Water Supply Reliability

Overview

- Reliability
- Uncertainty
- Design Considerations

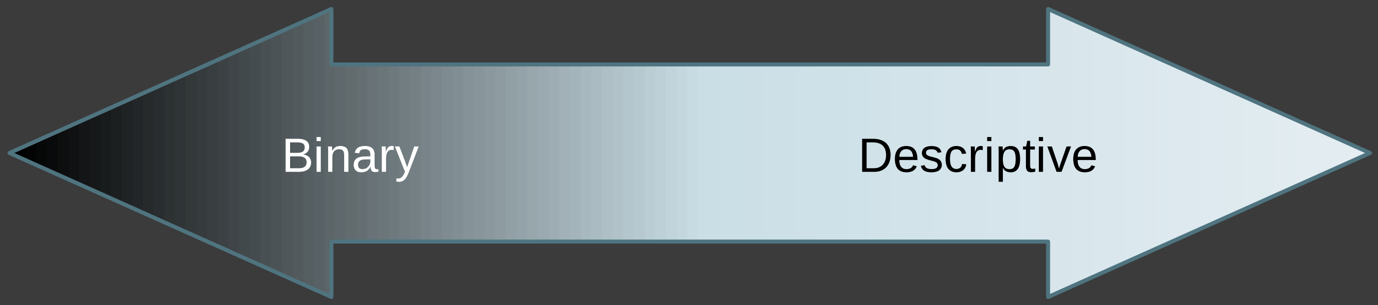
Reliability

Why Reliability?

- Faced with
  - Uncertainty
  - Increasing strain on resources
- Need a way to predict performance
- Reliability is an important indicator of system performance
  - Incorporates uncertainty under changing conditions
- Make better decisions

Reliability

- Ability of a system to perform and maintain its functions



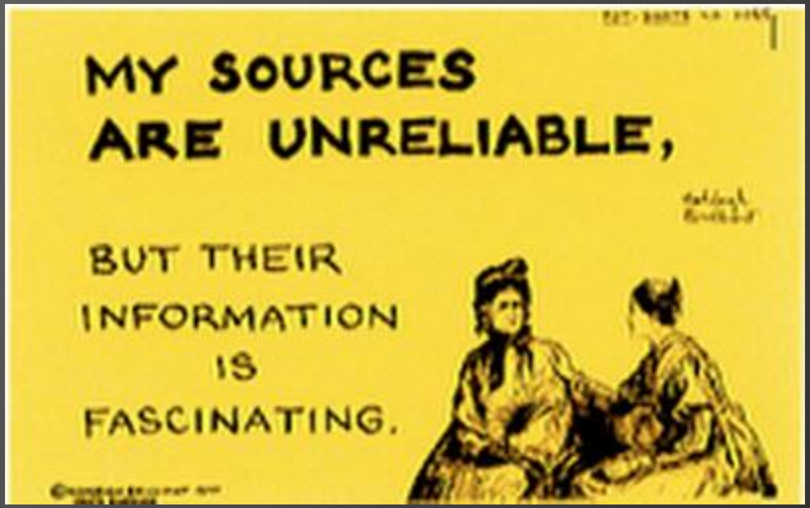
Reliability

- How long and how severe are shortages?
- Need a way to quantify
- Resilience
- Vulnerability

Reliability

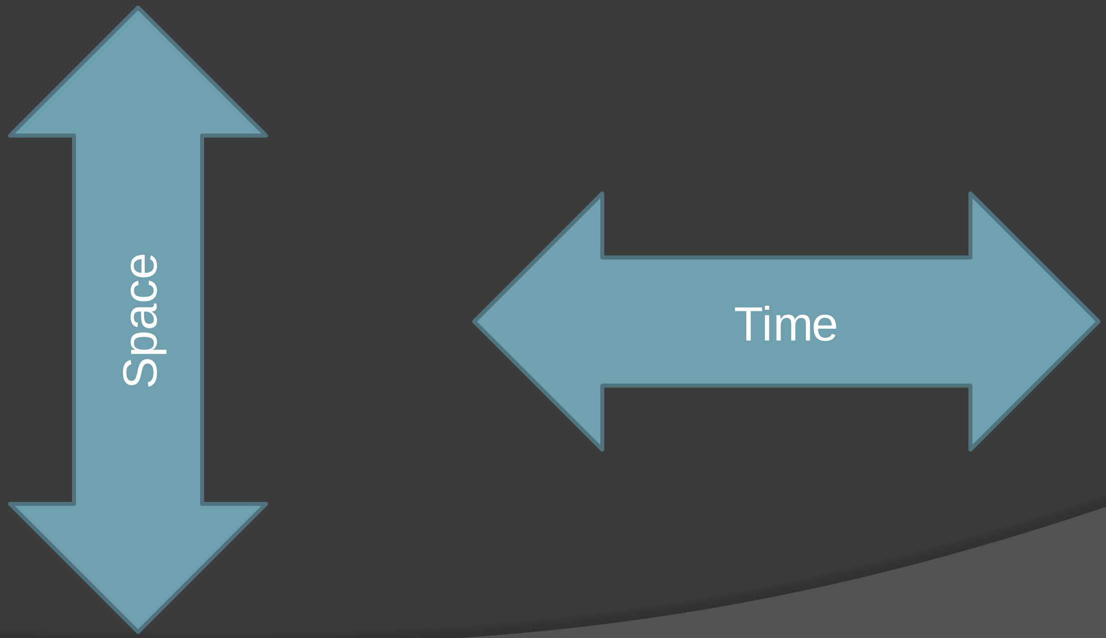
- Resilience: Ability to recover from a drought
  - Number of years with continuous supply
  - Average length of shortfall
- Vulnerability: Measure of the magnitude of failure
  - Average and Max. cumulative supply deficit
  - Maximum rate of shortage flow

Uncertainty



Error vs. Uncertainty

- Derived or assumed value ⇔ true value
- Uncertainty represents a range of true possibilities



Risk vs. Uncertainty

- A state of uncertainty
- Some possible outcomes have an undesired effect or significant loss

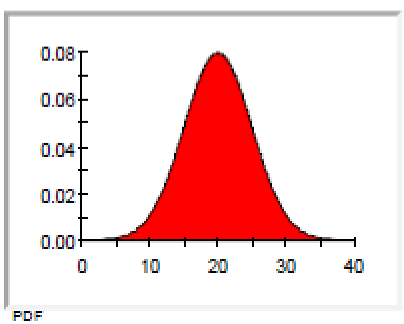
Quantifying Uncertainty

- Beta (generalized) Distribution
- Beta Distribution
- Binomial Distribution
- Boolean Distribution
- Cumulative Distribution
- Discrete Distribution
- Exponential Distribution
- Extreme Probability Distribution
- Extreme Value Distribution
- Gamma Distribution
- Log-Normal Distribution
- Negative Binomial Distribution
- Normal Distribution
- Pareto Distribution
- Pearson Type III Distribution
- Poisson Distribution
- Sampled Results Distribution
- Student's t Distribution
- Triangular Distribution
- Uniform Distribution
- Weibull Distribution

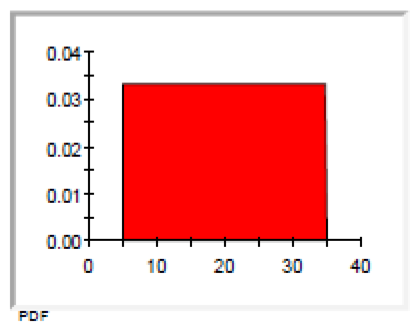
A *probability distribution* is a mathematical representation of the relative likelihood of an uncertain variable having certain specific values.

