Scale Issues in Sediment Risk Management - Conceptual and Practical Approaches

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My interests – the science, technology and policy of environmental management (primarily of sediments)

- Past studies focused on:
  - In situ and on site field screening tools
  - Sediment/contaminant interactions
  - PAH biodegradability under natural and engineered conditions
  - Contaminant fingerprints
  - Sediment treatment trains
  - Sediment management frameworks and policy (NRC, US Navy, HSRC, SMWG…)
- Current and future interests include:
  - In situ contaminant behavior/fate/risk
  - Integrated field studies and innovative instrumentation
  - Spatio-temporal heterogeneity
    - what controls it
    - how does one measure/predict it
  - Basin-scale management frameworks
  - How to move from data to decisions
- SedNet has given me the opportunity to tailor and improve our US approaches to European needs

We have been dredging sediments for centuries

- dredging technology is arguably one of the triumphs of human ingenuity in our battle to control nature
- notwithstanding some of its current press, it has given us our greatest cities, fuelled trade empires and continues to keep nations from disappearing beneath the sea

However, over time, this process grew more complex

- The waste products of our other technological triumphs bound with the sediments that were being dredged
- Dredged material (DM) slowly evolved from a precious resource to a waste material
- Environmental assessment and control became a “burden” that was added onto long-established processes
- Clever engineering solutions, have been developed and applied
  - but costs are higher and options are restricted

Now, sediment management can be divided into two basic categories

- Management of sediments to achieve socioeconomic goals (e.g., construction, navigational dredging, flood defense -managing sediment **quantity**, but sometimes with quality issues)
  - *Generally*, large volumes, low to moderate contaminant levels
  - Since removal is a given, assessment focuses on risks of resuspension, disposal and/or treatment options

- Management of sediment to achieve ecological goals (managing sediment **quality**, but sometimes with quantity issues)
  - *Generally*, smaller volumes, often higher contaminant levels
  - Assessment can focus on absolute and relative risk, as well as risks of in-place vs. removal options

These two types of management are done by different organisations, at different sites, with little interaction.

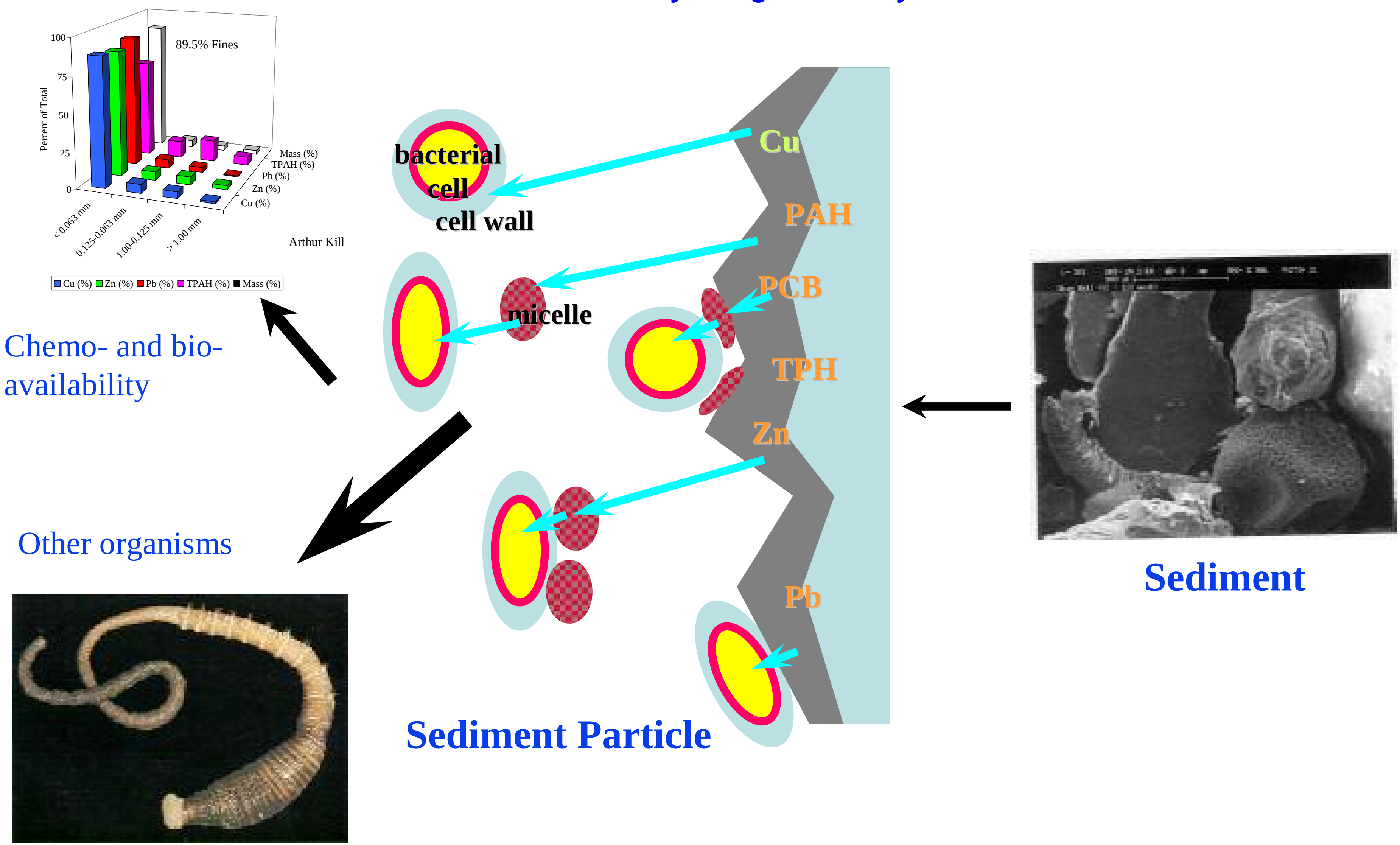
Because of the dredging legacy, we have addressed contaminated sediment management using a DM approach

