August Mack
ENVIRONMENTAL

Use of Monte-Carlo Analysis to Estimate Cost to Closure for Environmental Sites

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EXPERTISE. INNOVATION. COMMITMENT.

What is “Closure”?

- Environmental Closure:
  - *The point of the project where no additional investigation or remediation activities are required and the regulatory agency has provided a letter to that affect*.
  - No Further Action Letter, Relief of Liability, etc.
  - Can include a “tail” – e.g., maintaining site restrictions

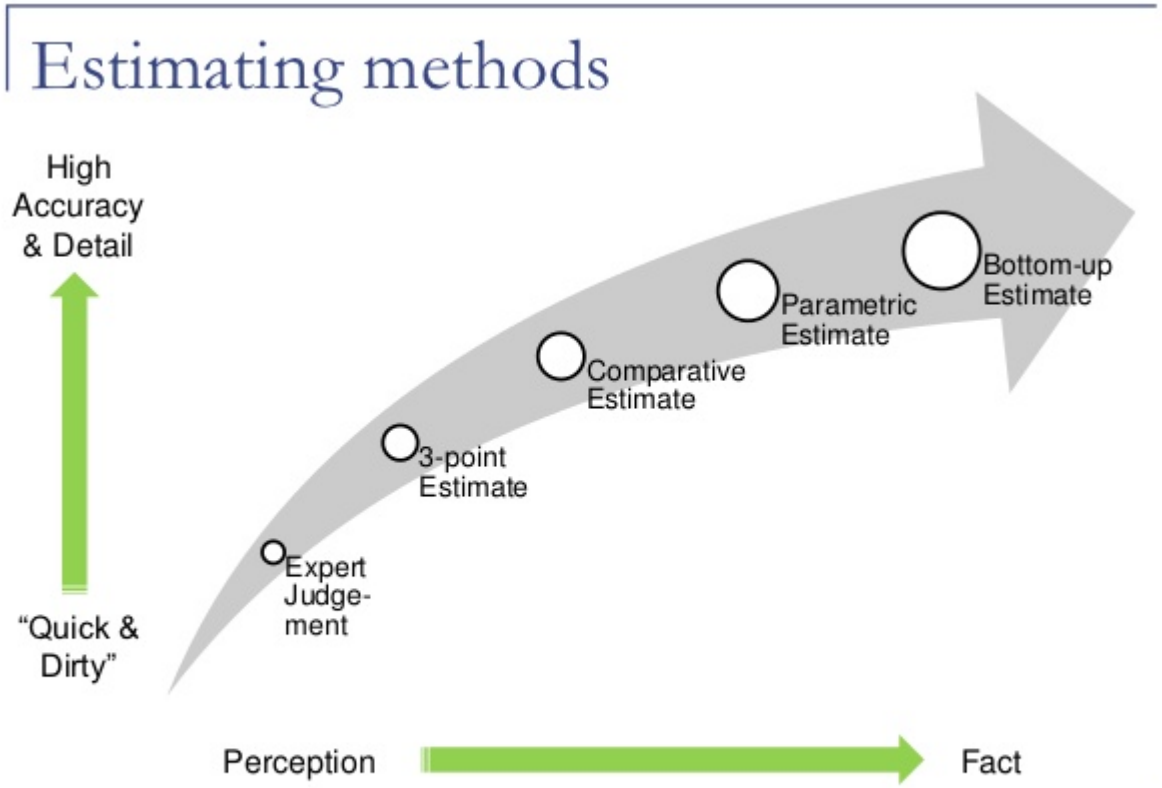
Why Are Future Environmental Costs Difficult to Estimate?

- Costs-to-closure for sites are often wanted early in a project life so before extensive data has been collected.
- Decisions of regulators can dramatically impact the cost and length of time for closure.
- Low Probability – High Cost items are difficult to capture in estimates.
- Balancing closure speed and cost can be complex and difficult to evaluate.

What is an estimate?

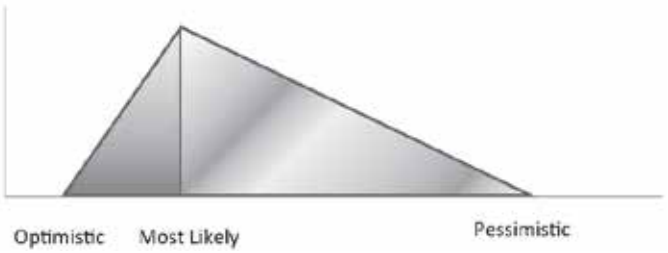
- Approximation of project time and cost
  - May be refined through project life cycle
  - May be developed with a number of tools and techniques

What is an estimate?



What is an estimate?

- Expert Judgement
  - A “guess” based on experience in the subject matter
- 3-Point Estimate
  - Realistic (most likely)
  - Best Case (optimistic)
  - Worst Case (pessimistic)

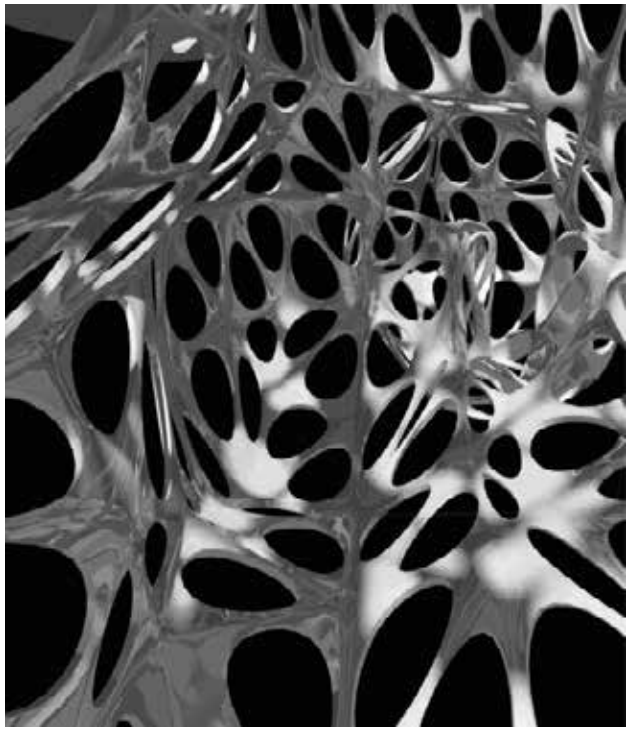


What is an estimate?