Height = probability density (integrate to get probability)

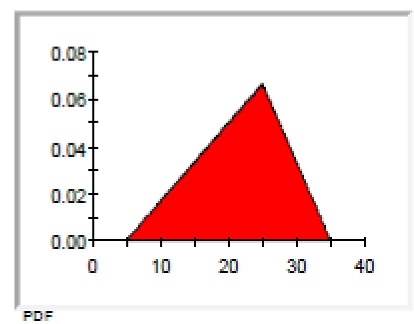
PDFs:



Normal Distribution



Uniform Distribution

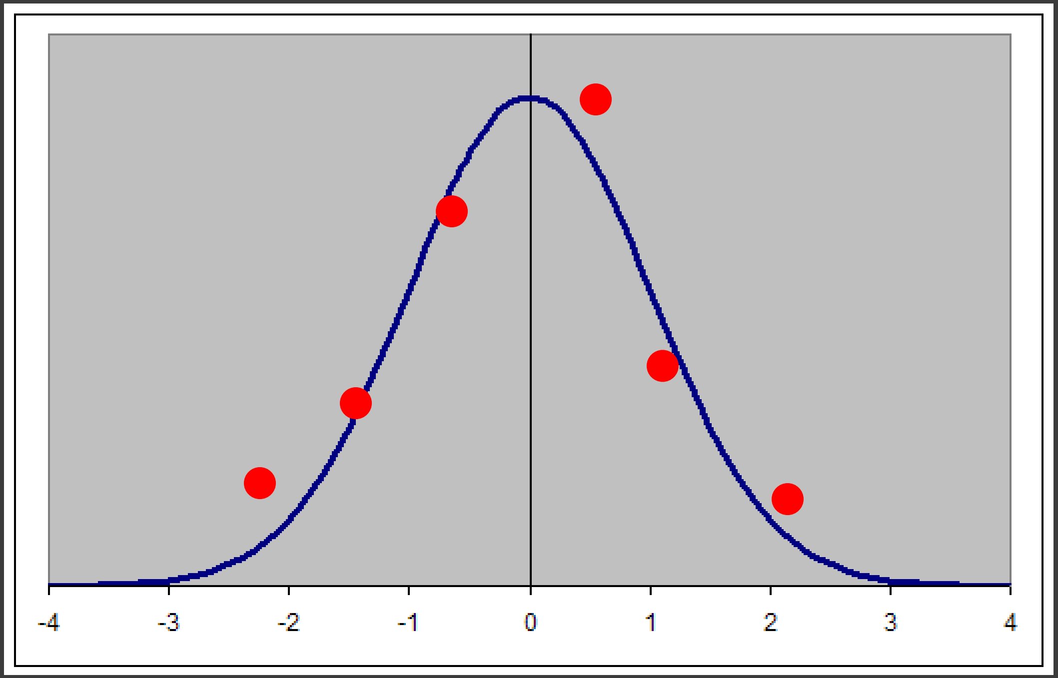


Triangular Distribution

Validating Model Uncertainty

- Best fit parametric distribution
  - Requires historic dataset (non-biased)
  - Tools: Excel, MatLab
- User-defined distribution (non-parametric)
- Subjective assessments and judgment
  - Expert elicitation (multi-disciplinary)