- Ten years ago, removal and treatment of contaminated sediments were the remedy of choice
  - This approach is a given for DM management
  - “Chemical engineering” approach to management
- Consequence: projected costs on the scale of national budgets
  - Thus, large volumes of contaminated sediments will be managed in place
  - Source control is a major component of such management
  - The goal is the least invasive, but sufficiently protective, management strategy
  - This can be called “sustainable sediment management”
- However, the way we assess and manage sediments in support of such an approach is different than if we are assessing the impact of DM disposal

This led to what could be called the first revolution in scale for sediment assessment and management

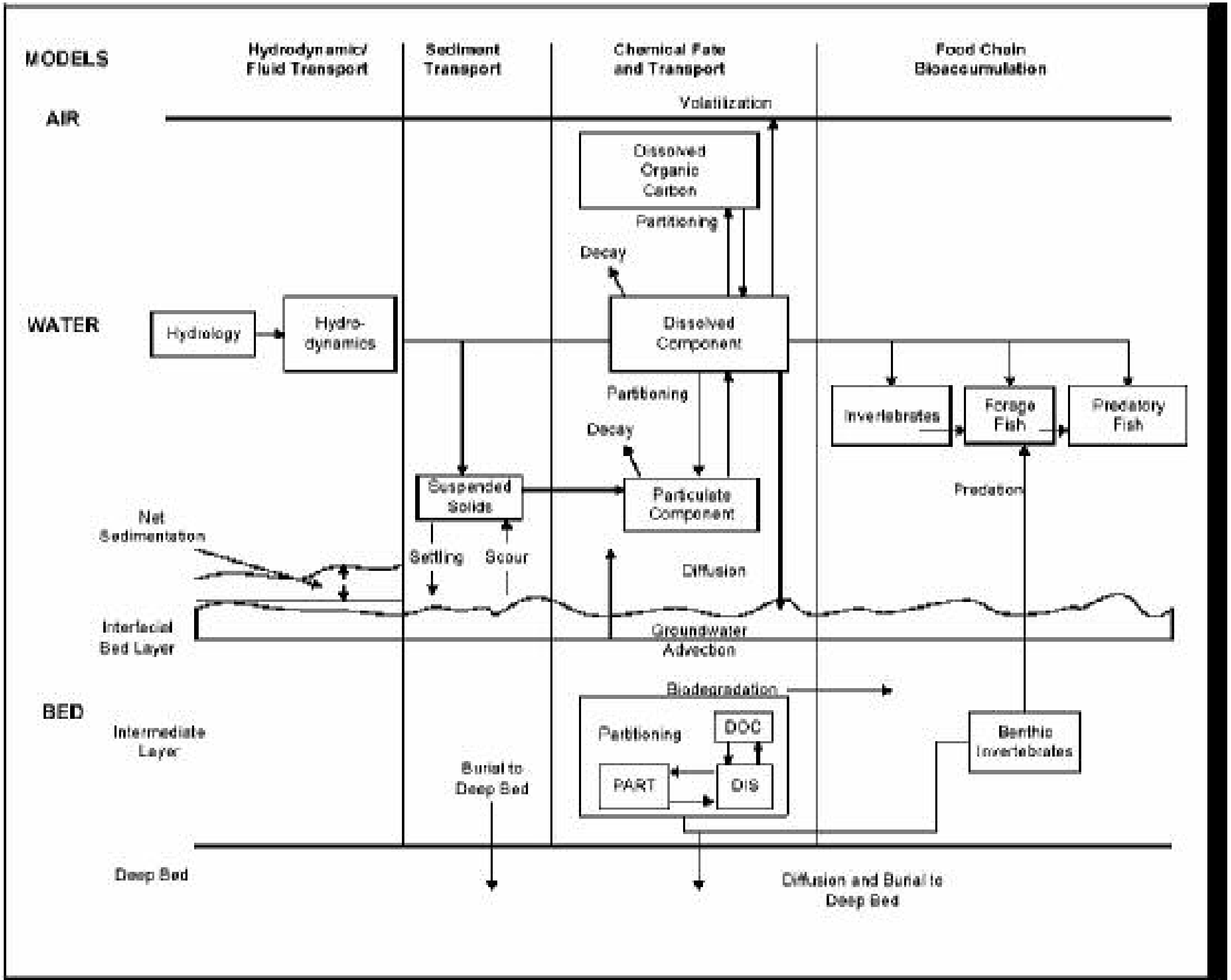
- Instead of treating sediments as volumes of material to be dumped, contained or treated, we now need to look at the micro- and meso-scale interactions
  - how contaminants interact with sediments
  - how contaminants may move between sediments, water and biota
  - how contaminants might move over time
- Thus we developed Conceptual Site Models to evaluate these processes, and have designed research to look at these pathways of contaminant – sediment – water - biota interaction

Sediments can bind contaminants in different ways, depending upon sediment characteristics, geochemical conditions and even degree of aging. This can affect contaminant mobility, bioavailability, degradability, fate and risk



