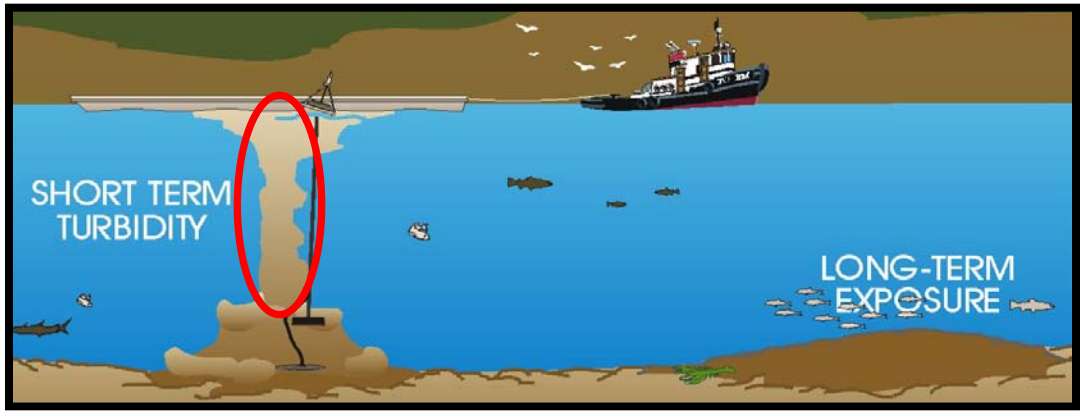
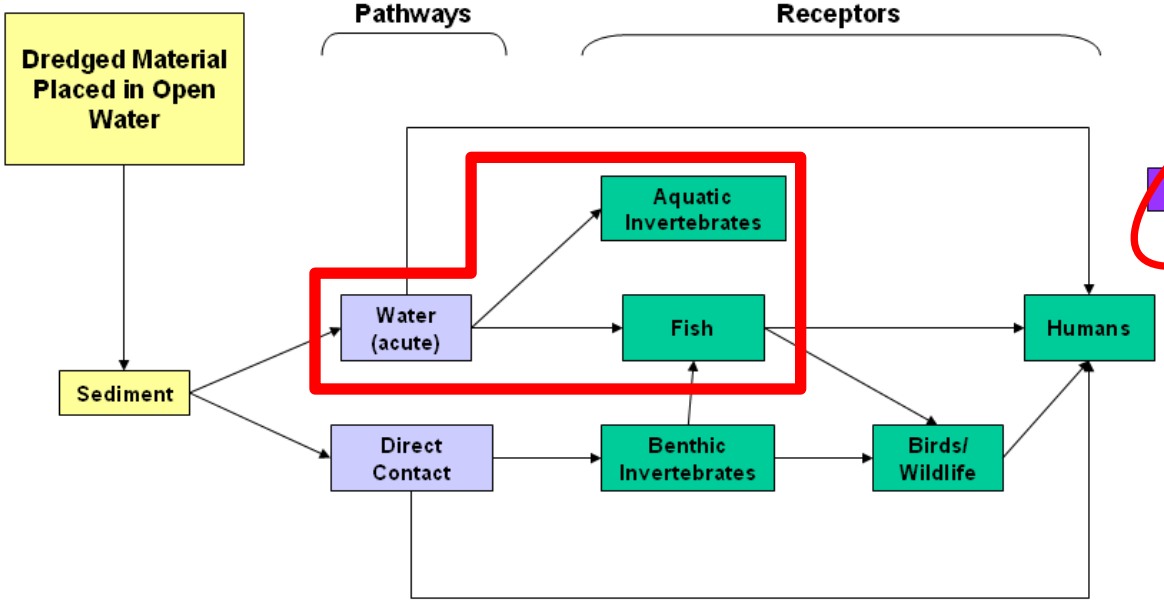
Water Column Evaluation

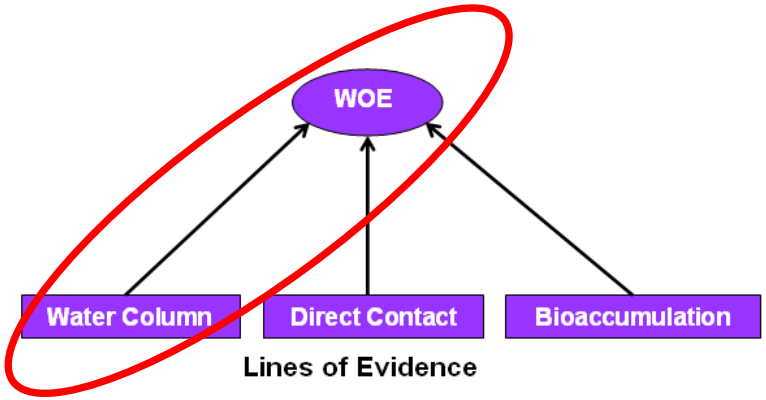
Alan J Kennedy
Research Biologist
US Army ERDC, Vicksburg, MS
Email: Alan.J.Kennedy@usace.army.mil

Water Column Evaluation
(Conceptual Model)

