Water Column Evaluation

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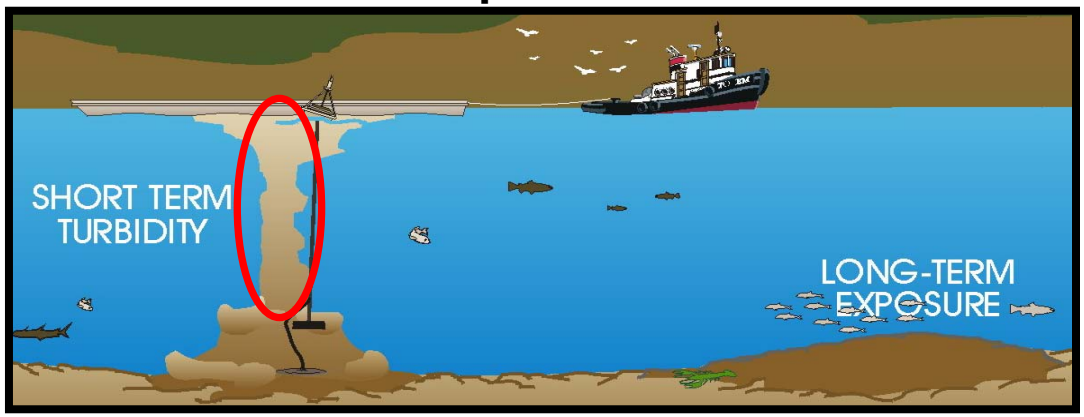
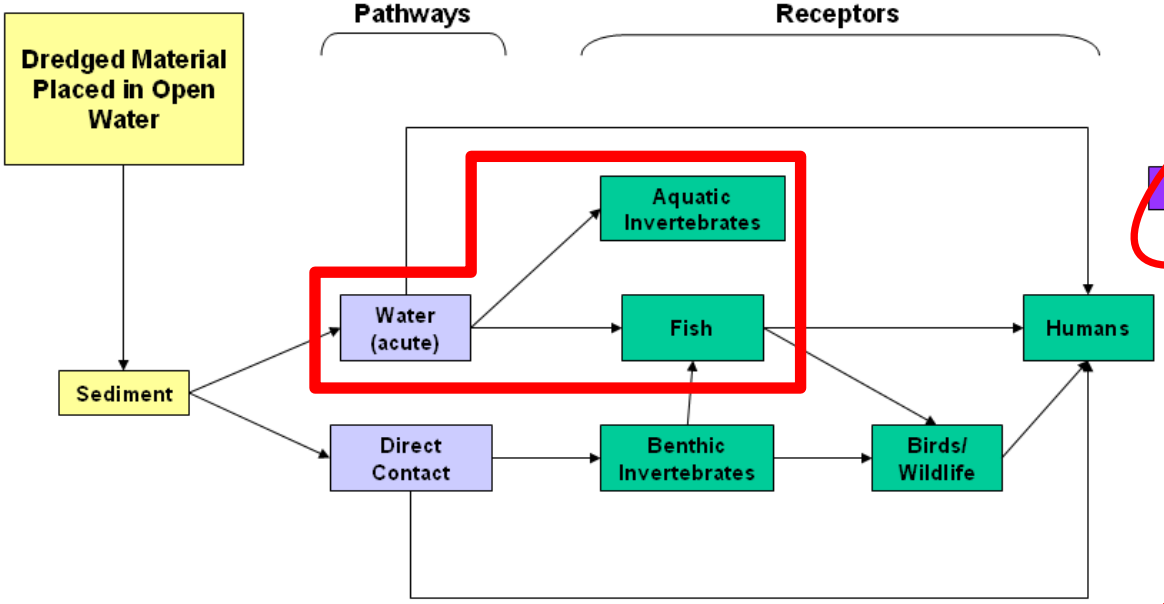
Water Column Evaluation
(Approach)

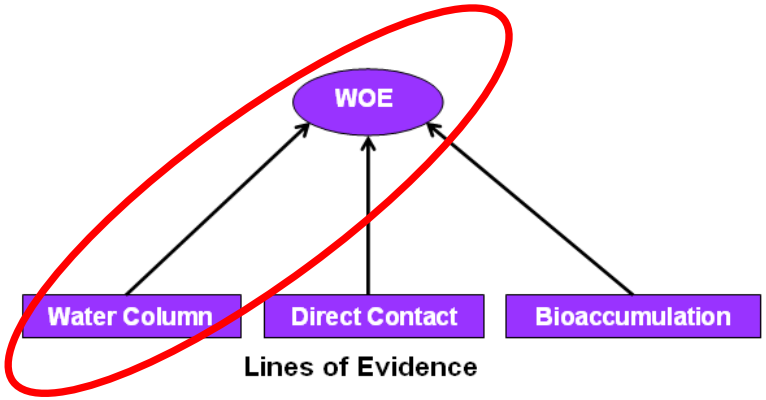
- **Main objectives**
  - **Assess potential for water column toxicity**
    - **Open water disposal of dredged material (DM)**
  - **DM suspended in water for short period**
    - **The concern is with short-term exposure and effects**
  - **Determine if chemical concentrations provide enough information?**
    - **How do contaminant concentrations relate to applicable standards?**
    - **Can an informed decision regarding toxicity potential be made?**
    - **If more information needed, move to bioassay testing**