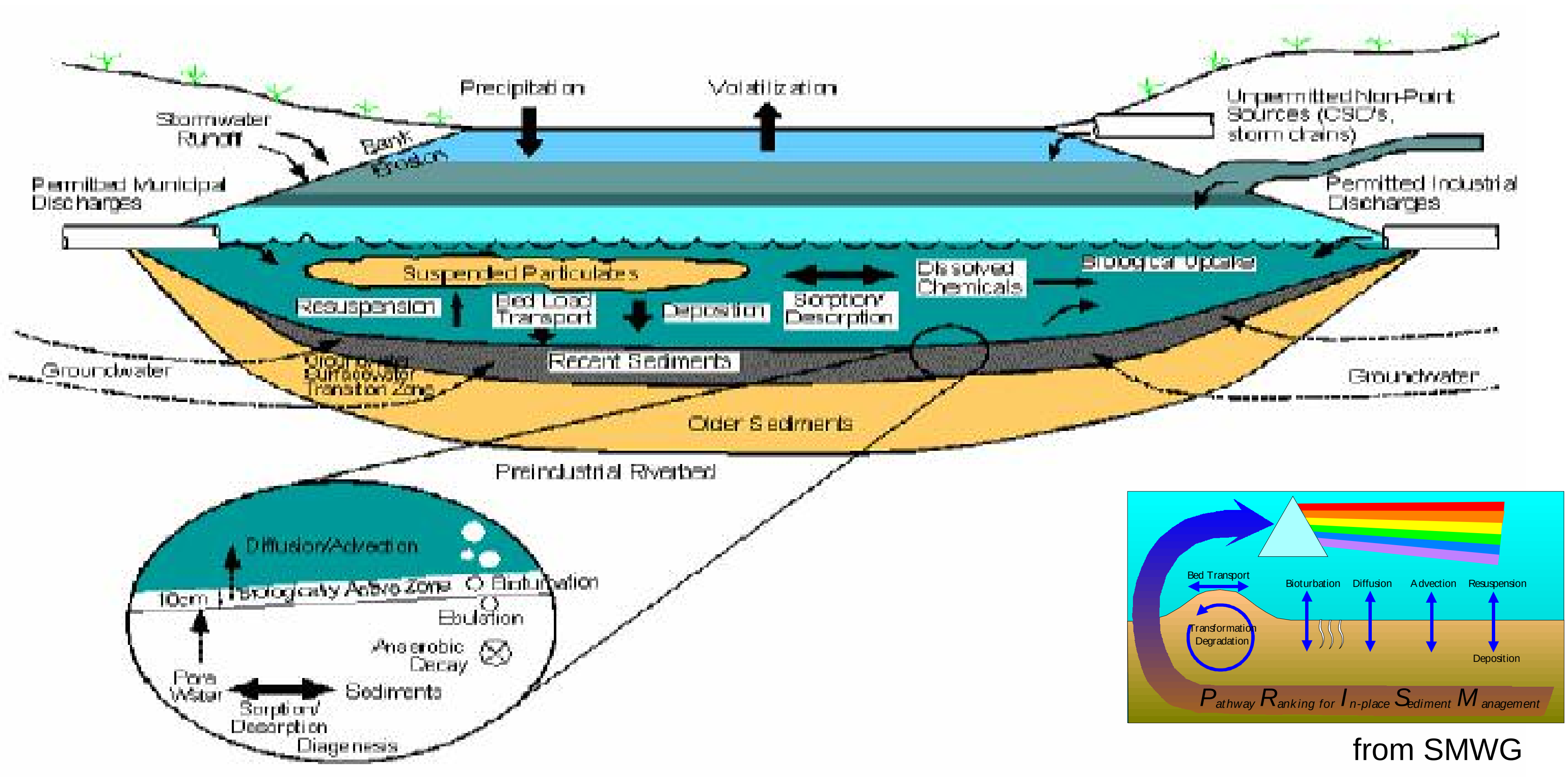
This conceptual model breaks down some of the chemical and physical processes that drive the transfers described above

- Changes in chemical and physical state (and thus mobility) often result in changes in bioavailability
- Thus, to understand exposure (and predict effects) one must understand mechanisms of transport



Source: (NRC 2001)

An understanding of pathways of contaminant transport (mode, media and mechanism) will inform CSMs, put biological observations in context and help design management strategies