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







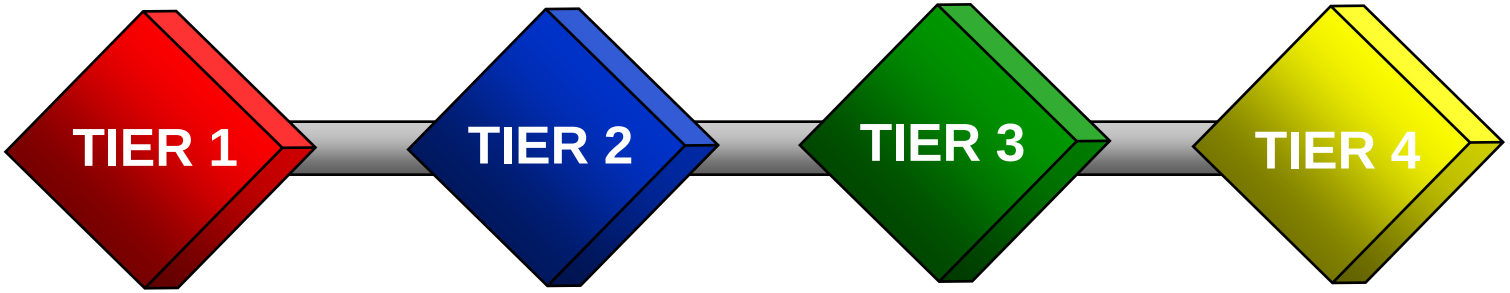
Water column toxicity is one assessment considered in DM disposal

Water Column Evaluation
Approach: Open water disposal of Dredged Material

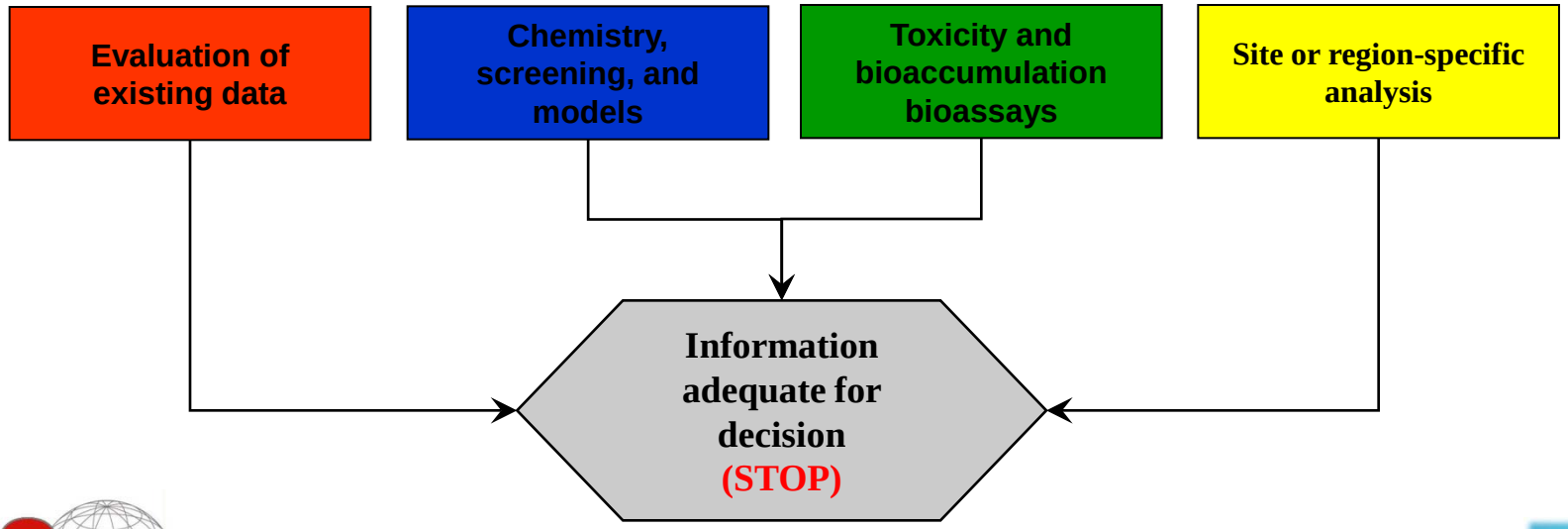
- **Main discussion points**
  - **DM is suspended in water for a short period**
  - **Short-term water column exposure and effects**
  - **Can a factual determination be made from existing information (chemical, toxicity values)?**
    - **Relate to applicable water quality standards**
    - **If more information needed, conduct bioassays**

