



# Sediment Quality Guidelines in Australia (and New Zealand)

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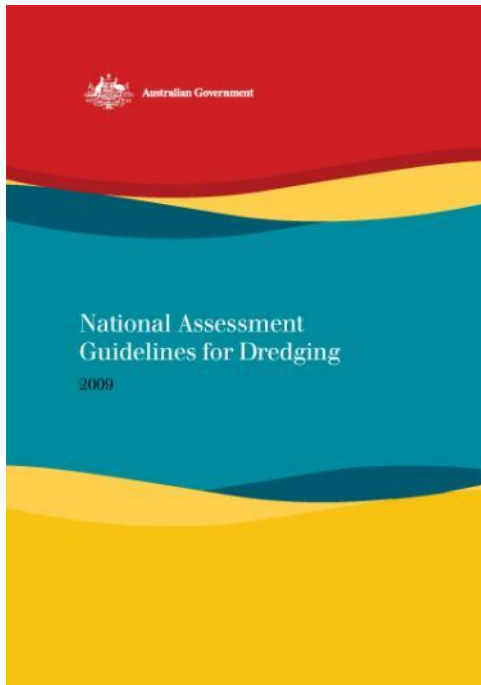
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# Sediment Quality Guidelines

- A component of the Water Quality Guidelines within the National Water Quality Management Strategy (NWQMS)

## User types



Planning



Licensing & Approvals



Monitoring, Assessment & Reporting

# Problem Formulation

Who is the **user**?

What is the (spatial) **scale** of the assessment?

- Site-specific and local vs broad-scale

**Where** is the assessment being undertaken?

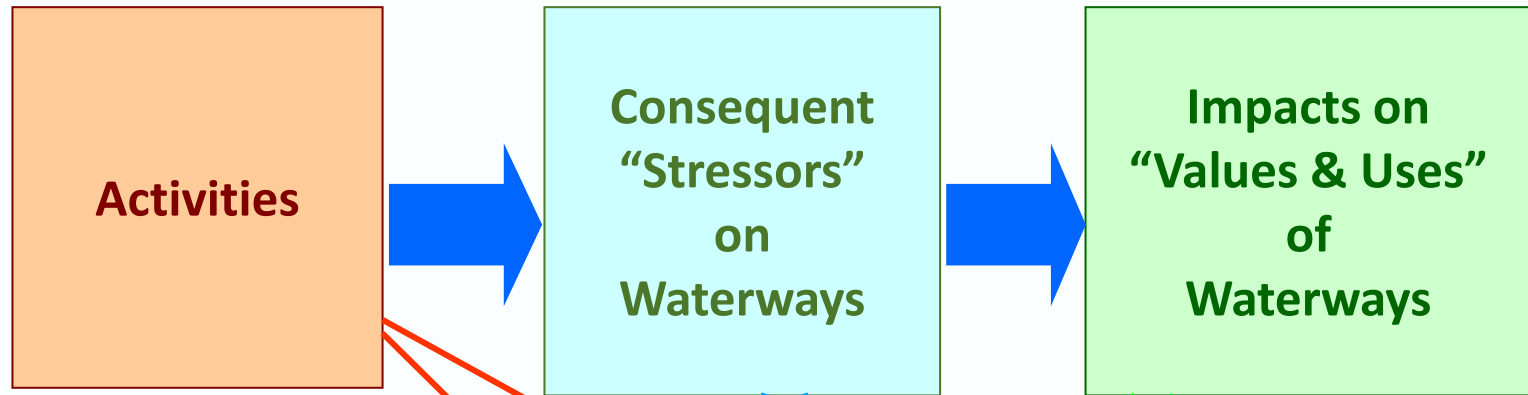
- Which Australian region?
- What is the ecosystem type?

What is the **level of protection**?

- e.g. early detection methods, more stringent default guidelines for locations of high conservation value?

Place in context of current understanding of the system through **conceptual modelling**

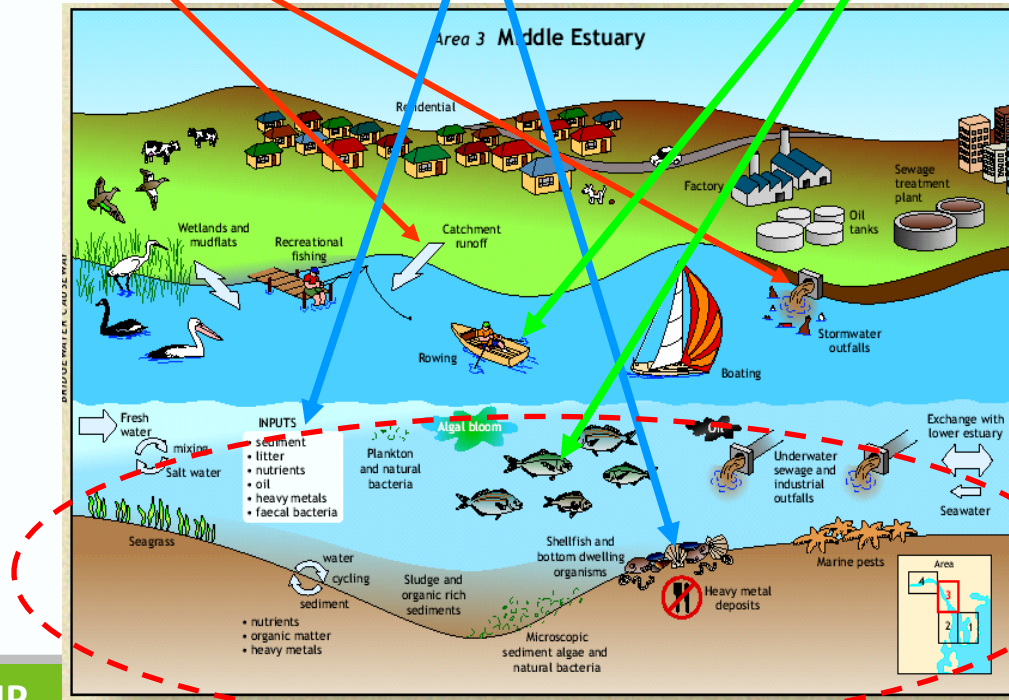
# Conceptual Models – Current understanding



