Mekong River Commission

Ecological Risk Assessment Training Program

Quantitative Risk Analysis

Water Science Pty. Ltd.

Water Studies Centre

Risk Analysis

1. For each **assessment endpoint** determine:
   - **Consequences (effects)**
   - **Likelihood (probability)**
2. Best practice is to provide a **probabilistic** assessment of risk
3. To **quantify** the important **cause-effect relationships** we are using **Bayesian Networks**

Risk management plan

Decision process
(Alternative scenarios
Assess options)

...gical
...hazards

Risk analysis
(assess likelihood & consequences)

Rank risks

```
                    ┌──────────────────────────────┐
                    │           Initial             │
                    │  qualitative or semi-quantitative │
                    │       risk assessment         │
                    │    for each ecological effect  │
                    └──────────────────────────────┘
                                   │
                                   ▼
        Low risk            Risk uncertain            High risk
           │                     │                       │
           ▼                     ▼                       ▼
   ┌──────────────┐    ┌──────────────────────┐    ┌──────────────────┐
   │ No further   │    │      Undertake        │◄───│      Risk         │
   │ action       │    │ quantitative risk     │    │  investigations   │
   │              │    │   assessment          │    └──────────────────┘
   └──────────────┘    │                       │    ┌──────────────────┐
                       └──────────────────────┘◄───│   Uncertainty     │
                                   │                │    analysis       │
                                   ▼                └──────────────────┘
```

Risk analysis

- Need information on:
  - Likelihood of hazards having an effect
  - Consequences (size, magnitude, severity) of effect if it does occur
- Three levels:
  - Tier 1 - qualitative risk analysis
  - Tier 2 - semi-quantitative risk analysis
  - Tier 3 - quantitative risk analysis
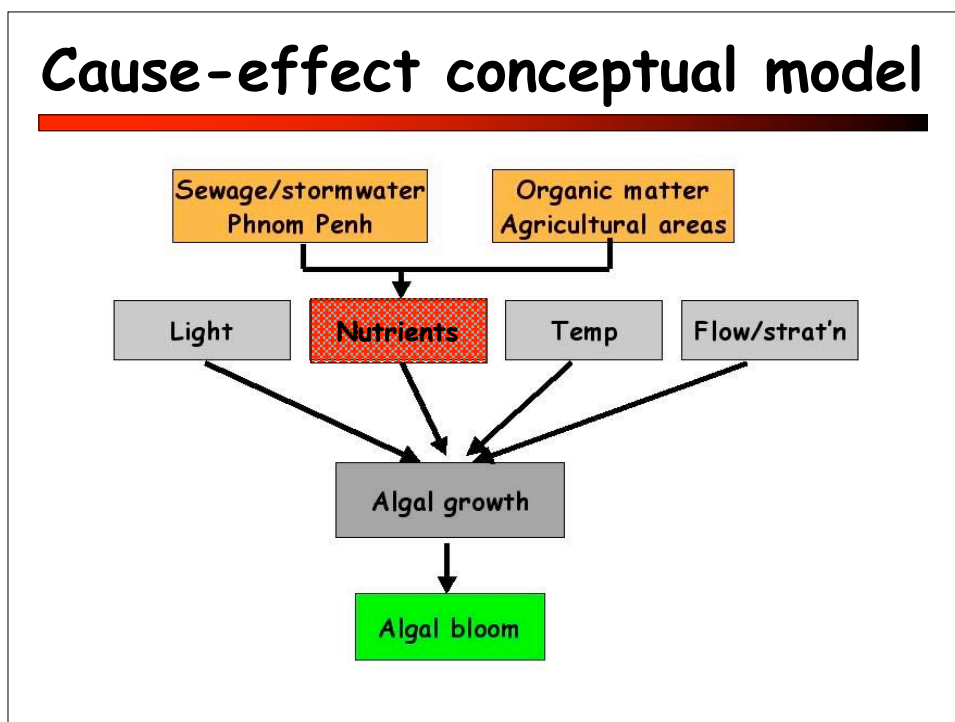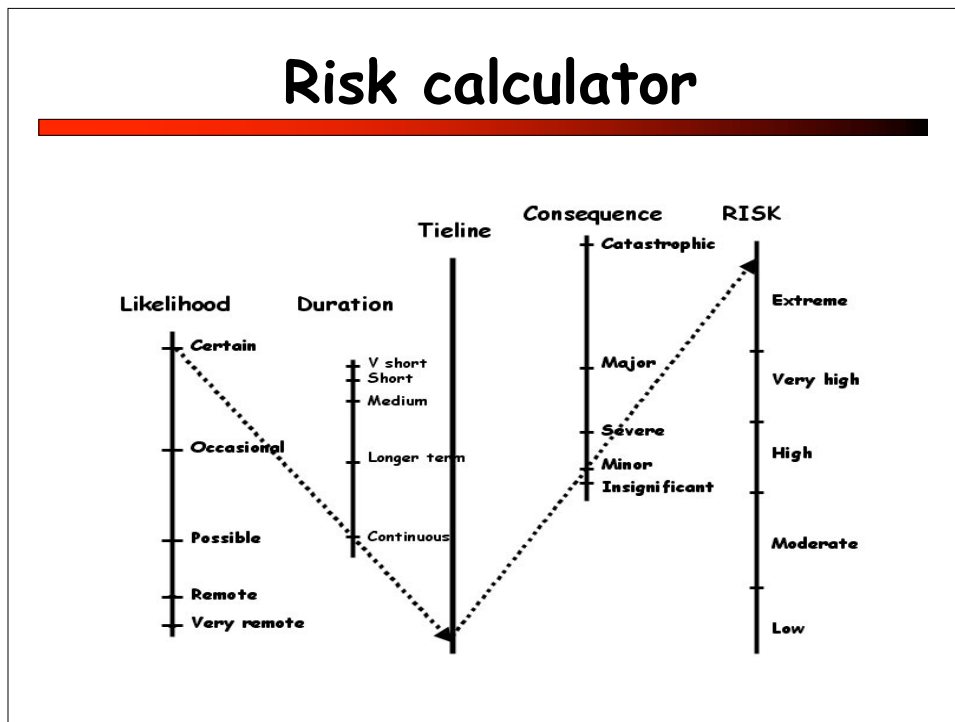
Qualitative risk analysis