Water Column Evaluation

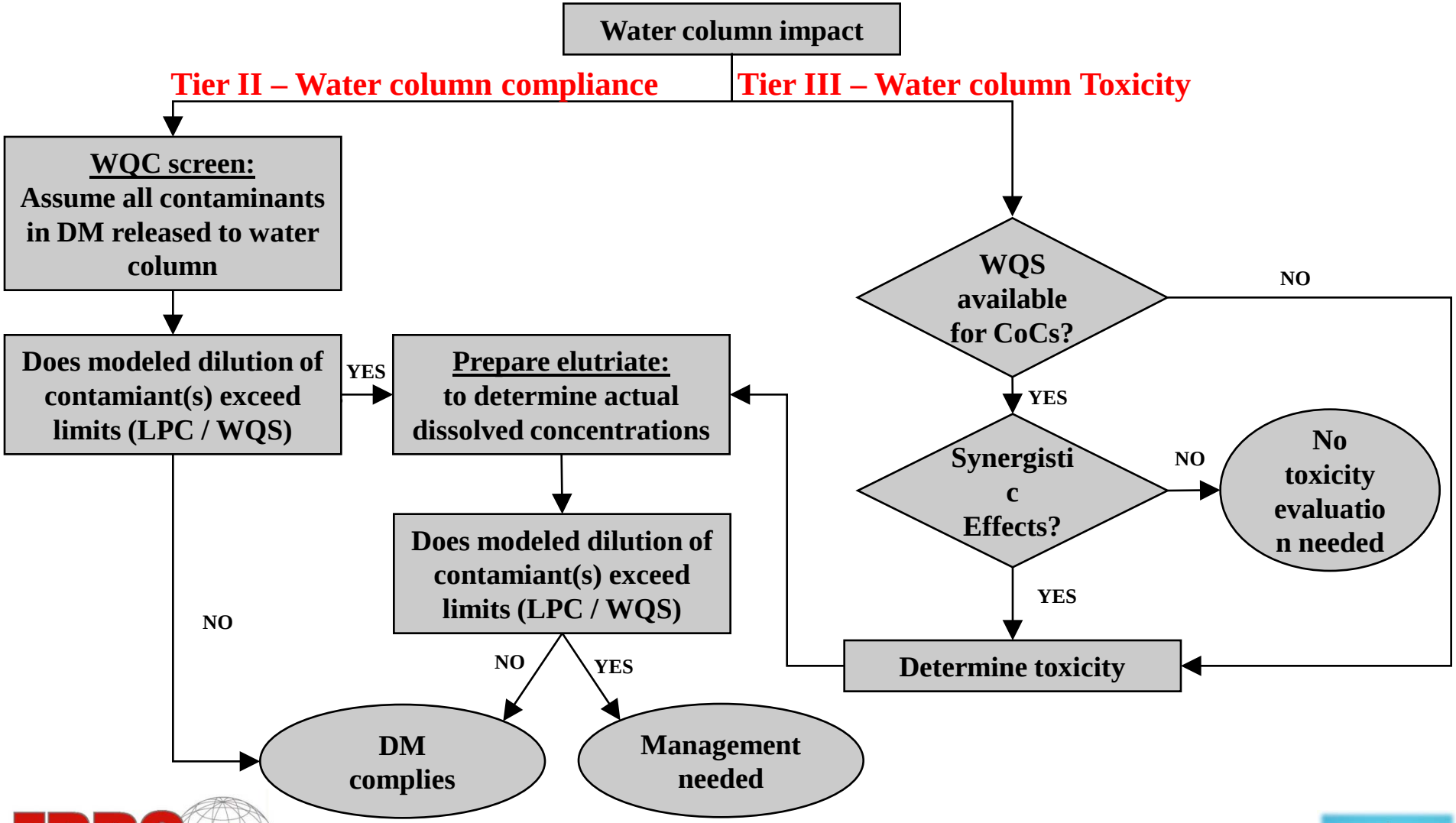
Increasing information and cost



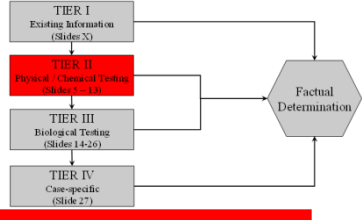
Tiered process → follow as far as necessary to make decision



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: Water concentration not to be exceeded by DM constituents after mixing
    - Based on Water Quality standards, or
    - An acute LC50 adjusted by an application factor (usually 0.01)
- **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)

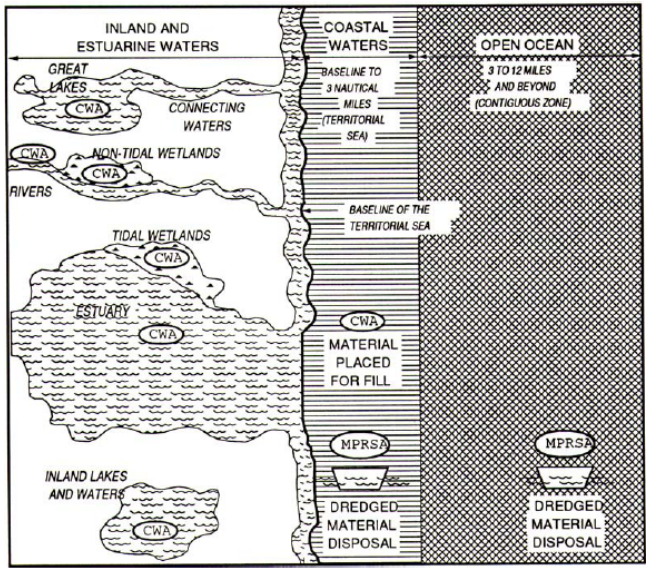
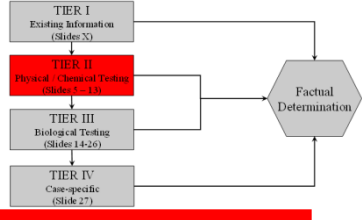


Figure 1-1. Geographical Jurisdictions of the MPRSA and CWA

From USEPA / USACE. 2004. EPA842-B-92-008.