Initial  
Conceptual  
Model



Select  
relevant  
indicators



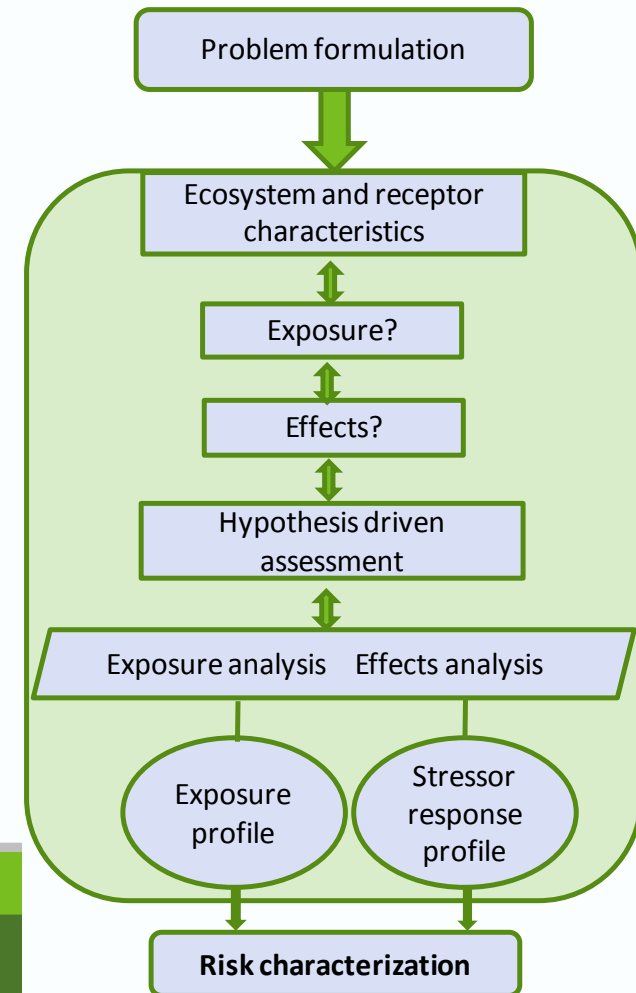
Key emphasis  
on documenting  
current  
understanding  
through  
conceptual  
modelling

Source: Derwent WQIP

# Framework for Sediment Quality Assessment

A tiered, decision-tree approach, in keeping with the risk-based approach introduced in the water quality guidelines.

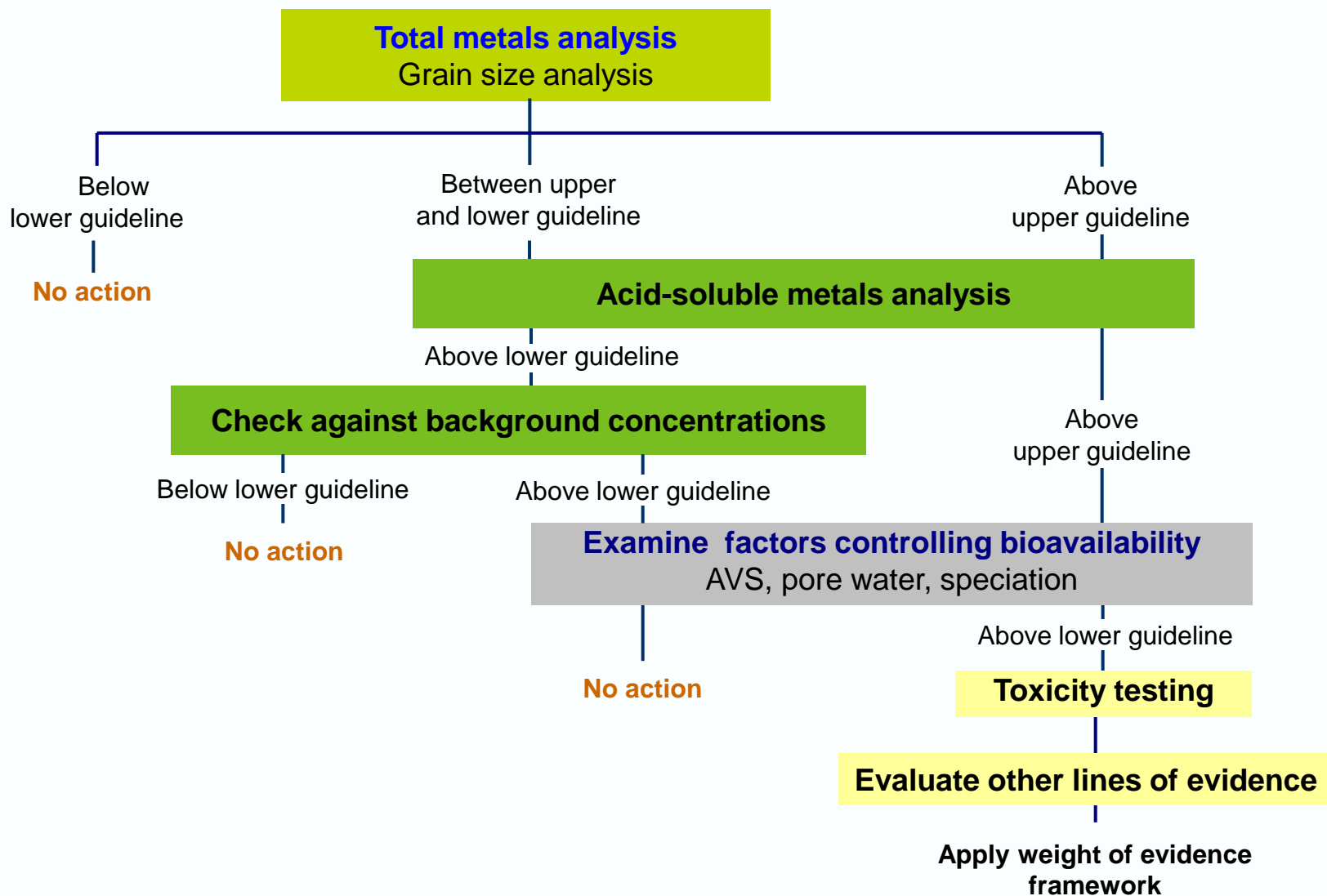
- Compare total contaminant concentration with a trigger value (TV)
- If the TV is exceeded, then consider bioavailability  
Bioavailable contaminants > TVs  
= contaminants of potential concern (COPCs)
- Evaluation of additional lines of evidence (LOEs) to determine whether the COPCs are likely to affect ecosystem health.
  - Chemistry (including bioavailability measures)
  - Ecotoxicology
  - Bioaccumulation
  - Benthic ecology
  - Other case-specific LOE
- Assess Risks based on multiple lines of evidence



