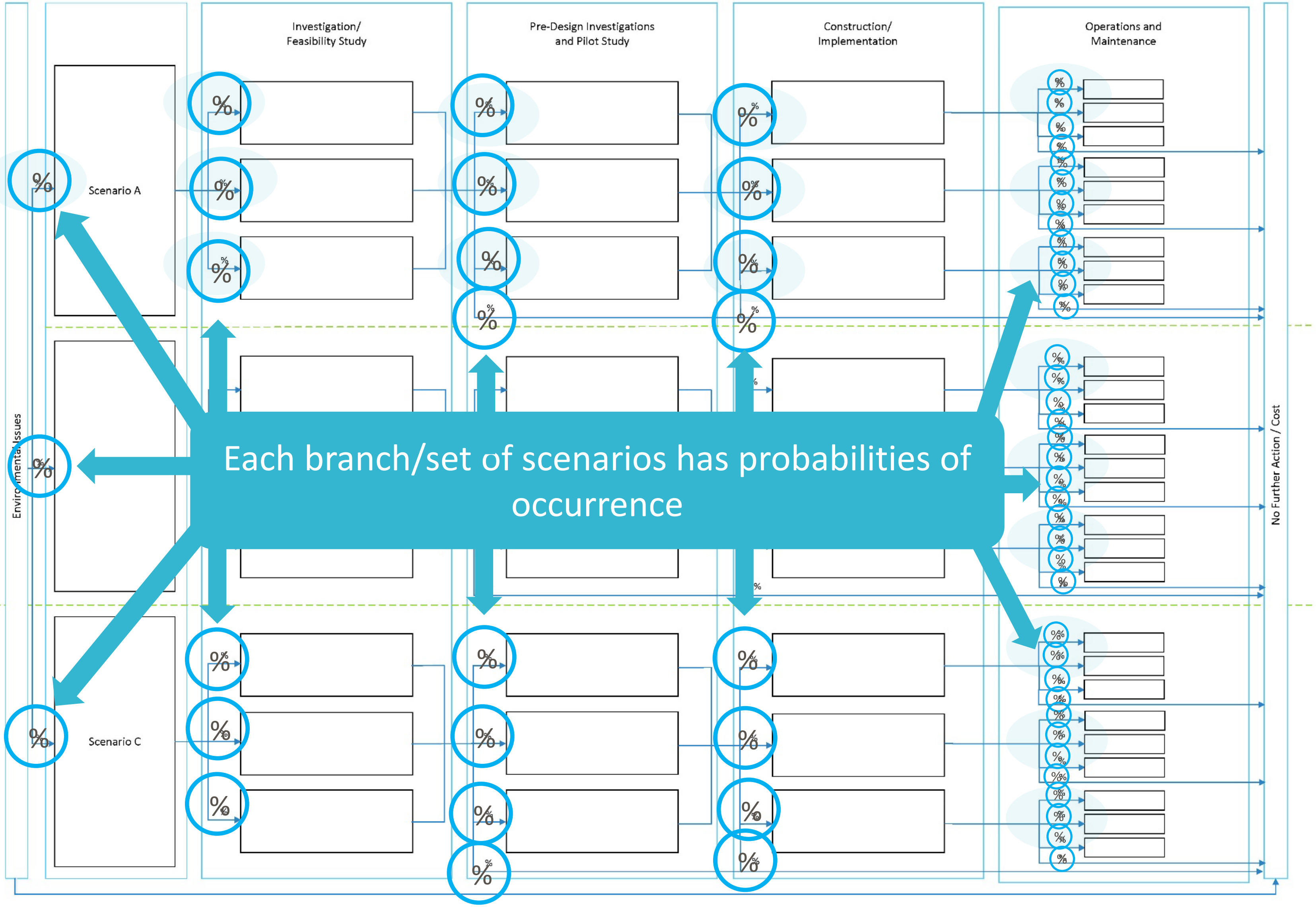


Cost model event tree example



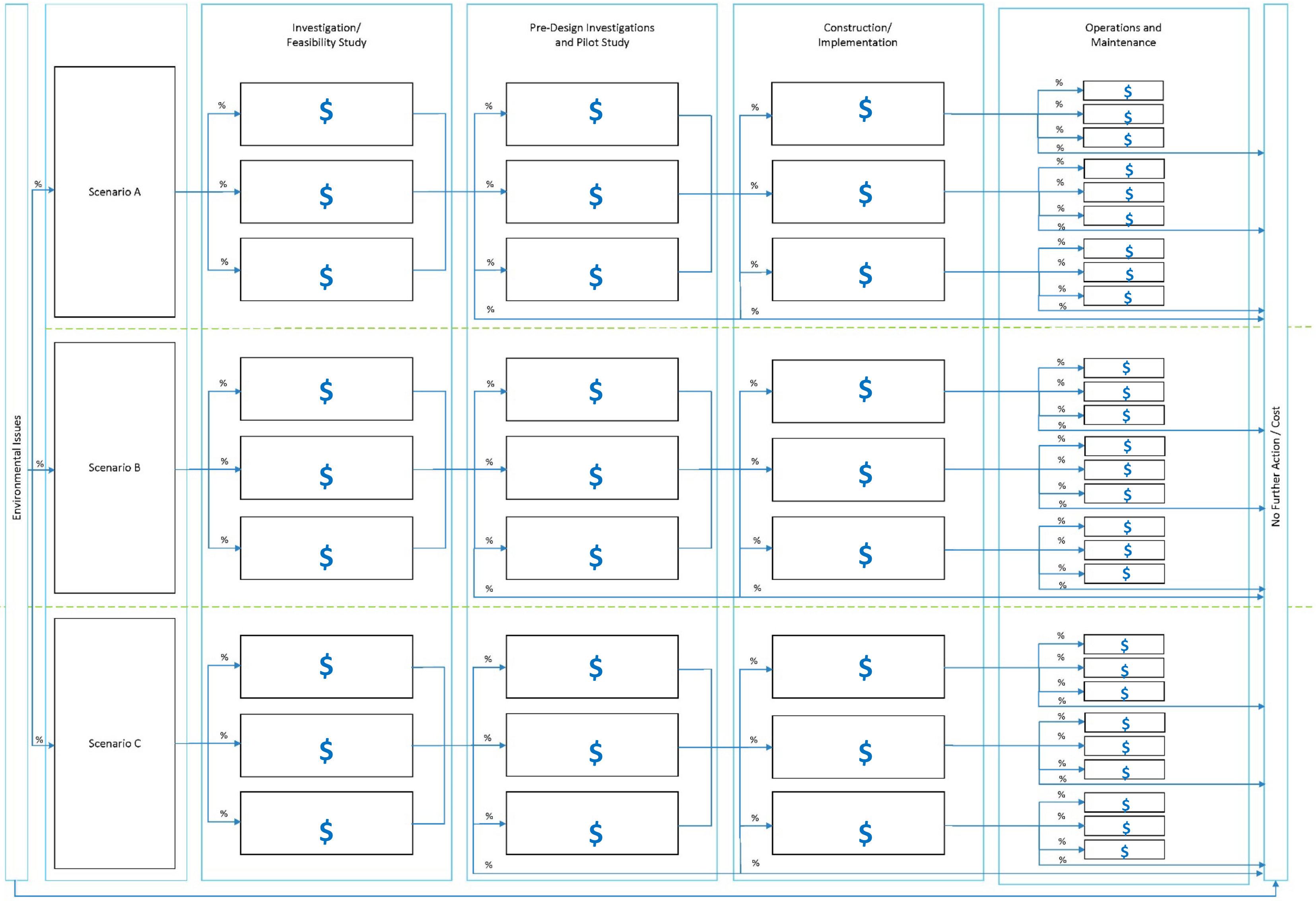
Cost model event tree example

Probability needs assigned for each branch



Cost model event tree example

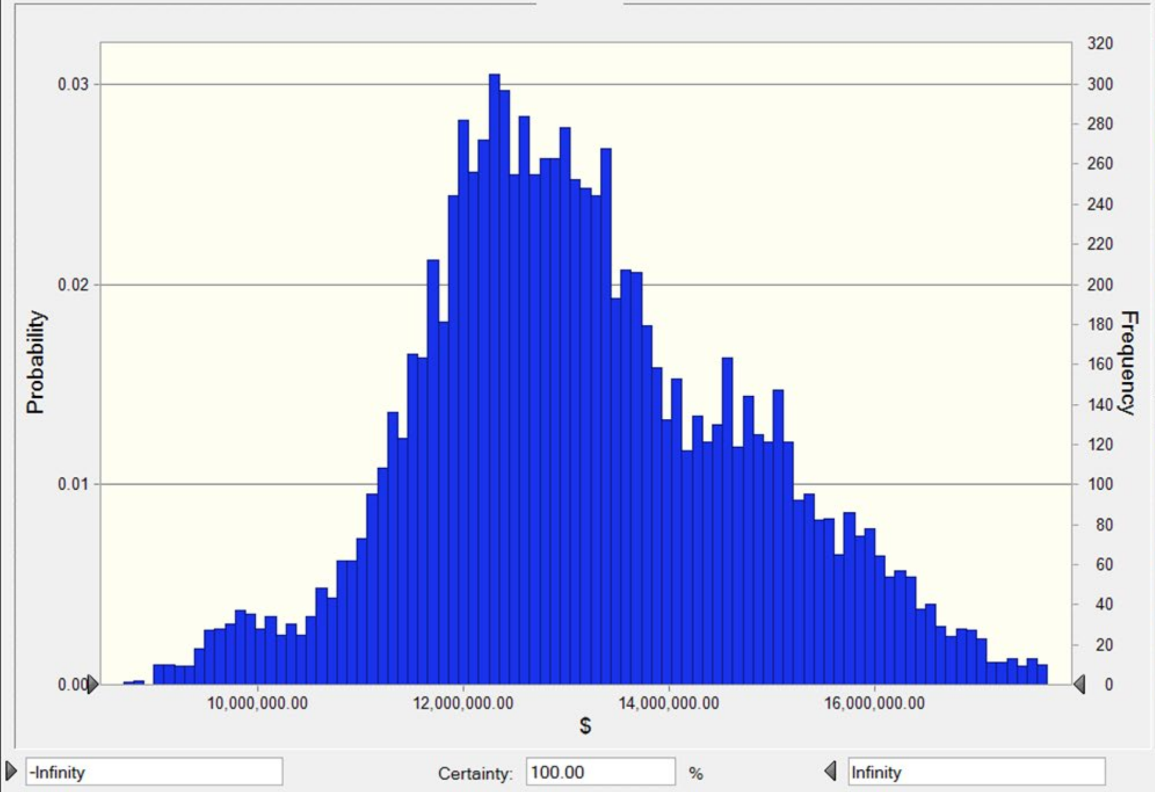
Each box is supported by a cost estimate



Distribution of Costs from Monte Carlo Simulations

- Percentiles
  - 10th to 90th
  - Median / 50th
