LimnoTech

Water Environment | Scientists Engineers

Uncertainty Analysis of Synoptic Survey Mass Balance Assessment

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Outline

- Mass balance assessment
- Uncertainty analysis
  - Uncertainty in inputs
  - Uncertainty in calculations

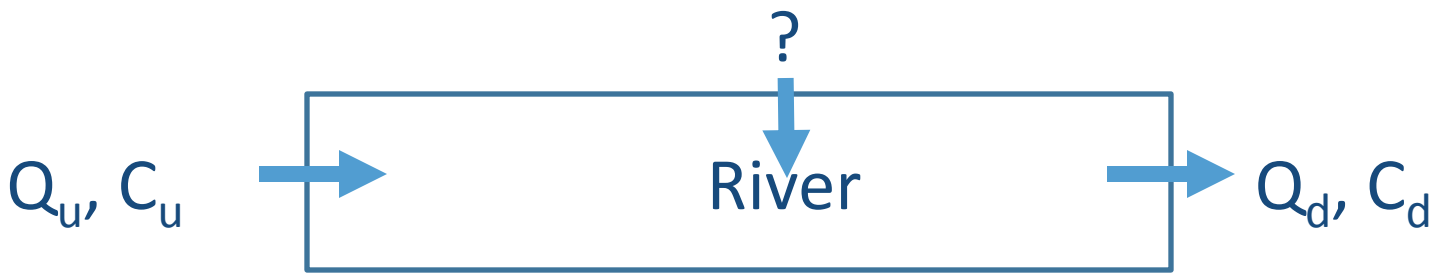
Mass Balance Assessment

- Measure flow (Q) and total PCB concentration (C) at paired upstream and downstream stations

Mass Balance Assessment

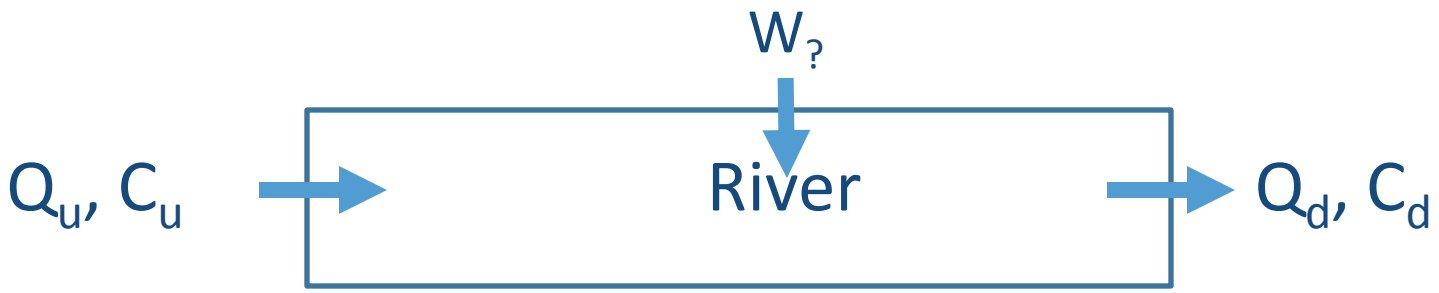
- Back-calculate unmonitored load between stations
  - Unmonitored load =

    Downstream load – upstream load



Mass Balance Equations

- Load (W) = Concentration times flow
  - Downstream load = $Q_d * C_d$
  - Upstream load = $Q_u * C_u$
  - Unmonitored load = $Q_d * C_d - Q_u * C_u$



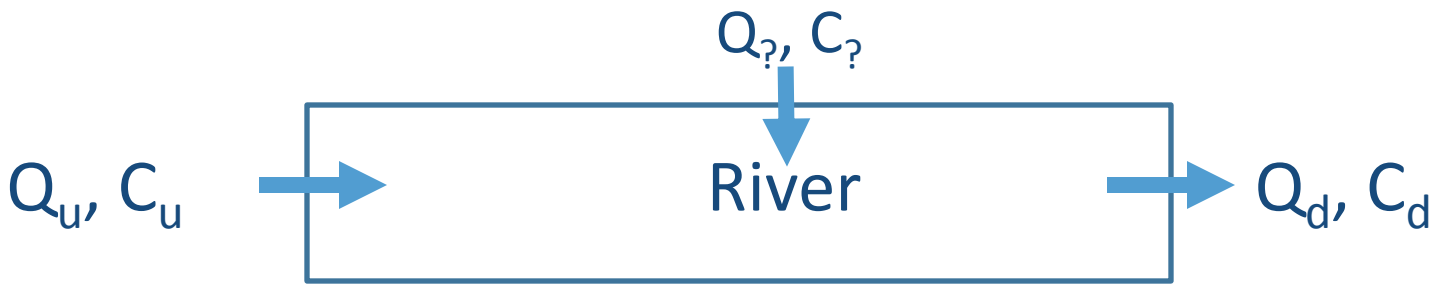
Unmonitored Load Components

- Calculate unmonitored flow and concentration

$$Q_? = Q_d - Q_u$$

$$Q_u * C_u + Q_? * C_? = Q_d * C_d$$

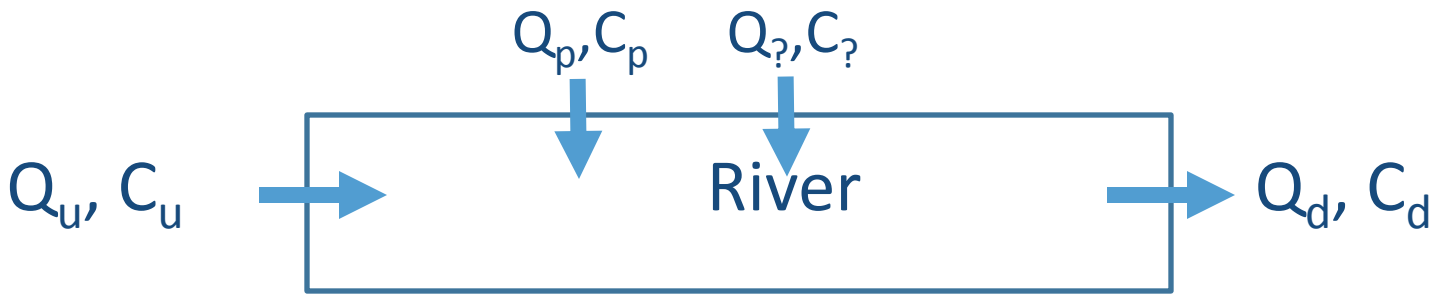
$$C_? = [Q_d C - Q_u * C_u]/Q_?$$



Expand to Consider Point Sources

- Equation can be expanded to consider point sources (and tributaries)
  - Unmonitored load =