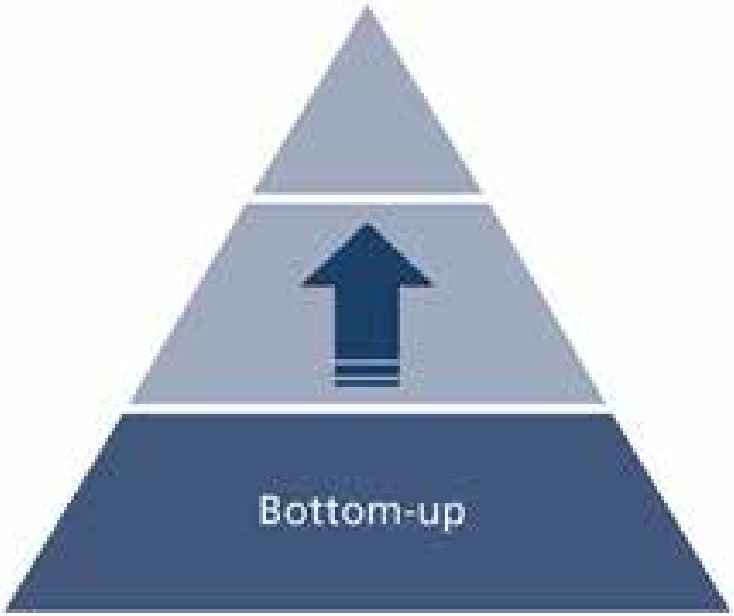
- Comparative Estimating
  - Uses actual costs of similar projects and make adjustments for differing conditions
  - Ex. If I can make 3 in 5 days I can make 6 in 9 days

What is an estimate?

- Parametric Estimating
  - Based on historical averaged data and statistical relationships between factors
  - Ex. 10% of total project cost will be spent on project management
  - Ex. Every 1 hour spent in the field will require 3 office hours to document



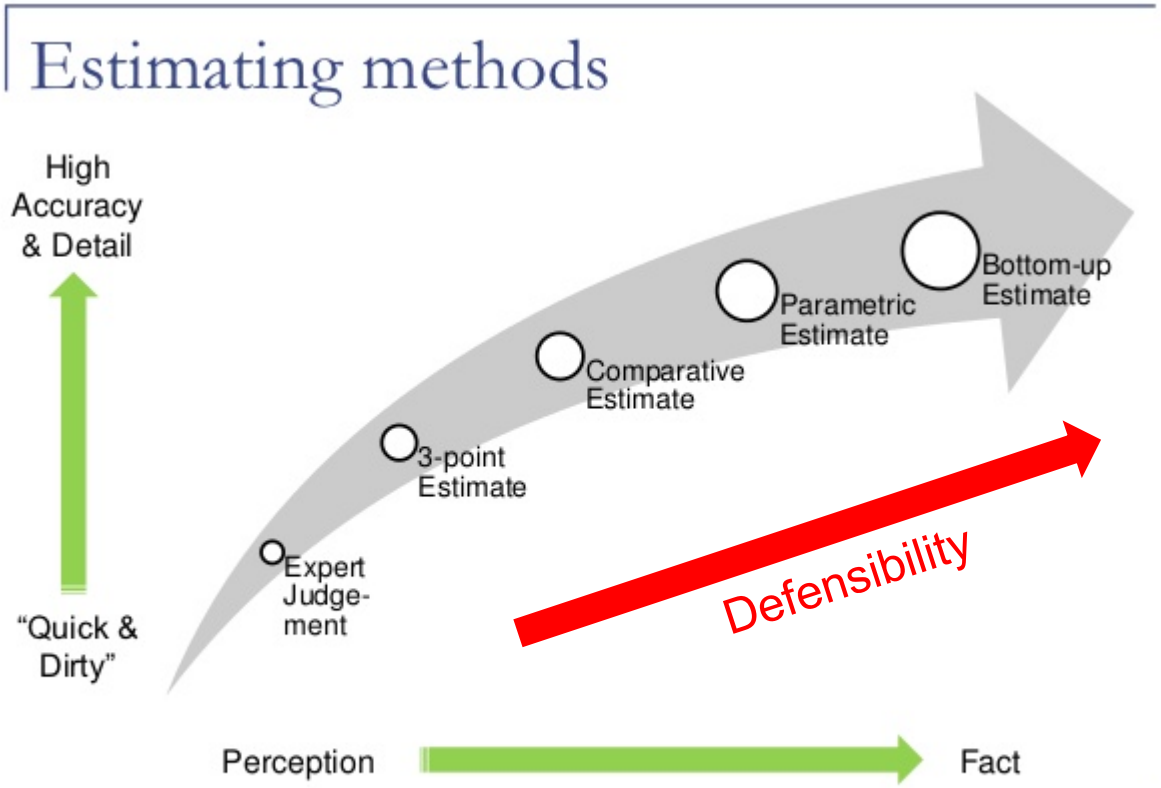
What is an estimate?