Water Column Evaluation
(Physical / Chemical Testing)



Must meet LPC after 4 hours mixing

Must meet LPC/WQS at all times

Mixing Zone

Outside Zone

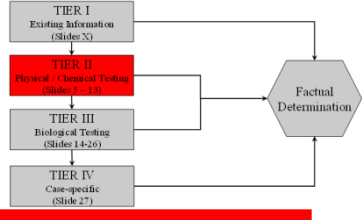
MPRSA

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
- Make very conservative assumption
  - 100% DM contaminants goes to water
- For 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
C_s = contaminant concentration in the sediment
SS = suspended solids concentration
C_{wq} =WQS and / or WQC
C_{ds} = Disposal site concentration

2. Elutriate preparation step:

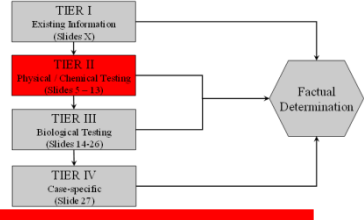
- More realistic chemical analysis
- Use more representative dissolved concentrations in mixing model
- No biological testing

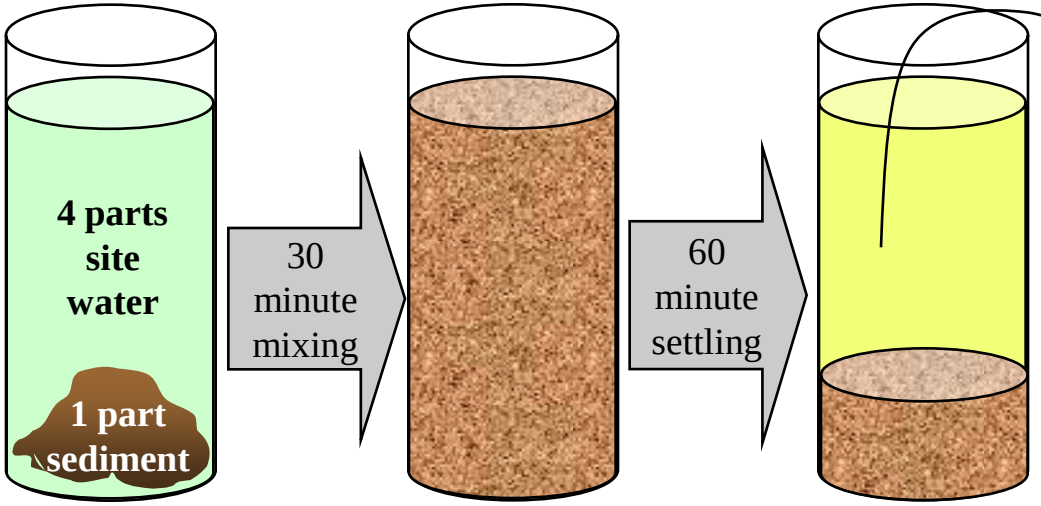
$$D = \frac{C_e - C_{wq}}{C_{wq} - C_{ds}}$$

C_e =concentration of the dissolved contaminant in the standard elutriate

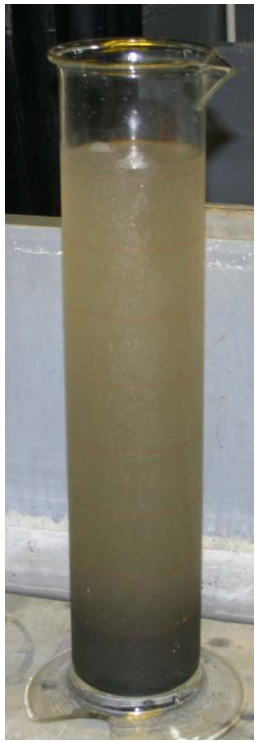
Compare above values to LPC / WQS
Apply data into predictive numerical mixing model (Appendix C)

TIER II:
Step Two: Prepare Elutriate



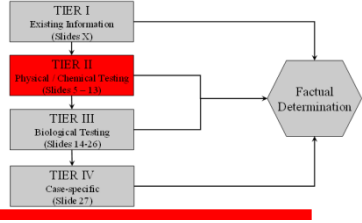


1. Remove overlying water
2. Centrifugation / filtration
3. Chemical analysis



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

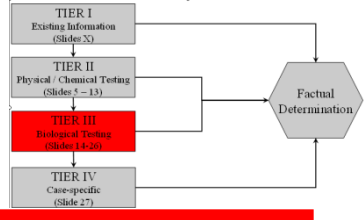
2. DM meets LPC / WQS:

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

3. DM meets LPC / WQS but…

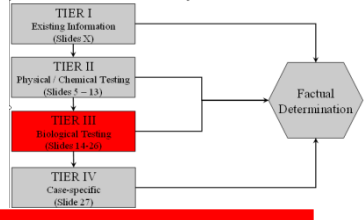
- ✓ WQC not available some contaminant(s)
- ✓ Concern for contaminant interactions
  - ➢ Move to Tier III analysis

TIER III:
Overview

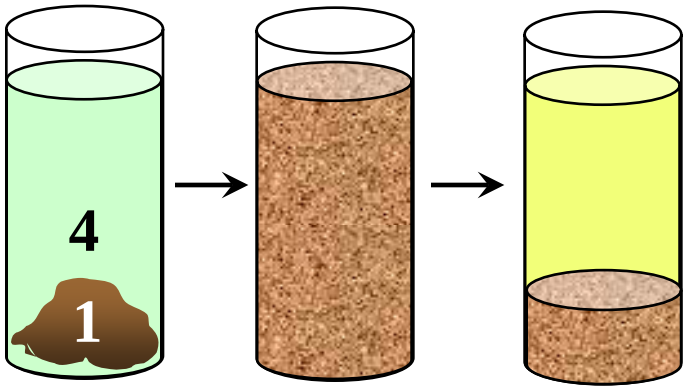


- **Biological testing conducted if Tiers I / II:**
  - **Inadequate information for factual determination**
  - **CoCs that lack WQS**
  - **Contaminants present at potentially adverse levels (gray area)**
  - **Potential for unknown chemicals or interactions**
- **Tier III**
  - **Biological exposures conducted**
  - **Evaluate potential for toxicity**
    - **Generate lethal/effective median concentration (L(E)C50)**
    - **Relate toxicity information to mixing model / standards**