Water Column Evaluation
(Conceptual Model)

Potential of DM disposal to cause adverse effects on water column organisms



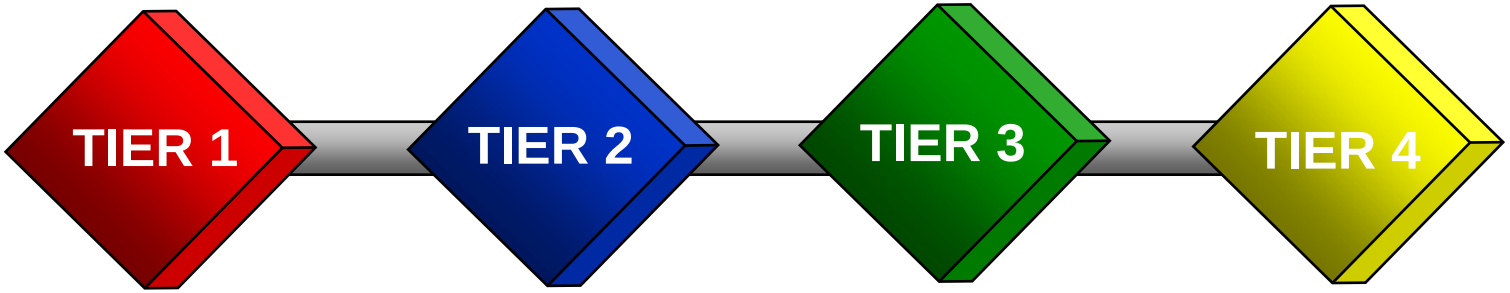




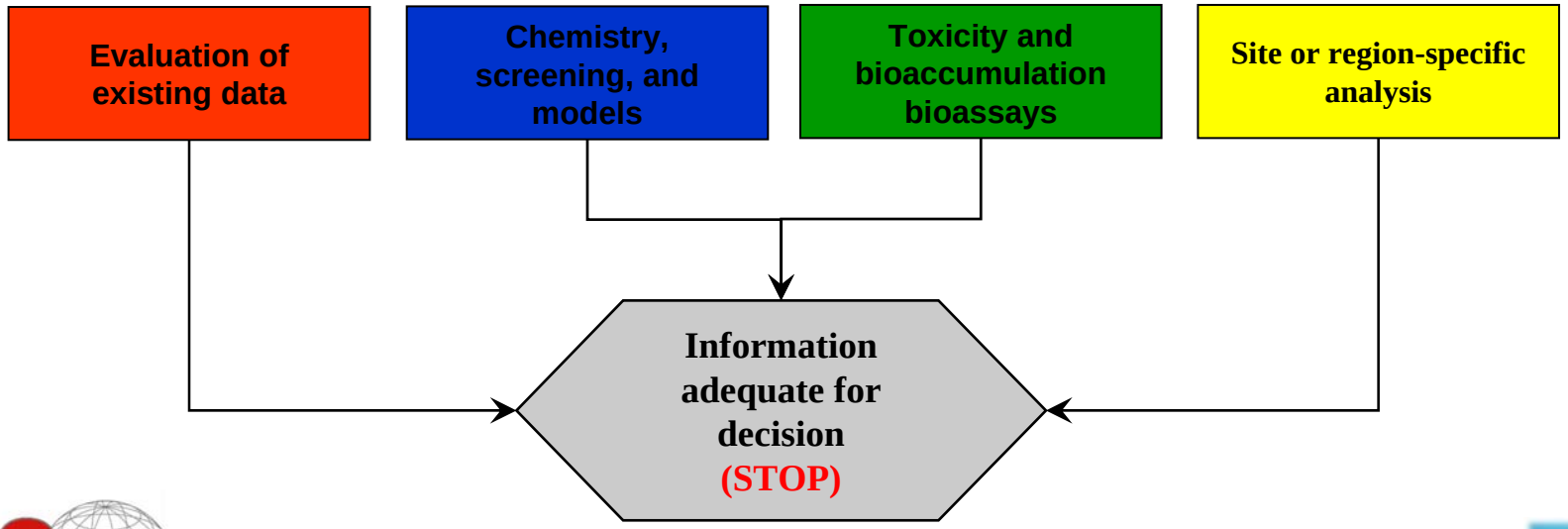
Water column toxicity is one assessment considered in DM disposal