    Downstream load – upstream load – point source load



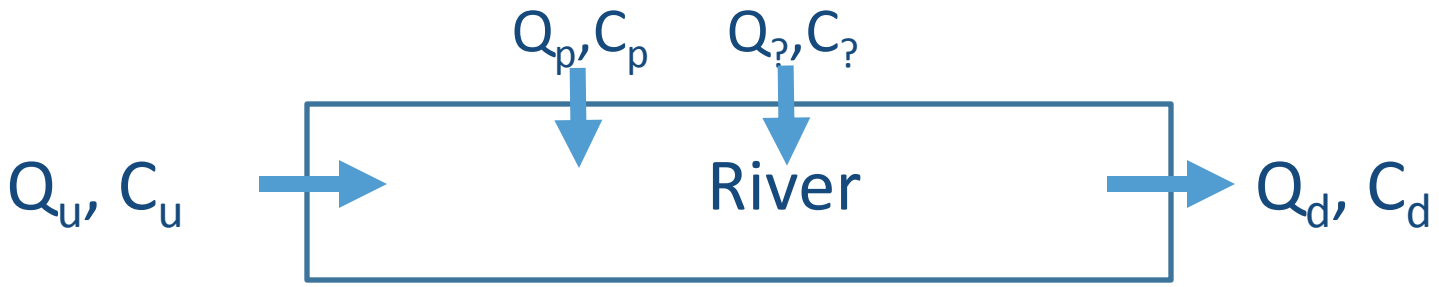
Expand to Consider Point Sources

- Calculate unmonitored flow and concentration

$$Q_? = Q_d - Q_u - Q_p$$

$$Q_u * C_u + Q_? * C_? + Q_p * C_p = Q_d * C_d$$

$$C_? = [Q_d C_d - Q_u * C_u - Q_p * C_p]/Q_?$$



Other Considerations

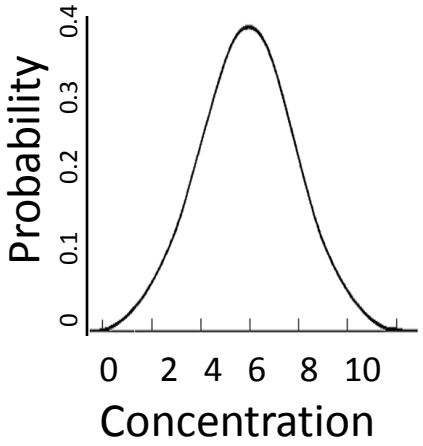
- Approach assumes in-stream PCB loss processes are small
  - This has been investigated and confirmed
- Approach can also be applied to estimate unmonitored sources in losing reaches
- Above topics to be discussed in more detail in January

Consideration of Uncertainty

- Need to recognize uncertainty/variability in flows and concentrations
  - Uncertainty: Concentrations close to blanks
  - Variability: Concentrations and flows vary from day-to-day
- Re-state model inputs as probability distributions rather than single values
  - $W_i = Q_d * C_d - Q_u * C_u$

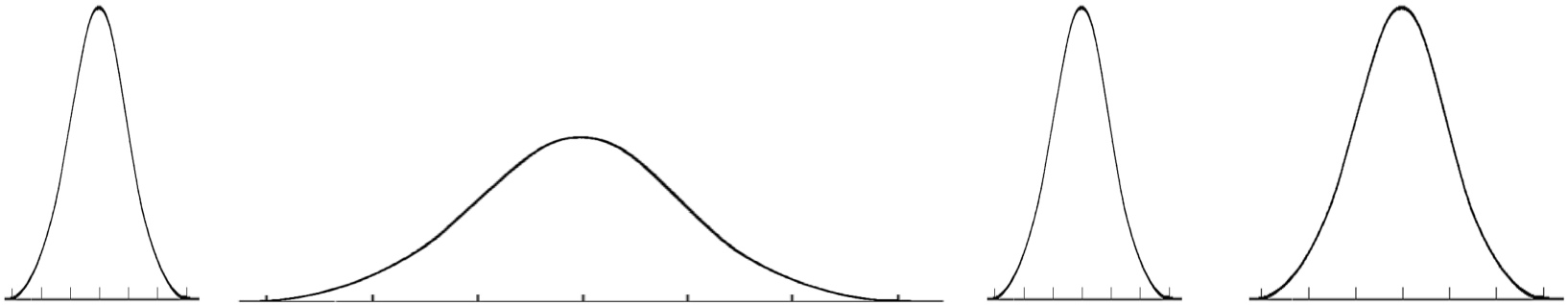
Probability Distributions

- Describe expected probability of occurrence of entire range of values



Probability Distributions

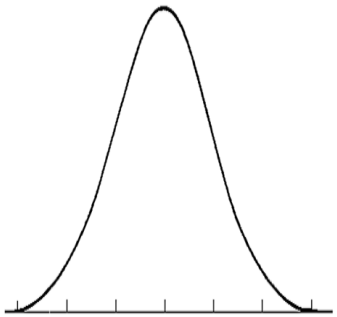
- Higher uncertainty corresponds to broader curves



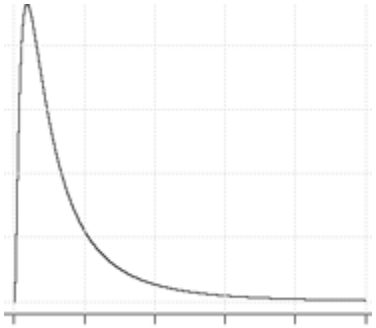
Defining Probability Distributions

- Need three pieces of information
  - Central tendency (mean)
  - Variance (spread)
  - Shape of distribution