TIER III:
Biological Testing Summary



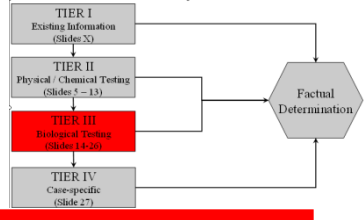
- **Prepare elutriate (as before)**



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

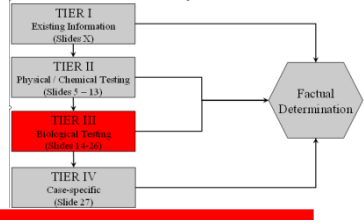
Media Type	Application
Dredged Material (1 part)	Elutriate preparation
Dredging Site Water (4 parts)	Elutriate preparation
Disposal Site Water (prefered)	Dilution of elutriate Reference water
Reconstituted Water (other approved water)	

TIER III:
Test Species Selection



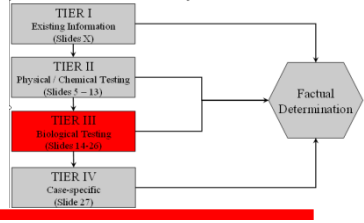
- **Three species of different phyla recommended to evaluate the potential for elutriate toxicity**
  - **Zooplankton, crustaceans, fish, molluscs, (phytoplankton)**
  - **MPRSA → must test three species**
  - **CWA → should test multiple species**
  - **At least one needs to be a recommended species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

TIER III:
Test Species Selection

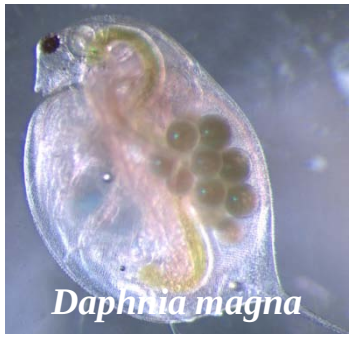


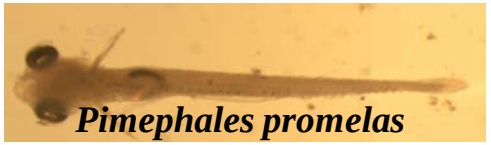
- **Other test species**
  - Represent organisms indigenous to the disposal site
  - Locally important
  - Regional Implementation Manuals
- **Species selection considerations**
  - Ecological relevance / indigenous
  - Appropriate chemical sensitivity / age class (e.g., larvae, juveniles)
  - Availability of standardized protocol / consistent track record
  - Susceptibility to confounding factors (DO_2, laboratory handling)
  - Availability year round

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 ****



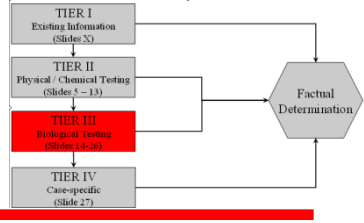


Lepomis macrochirus

OK Dept Wildlife Conservation

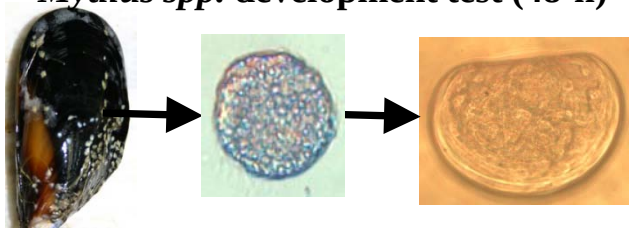
*** Recommended species**

Tier III: Test Species
Marine/estuarine disposal



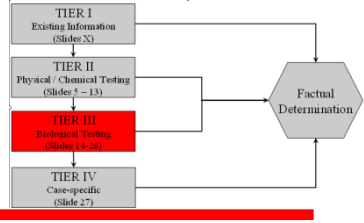
- **Marine (> 25 ‰)**
  - Echinodermata
    - Urchins, *Strongylocentrotus, Arbacia*
    - Sand Dollar, *Dendraster spp.*
  - Arthropoda / crustacea
    - *Shrimp*
      - *Americamysis bahia* *
      - *Neomysis* *
      - *Holmesimysis spp.* *
    - Copepods, *Acartia* sp. *
- **Estuarine / Marine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

Mytilus spp. development test (48-h)