Bottom-up Estimating

- Uses detailed costs of components added together to derive total project cost
- Requires that all project components be accounted for

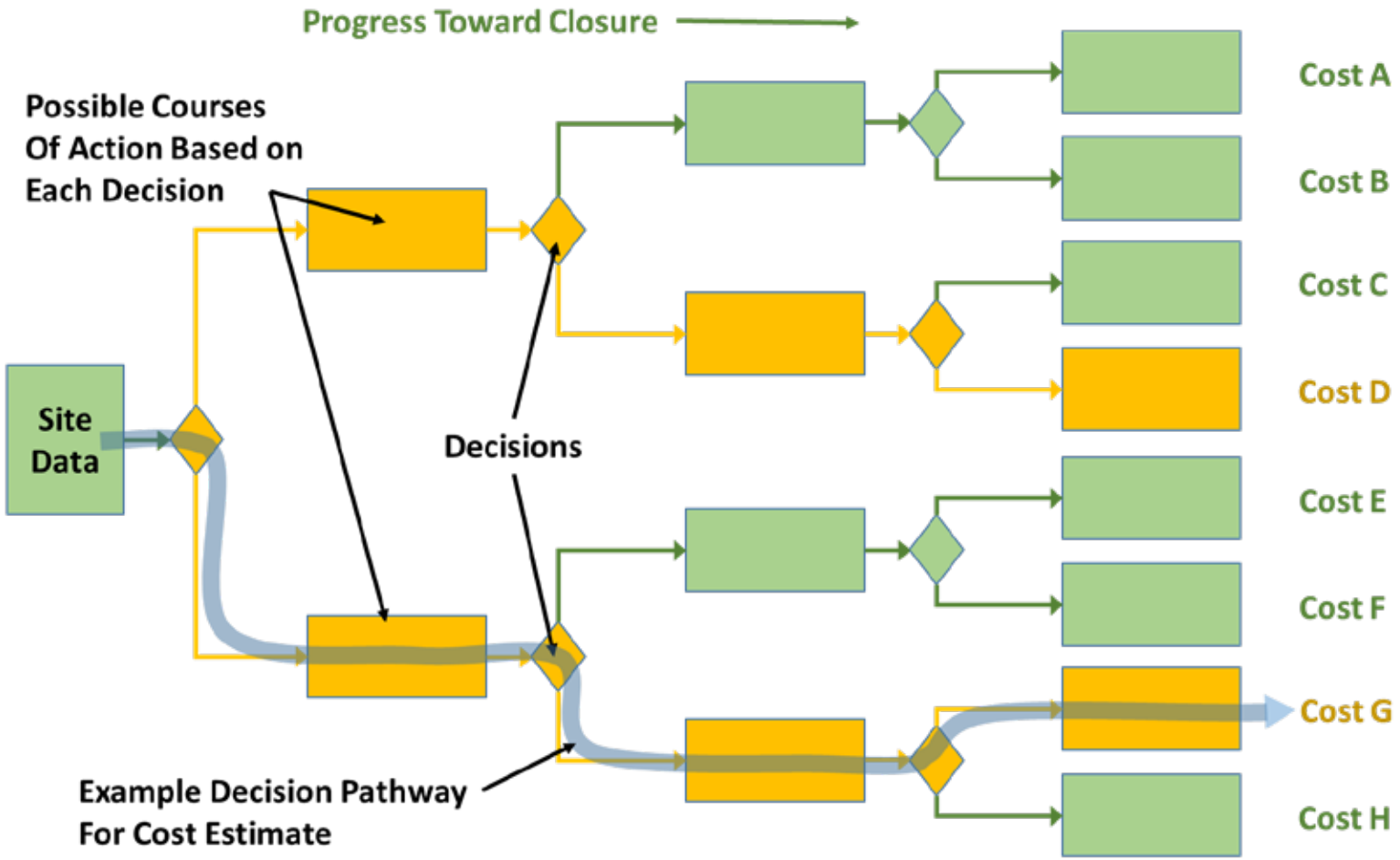
What is an estimate?



Problems With Common Cost Estimation Methods

- Early estimates are usually given in ranges.
  - Examine one or two options.
  - Uncertainty is unknown or overlooked
  - Miss low probability – high risk items
  - Process is not very transparent.
  - Lack of confidence

Traditional Cost Estimation Scenario



What Would We Like to Be Able To Do?

- Simultaneously evaluate the results of multiple possible scenarios
- Account for a large number of dependent and independent variables

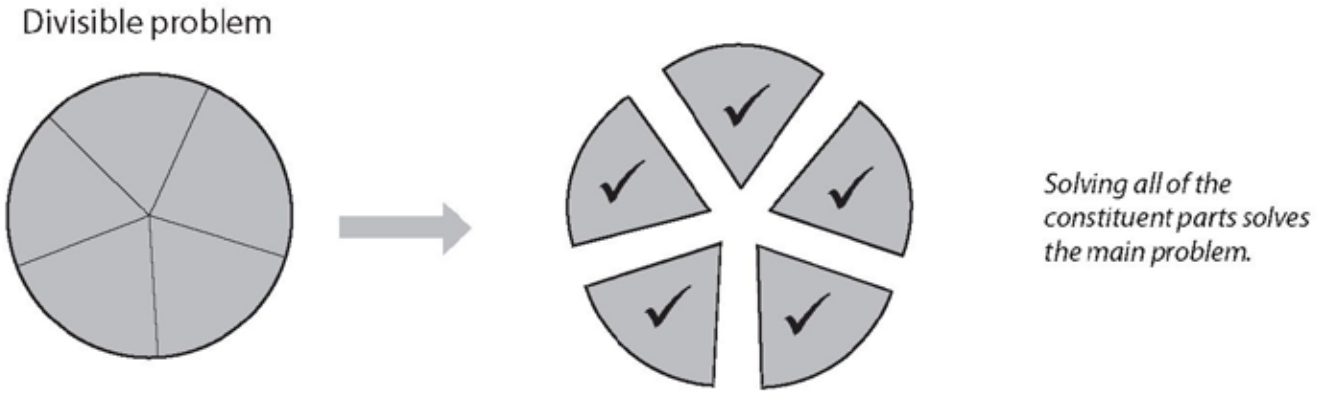
- Develop statistically defensible estimates of remedial costs
- Find a way to account for low-probability high value options
- Speed of 3-Point and the defensibility/ transparency of Bottom-up

What is Monte Carlo Simulation?