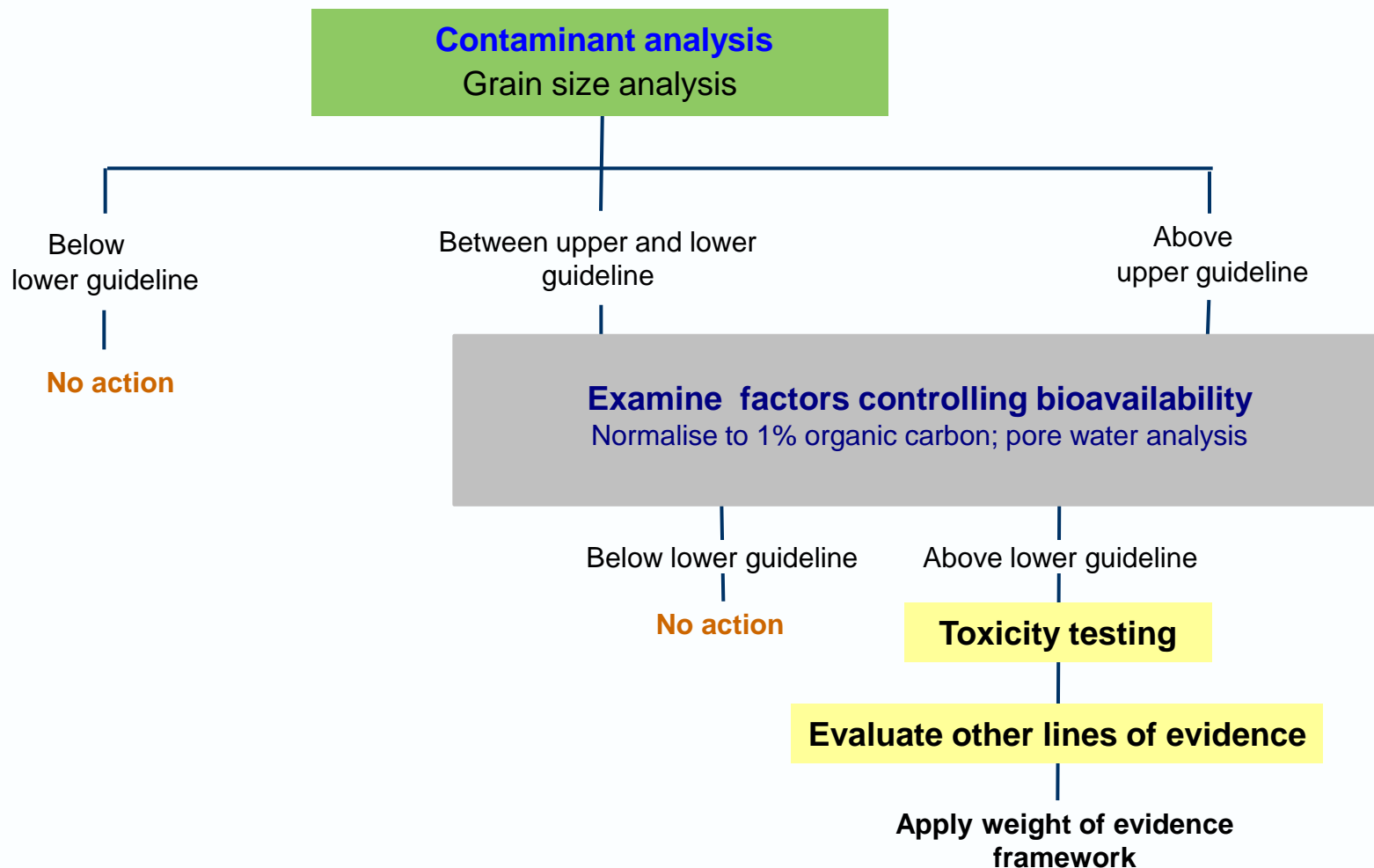
Contaminants with no TVs = use other lines of evidence (LOEs)



# Sediment quality decision tree for metals



# Sediment quality decision tree for organics



# Sediments: contaminant binding and exposure

## Incorporating bioavailability

### Metals in sediments:

Bioavailability strongly influenced by sediment properties:

- oxidised nearer surface
- sulfidised deeper down

Water column:  
dissolved copper exposure

Sediments:  
Particulate & porewater copper exposure

Overlying water - Cu

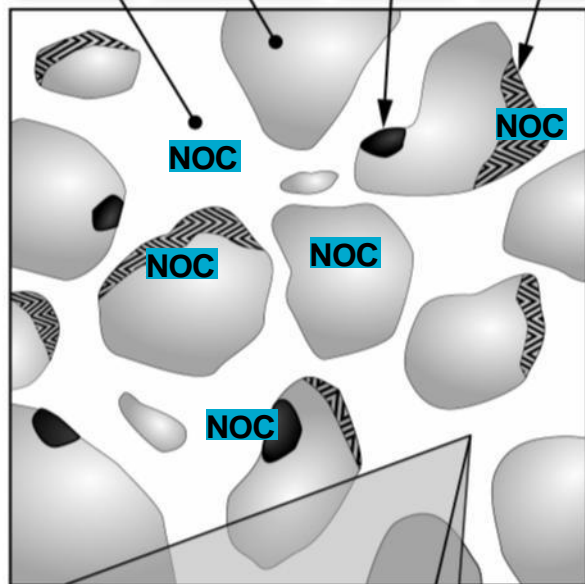
{Dissolved copper}  
 $\text{Cu}^{2+}, \text{CuSO}_4, \text{CuCO}_3, \text{CuCl}^+, \text{OC-Cu}$

$\equiv\text{OC-Cu}$  {Organic carbon}  $\rightleftharpoons$   $\equiv\text{FeO-Cu}$  {Iron}

Porewater-Cu

Metal sulfides

Water    Sediment Particle    BC<sup>1</sup>    NSOC<sup>2</sup>



<sup>1</sup> Black carbon combustion residue

<sup>2</sup> Natural sedimentary organic matter

<sup>3</sup> Dissolved organic carbon



### Organics in sediments:

Bioavailability of non-ionic organic contaminant (NOC) influenced very strongly by concentrations and forms of organic carbon



# The SQG Trigger Values (TVs)

not be used on a pass/fail basis, but to trigger further assessment

**Empirically derived**: matching sediment chemistry and observed biological effects (from toxicity tests and benthic community information) (ERL/ERM, TEL/PEL) **Basis of the SQGs**

- “Would we predict this sediment to be toxic?”