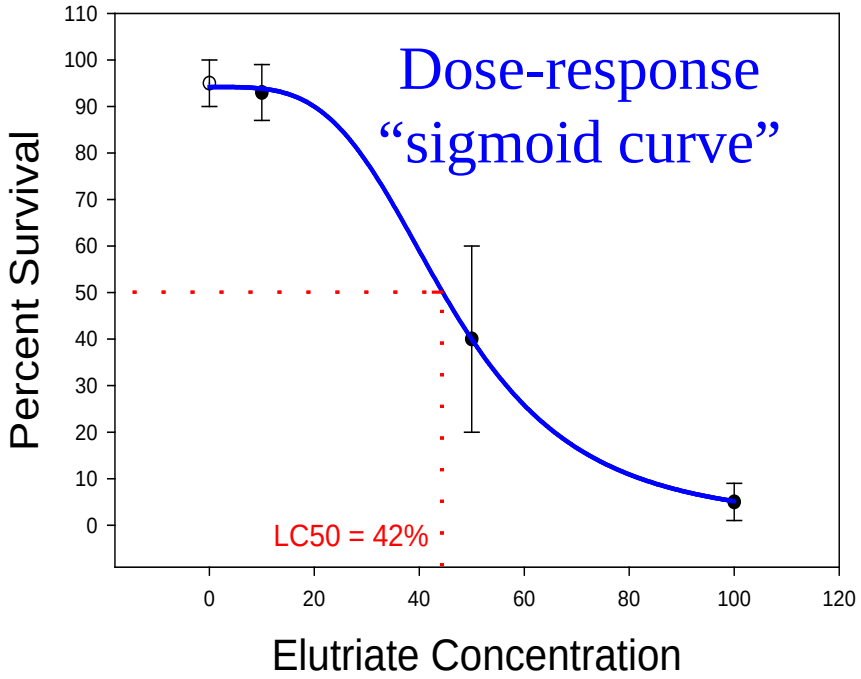


* Recommended species

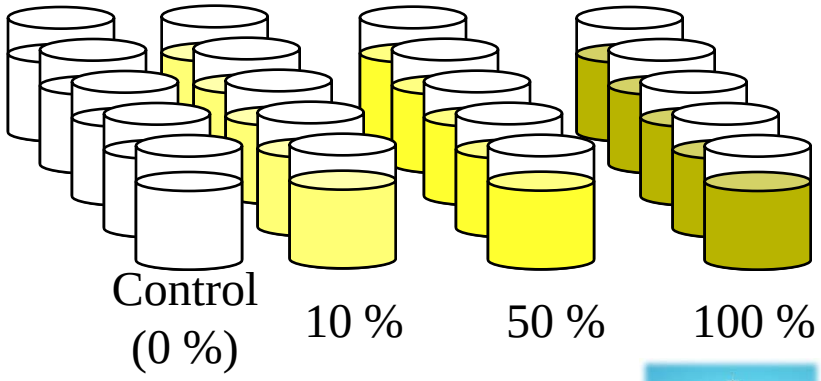
TIER III:
Conduct of Bioassays



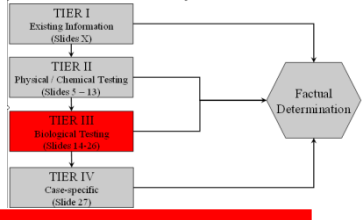
Test methods	ITM Appendix E
Exposure	48 or 96-hours
Primary endpoint	Survival or development
Dilutions	Three (10, 50, 100%)
Replicates / dilution	Five
Organisms / replicate	Usually 10
Acceptability criterion	• ≥70 or 90 % survival • Reference toxicity test within range



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



TIER III:
Data analysis



STEP 1: Is survival in undiluted elutriate significantly reduced relative to the reference? (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

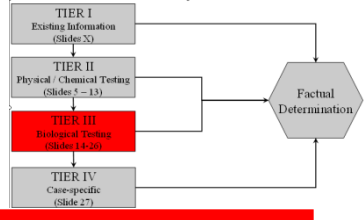
STEP 2: Does the concentration predicted by the model exceed the LPC at the point of compliance?

no

yes

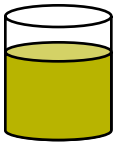
1. Elutriate "acutely toxic," or
2. Elutriate exceeds the LPC / WQS

TIER III:
Data Analysis (Step 1)

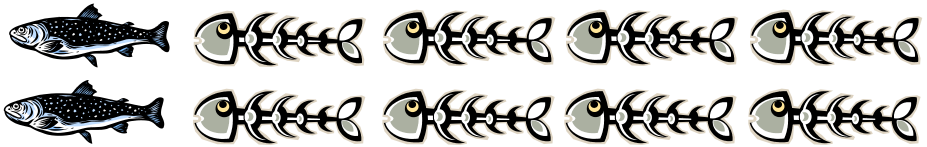


- **Survival in undiluted elutriate reduced more than 10% relative to the control?**
- **Statistical reduction of survival in the undiluted elutriate relative to the control (dilution water)?**

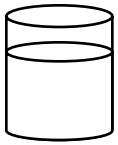
Undiluted Elutriate



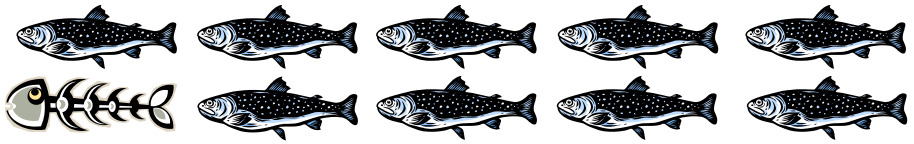
= 20 ± 8% Survival



Dilution water (control)