Range of Input

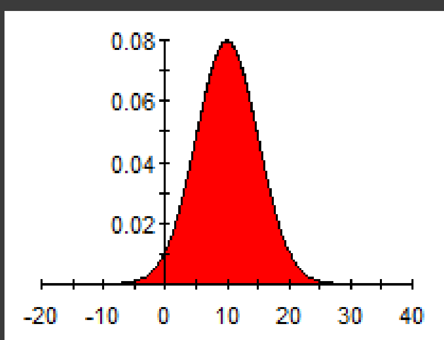


Monte Carlo Simulation

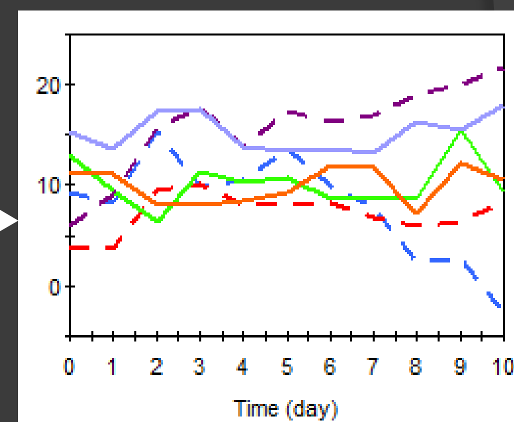
Random Inputs

Computations

Aggregate Results



Multiple, Deterministic Computations

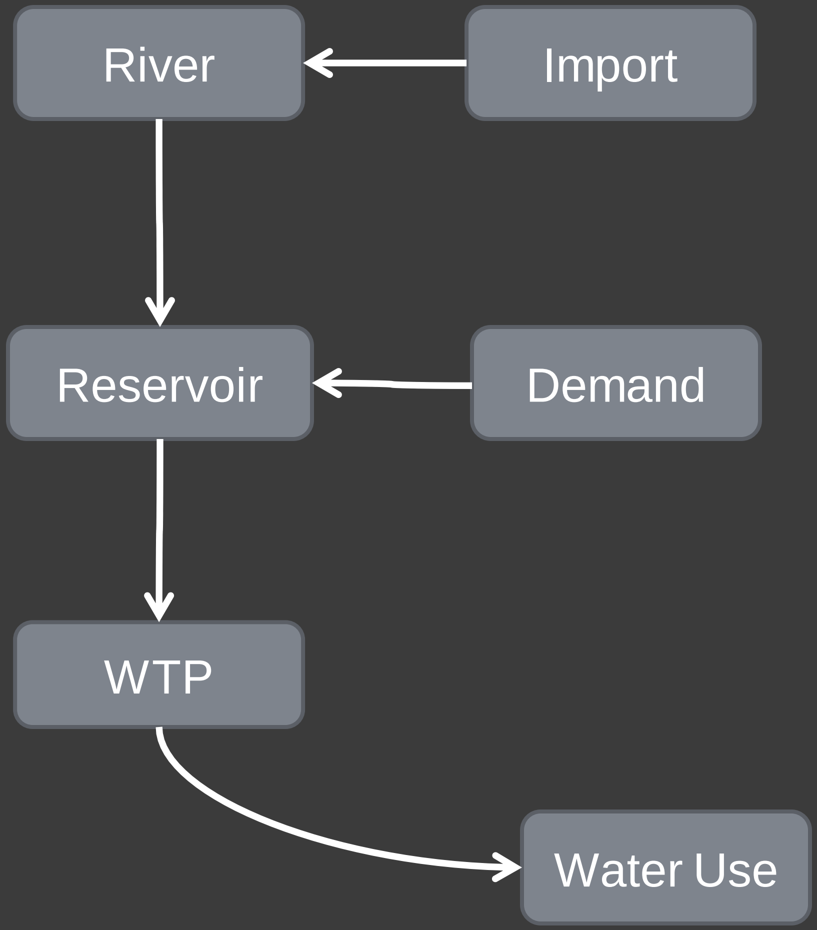


Results of Uncertainty

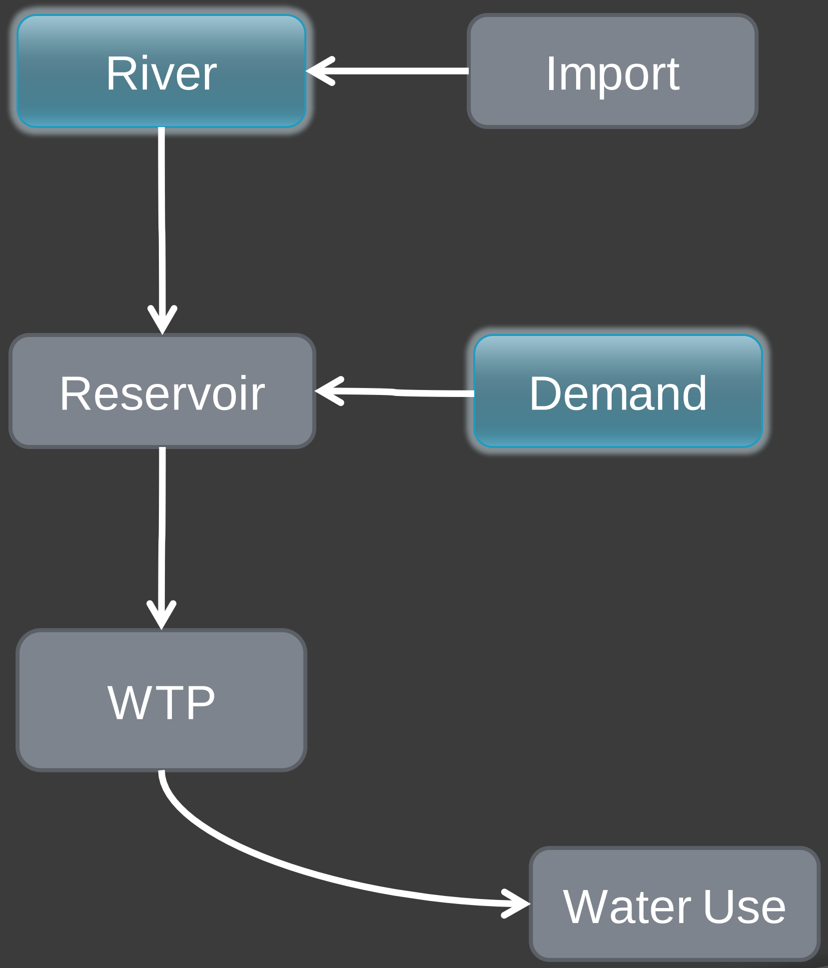
If the inputs describing a system are *uncertain*, the prediction of future performance is necessarily *uncertain*. That is, the result of any analysis based on inputs represented by probability distributions is itself a probability distribution.