- Expected value (mean)
- Different values may be appropriate for different purposes. Repurposing any single value should be done carefully.

10,000 Trials | Split View | 9,959 Displayed



Statistic	Forecast values
Trials	10,000
Base Case	13,300,428.20
Mean	13,184,803.05
Median	12,993,539.70
Mode	11,804,192.70
Standard Deviati	1,606,038.65
Variance	2,579,360,159.09
Skewness	0.3223
Kurtosis	2.96
Coeff. of Variatio	0.1218
Minimum	8,597,125.70
Maximum	18,315,189.60
Mean Std. Error	16,060.39

Percentile	Forecast values
0%	8,597,125.70
10%	11,340,586.70
20%	11,903,451.90
30%	12,271,537.70
40%	12,624,956.70
50%	12,992,906.70
60%	13,383,247.20
70%	13,878,124.60
80%	14,604,837.90
90%	15,426,639.10
100%	18,315,189.60

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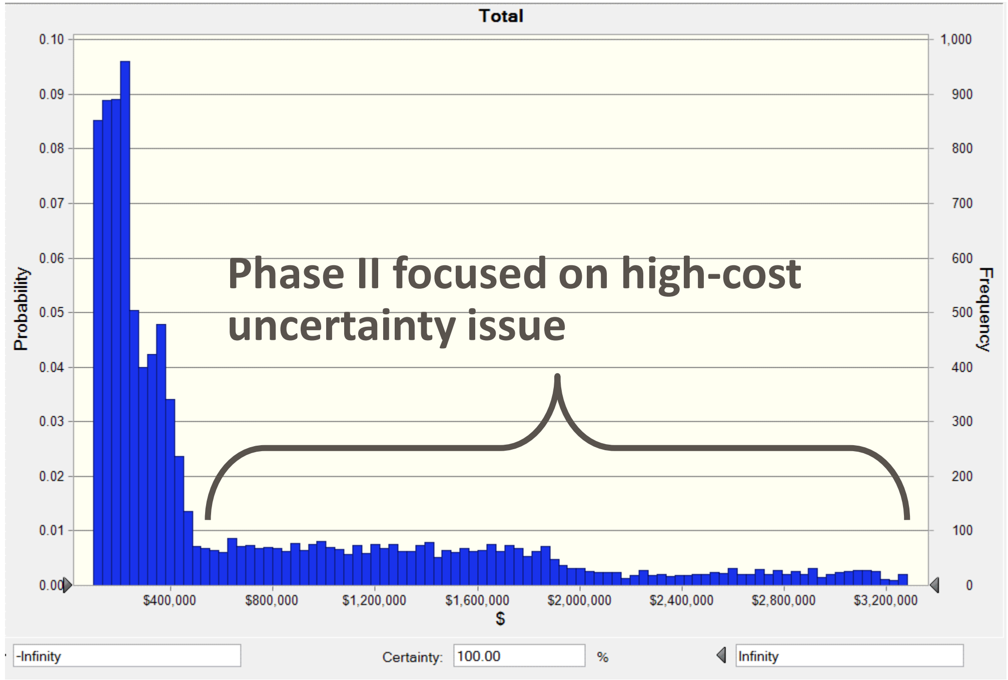
Example – Acquisition due diligence