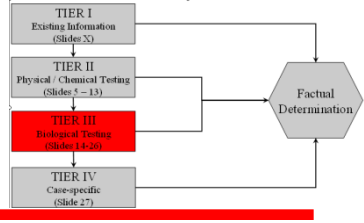


= 90 ± 5% Survival



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

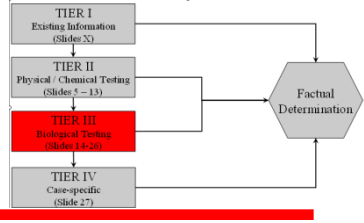
TIER III:
Data Interpretation



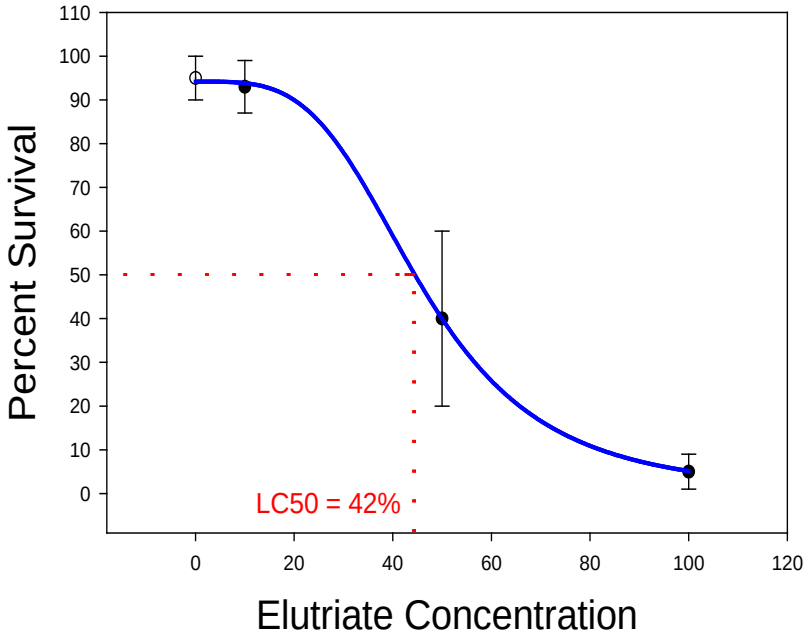
Outcome	Bioassay Interpretation	LC / EC50	Action	Value for model
Survival in undiluted elutriate not statistically reduced relative to control	No acute toxicity predicted	Cannot be calculated (assumed >100%)	No need to run mixing model	
Survival in undiluted elutriate statistically reduced but > 50%	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

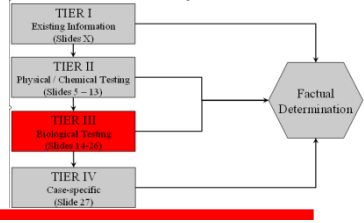


LC50 (42%) X 0.01 (LPC) = 0.42%

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”)

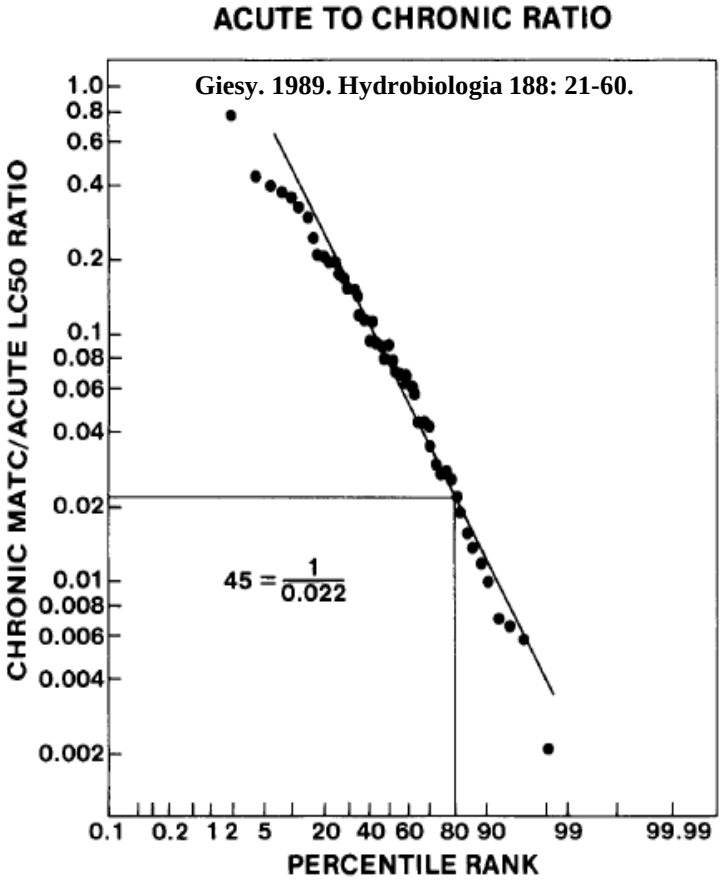
Application Factors
Considerations



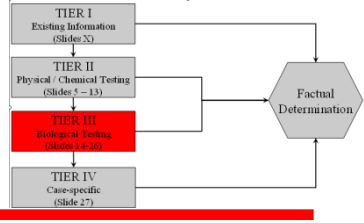
- **NAS (1972): Default = 0.01**

- **EPA: 40cfr 227.29 (3)**
  - Use different AF with scientific rationale
  - ACR = LC50 / NOEC, AF = 1 / ACR
  - AF = 0.1 to 0.01 (Verma 1981)
  - 90th ACR: 73 (AF = 0.01) (Lange 1998)
  - Fish AF = 0.15 (Arsenic) (Lima 1984)
  - AF = 0.1 → 60% of fish (Heger 1995)
    AF = 0.01 → 90% of fish

- **AF is chemical class specific**
  - Persistent: AF = 0.01
  - Non persistent (half life <8 wks):
    - AF = 0.05 to 0.1
    - Ammonia: AF = 0.11 (Thurston 1986)



TIER III:
Possible conclusions

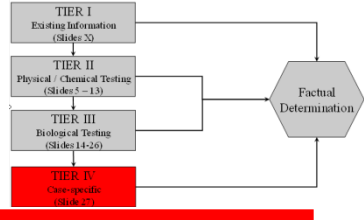


1. DM discharge toxicity <u>not predicted</u> relative to the reference condition

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

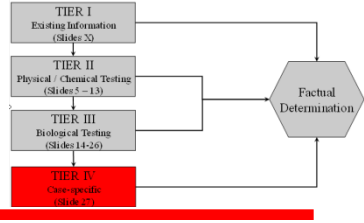
3. Further information needed for actual determinations
   - Move to Tier IV (less common)