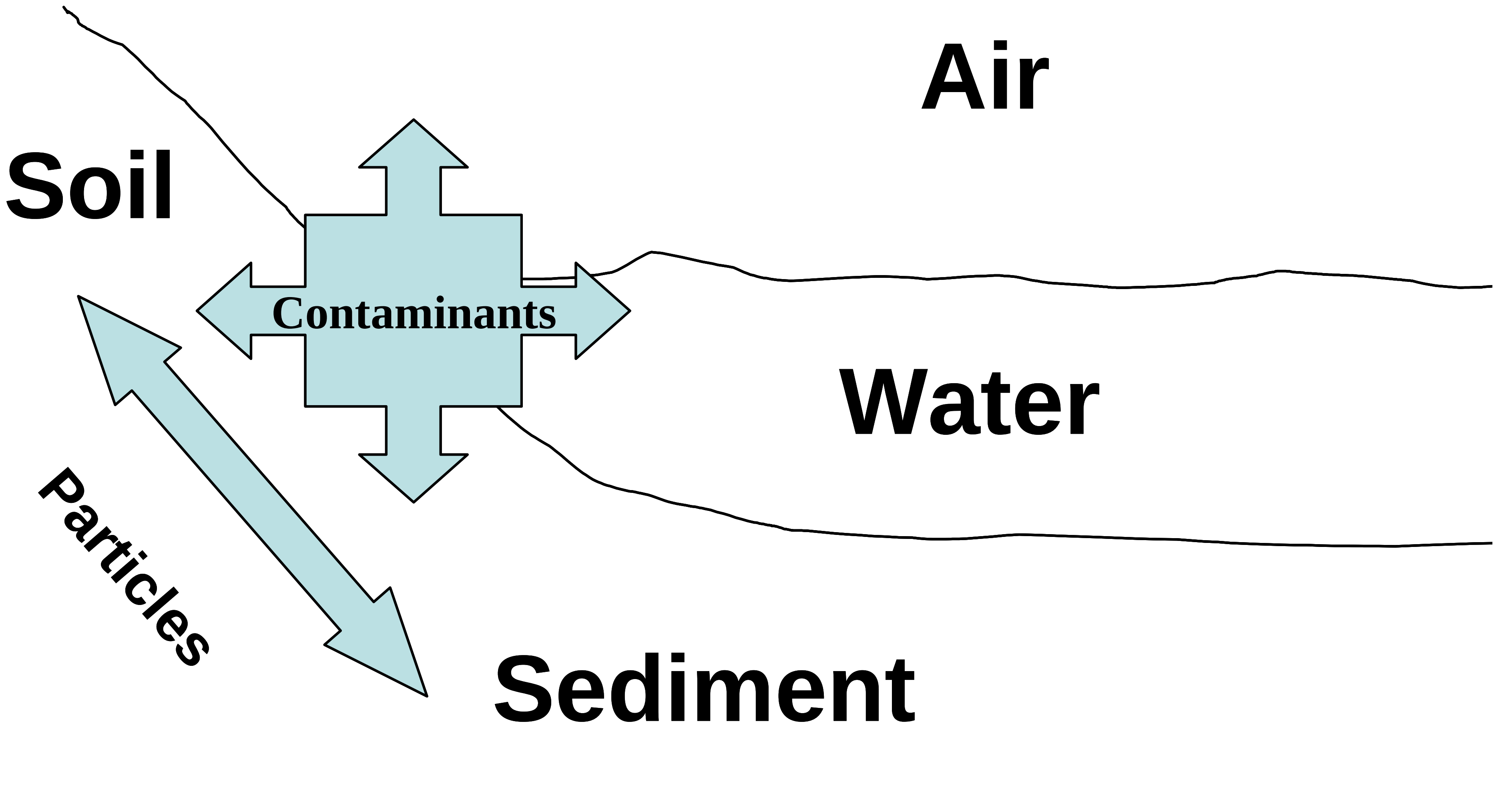
from SMWG

Managing Contaminants in Sediments – site-specific studies flesh out the Conceptual Site Models to inform decisions

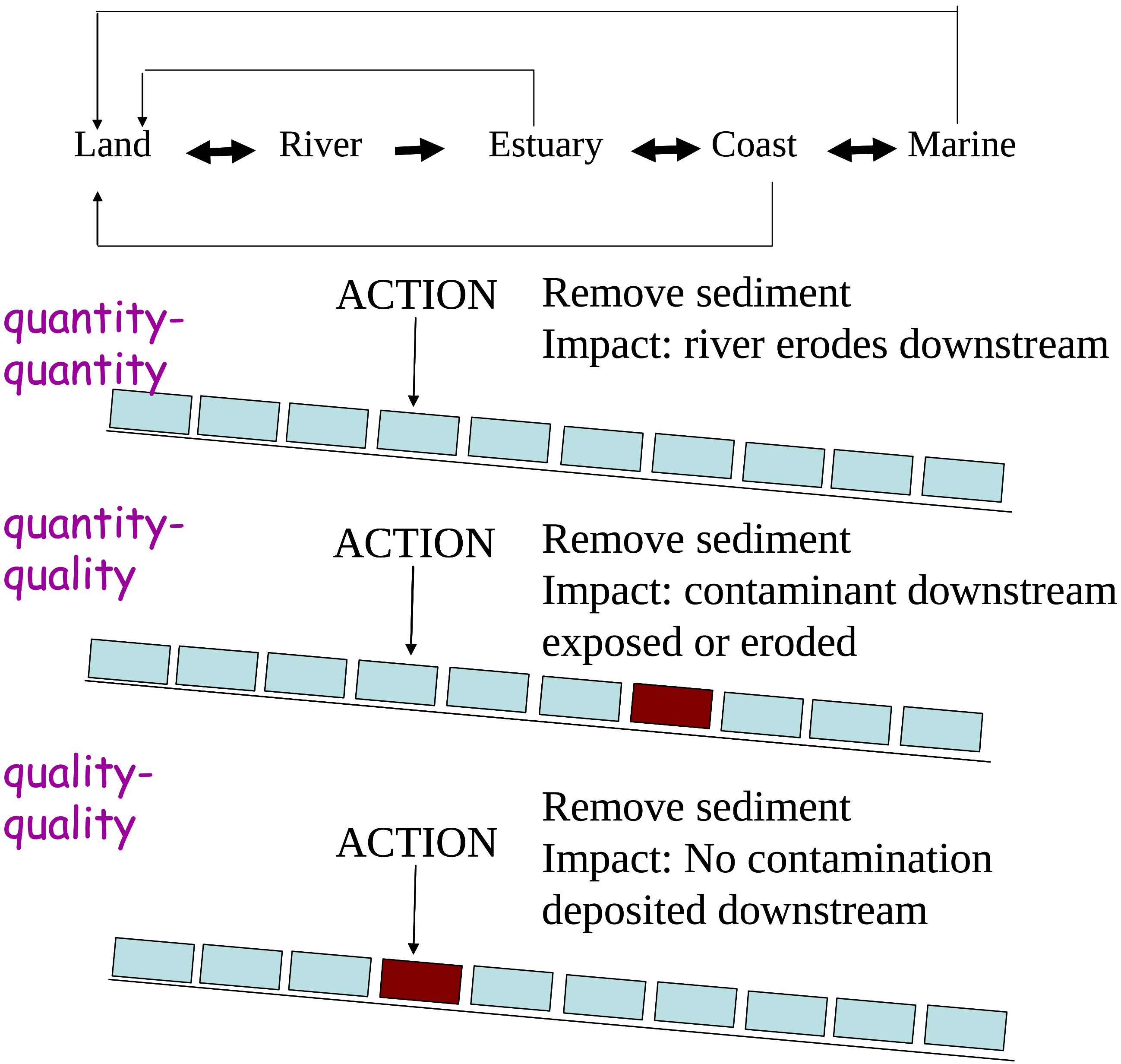
- Where are they?
  - Site assessment, field screening, historical documents
- What are they? What form?
  - Analytics, fingerprinting, sediment/contaminant biogeochemical interactions
- Are they a problem?
  - Biomarkers, bioassays, bioavailability, community analysis, risk assessment
- Are they mobile?
  - hydrodymamics, flux and porewater
- Where do they come from?
  - Forensics, geochemistry
- What do we do about them?
  - Management, monitoring, remediation
- How do we prevent contamination in the future?