- A buyer negotiating the purchase of manufacturing facility struggled to quantify the meaning of environmental conditions described in a Phase I ESA completed by others
- Simple probabilistic modeling and sensitivity analysis quantified (and shows in graphics) the range of potential liabilities
- Potential *lower-probability, high-cost event* would have made deal untenable for buyer
- Buyer saved time and money during remaining due diligence period by focusing Phase II ESA **only on issues related to the high-cost uncertainty issue** (potential off-site groundwater migration)



Considerations for cost allocation

Example equitable allocation factors based on Section 113(f)(1) of CERCLA and the "Gore Factors" and "Torres Factors" used in a recent Superfund allocation model:

Remedy Cost Drivers

- Degree to which a party's waste and/or operations are likely to have contributed to the contamination that is driving the remedy (remedy cost driver analysis).
- Degree to which the parties have differentially contributed to the remedy-driving contamination in different areas
- Degree to which parties have differentially contributed to distinguishable remedial components, e.g., dredging of soft sediments, capping of native sediments, in situ stabilization/solidification (ISS), etc.
- Degree to which different contaminants of concern (COCs) are differentially contributing to the costs of the remedy

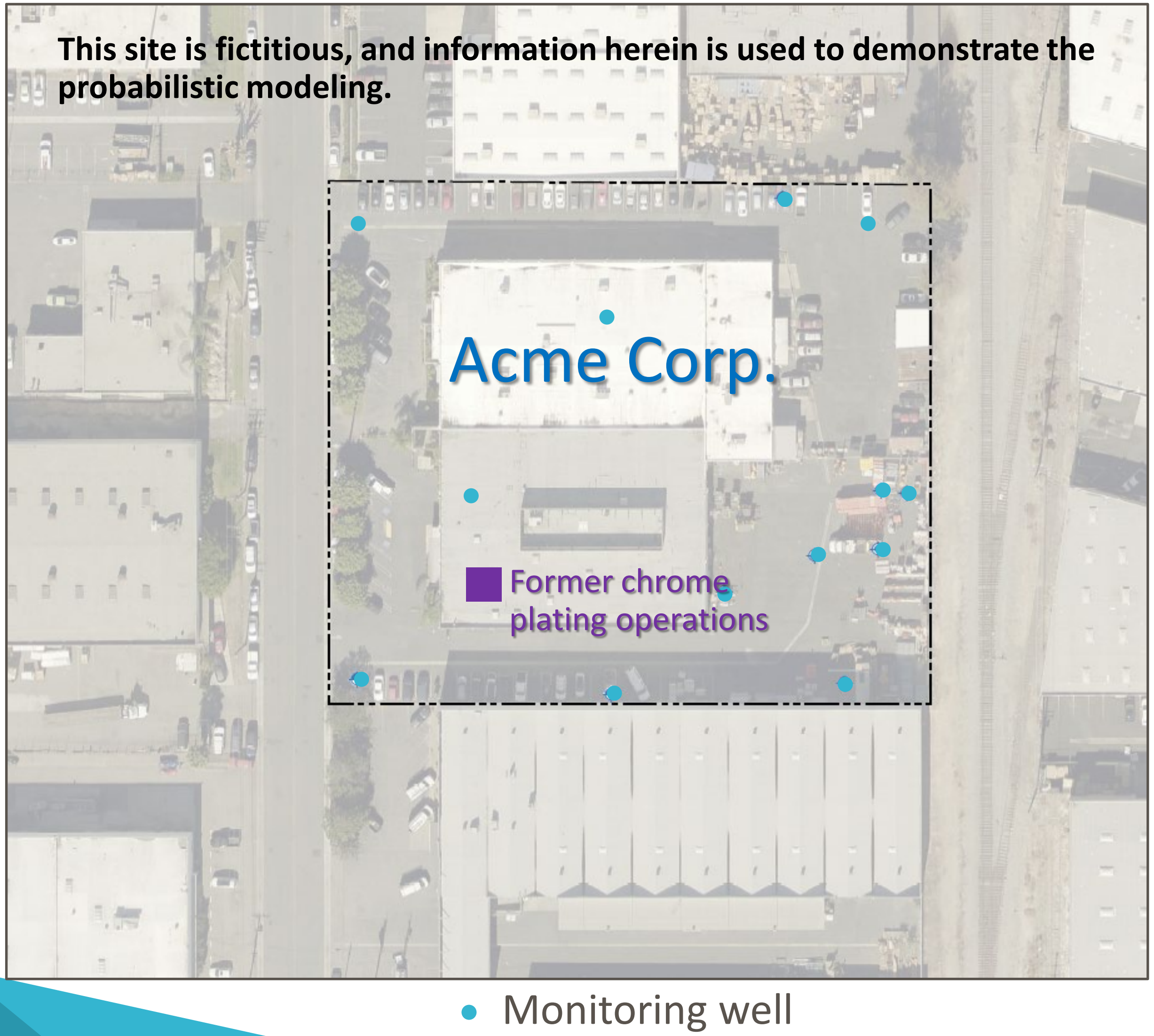
Considerations for cost allocation (continued)