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

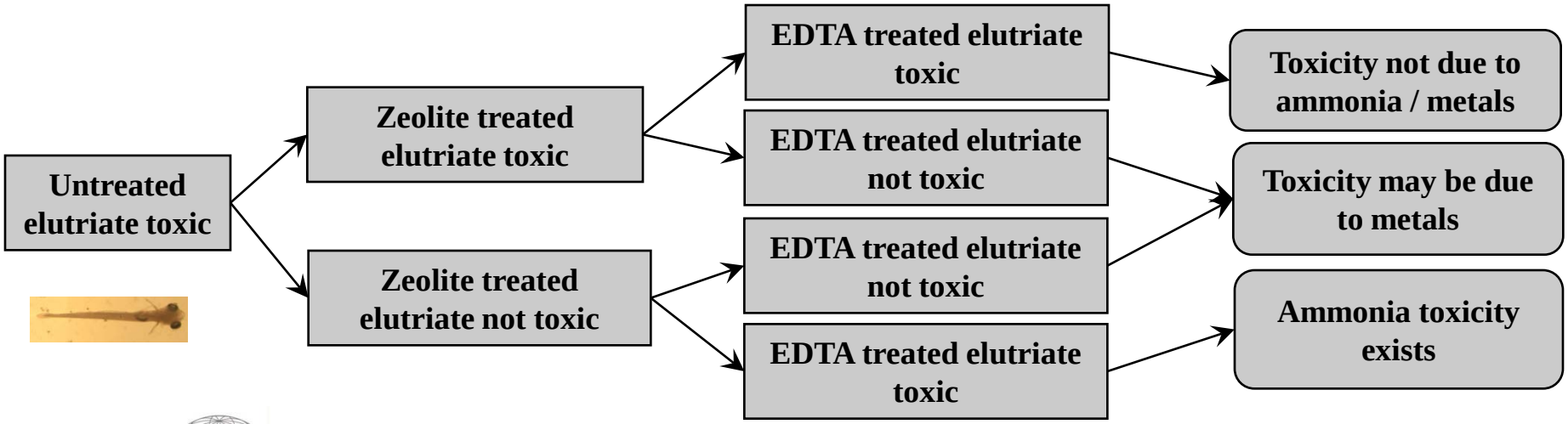


- **Lower tiers <u>do not</u> provide enough information for factual determinations**
  - Rare occasions
  - Inconclusive test results
  - Conflicting evidence
  - Ammonia toxicity suspected
- **Specific studies may include:**
  - Use of different test species / exposure durations / endpoints (e.g.,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

Confounder: Ammonia
Methods for removal in bioassays

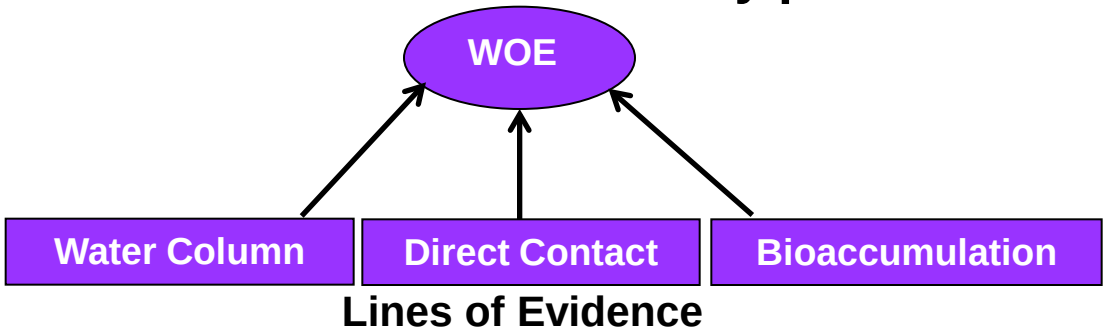


- **Algae: *Olva* (Marine)**
- **pH modifications**
  - **Increase pH (10) and aerate → decrease pH → test**
  - **PROBLEM: alteration of metals speciation**
- **Zeolite Column Treatment (freshwater)**
  - **Zeolite removes ammonia and metals toxicity**
  - **EDTA treatment to remove metals**
  - **PROBLEM: Cannot completely rule out metals toxicity**



Synthesis: Water Column

- **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 effects)**
- **Generate data to estimate toxicity potential of DM disposal**



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

References cited

•Fava JA, McCulloch WL et al. 1984. Marine Technology Society, Washington DC, 10-12 Sept 1984
•Giesy JP, Graney RL. 1989. Hydrobiologia 188/189: 21-60.
•Heger W, Jung SJ, Martin S, Peter H. 1995. *Hydrobiologia* 31: 2707 – 2726.
•Lange R, Hutchinson TH, Scholz N, SolbeJ. 1998. *Chemosphere* 36: 115–127.
•Lima AR, Curtis C, Hammermeister DE et al. 1984. Arch Environ Contam Toxicol 13:59 –601.
•Thurston RV, Russo RC, Meyn EL, Zajdel RK, Smith CE. 1986. Trans Am Fish Soc 115:196-207.
•Verma SR, Tonk IP, Dalela RC. 1981. *Acta Hydrochim Hydrobiol* 9(3): 247-254.