- Use words to describe likelihoods and consequences
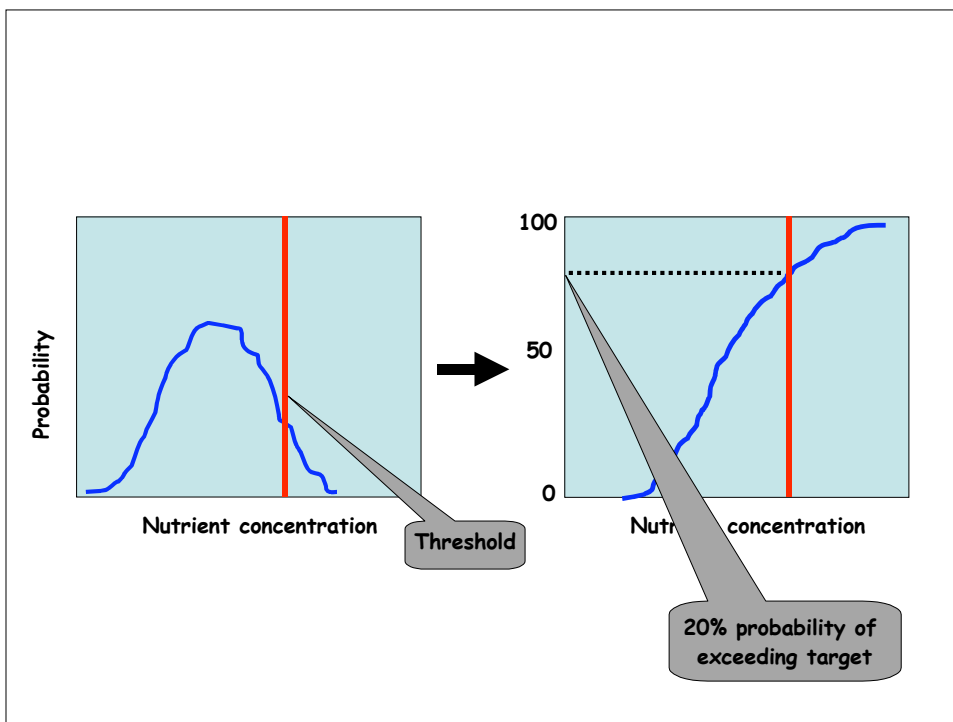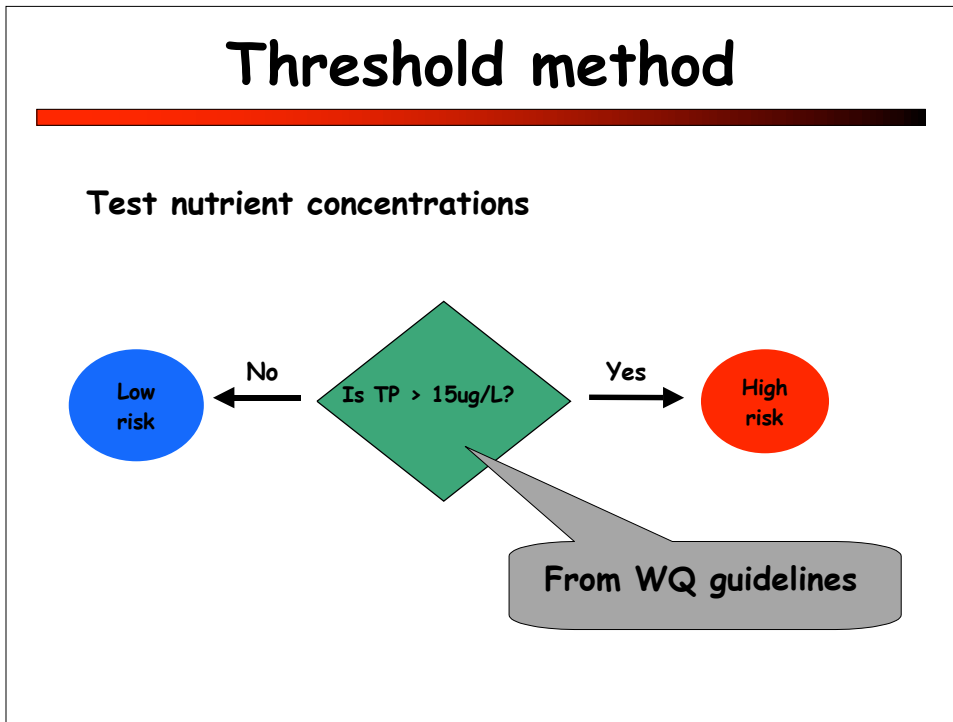- These types of analyses suffer