Normal



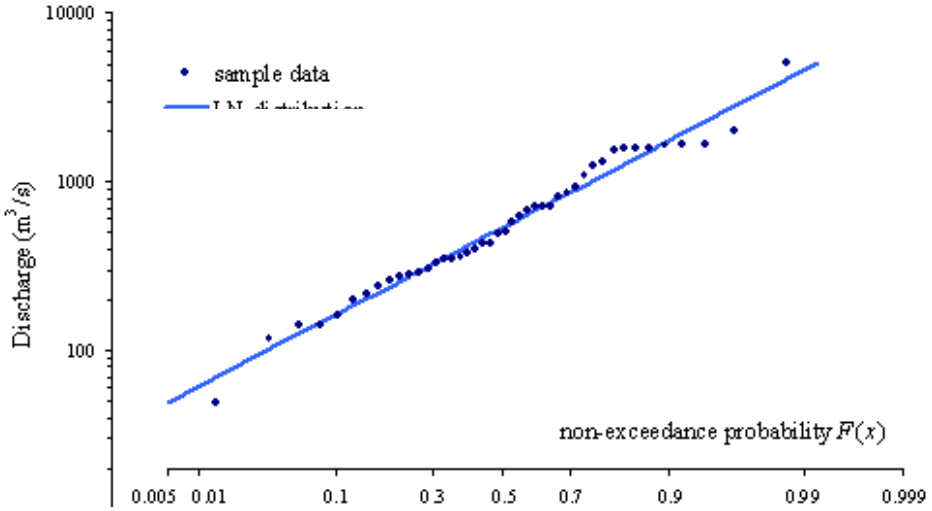
Log-Normal



- Determined by goodness-of-fit testing

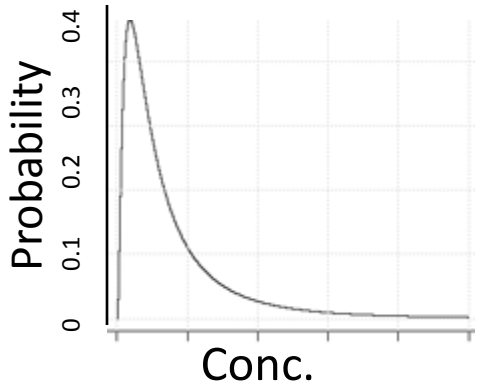
Goodness-of-Fit Testing

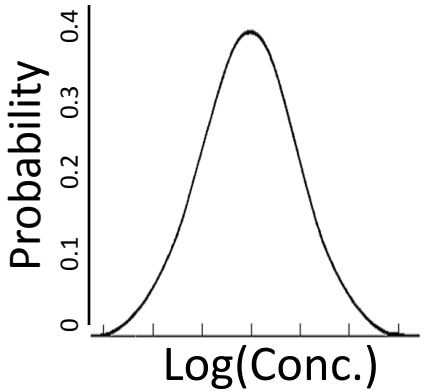
- Compare observed distribution of data to idealized distribution
  - Rank values
  - Plot on probability paper
  - Examine fit
- Process now applied via statistical packages



Normalizing Distributions

- Many statistical tests are based on the assumption that data follow a normal distribution
- Data are commonly “normalized” to make them fit a normal distribution
- For example, if data are log-normally distributed, taking the logarithm of the data values makes them normally distributed





Defining Uncertainty in Model Inputs

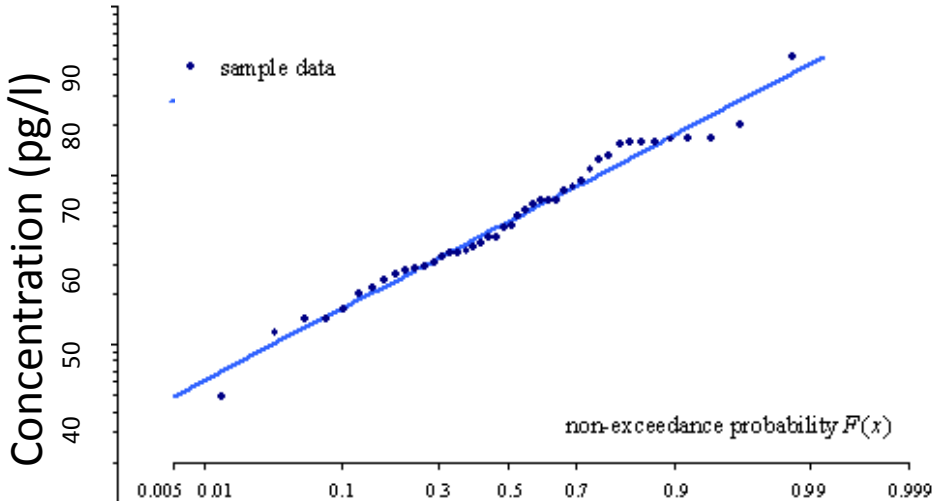
- PCB Concentrations
  - Variability in day to day concentrations
  - Uncertainty due to lab and field contamination
- Flows
  - Variability in day to day flows

Uncertainty in Concentration Inputs

- Uncertainty in concentration inputs has two components
  - Day to day variability at each station
  - Uncertainty due to contamination
    - Laboratory and field
- Each component will be evaluated separately, then combined

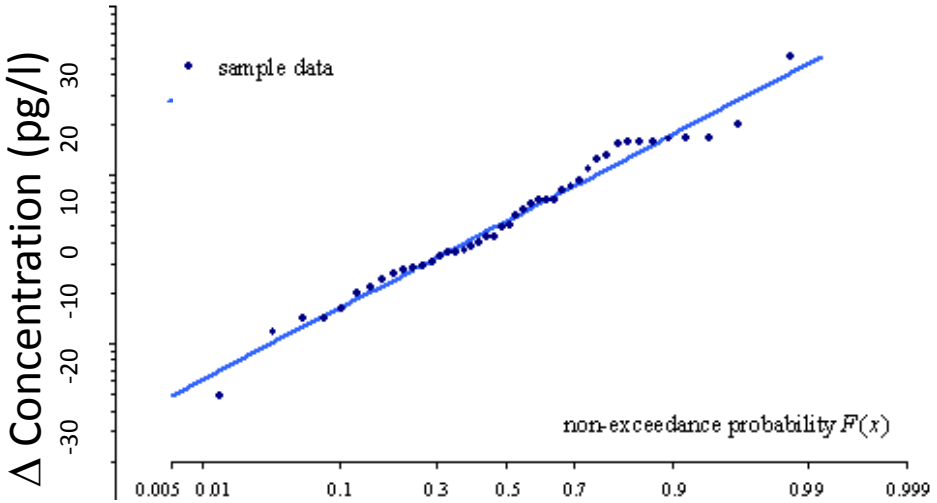
Daily Variability in Concentration

- Characterize day to day variability at each station using the blank-correction method defined in the QAPP