**Mechanistically derived**: theoretical understanding of factors that govern bioavailability and known relationships between chemical and environmental, exposure, and toxicity interactions

- “Can this contaminant, at this concentration, in this sediment, contribute to toxicity?”

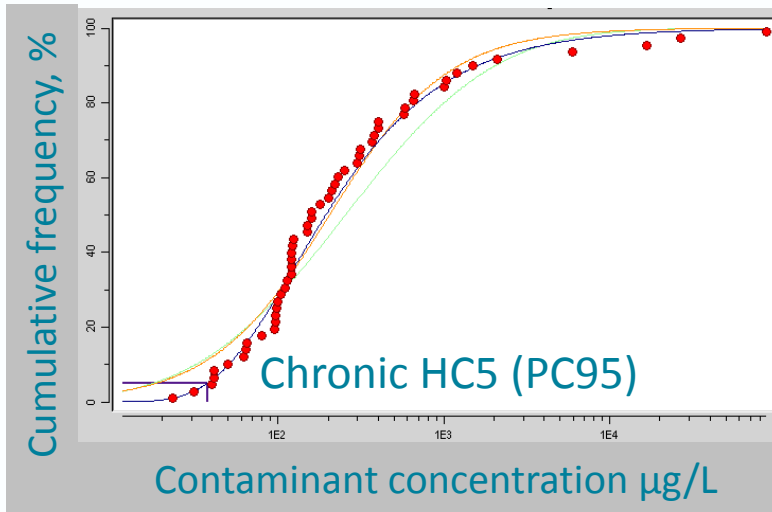
**Encouraging use**

**Contaminants with no TVs** = use of other lines of evidence (LOEs)

# Co-occurrence and empirical guidelines

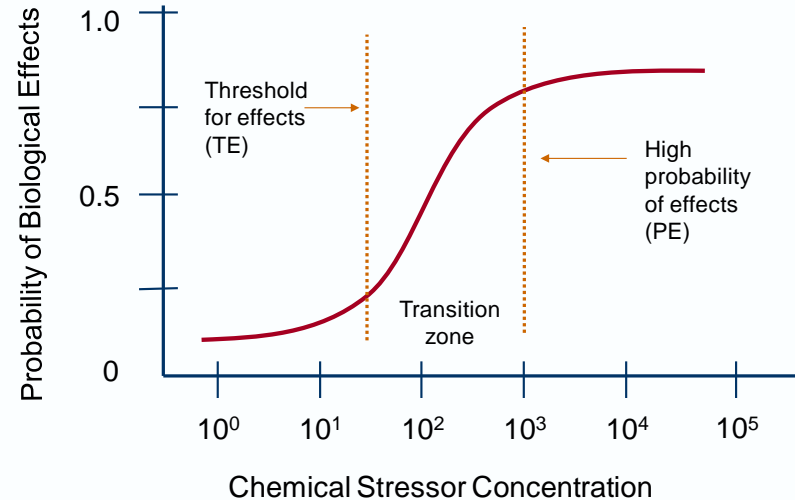
## Water quality guidelines

- Based on effects data for individual contaminants (SSDs of NOEC, EC10s)



## Empirical sediment quality guidelines

- Effects data suffer from co-occurrence of contaminants and influences the derived guideline value



**Bioavailability assessment, toxicity testing ... are the key steps for improving assessment quality**

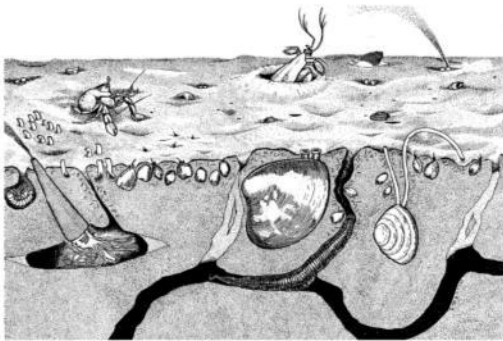
# Mechanistic guidelines (models)

## Equilibrium partitioning sediment benchmark approached (ESBs)

- Mixtures of non-ionic organic contaminants (e.g. PAHs)
- Metal mixtures (SEM-AVS/fOC; Cd, Cu, Pb, Ni, Zn ( and Cr))
- Next generation SQGs

 United States  
Environmental Protection  
Agency

**Procedures for the  
Derivation of Site-Specific  
Equilibrium Partitioning  
Sediment Benchmarks  
(ESBs) for the Protection of  
Benthic Organisms:  
Nonionic Organics**