Design Considerations

Hypothetical Example

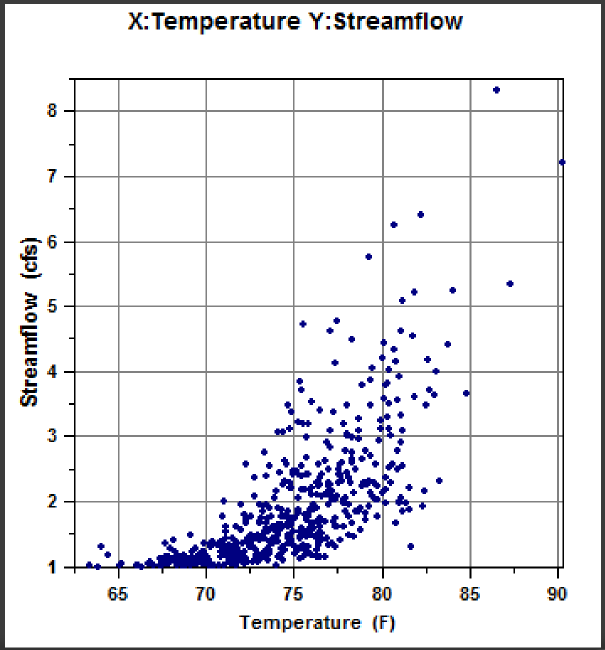


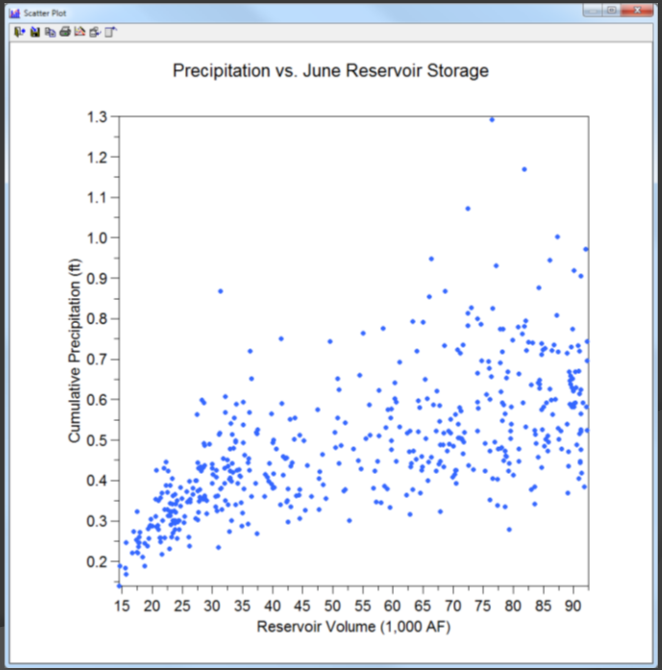
Sources of Uncertainty



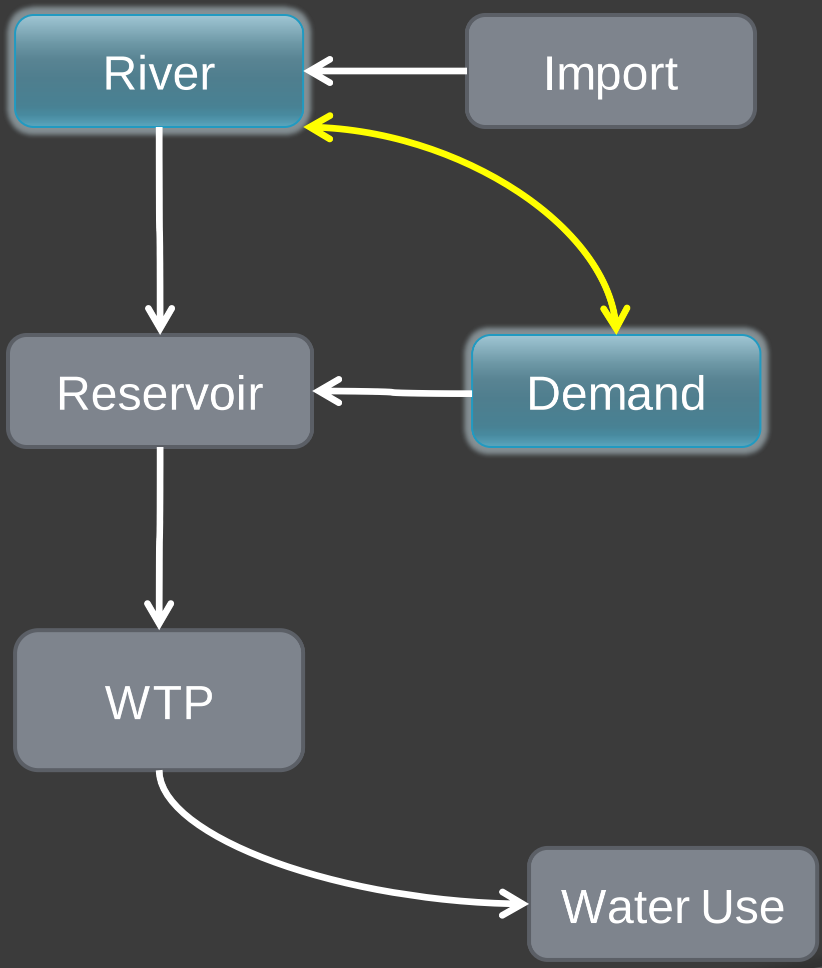
Empirical modeling