from following (non-transparent) problems:
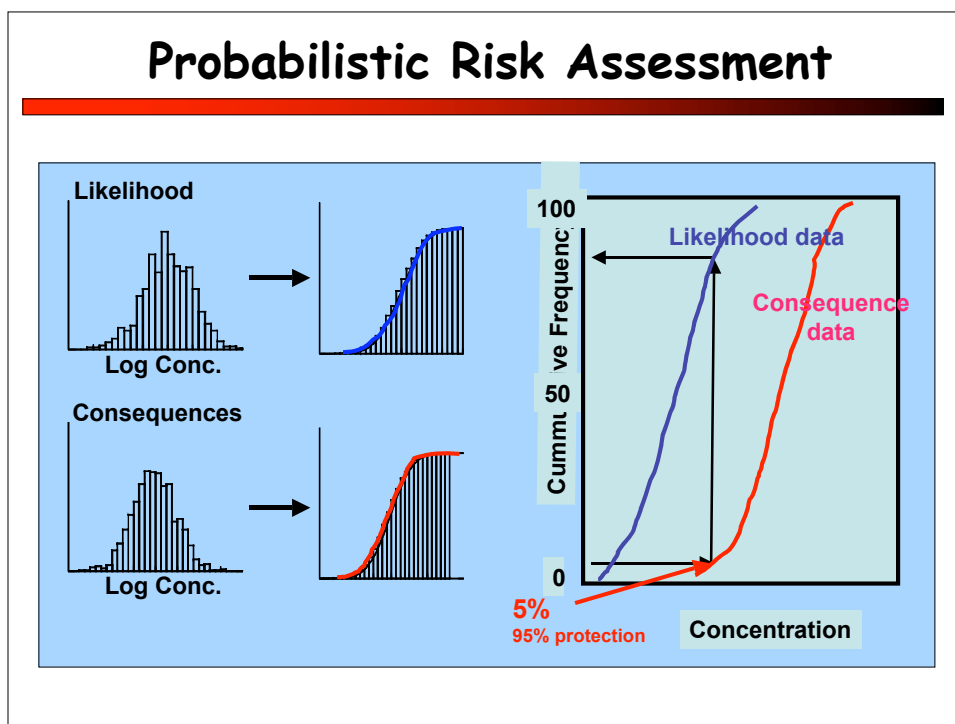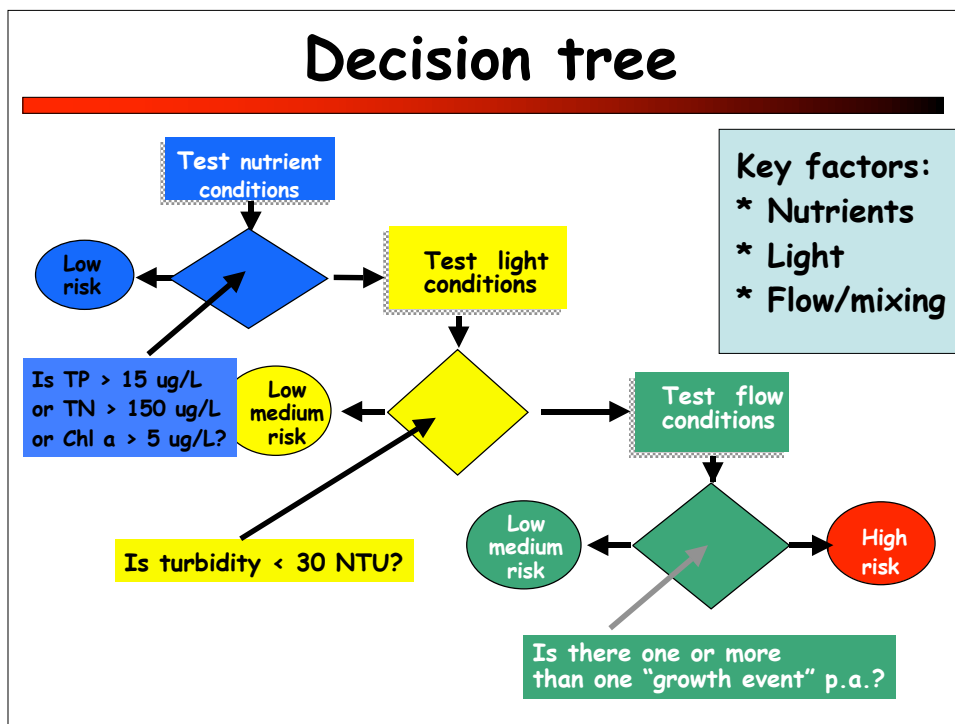 - Vagueness
  - Subjectivity
  - Bias