## Advantages

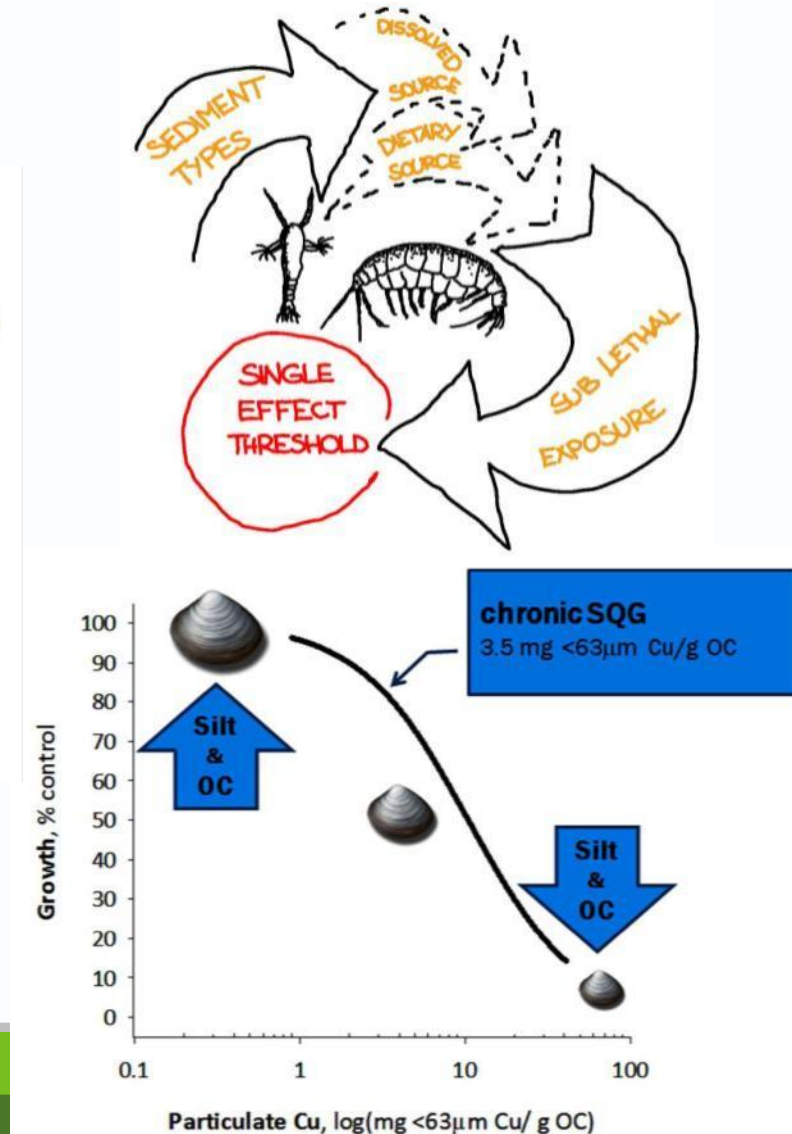
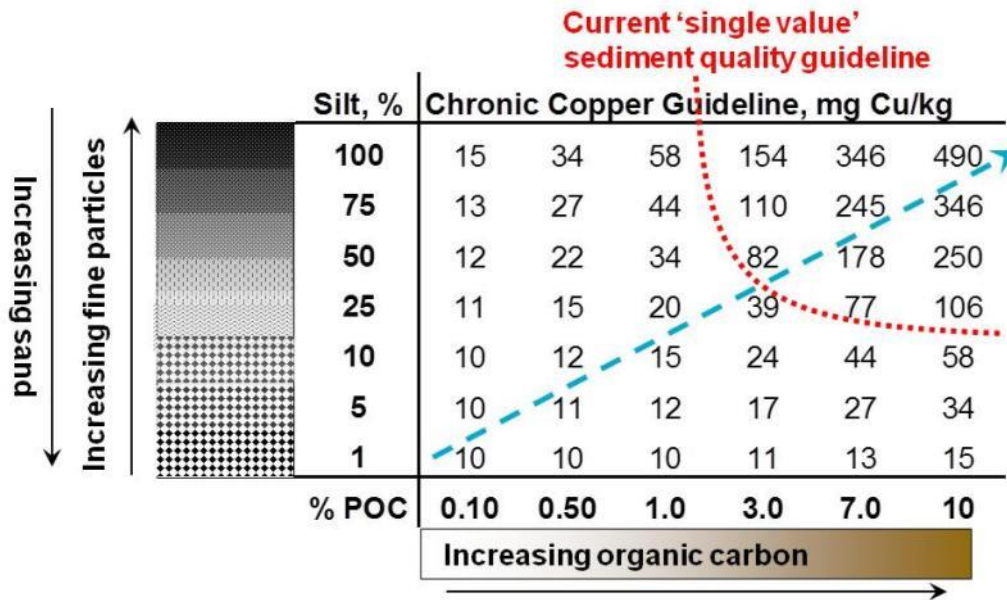
- Based on effects data for individual contaminants
- Incorporating bioavailability

## Limitations

- Upper thresholds for model use ?
- Passive samplers for metals (DGT) and organics (SPME, PED) used for validating bioavailability models

# Next generation sediment quality guidelines?

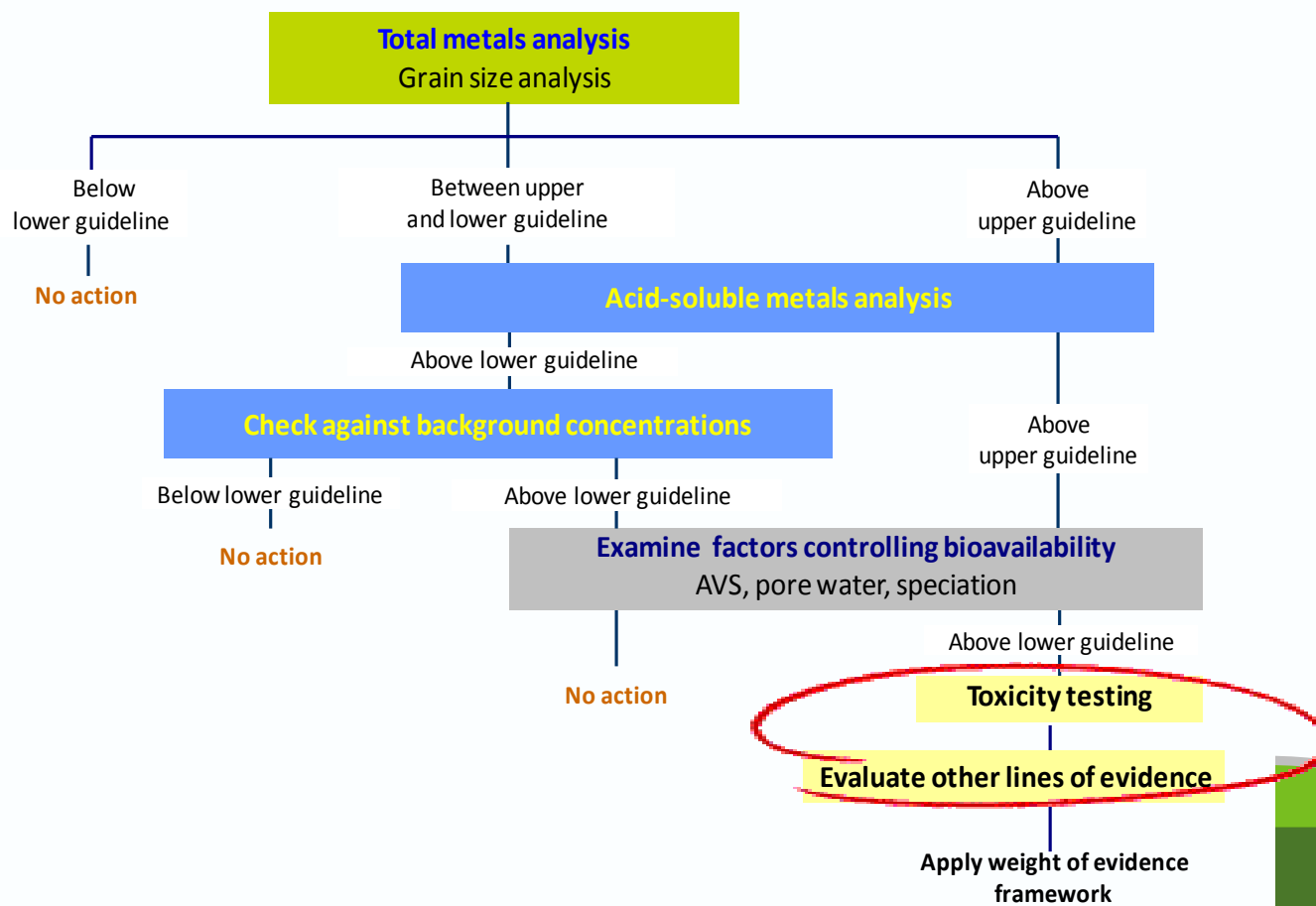
e.g. dietary exposure; metals in oxidised sediments