- Modern Computer methods developed at Los Alamos in 1940s
  - "Monte-Carlo" was the project code name
  - Developed to track neutrons
- Inspired by thinking about solitaire

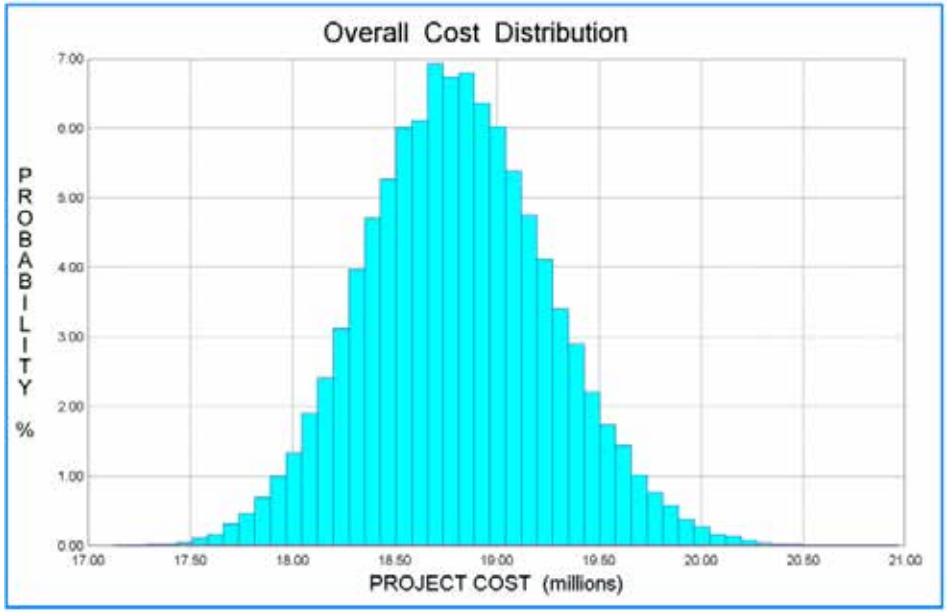
How Does Monte Carlo Simulation Work?

1. Problem is divided up into individual components (tasks) with known (estimated) uncertainty



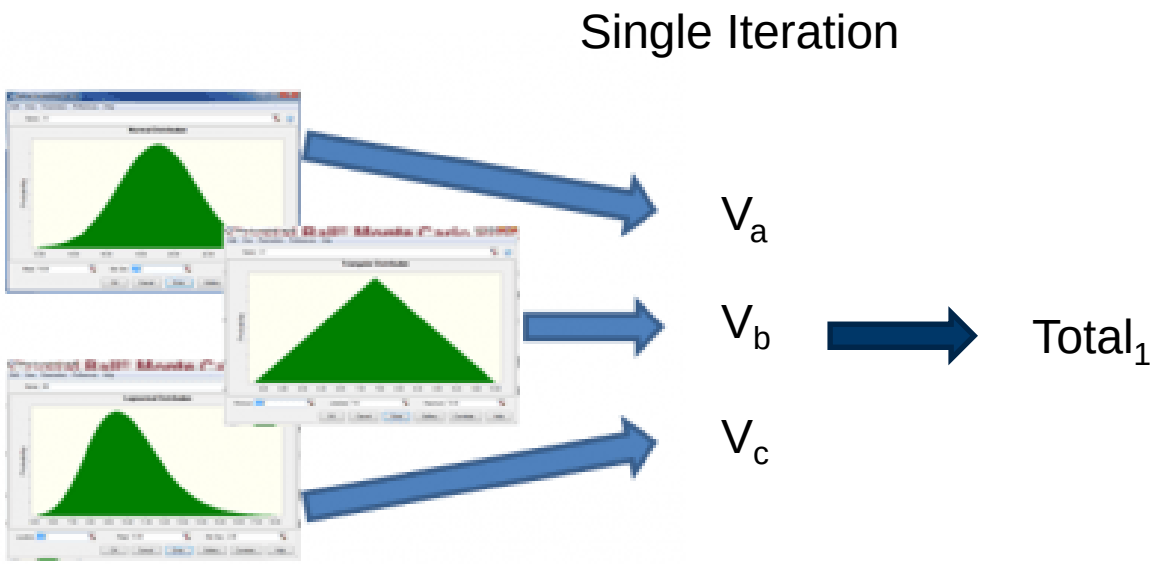
How Does Monte Carlo Simulation Work?

2. A range of values (costs) is defined for each component along with the probability of any single value being selected (probability distribution)



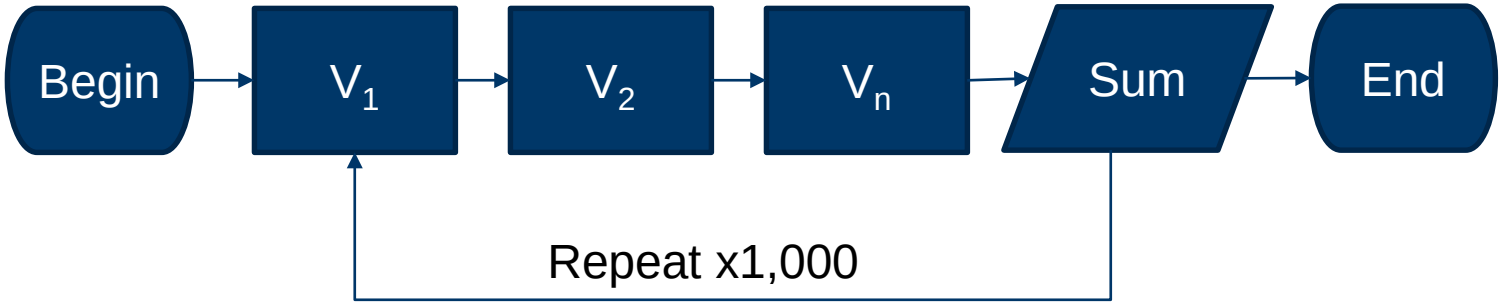
How Does Monte Carlo Simulation Work?