Other Allocation Considerations

- Status of the parties under Section 107 of CERCLA as owners, operators, generators, and transporters
- Whether a party's waste generating and/or disposal activities were conducted in violation of applicable law, governmental orders, enforcement directives or consent agreements, orders or decrees
- Avoided costs as a result of waste disposal, directly or indirectly
- Economic benefit to be realized as a result of the remediation
- Degree to which uncertainty affects the application of the above factors

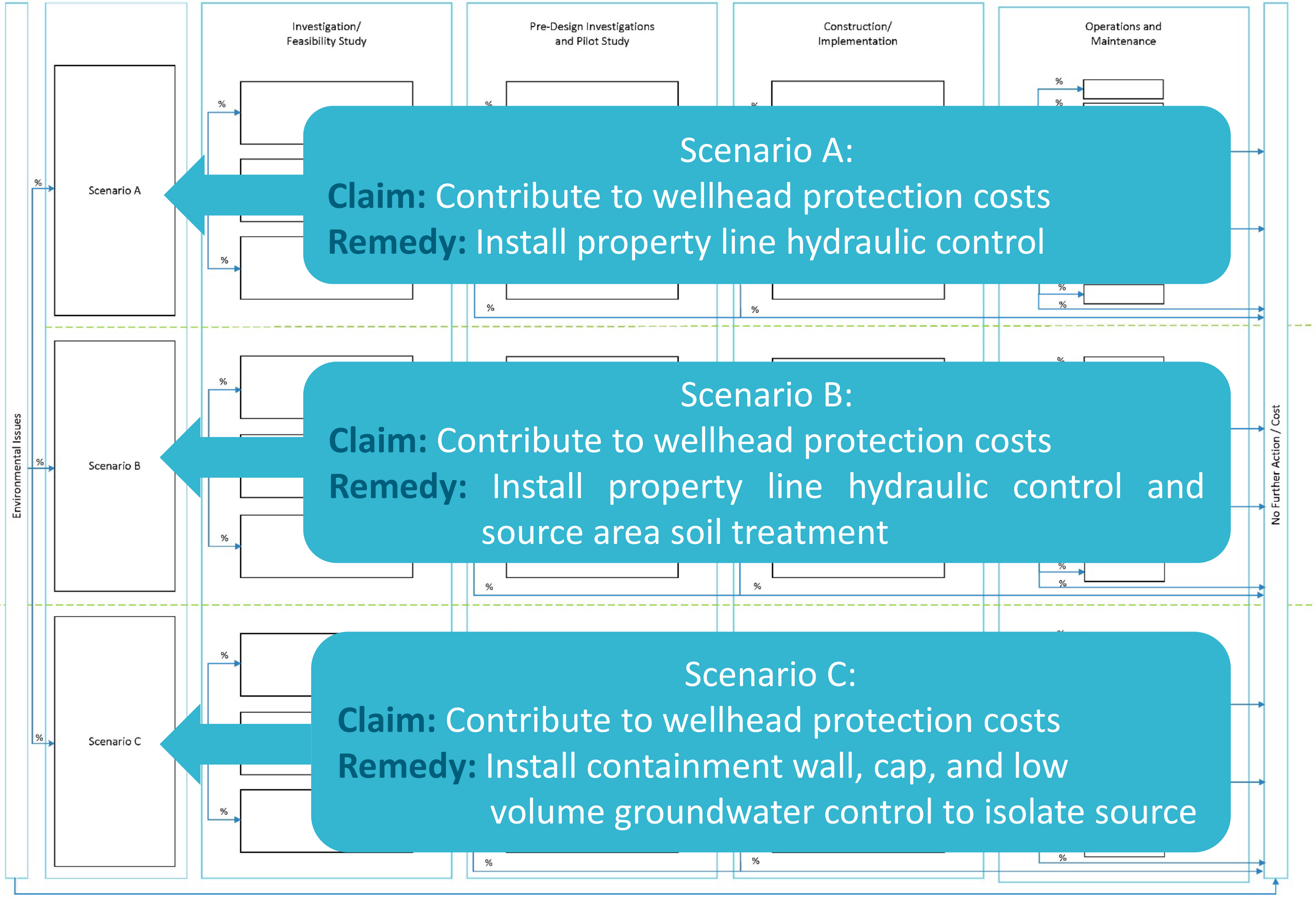
PFAS Cost model – theoretical case

New challenges – Acme Corp.



- Acme Corp operations is suspected contributor of PFAS in aquifer
- Water purveyor files a $750M lawsuit against Acme Corp. and others for wellhead protection costs
- Agency issues an order to investigate and remediate PFAS compounds associated with the former chrome plating operations
- A cost model was constructed to provide a range of costs, for Acme Corp. to evaluate options and inform management strategy and planning

Three Scenarios – Acme Corp.



Scenario A:

Claim: Contribute to wellhead protection costs

Remedy: Install property line hydraulic control

Scenario B:

Claim: Contribute to wellhead protection costs

Remedy: Install property line hydraulic control and source area soil treatment

Scenario C:

Claim: Contribute to wellhead protection costs

Remedy: Install containment wall, cap, and low volume groundwater control to isolate source

This site is fictitious and information herein are used to demonstrate the Monte Carlo method

Input variables – claim (well head protection cost)

Two variables

- Total claim value: approximately $650M (low), $750M (med), and $850M (high) split into phases
- Claim allocation: uniformly between 2.5% and 7.5%

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Input variables – PFAS Remedy

	Investigation, feasibility and pilot studies	Design and construction	O&M and monitoring
Scenario A: Install property line hydraulic control	• # of wells • # of GW samples	• # of recovery wells and length of conveyance pipe • Treatment technology (carbon and resin)	• Treatment technology • # of wells to be sampled
Scenario B: Install property line hydraulic control and source area soil treatment	• # of wells • # of GW samples • # of borings • # of soil samples	• # of recovery wells and length of conveyance pipe • Treatment technology (carbon and resin) • Volume of excavation	• Treatment technology • # of wells to be sampled
Scenario C: Install containment wall, cap, and low volume groundwater control to isolate source	• # of wells • # of GW samples • # of borings • # of soil samples	• Area of containment • # of recovery wells • GW volume to be treated	• Volume of water treated • # of wells to be sampled