# Multiple lines of evidence

## Contaminants with no TVs = use of other lines of evidence (LOEs)

- In practice, levels of protection and timeliness of information govern decisions on when to invoke different lines of evidence
- The guidelines **do not** consider different lines of evidence **at the outset**

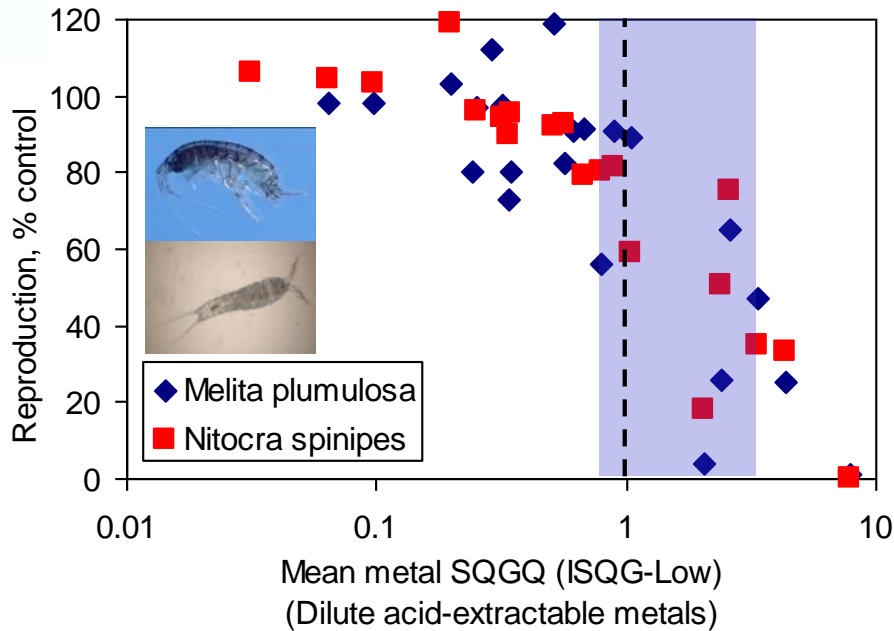




# Ecotoxicology: Rapid, sensitive, robust & sublethal

## Estuarine–marine species

- OK, but room to improve ...



Rapid and sensitive bioassays assessing reproductive effects to amphipod *Melita plumulosa* and copepod *Nitocra spinipes*.

## Freshwater species

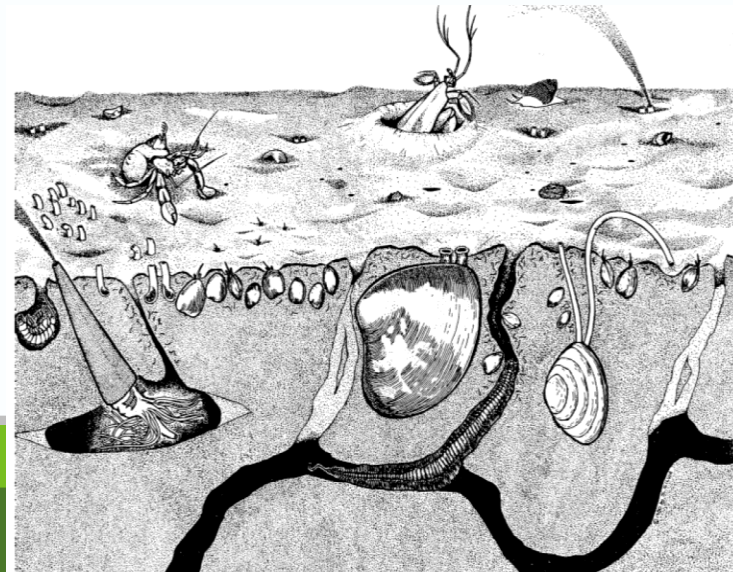
- Greater range needed ...

Midge (*Chironomus tepperi*)

- sub-chronic (growth, emergence, survival and sex ratios).