3. The simulation randomly selects a value from each probability distribution and combines them to create a possible outcome

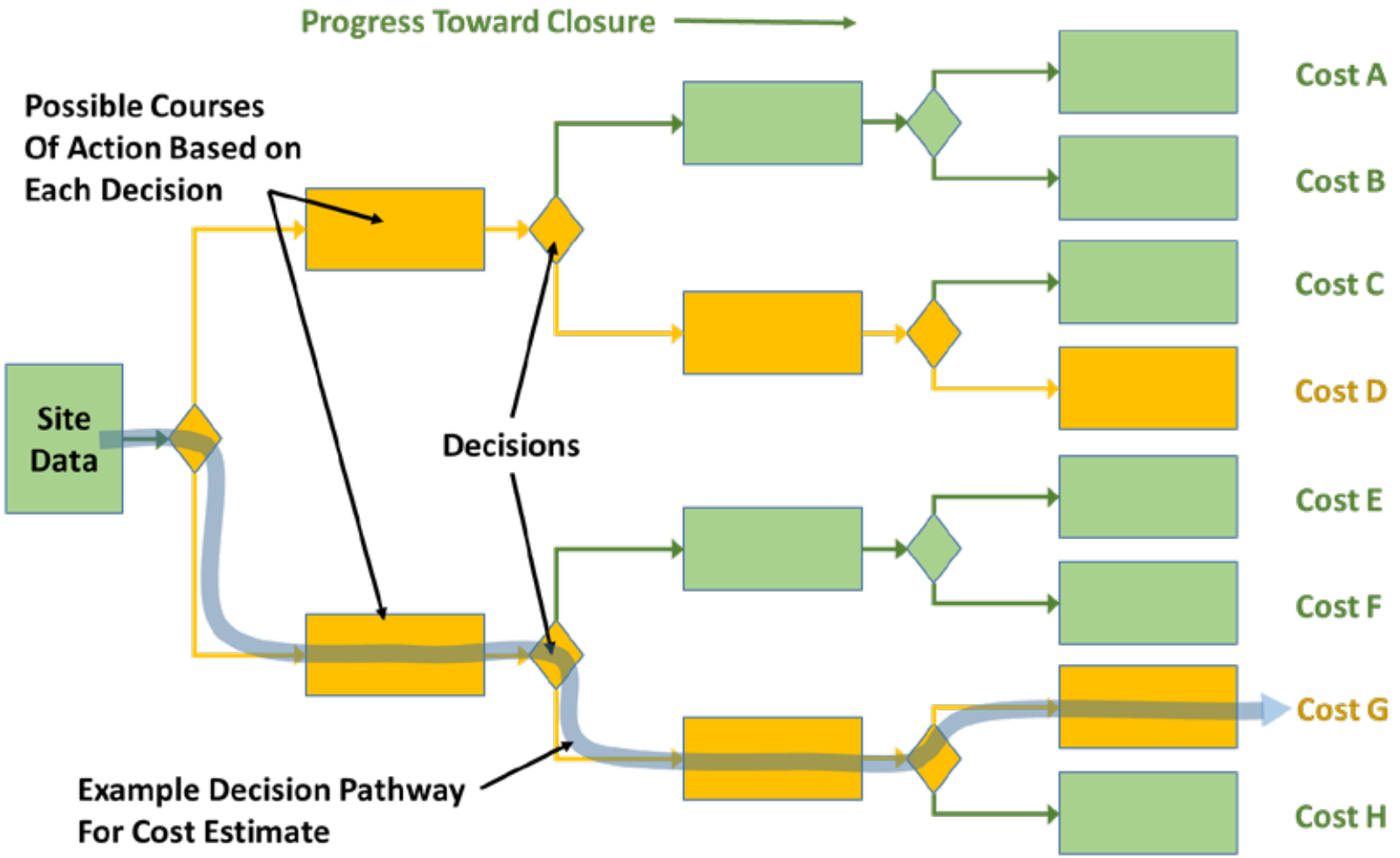


How Does Monte Carlo Simulation Work?