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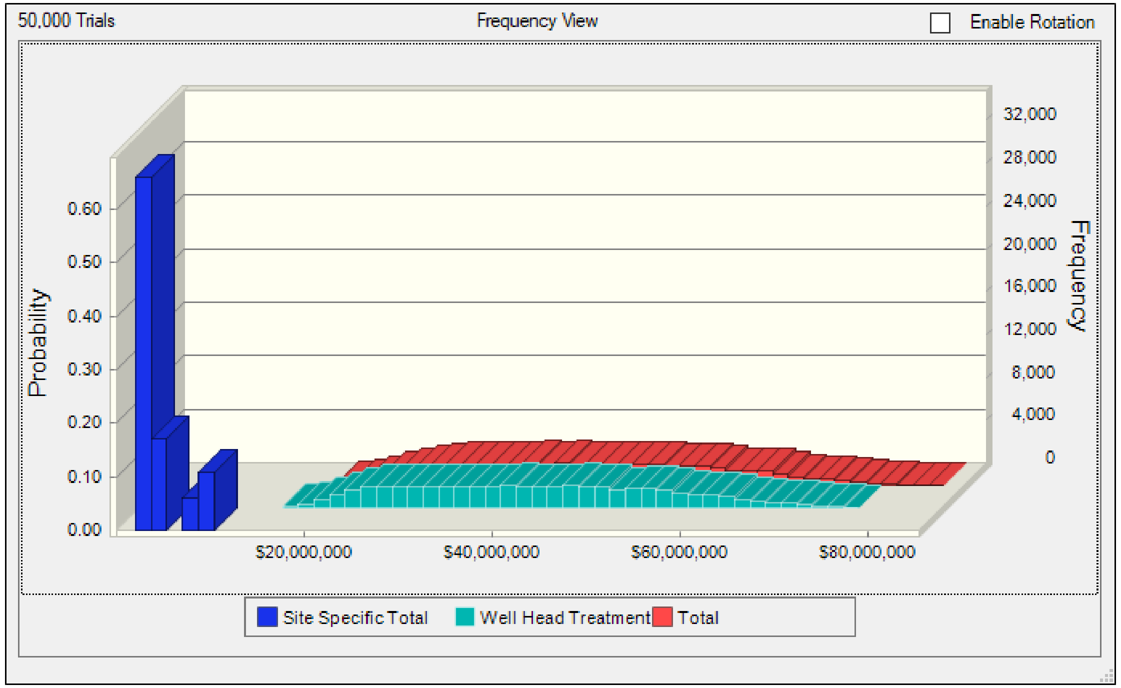
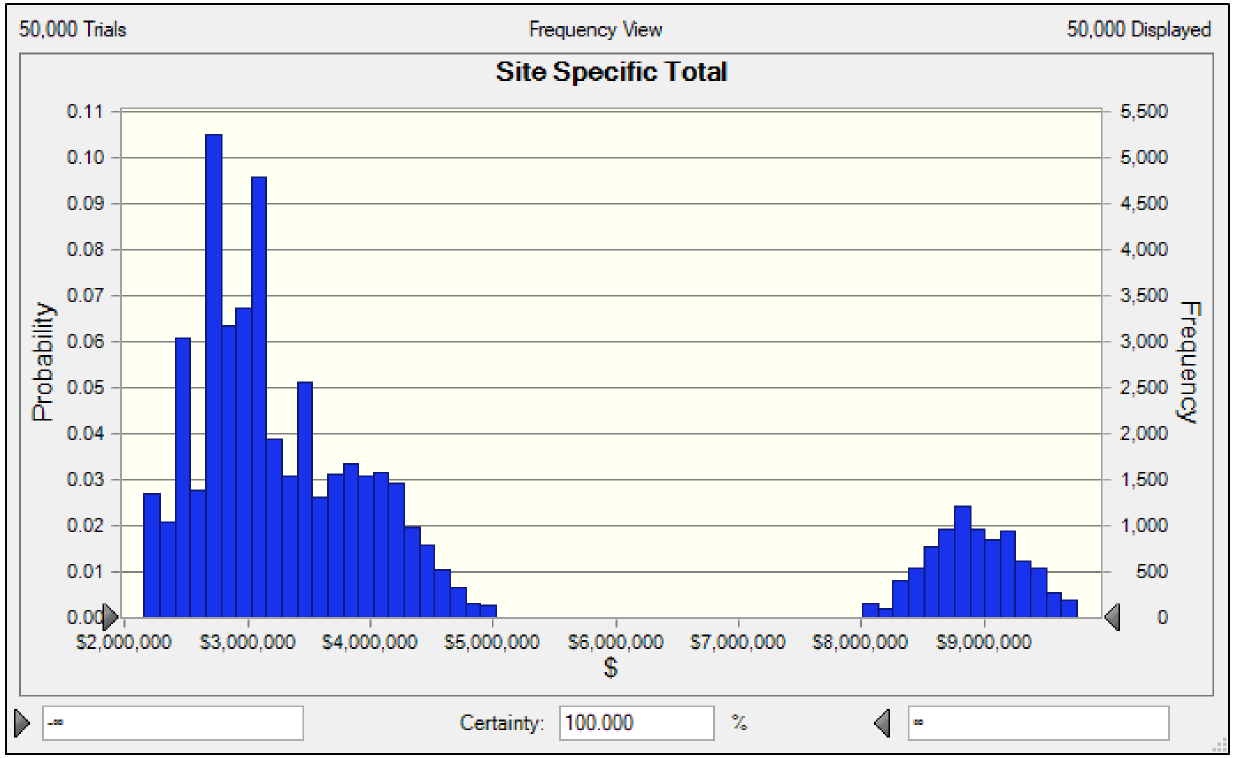
Results of Monte Carlo simulations – Acme Corp.