Extensive research in Europe and elsewhere, is increasing our understanding of the systems and aiding in informed ***site-specific*** risk management.

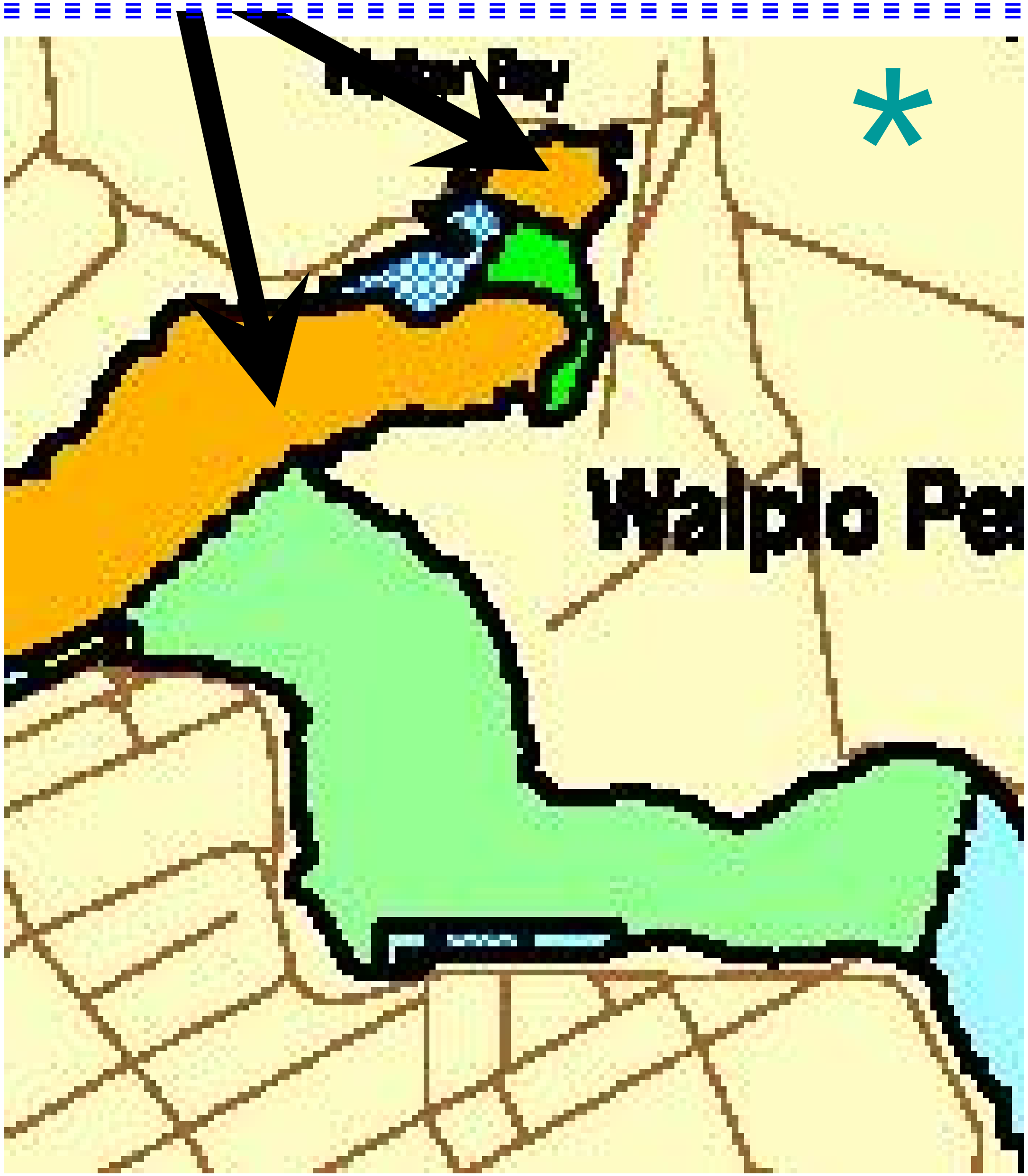
However, contaminants and mass transfer between all environmental media. We cannot manage one medium without taking this into account, nor can we manage connected sites in