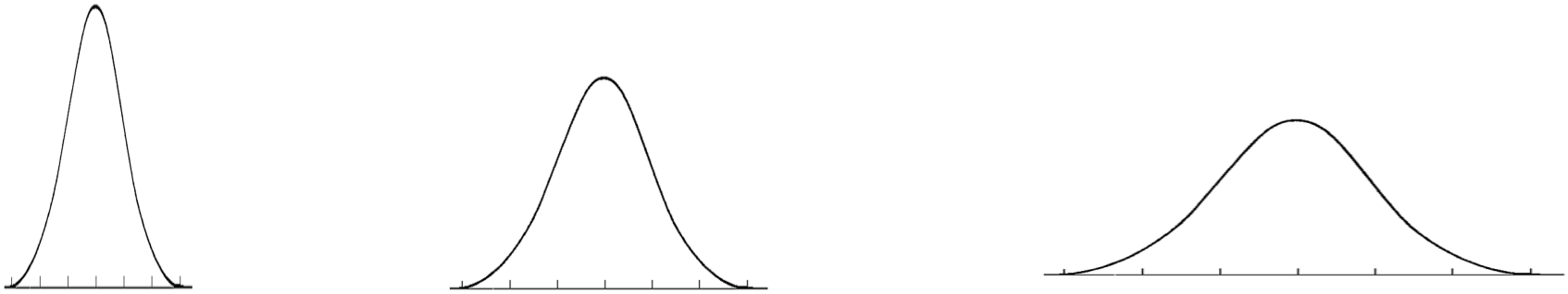
Uncertainty Due to Contamination

- Characterize uncertainty due to contamination by calculating concentrations using a range of blank correction methods
  - Expressed as difference from the QAPP method



Combining Sources of Uncertainty

- Statistical theory:
  - Addition of two normally distributed variables results in a variable that is also normally distributed



Daily Variability + Contamination Uncertainty = Total Uncertainty

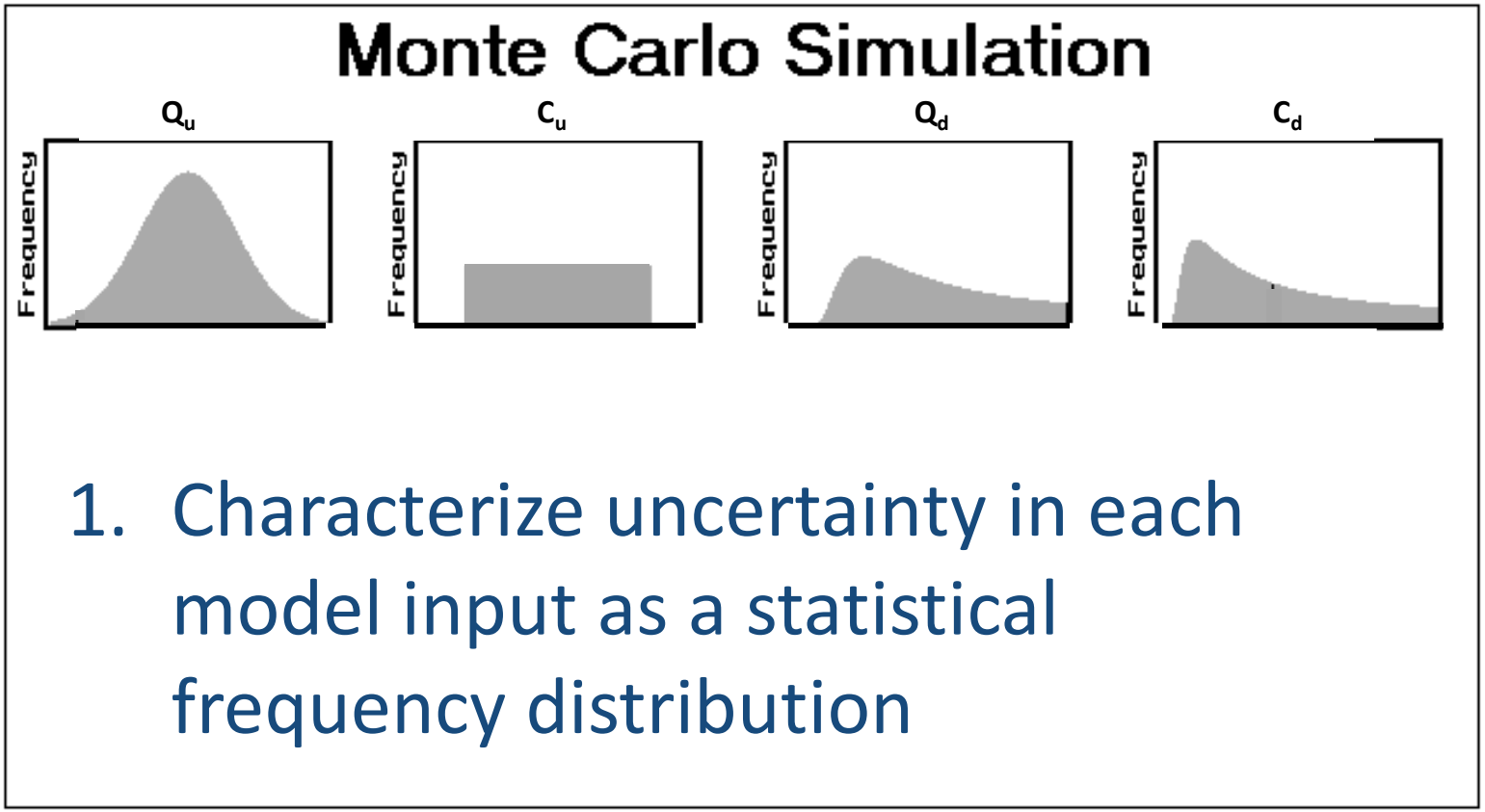
Defining Flow Uncertainty

- Characterize day to day variability at each station
  - Goodness of fit testing, normalize if necessary
- Assume measurement uncertainty is small
  - Can be added if anyone believes that it is important