Water Column Evaluation

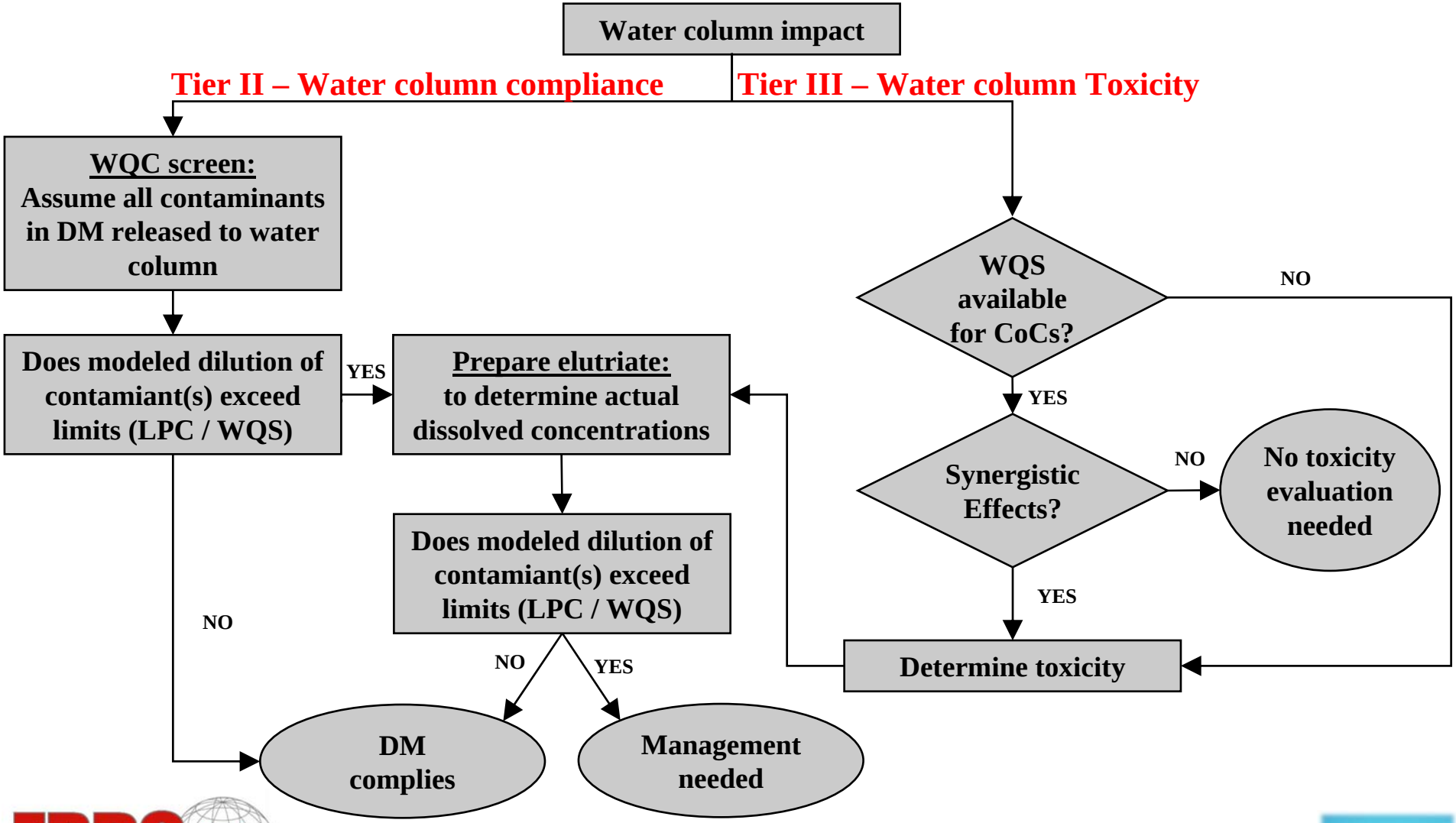
Increasing information and cost



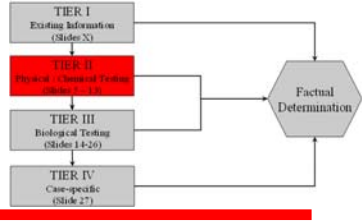
Tiered process → follow as far as necessary to make decision



Water Column Evaluation
(Decision Tree)

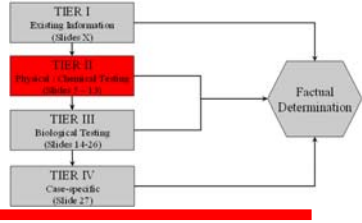


Water Column Evaluation
(Physical / Chemical Testing)



- **Contaminant concentration in disposed DM:**
  - **Ocean disposal (Ocean Testing Manual)**
    - **Seaward of national baseline**
    - **Marine Protection, Research and Sanctuaries Act (MPRSA)**
    - **Limiting Permissible Concentration (LPC)**
      - Definition: concentration of DM constituents in the water after mixing that does not exceed applicable marine WQC
      - Usually 0.01 factor applied to LC50
  - **Inland disposal (Inland Testing manual)**
    - **Landward of national baseline, rivers, lakes**
    - **Clean Water Act**
    - **Mixing zones variable – contingent on state, water body**
    - **Compliance with WQS (at least as strict as national standards)**

Water Column Evaluation
(Physical / Chemical Testing)