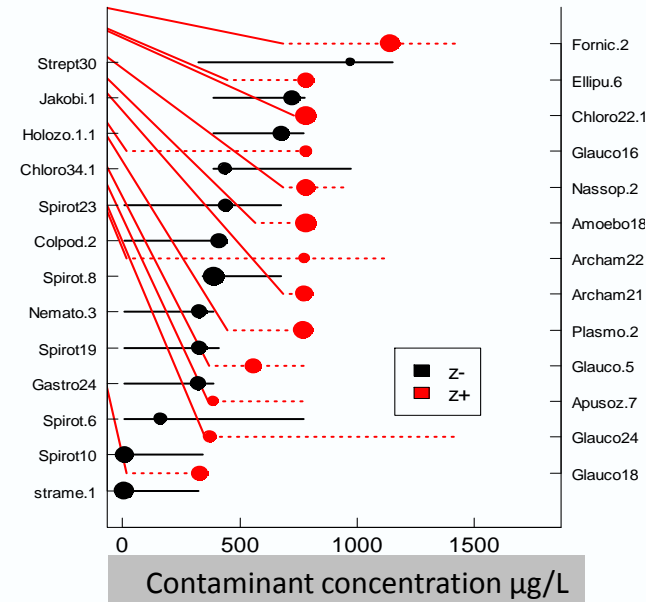
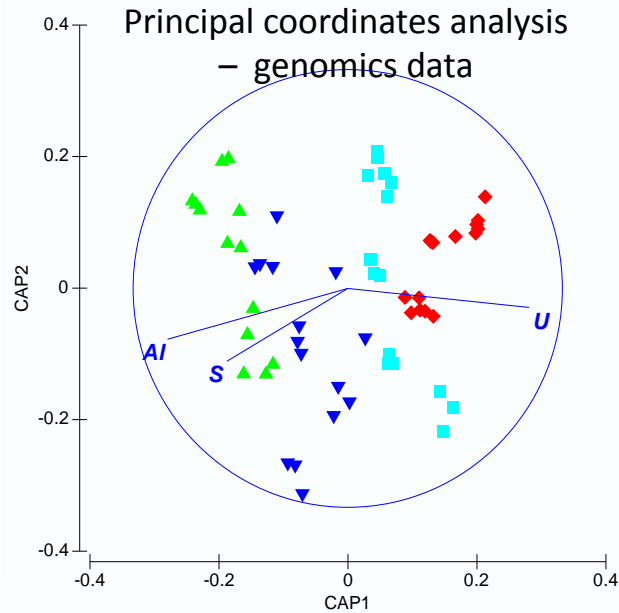
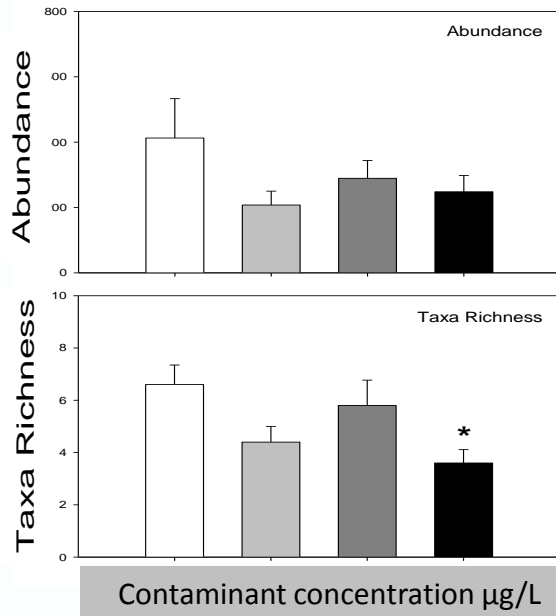


Snail (*Potamopyrgus antipodarum*)

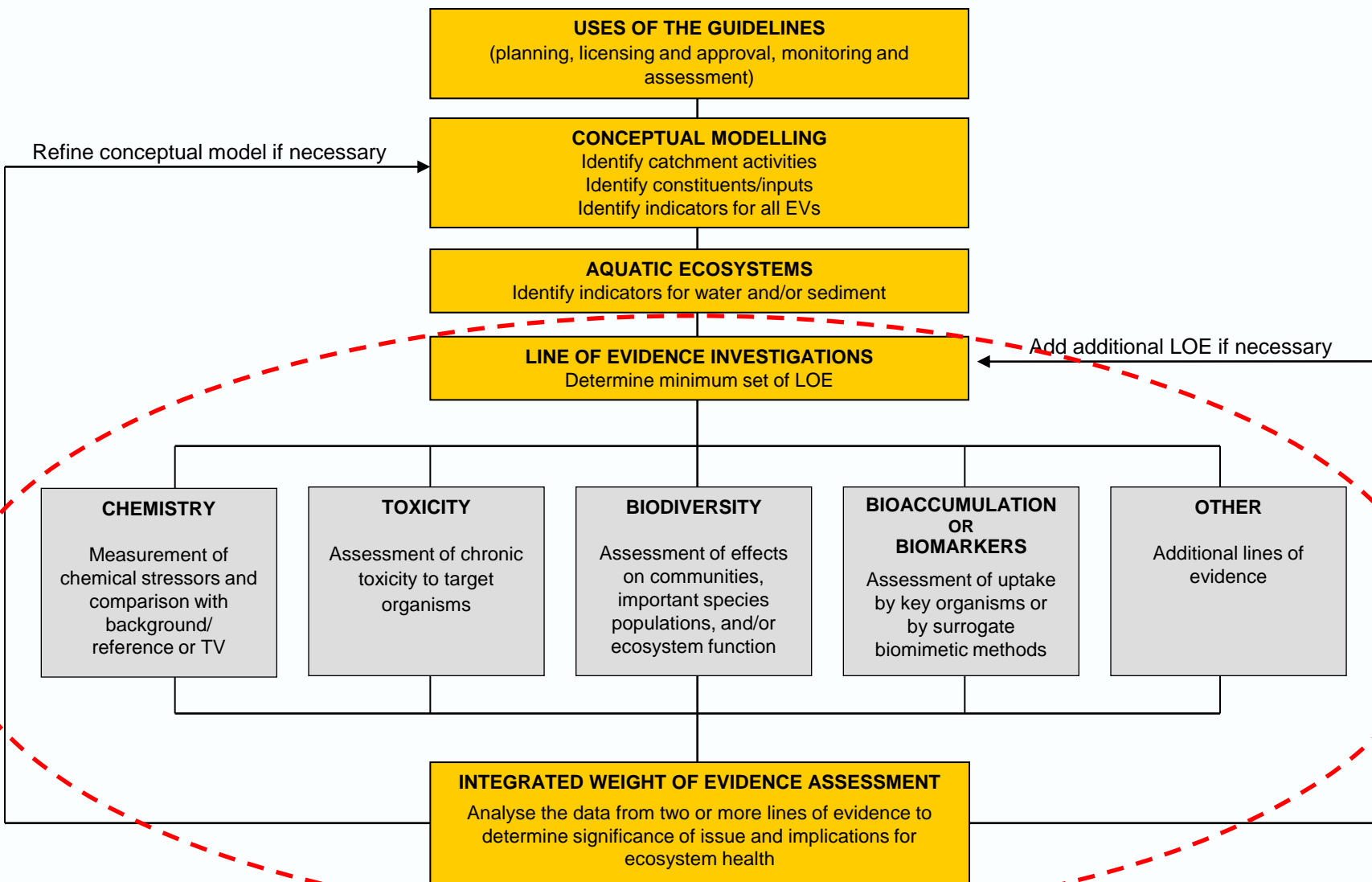


# Ecological Assessment

- Traditional versus ecogenomics (pyrosequencing) approaches to assessments – are they complementary ?
- Advances in statistical methods