Defining Uncertainty in Results

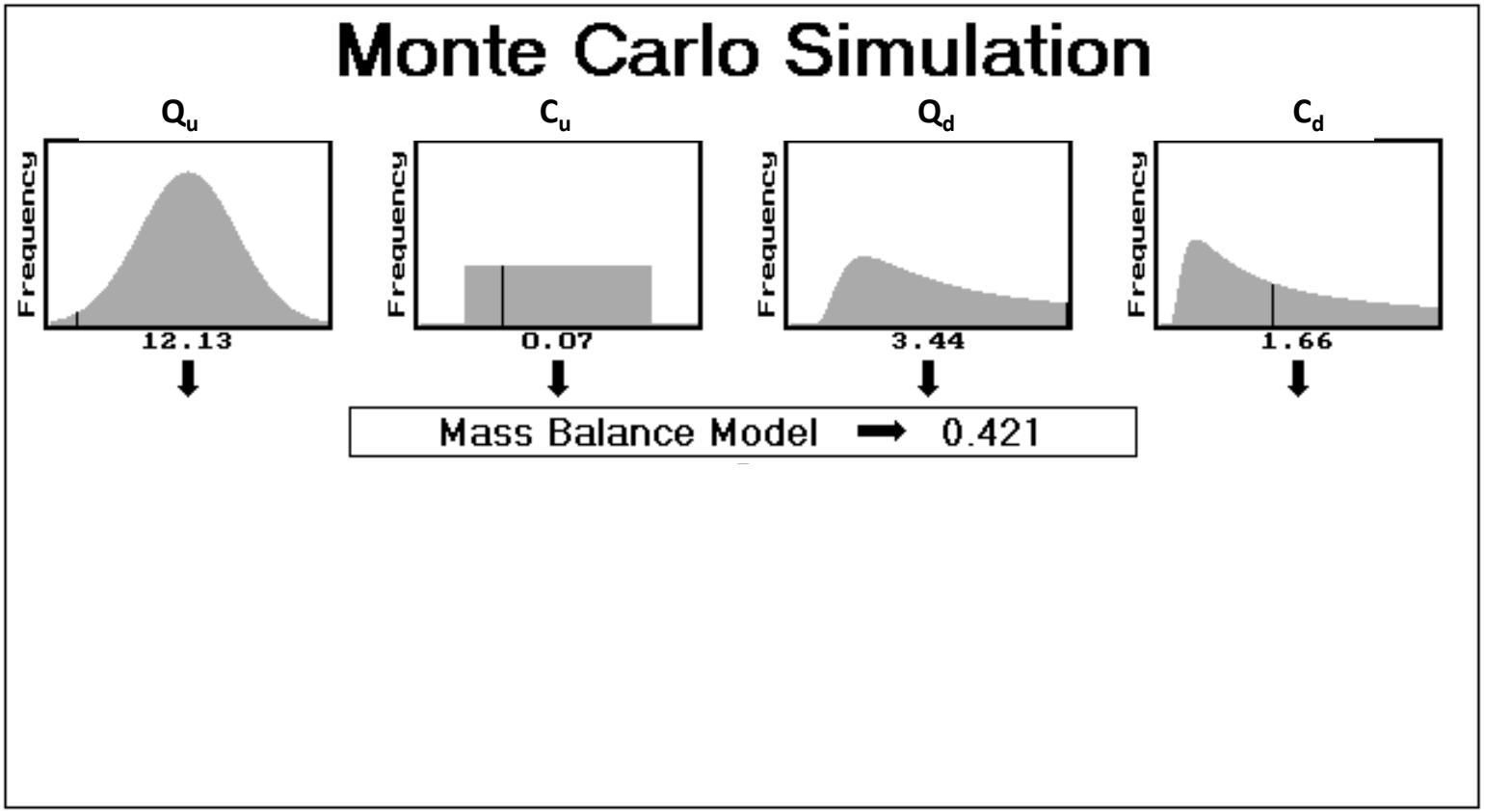
- Characterize uncertainty in each model input
  - Using best-fit statistical distribution
- Use Monte Carlo analysis to characterize uncertainty in mass balance assessment

Defining Uncertainty in Results



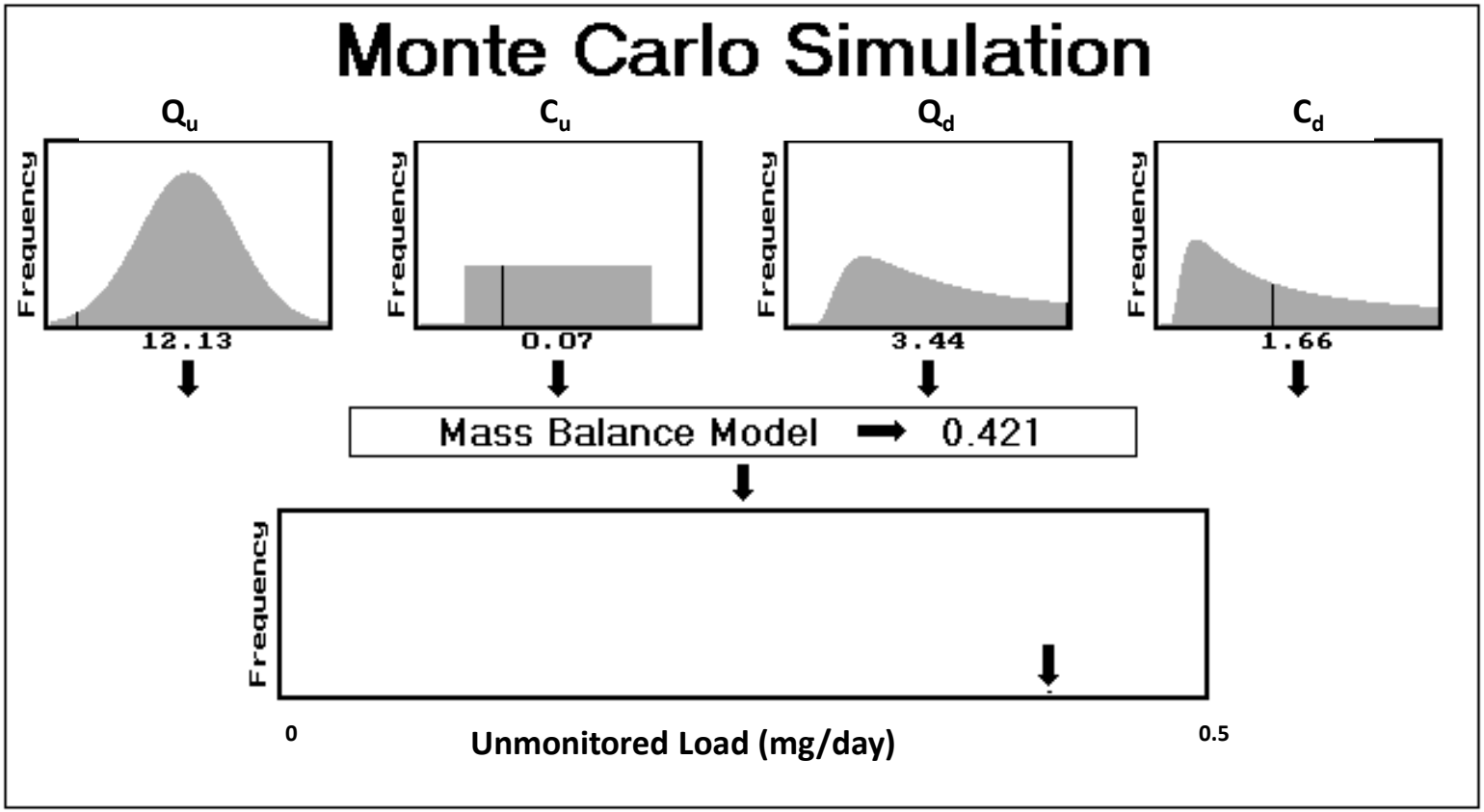
1. Characterize uncertainty in each model input as a statistical frequency distribution