Must meet LPC after 4 hours mixing

Must meet LPC/WQS at all times

Mixing Zone

Outside Zone

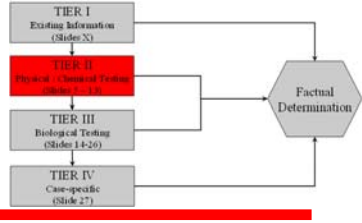
MPRSA

DM

Sediment

"The discharge of dredged material cannot cause the WQS to be exceeded outside the mixing zone unless the State provides a variance to the standard."
---Inland Testing Manual (1998)

TIER II:
Two step process



1. Screening Step:

- Conduct chemical analysis of DM for CoCs
- Very conservative assumption
  - 100% DM contaminants goes to water
- Apply to contaminant requiring greatest dilution (D)
  - DM < LPC or WQS → DM complies → STOP
  - DM > LPC or WQS → Move to step 2

$$D = C_s * \frac{SS}{1000} - \frac{C_{wq}}{C_{wq} - C_{ds}}$$

D = Dilution to meet WQS and / or WQC
Cs = contaminant concentration in the sediment
SS = suspended solids concentration
Cwq =WQS and / or WQC
Cds = Disposal site concentration

2. Elutriate preparation step:

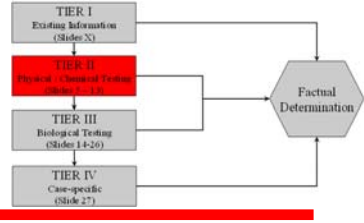
- More realistic chemical analysis
- Use more representative dissolved concentrations in mixing model
- No biological testing

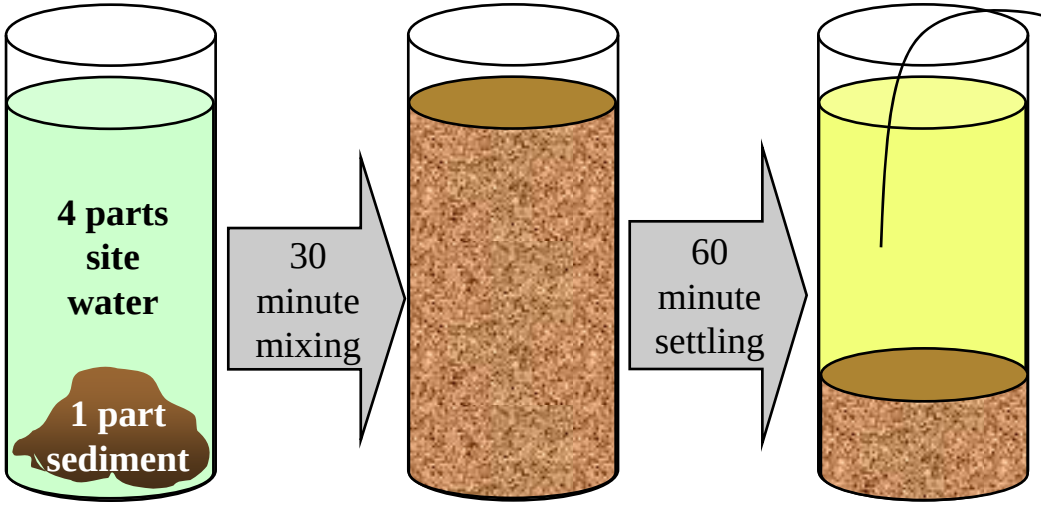
$$D = \frac{C_e - C_{wq}}{C_{wq} - C_{ds}}$$

Cwq =WQS and / or WQC
Cds = Disposal site concentration micrograms per liter
Ce =concentration of the dissolved contaminant in the standard elutriate

Compare above values to LPC / WQS
Apply data into predictive numerical mixing model (Appendix C)

TIER II:
Step Two: Prepare Elutriate

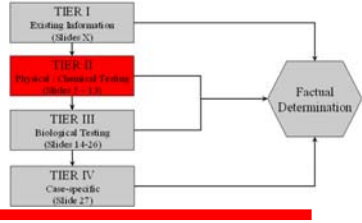




1. Remove overlying water
2. Centrifugation / filtration
3. Chemical analysis

Media Type	Application
Dredged Material (1 part)	Elutriate preparation
Dredging Site Water (4 parts)	Elutriate preparation

TIER II:
Possible conclusions



Modeled prediction of concentration

- If concentration > LPC/WQS **Exceeds guidelines** **(STOP)**
- If concentration < LPC/WQS **Meets guidelines** **(STOP)**
- Inadequate information for decision → **Tier III**

1. DM exceeds LPC / WQS

- ✓ Needs management action
- ✓ No further testing needed

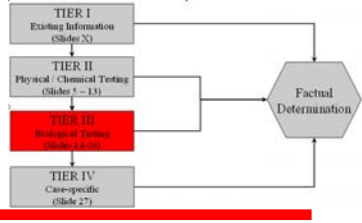
2. DM meets LPC / WQS:

- ✓ 4-hours within mixing zone (MPRSA)
- ✓ At all times outside mixing zone

3. DM meets LPC / WQS but…

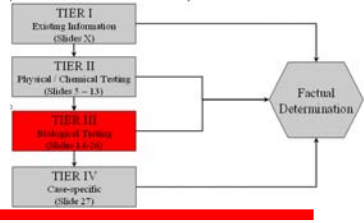
- ✓ WQC not available some contaminant(s)
- ✓ Concern for contaminant interactions
  - ➢ Move to Tier III analysis