- Rely heavily on historic data sets
- Correlate uncertainty



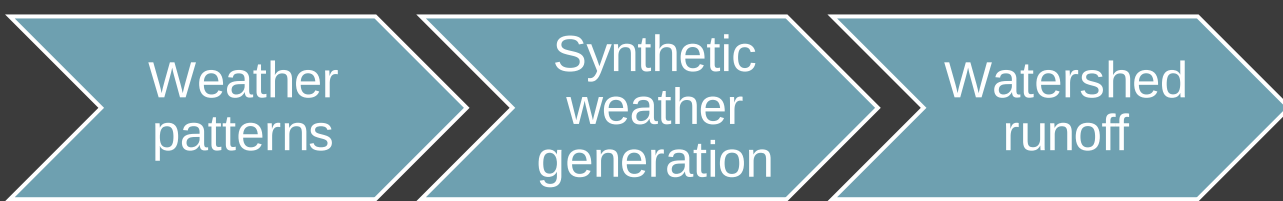


Correlate Uncertainty

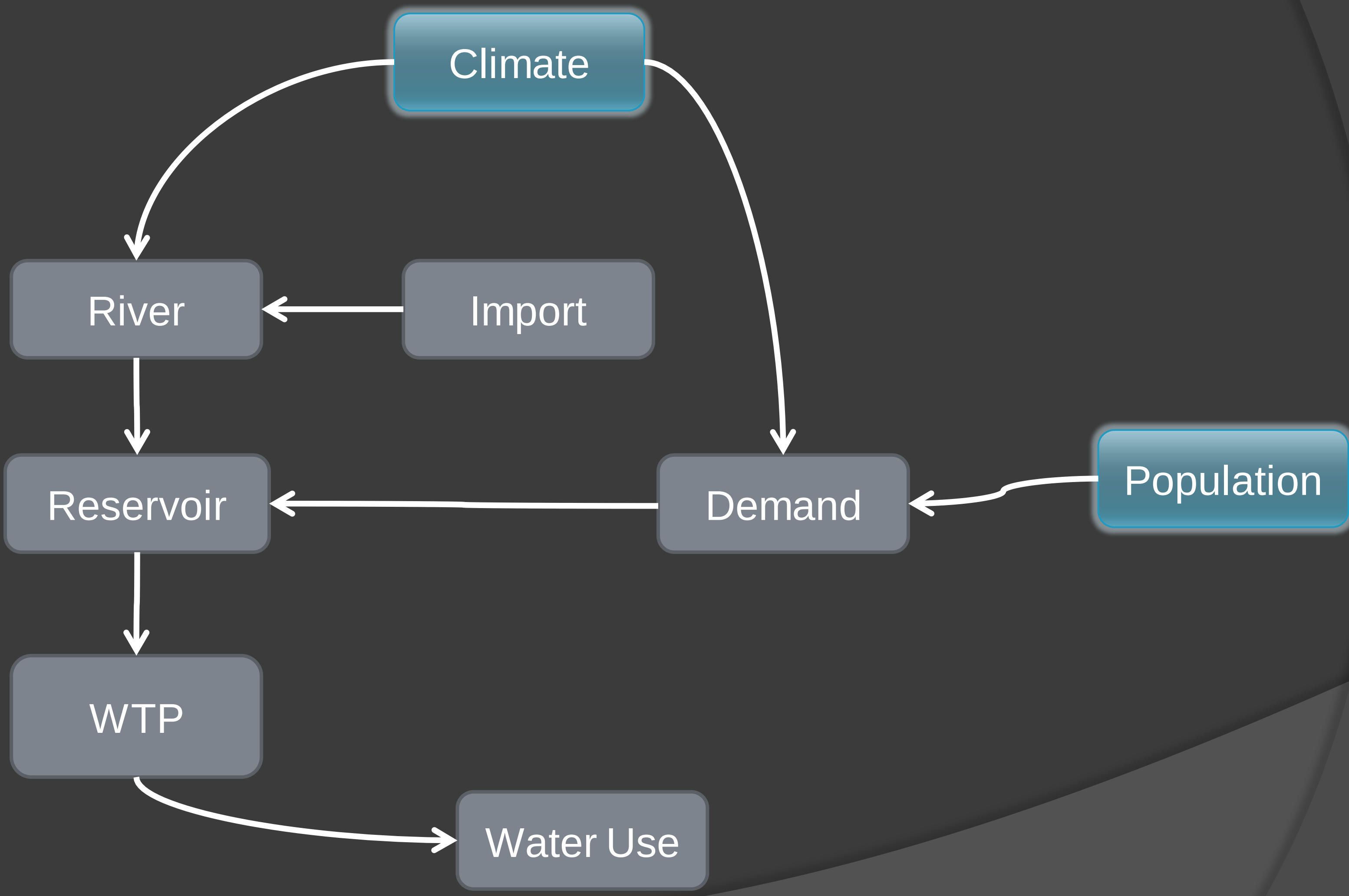


Physical Modeling

- Define boundaries



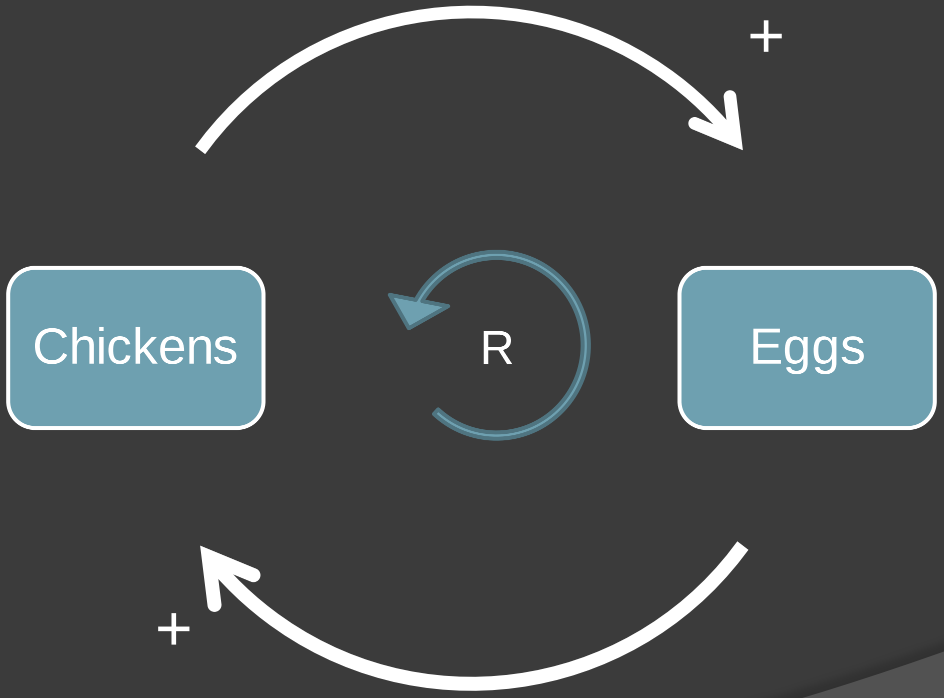