Defining Uncertainty in Results



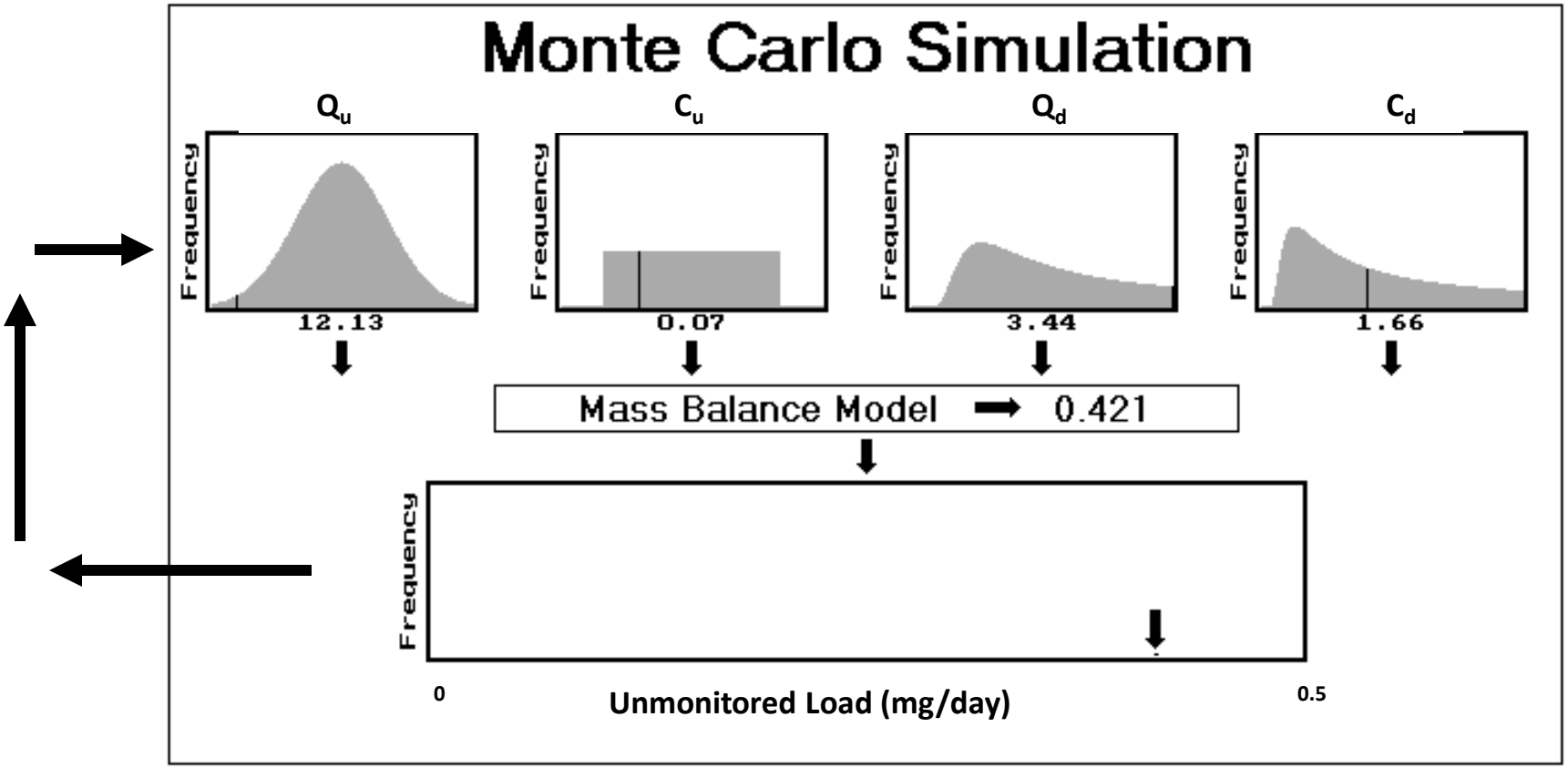
2. Randomly select inputs and run model

Defining Uncertainty in Results



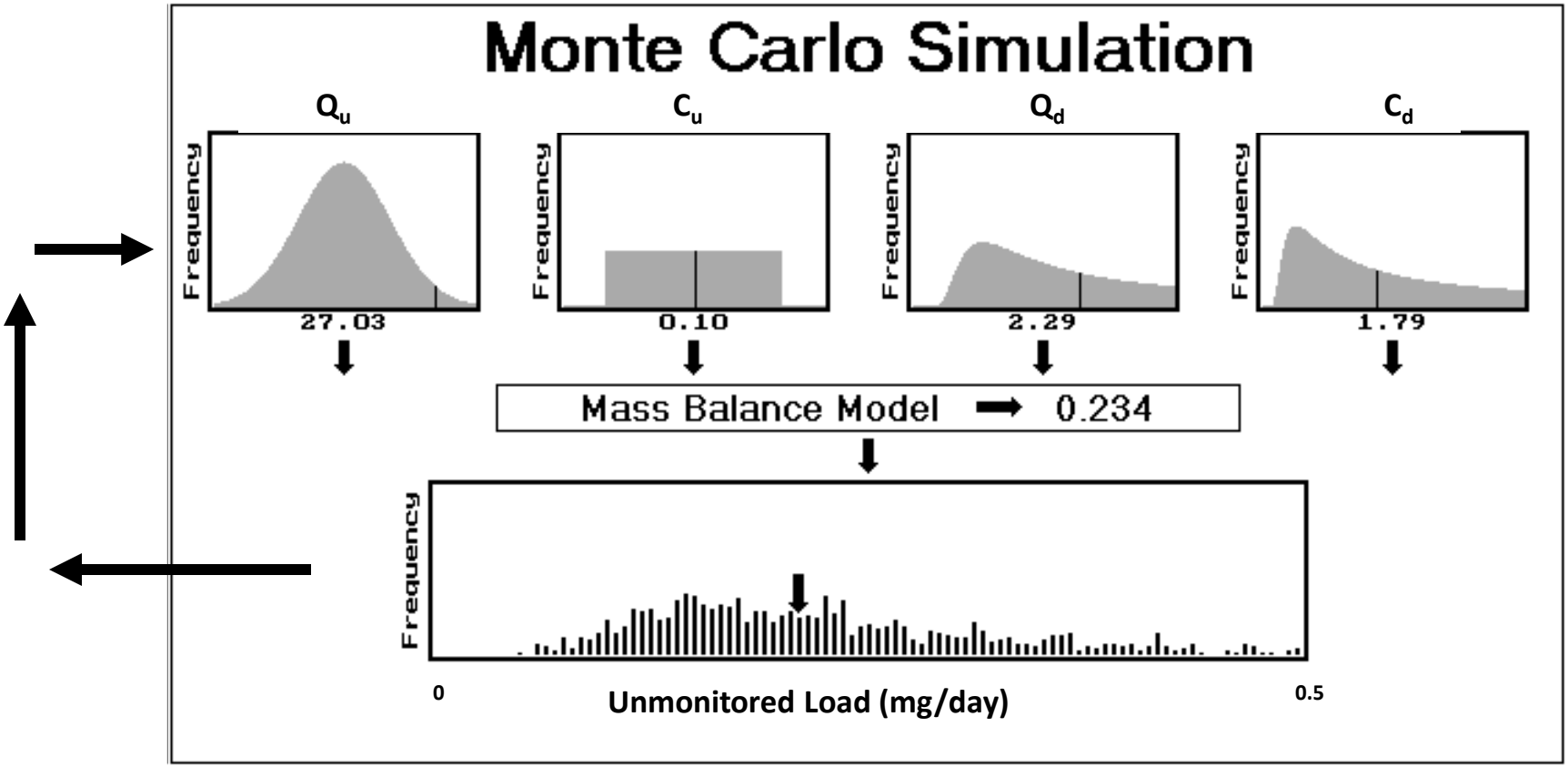
3. Tabulate results

Defining Uncertainty in Results



4. Repeat process

Defining Uncertainty in Results

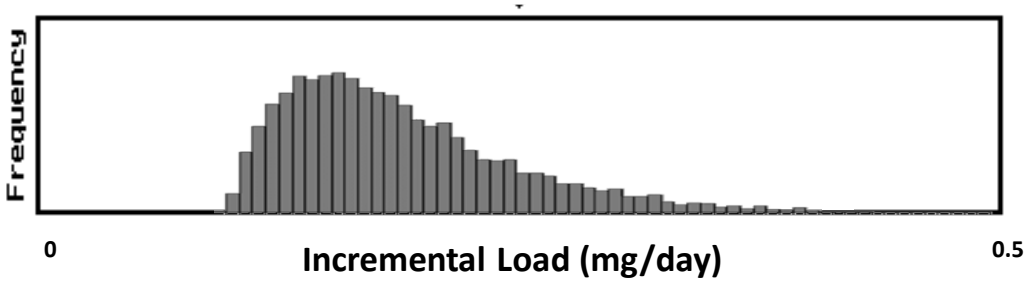


4. Repeat process

Defining Uncertainty in Results

Monte Carlo Simulation

5. Output distribution completely characterizes uncertainty
   - As long as inputs are characterized properly

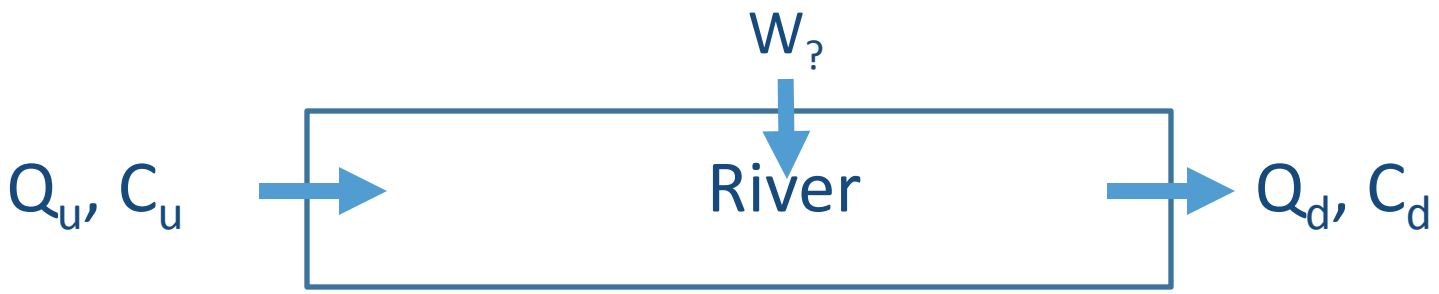