Percentile	Site Specific Total	Well Head Treatment	Total
0%	$2,155,890	$16,259,197	$18,733,192
10%	$2,492,875	$24,621,496	$28,550,000
20%	$2,726,240	$28,786,148	$32,946,475
30%	$2,864,125	$32,974,417	$37,200,654
40%	$3,087,425	$37,146,767	$41,310,743
50%	$3,273,325	$41,208,321	$45,399,733
60%	$3,575,344	$45,407,389	$49,557,444
70%	$3,969,144	$49,568,387	$53,855,790
80%	$4,484,494	$54,287,155	$58,447,109
90%	$8,829,219	$59,873,781	$64,239,225
100%	$9,752,256	$74,997,992	$84,385,962

Statistic	Site Specific Total	Well Head Treatment	Total
Mean	$4,185,183	$41,803,336	$45,988,519
Median	$3,273,325	$41,208,322	$45,400,689
Standard Deviation	$2,219,888	$13,096,604	$13,292,770
Skewness	1.52	0.2041	0.2035
Kurtosis	3.72	2.15	2.2
Coeff. of Variation	0.5304	0.3133	0.289
Minimum	$2,155,890	$16,259,197	$18,733,192
Maximum	$9,752,256	$74,997,992	$84,385,962
Mean Std. Error	$9,928	$58,570	$59,447

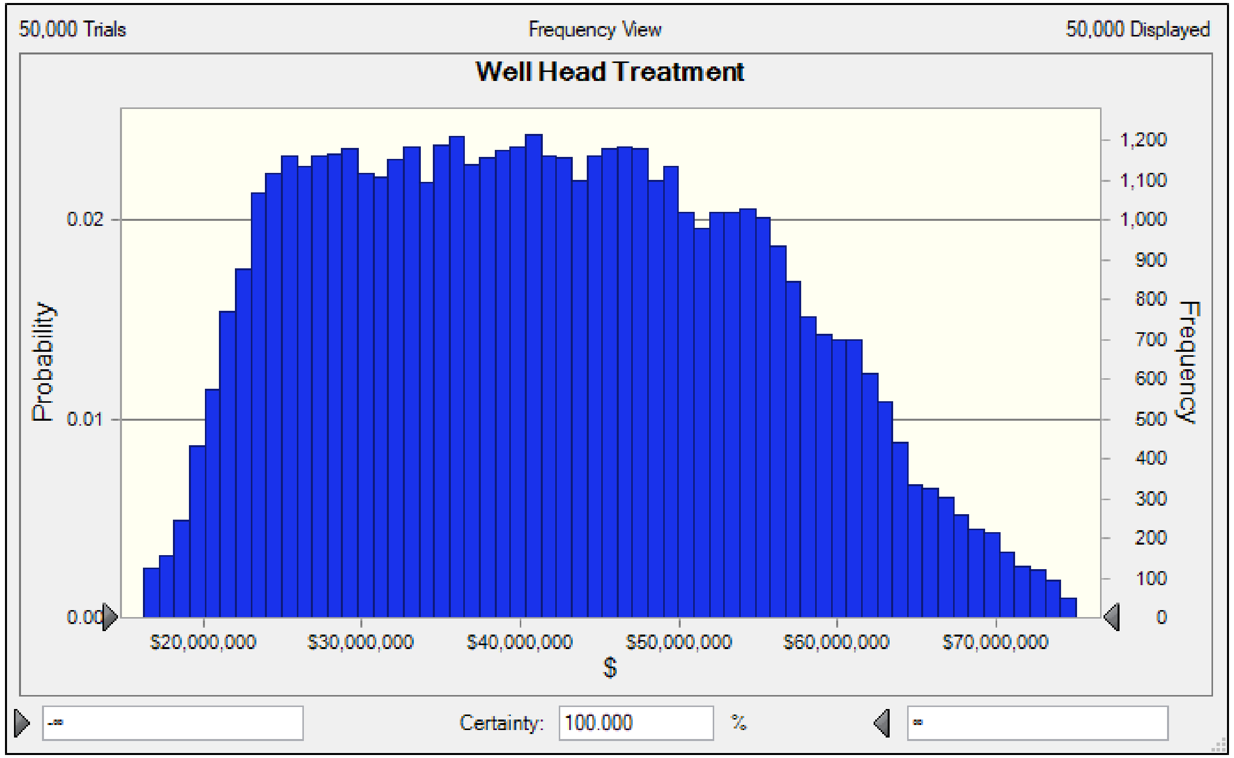


Results of Monte Carlo Simulations of Scenarios



PFAS remedy cost Range

Third Party claim range



Questions and discussions

Lloyd S. Ross
Haley & Aldrich, Inc.
LRoss@HaleyAldrich.com
1.216.706.1327

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