TIER III:
Overview

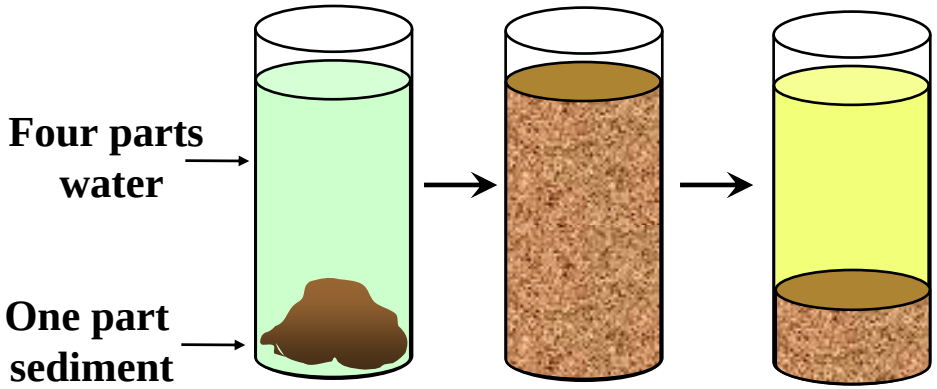


- **Biological testing conducted if Tiers I / II:**
  - Do not supply adequate information for decision
  - Identify CoCs that lack WQS
  - Suggest DM contains contaminants at potentially adverse levels (gray area)
  - Suggest potential for unknown chemical interactions
- **Tier III**
  - Biological exposures conducted
  - Evaluate potential for toxicity
    - Generate lethal / effective median concentration (LC / EC50)
    - Relate toxicity information to mixing model / standards

TIER III:
Biological Testing Summary



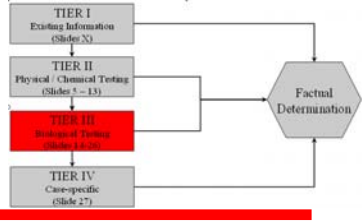
- Prepare elutriate (as before)



- Remove overlying water
- Contains both dissolved and suspended DM
  - Centrifuge / filter (only if necessary to assess survival)
- Assess survival across elutriate dilution
- Apply resulting toxicity data to mixing model

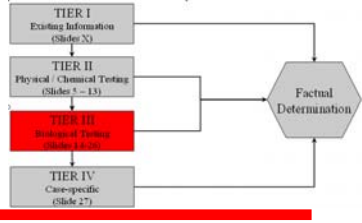
Media Type	Application
Dredged Material (1 part)	Elutriate preparation
Dredging Site Water (4 parts)	Elutriate preparation
Disposal Site Water	Dilution of elutriate for bioassay
Reconstituted (or other approved) water	

TIER III:
Test Species Selection



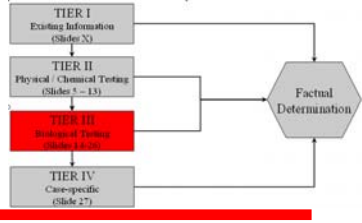
- **Three species of different phyla recommended to evaluate the potential for elutriate toxicity**
  - **Zooplankton, crustaceans, fish, molluscs, (phytoplankton)**
  - **MPRSA → must test two species**
  - **CWA → should test multiple species**
  - **At least one needs to be a recommended species (previously "benchmark")**
    - **Routinely utilized**
    - **Proven track record**
    - **National guidance or RIM**

TIER III:
Test Species Selection

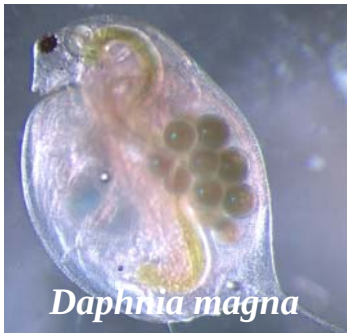


- **Other test species can represent organisms indigenous to the disposal site**
  - **Important local species**
  - **Regional Implementation Manuals**
- **Factors to consider during selection (no order of importance)**
  - **Ecological relevance / indigenous**
  - **Appropriate chemical sensitivity / age class (juveniles)**
  - **Availability of standardized protocol / consistent track record**
  - **Availability year round**
  - **Susceptibility to confounding factors (DO_2, laboratory handling)**

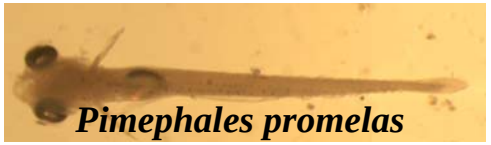
Tier III: Test Species
Freshwater disposal



- **Freshwater (< 1 ‰)**
  - **Arthropoda / Crustacea**
    - Cladocerans (i.e., zooplankton)
      - *Daphnia magna / pulex **
      - *Ceriodaphnia dubia **
  - ***Vertebrata***
    - Fish
      - *Pimephales promelas **
      - *Lepomis macrochirus*
      - *Oncorhynchus mykiss **