Physical Modeling

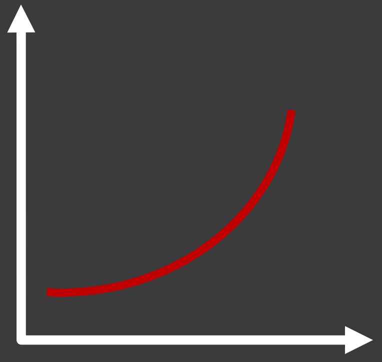


Feedback

Feedback

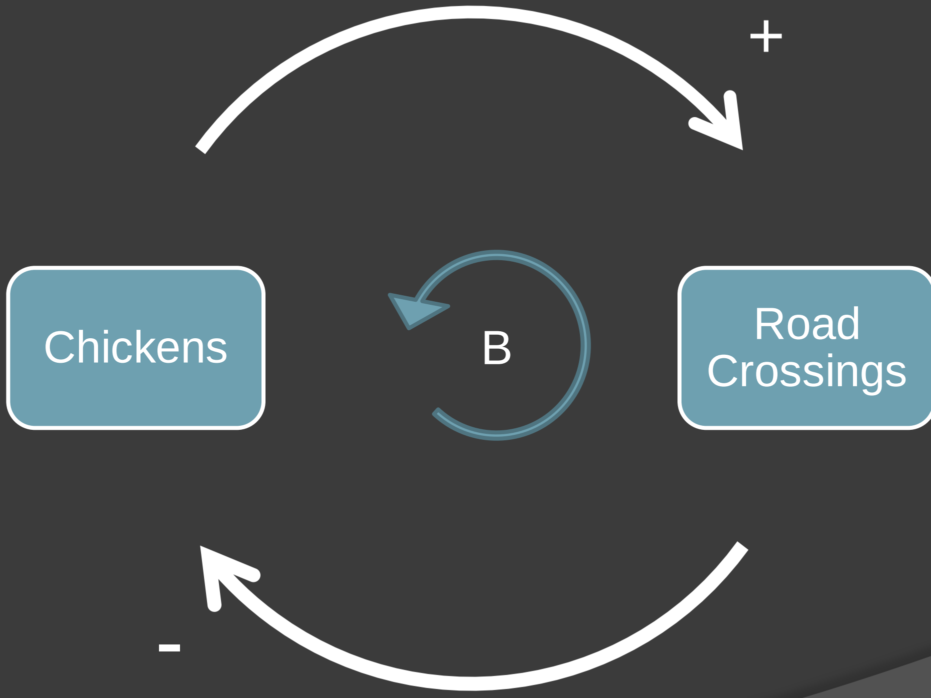
- Positive (Self-reinforcing) Feedback

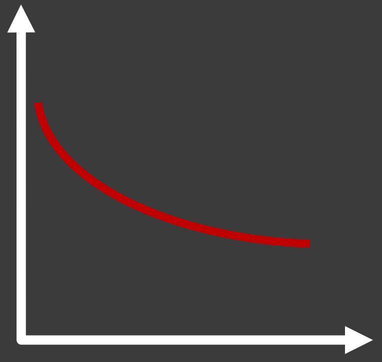




Feedback