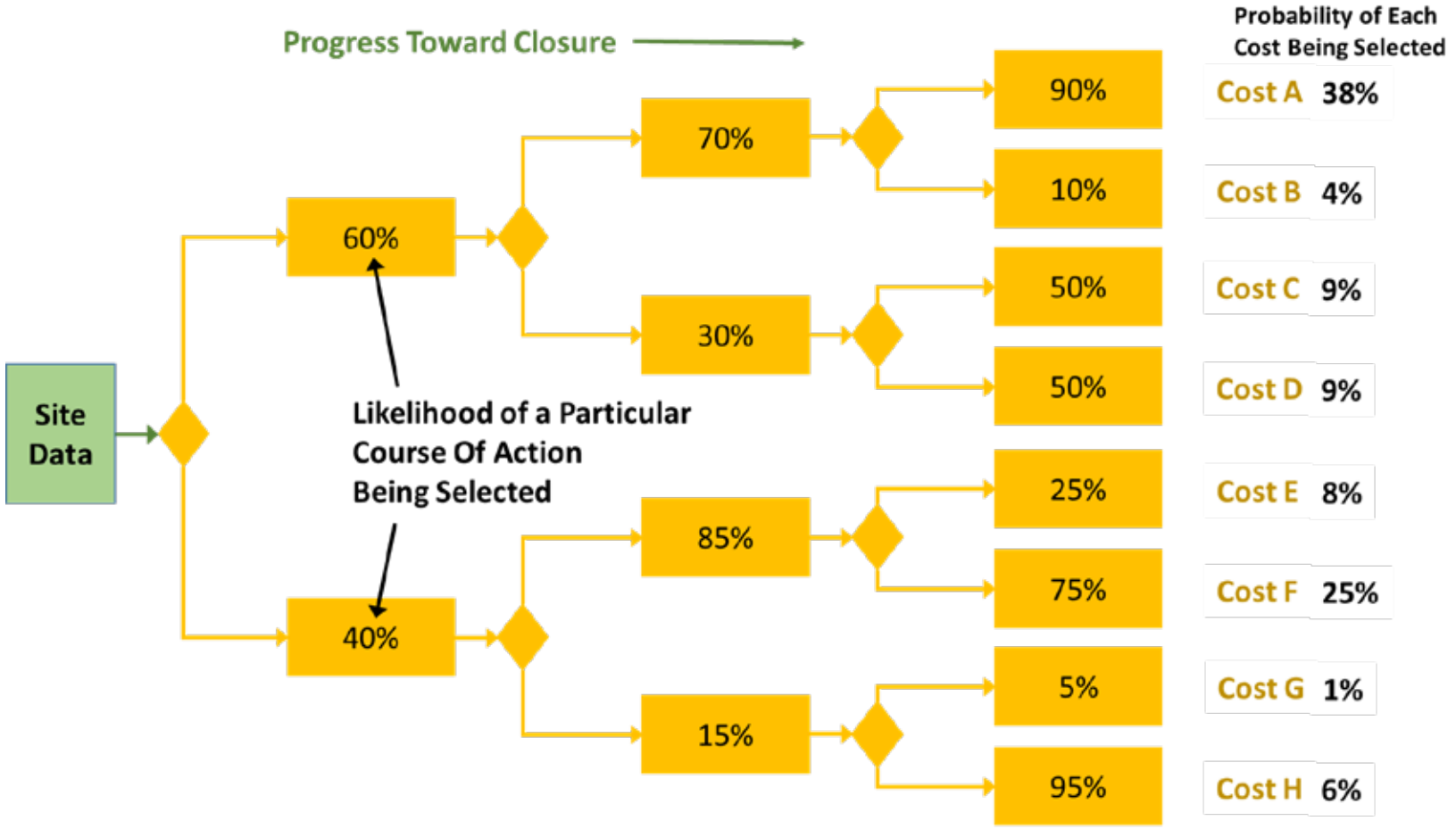
4. The simulation may be rerun thousands of times to create a probability distribution of possible outcomes