Daphnia magna


Ceriodaphnia dubia

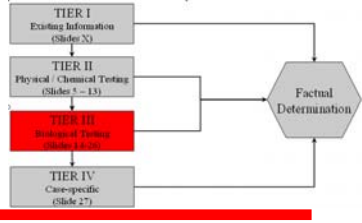

Pimephales promelas


Lepomis macrochirus

OK Dept Wildlife Conservation

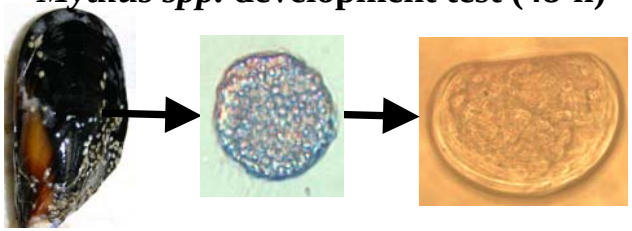
*** Recommended species**

Tier III: Test Species
Marine/estuarine disposal



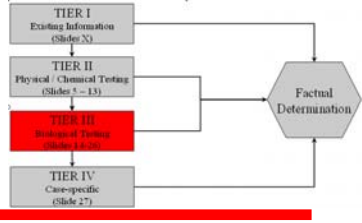
- **Marine (> 25 ‰)**
  - Echinodermata
    - Urchins, *Strongylocentrotus, Arbacia*
    - Sand Dollar, *Dendraster spp.*
  - Arthropoda / crustacea
    - *Shrimp*
      - *Americamysis bahia* *
      - *Neomysis* *
      - *Holmesimysis spp.* *
    - Copepods, *Acartia* sp. *
- **Estuarine / Marine (1 – 25+ ‰)**
  - Bivalve Molluscs
    - Oysters, *Crassostrea spp.* *
    - Mussels, *Mytilus spp.* *
  - Vertebrata
    - Silversides, *Menidia* *
    - *Cyprinodon variegatus* *

***Mytilus spp.* development test (48-h)**

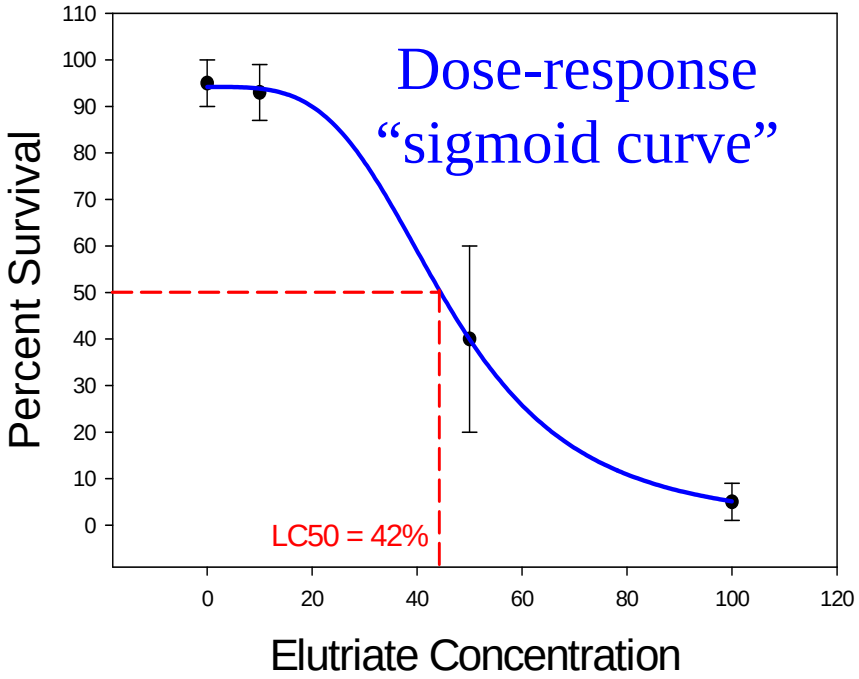


*** Recommended species**

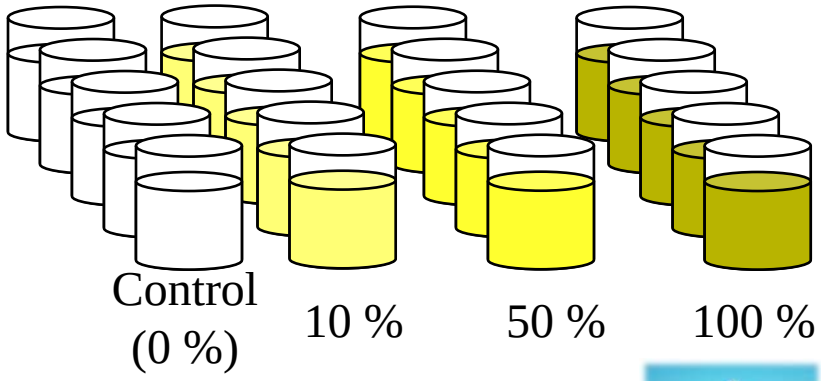
TIER III:
Conduct of Bioassays



Test methods	ITM Appendix E
Exposure	48 or 96-hours
Primary endpoint	Survival or development
Dilutions	Three (10, 50, 100%)
Replicates / dilution	Five
Organisms / replicate	Usually 10
Acceptability criterion	• ≥70 or 90 % survival • Reference toxicity test within range