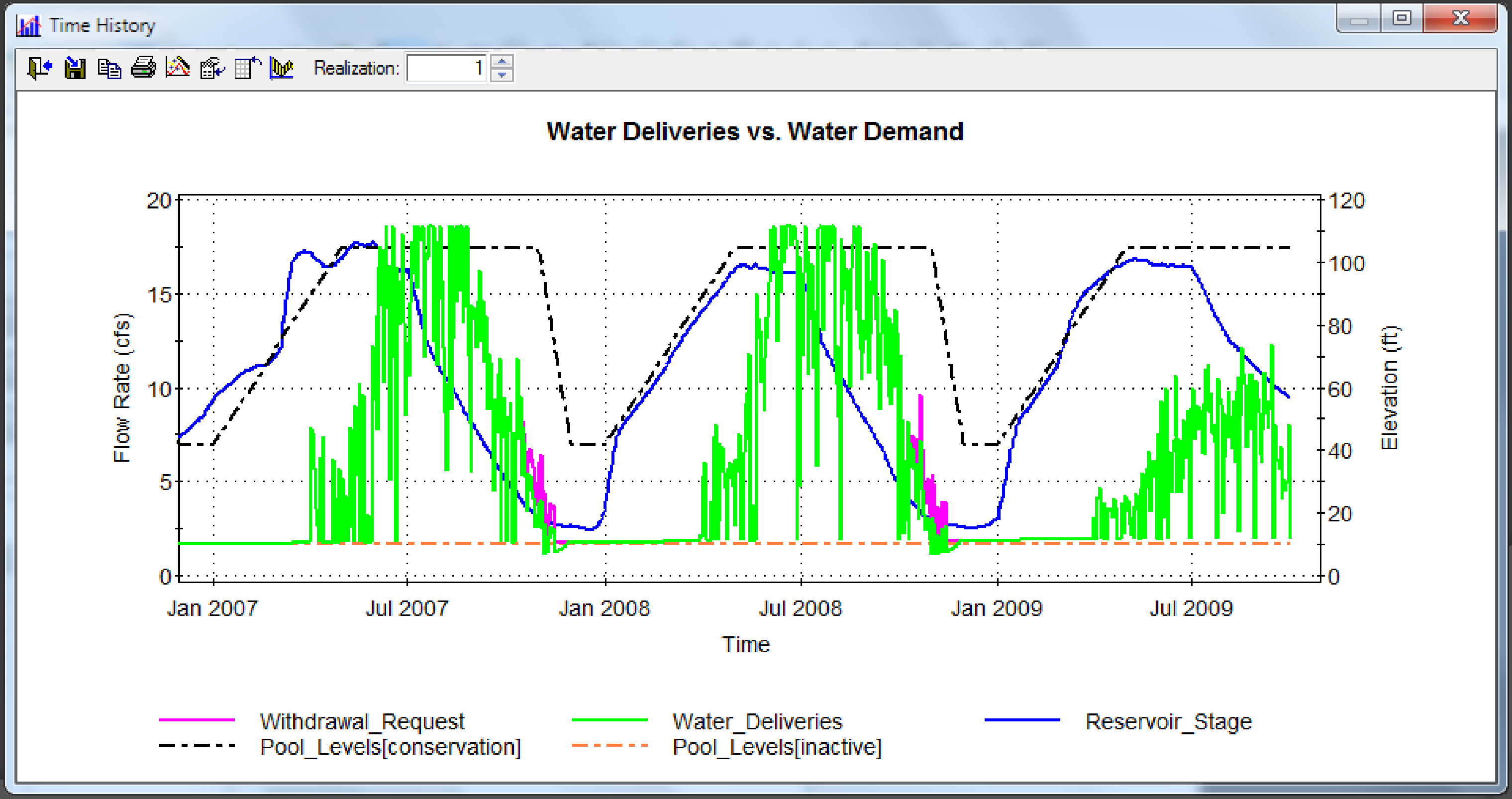
- Negative (Balancing) Feedback



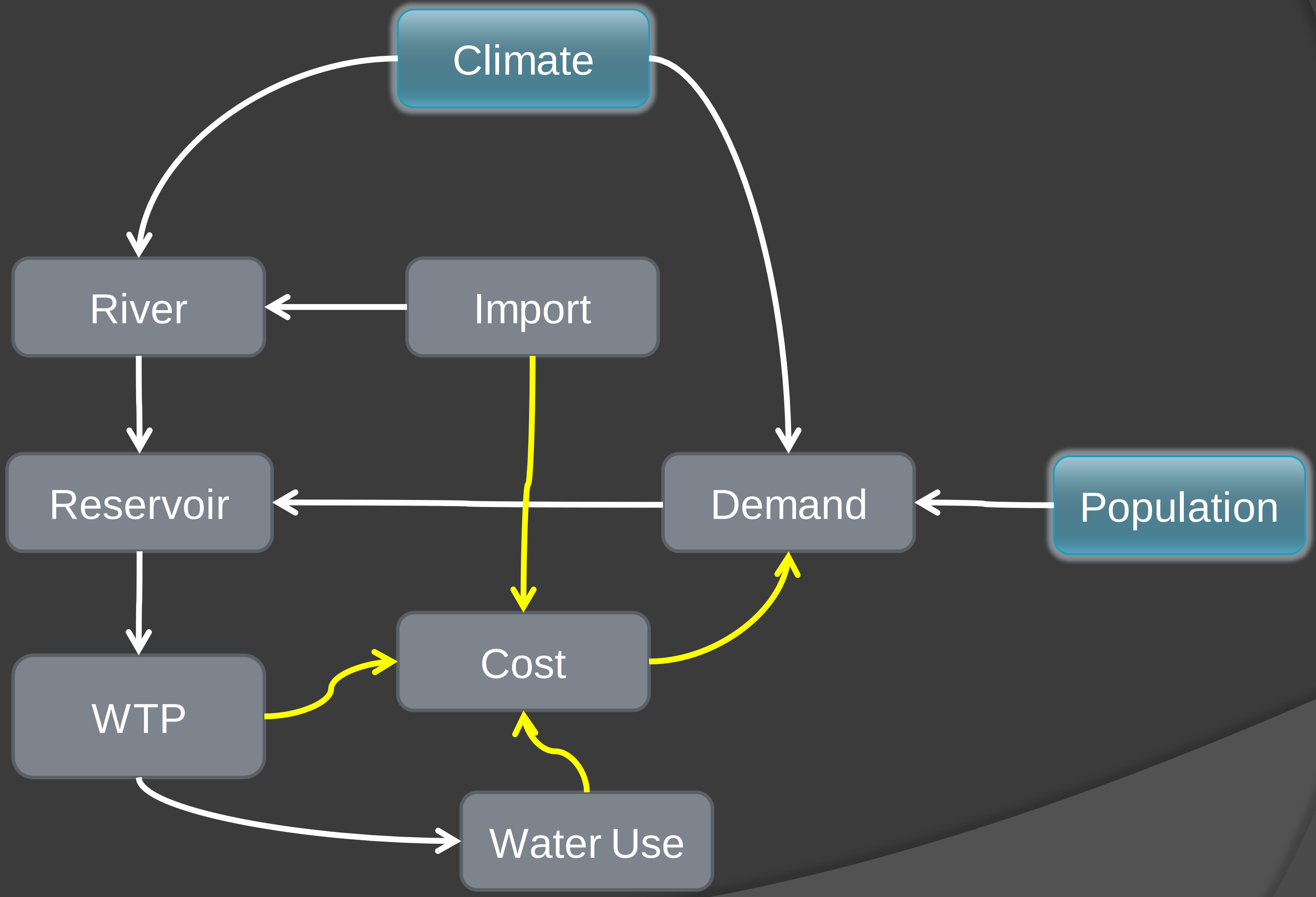


Reliability and Feedback

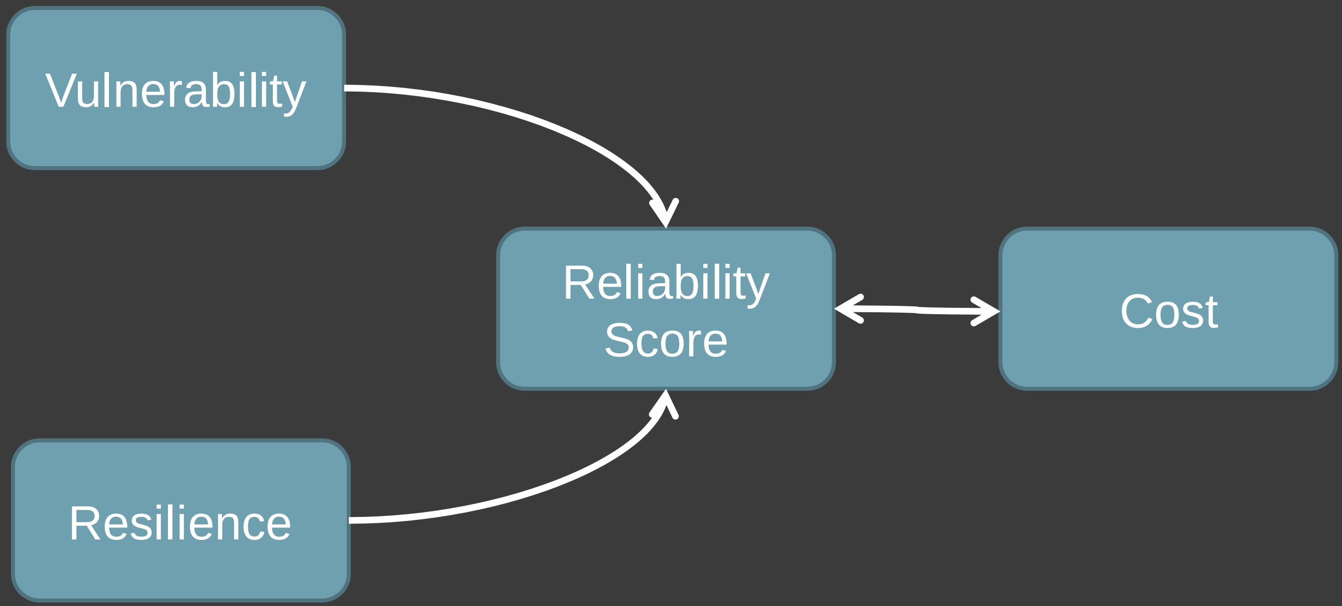
- Reliability ⬄ Water Use
  - Cost increases