What Do We Do with the Results?

- Examination of unmonitored load in a vacuum can be misleading
  - Gaining reach with low concentrations could still be portrayed as a large load (Load = flow x conc.)
- May be more meaningful to look at “excess unmonitored load”
  - i.e. incremental load above what we’d expect

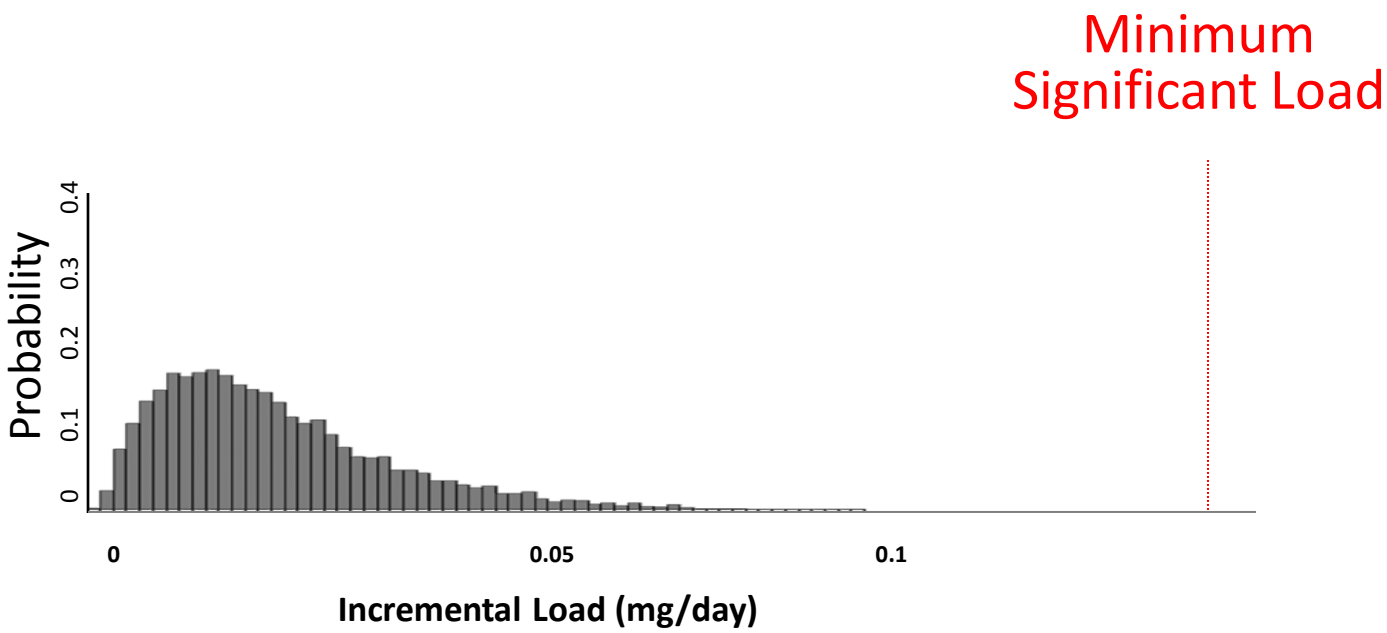
Excess Unmonitored Load

- Load (W) = Concentration times flow
  - Unmonitored load = $Q_d * C_d - Q_u * C_u$
  - "Excess" load = $Q_d * C_d - Q_u * C_u - (Q_d - Q_u) * C_u$