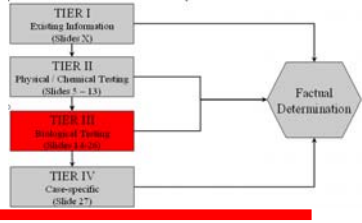


Specific testing protocols
- **ITM Appendix E**
- **US EPA / ASTM citations within**



ERDC
Engineer Research and Development Center

TIER III:
Data analysis



<u>STEP 1</u>: Is survival in undiluted elutriate significantly reduced relative to the control? (t-test if > 10%)

no

1. Elutriate not "acutely toxic"
2. meets the LPC / WQS

Still need to consider benthic effects

yes

Can a LC50 be generated?

yes

LPC = 0.01 LC50

no

LPC = NOEC or LOEC

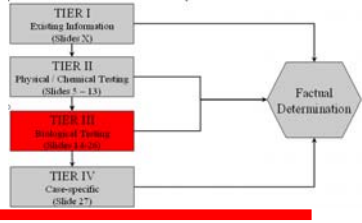
<u>STEP 2</u>: Does the concentration predicted by the model exceed the LPC at the point of compliance?

no

yes

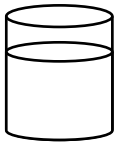
1. Elutriate "acutely toxic," or
2. Elutriate exceeds the LPC / WQS

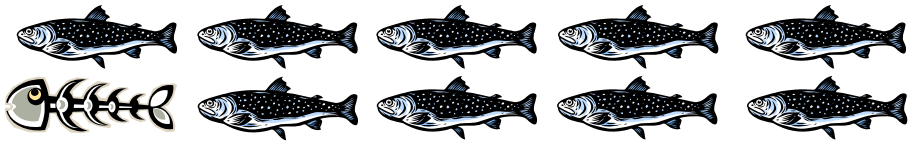
TIER III:
Data Analysis (Step 1)



- **Is survival in the undiluted elutriate reduced more than 10% relative to the control?**
- **Is the undiluted elutriate statistically reduced relative to the control (dilution water)?**

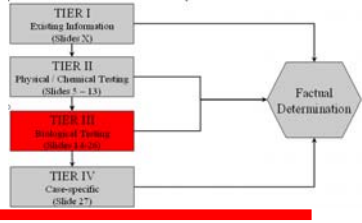
Undiluted Elutriate  **= 20 ± 8% Survival**

Dilution water (control)  **= 90 ± 5% Survival**



- **Next step: determine LC50 value, LPC and modeled dilution**

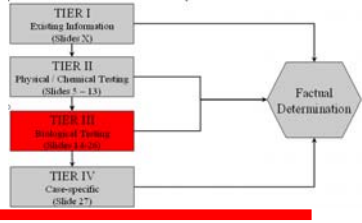
TIER III:
Data Interpretation



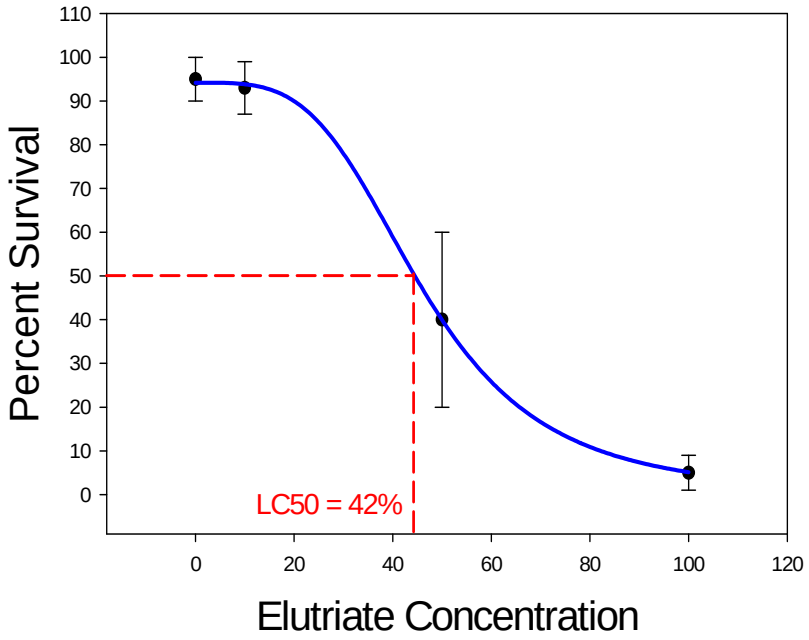
Outcome	Bioassay Interpretation	LC / EC50	Action	Value for model
Survival in undiluted elutriate not statistically reduced relative to control	No acute toxicity predicted	Cannot be calculated (assumed >100%)	No need to run mixing model	
Survival in undiluted elutriate statistically reduced but > 50%	Acute toxicity predicted	Cannot calculate Compute LC50	Run mixing model	NOEL or LOEL
Survival in highest undiluted elutriate < 50%	Acute toxicity predicted	Compute LC50/EC50	Run mixing model	0.01 LC/EC50
Survival < 50% in all dilutions	Acute toxicity predicted	Cannot be calculated by interpolation	Repeat bioassay with greater dilutions	

e.g., 42%

TIER III:
Data Analysis (Step 2)