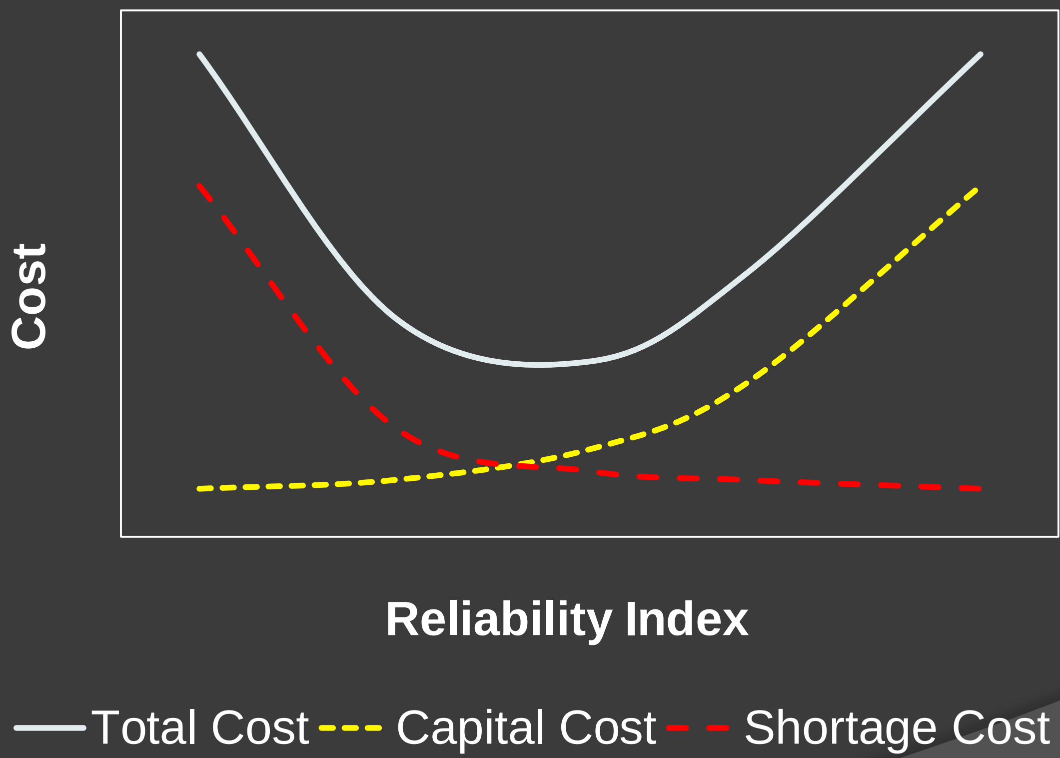
Modeling Feedback



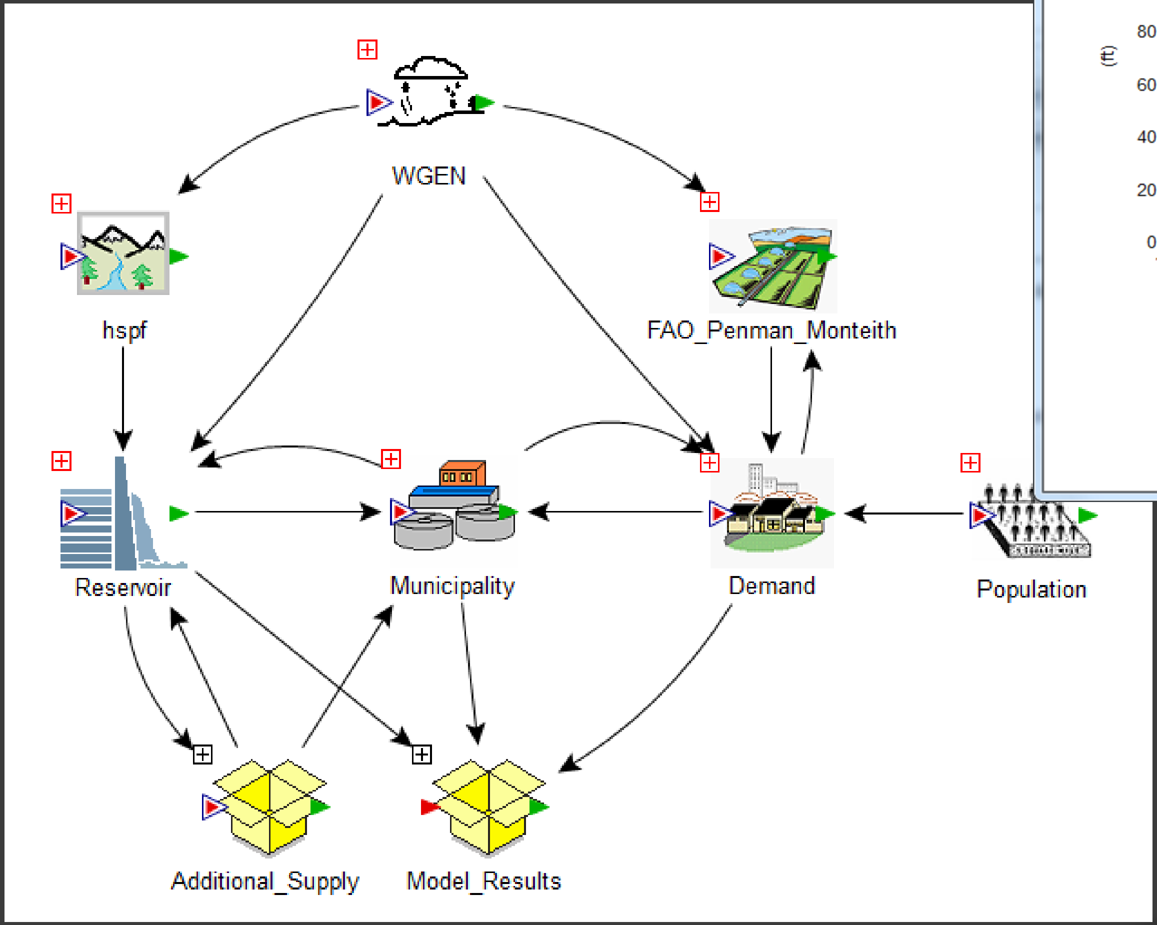
Reliability Score

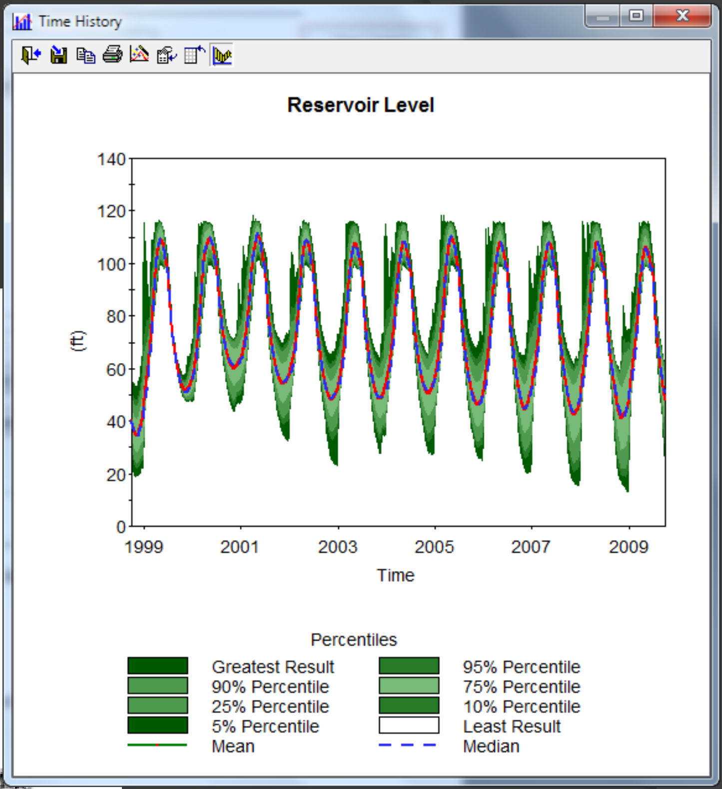


Trade-Off Function

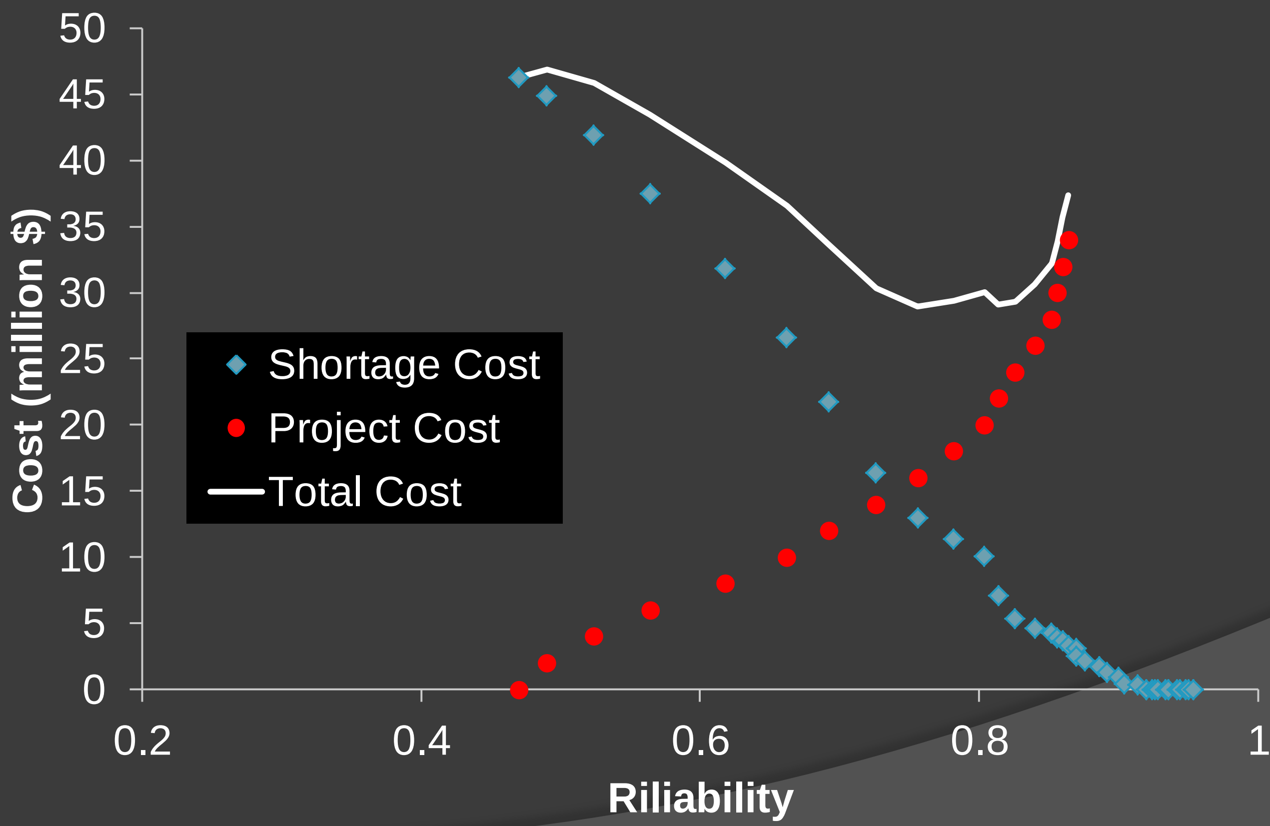


Application





Trade-Off Analysis



Thank you!