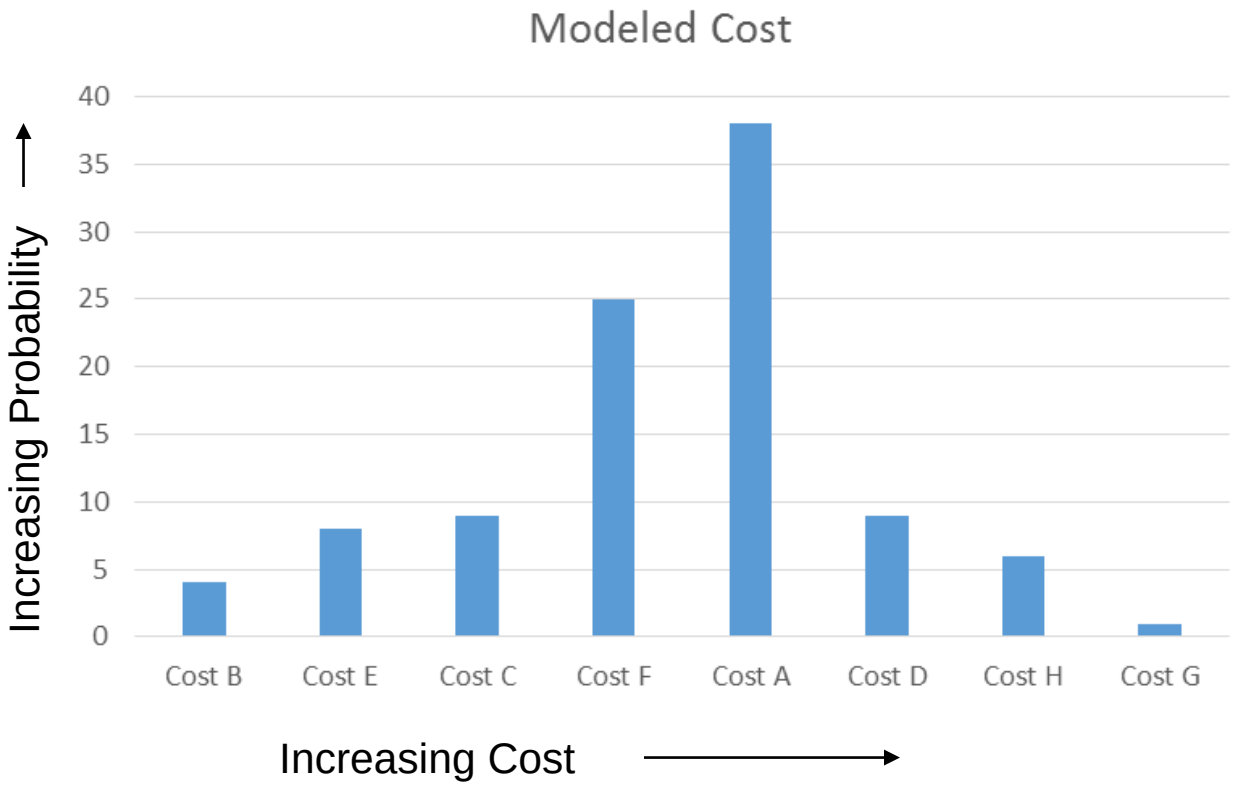
Traditional Cost Estimation Scenario



Monte-Carlo Cost Modeling

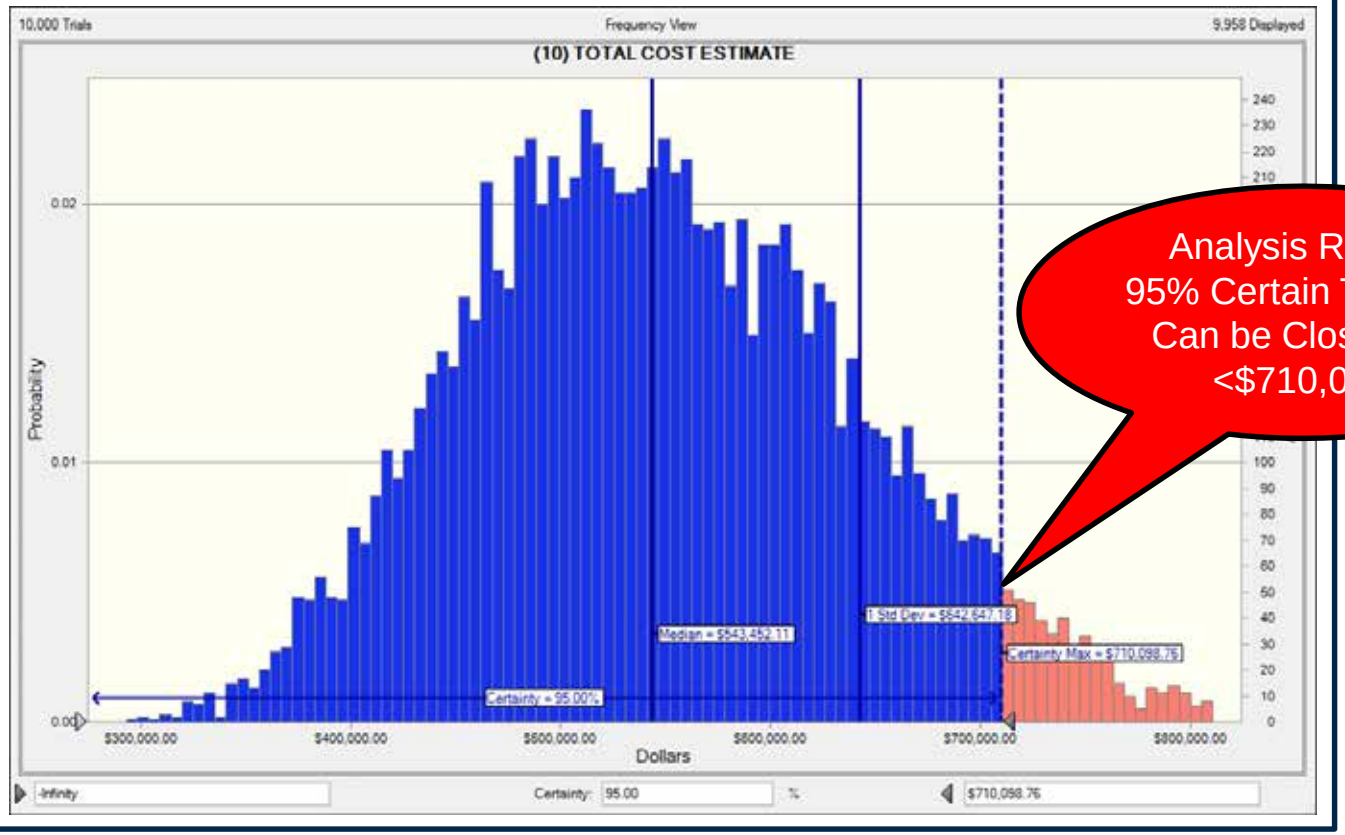


Monte-Carlo Cost Modeling



Total Modeled Cost Distribution

Final Scenario Output After 30,000 Iterations



Analysis Result:
95% Certain The Site Can be Closed for <$710,000

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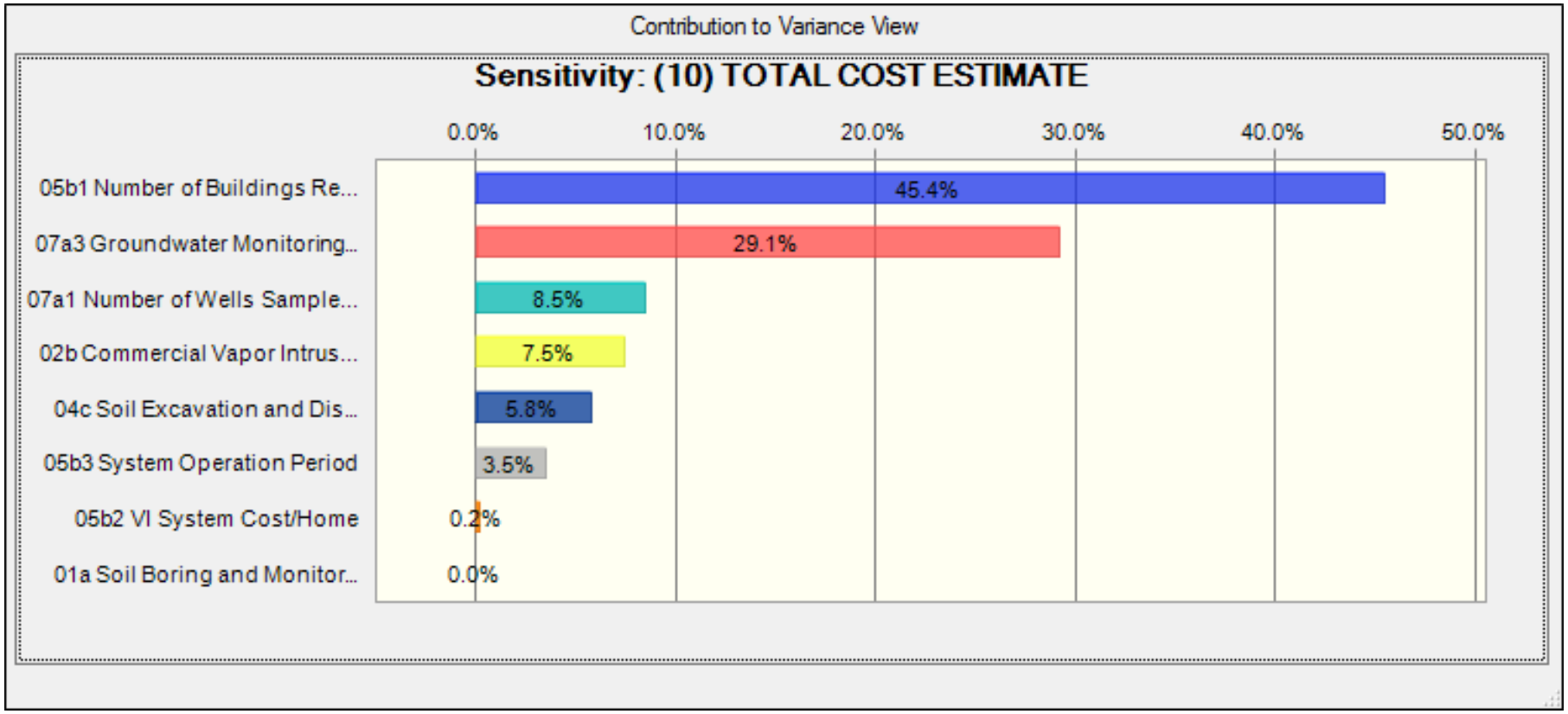
Model Sensitivity Analysis




CAUTION
PROCEED WITH
CAUTION

Fundamental Rule of Modeling

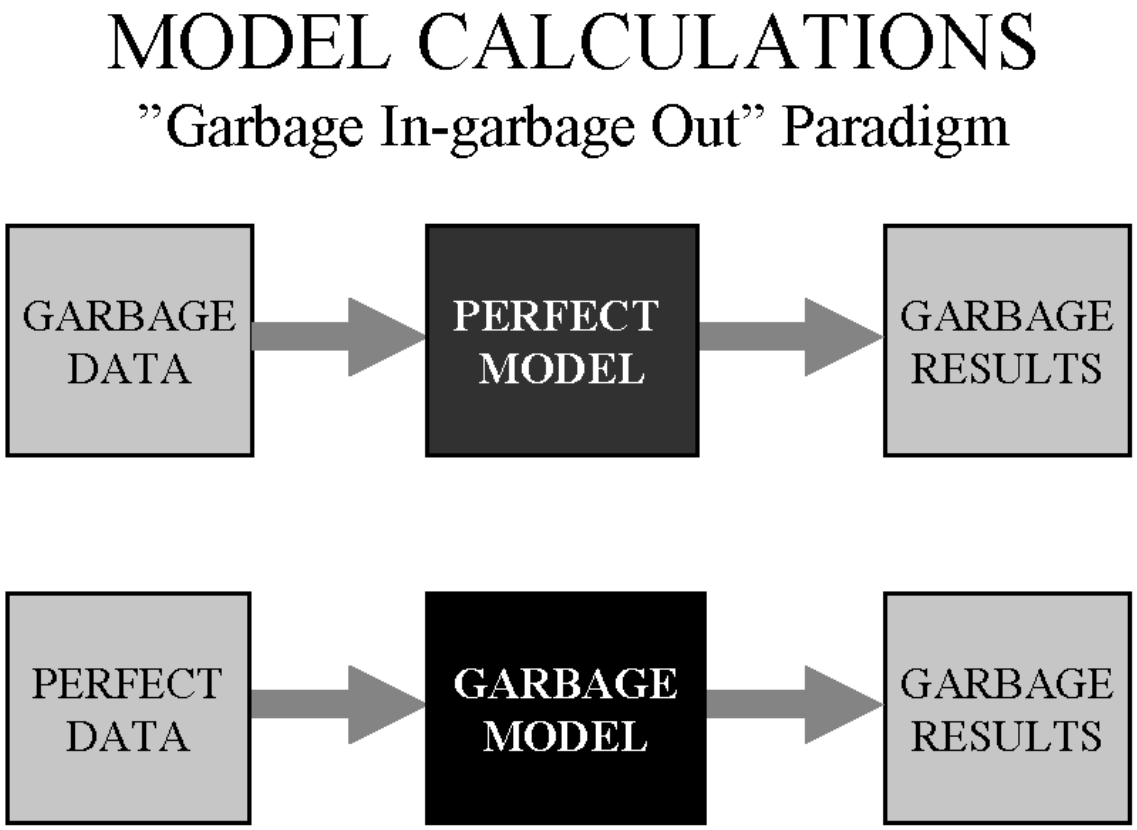
Fundamental Principal:

ALL MODELS ARE WRONG

"As far as the laws of mathematics refer to reality, they are not certain; and as far as they are certain, they do not refer to reality"

-A. Einstein

Fundamental Rule of Modeling



Limitations

- This analysis is only as good as the people selecting the variables
  - Probabilities
  - Costs
  - Inclusivity
- Much of the data used in the model falls into the realm of “opinion”.
- Usually requires education of the end-user

Summary of Monte-Carlo Cost Estimation Method Discussion

- Estimates of environmental liabilities/costs are often needed early
- Traditional estimating techniques are limited in scope

- Monte-Carlo analysis can provide credible, defensible and transparent cost-to-closure estimates early in a project life.
- Analysis is relatively inexpensive and can be performed reasonably rapidly.

Questions?

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