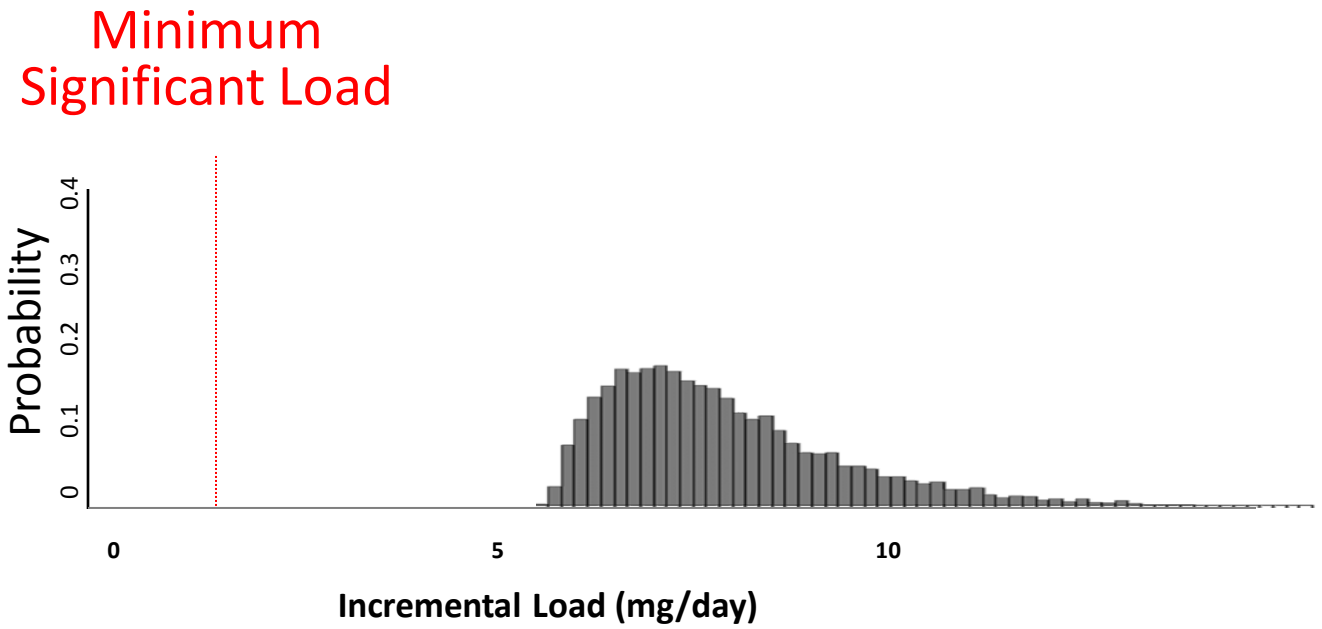
What Do We Do with the Results?

- Three potential outcomes
  1. Uncertain, but insignificant



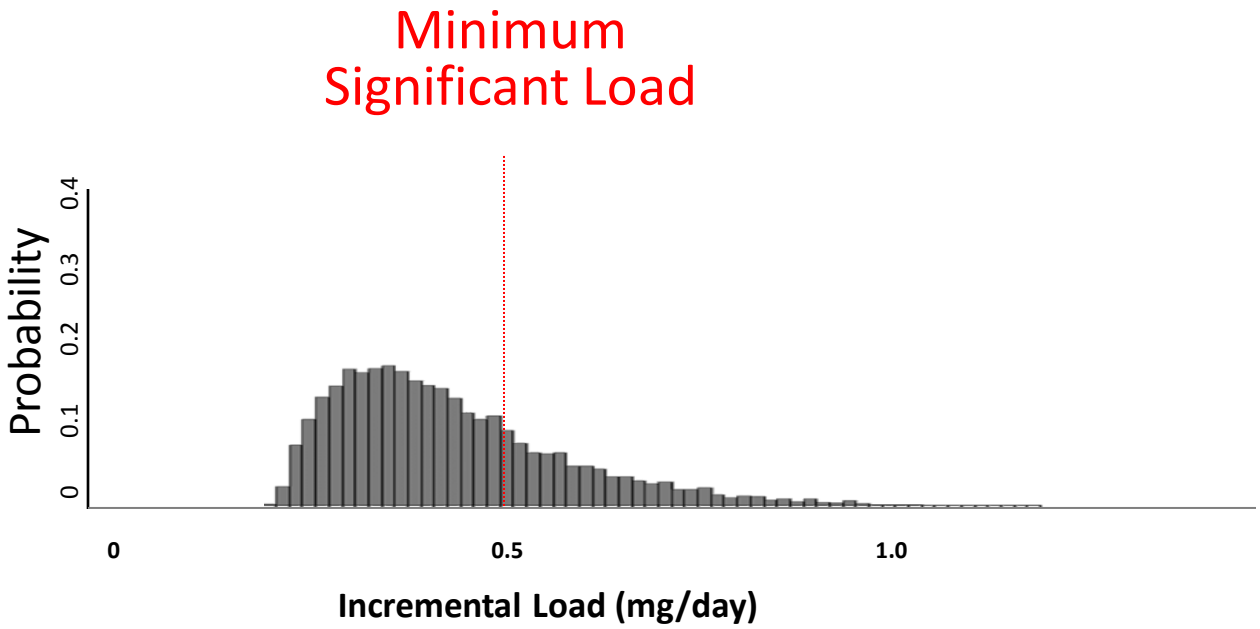
What Do We Do with the Results?

- Three potential outcomes
  2. Uncertain, but significant



What Do We Do with the Results?

- Three potential outcomes
  3. Uncertain, unclear significance



What Do We Do with the Results?

- Three potential outcomes
  1. Uncertain, but insignificant
     - Rule out (for near term) as potential source
  2. Uncertain, but significant
     - More detailed study of source(s)
  3. Uncertain, unclear significance
     - Additional exploration