Likelihood	Consequences			
	Marginal	Minor	Intermediate	Major
Almost always	Low	Moderate	High	High
Likely	Negligible	Low	High	High
Unlikely	Negligible	Low	Moderate	High
Almost never	Negligible	Negligible	Low	Moderate

Quantitative risk analysis

- Use numerical values for both likelihood and consequence
- Wide range of approaches:
  - Risk calculator
  - Decision/logic trees
  - Probabilistic (ecotoxicological) methods
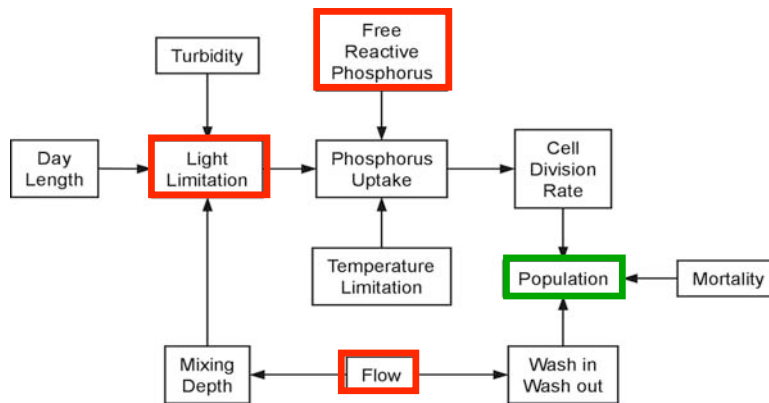 - Predictive models
  - Bayesian networks