Determine the LC50 value

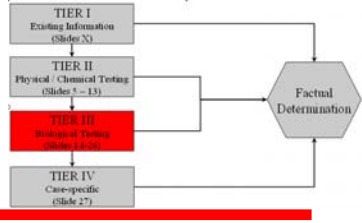


LC50 (42%) X 0.01 (LPC) = 0.42%

Model output indicates DM is < 0.1% inside and outside the mixing zone

- DM diluted to lower concentration (0.1%) than LPC (0.42%)
- DM elutriate does not exceed LPC / WQS (“passes”)

TIER III:
Possible conclusions

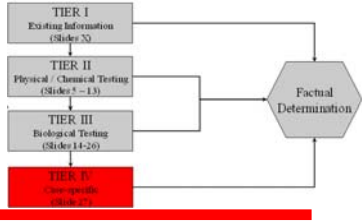


1. **DM discharge toxicity <u>not predicted</u> relative to the reference condition**

2. **DM discharge toxicity <u>is predicted</u> relative to the reference condition**

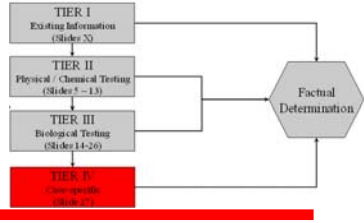
3. **Further information needed for actual determinations**
   - **Move to Tier IV (less common)**

TIER IV: Case-specific
(laboratory / field testing)



- **Implemented when lower tiers <u>do not</u> provide enough information for factual determinations**
  - Rare occasions
  - Inconclusive test results
  - Conflicting evidence
  - Ammonia toxicity suspected
- **Specific studies may include:**
  - Use of different test species / exposure durations / endpoints (e.g., growth, reproduction)
  - Laboratory *or in situ* exposures (field)
  - TRE / TIE to discriminate ammonia from metals / organics

Contaminant
TRE/TIE (ammonia)



Untreated elutriate toxic

Zeolite treated elutriate toxic

EDTA treated elutriate toxic

Toxicity due to factor other than ammonia / metals

EDTA treated elutriate not toxic

Toxicity may be due to metals

Zeolite treated elutriate not toxic

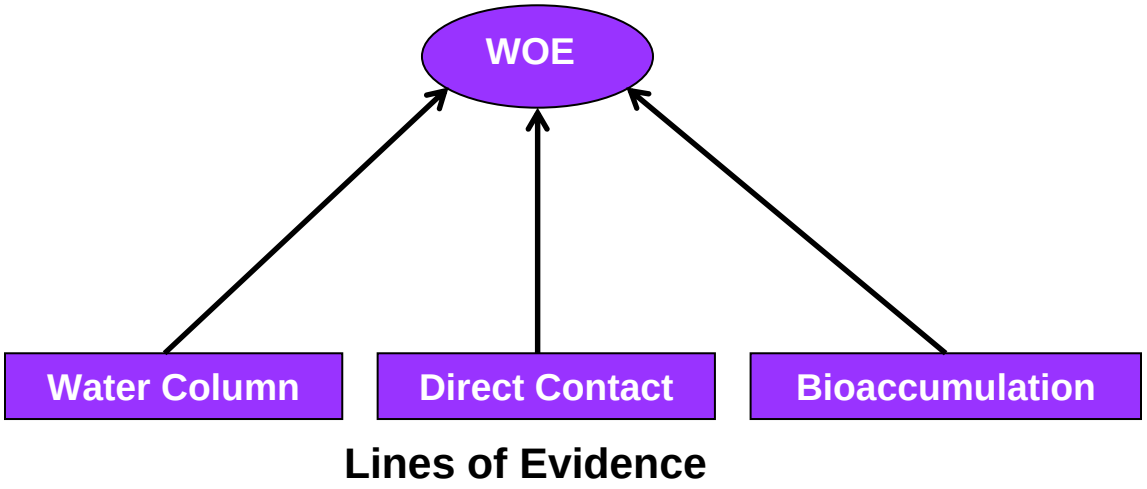
EDTA treated elutriate not toxic

EDTA treated elutriate toxic

Toxicity may be due to ammonia

Synthesis

- Main Goal: Evaluate potential of DM to cause adverse effects on water column organisms
- This is just one pathway to establish a weight of evidence
- Still need to consider other pathways (e.g., benthic toxicity)
- Process: Generate / analyze data to estimate potential for toxicity of DM disposal



- Procedure: Follow tiered process only as far as necessary to make risk-based decision