# Approach to multiple lines of evidence



# Approach to multiple lines of evidence

## Four main lines of evidence

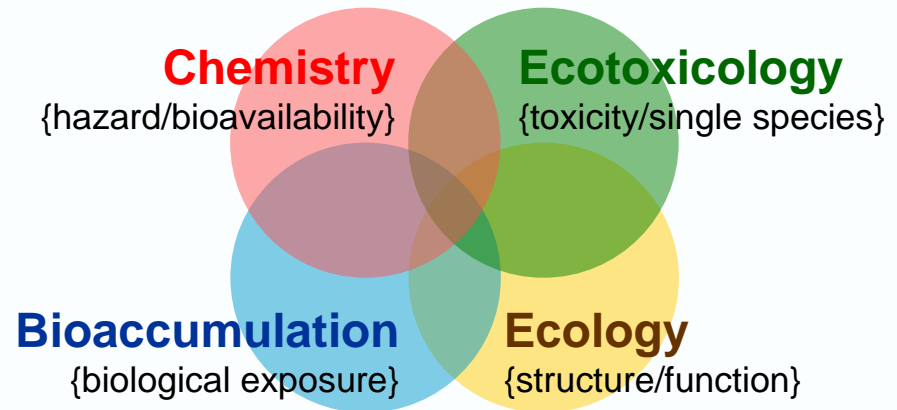
Simple three-level scoring matrix:

- Not significant : **score 1**
- Moderately significant : **score 2**
- Highly significant : **score 3**

Scoring of each LOE then  
combined in WOE assessment

Tabulation of a range of possible  
examples for each LOE

Refinement of SQGs where possible



## Options include:

- Qualitative WOE studies  
– best professional judgment
- Semi-quantitative approaches,  
e.g. Sediment quality triad - visual  
representations, +/- matrix effect ranking
- Quantitative rankings using probability  
/likelihood/multivariate approaches

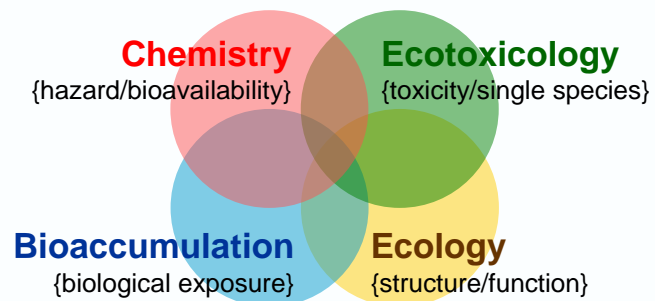
# Weight-of-evidence assessment

LOE	Score		
	3	2	1
<b>Chemistry</b>			
<i>Sediment contaminants</i>	Concentration > SQG-high	Concentration > TV, < SQG-high	Concentration < TV
<i>Pore water contaminants</i>	Concentration > WQG-HC10	Concentration > WQG-HC5, < WQG-HC10	Concentration < WQG-HC5
<b>Toxicity</b>	≥50% effect vs control	20-50% effect vs control	<20% effect vs control
<b>Bioaccumulation</b>	Significantly different (p<0.05) and >3× control	Significantly different (p<0.05) and ≤3× control	Not significantly different from control
<b>Ecology</b>	Significant and high effects on abundance and/or diversity	Significant but moderate effects on abundance and/or diversity	No significant effects on abundance and/or diversity
<b>Weight-of-evidence</b>	Significant adverse effects	Possible adverse effects	No adverse effects

TV= guideline trigger value, HC5 and HC10 = Chronic effects to 5% and 10% of species, respectively.



# WOE ranking



Case	Line of Evidence <sup>a</sup>				Weight-of-evidence (WOE) Score	Overall Assessment
	Chemistry (metals-organics)	Toxicity	Bioaccumulation / Biomagnification	Ecology		
W1	3	3	2 or 3	3	3	Significant adverse effects from sediment contamination
W2	3	3	2 or 3	2	3	Significant adverse effects from sediment contamination
W3	2 or 3	3	2	2	3	Significant adverse effects from sediment contamination
W4	2 or 3	2	1 or 2	2	2	Possible adverse effects from sediment contamination
W5	2	2 or 3	1 or 2	2	2	Possible adverse effects from sediment contamination
W6	2	2	1 or 2	2 or 3	2	Possible adverse effects from sediment contamination
W7	2 or 3	2 or 3	2 or 3	1	2	Toxic chemical stressing system but resistance may have developed at community level
W8	1	2 or 3	1	2 or 3	2	Unmeasured toxic chemicals causing effects on communities is possible
W9	1	2 or 3	1	1	2	Unmeasured physical or chemical causes of toxicity
W10	2 or 3	1	1	2 or 3	2	Chemicals are not bioavailable or community change may not be due to chemicals
W11	1	1	1	2 or 3	1	Changes probably not due to measured contaminants
W12	1 or 2	1	1 or 2	1	1	No adverse effects
W13	1	1	1	1	1	No adverse effects
W14	2 or 3	1	1	1	1	Contaminants unavailable

# Revisions underway:

## Web-based platform for the new Guidelines

Necessitated:

- Expense in maintaining and updating hard copy versions
- Global move to e-availability of technological information and guidance
- Far superior medium for delivering complex, cross-cutting and integrative guideline components (e.g. one-screen, decision framework with hyperlinks)

Consequences for revision

- Opportunity to vastly improve:
  - Correct pathway that *different users* take in undertaking water quality assessments
  - Acquiring more accurate assessments through *weight of evidence* science, integrating information across different indicators
- Challenges in drawing in current and new information to new decision support system