Risk calculator

Likelihood | Duration | Tieline | Consequence | RISK

- Certain
- Occasional
- Possible
- Remote
- Very remote

Duration:
- V short
- Short
- Medium
- Longer term
- Continuous

Consequence:
- Catastrophic
- Major
- Severe
- Minor
- Insignificant

RISK:
- Extreme
- Very high
- High
- Moderate
- Low

Cause-effect conceptual model

| Sewage/stormwater Phnom Penh | Organic matter Agricultural areas |

| Light | Nutrients | Temp | Flow/strat'n |

Algal growth

Algal bloom

Threshold method

Test nutrient concentrations

Low risk ← No — Is TP > 15ug/L? — Yes → High risk

From WQ guidelines

Probability

Nutrient concentration

Threshold

100

50

0

Nutrient concentration

20% probability of exceeding target

Decision tree

Test nutrient conditions

Low risk

Is TP > 15 ug/L or TN > 150 ug/L or Chl a > 5 ug/L?

Low medium risk

Test light conditions

Is turbidity < 30 NTU?

Test flow conditions

Low medium risk

High risk

Is there one or more than one "growth event" p.a.?

Key factors:
* Nutrients
* Light
* Flow/mixing

Probabilistic Risk Assessment

Likelihood

Log Conc.

Consequences

Log Conc.

100

Cummulative Frequency

Likelihood data

Consequence data

50

0

5%
95% protection

Concentration

Predictive models

- **Many process-based models available**
  - Catchment transport models (salinity, sediment, nutrients)
  - Eutrophication models

Predictions - Bourke Weir Pool
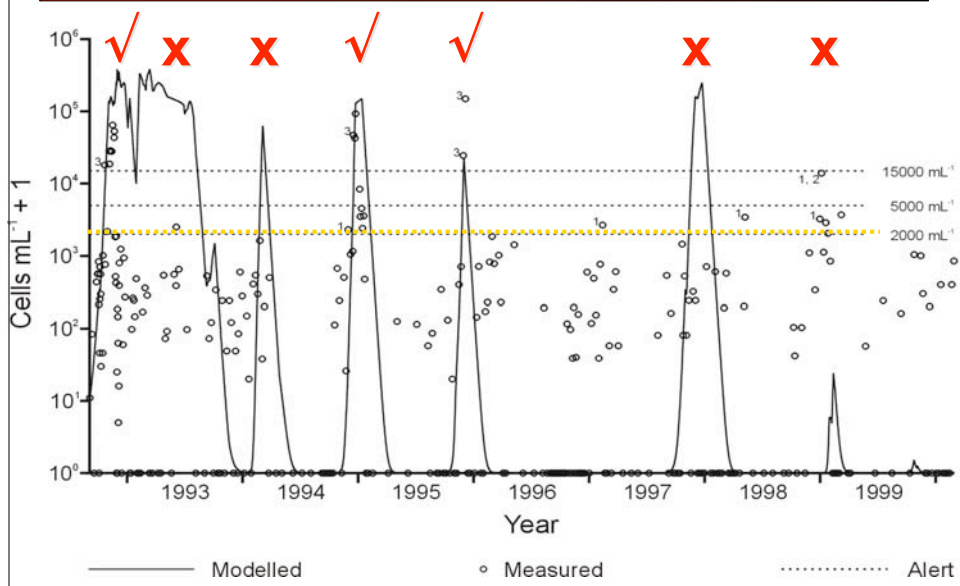
Predictive models

- Deficiencies
  - Often built on many (hidden) assumptions
  - Often many fitted parameters
  - Need to be recalibrated if applied to another system
  - Not able to address multiple stressors
  - Rarely treat uncertainty explicitly
  - Rarely couple contaminant transport with ecological effects (not good cause-effect models)
- Given inherent complexity and lack of knowledge about many basic processes and relationships - other types of models may offer promise

Bayesian approaches

- Useful when scant data is available
- Can use both subjective (e.g. expert opinion) and quantitative (e.g. monitoring data, modelling results) information
- Can be used to compare likelihood of different management actions (predictive)
- Iterative - can incorporate new information
- Explicitly incorporates uncertainty in analyses - provides a probability distribution for predicted variables
- Software packages now available:
  - Netica (www.norsys.com)
  - HUGIN (www.hugin.com)

Key messages

- Risk analysis phase provides information on the consequences & likelihood of each issue
- Qualitative methods (e.g. Risk matrix) can assist - but issues of bias, subjectivity,…
- Quantitative methods best where issue warrants it
- Many quantitative methods available
- Will consider in detail on new promising method - Bayesian decision networks