isolation. To reduce risk, we must assess and manage it holistically and at the ***basin scale***.

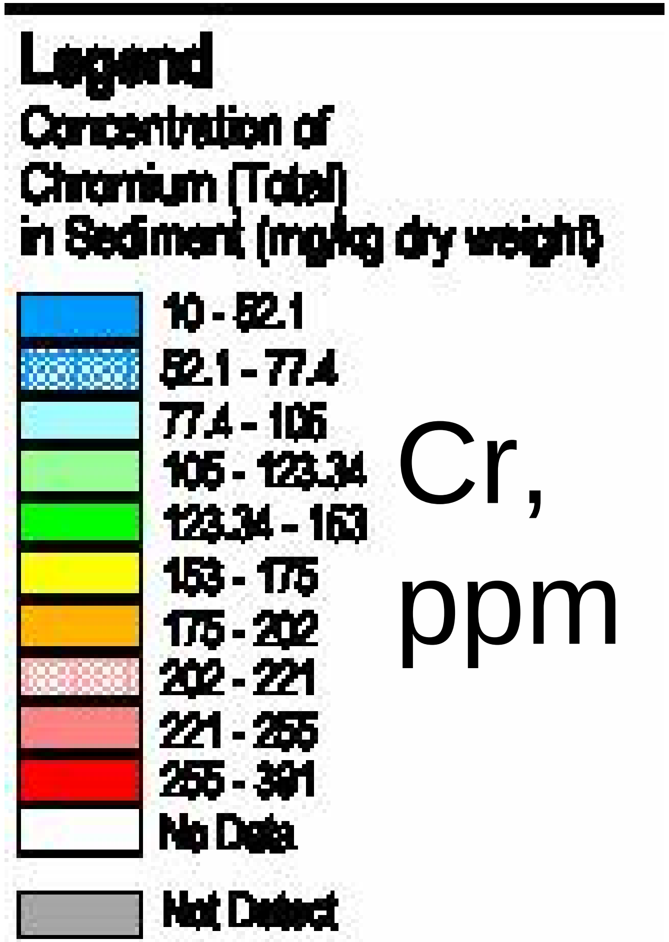


Sediment is part of the hydrodynamic continuum – actions on a sediment unit can affect other parcels, resulting in conflicting, counterproductive or inefficient management actions if not coordinated, regardless of goals



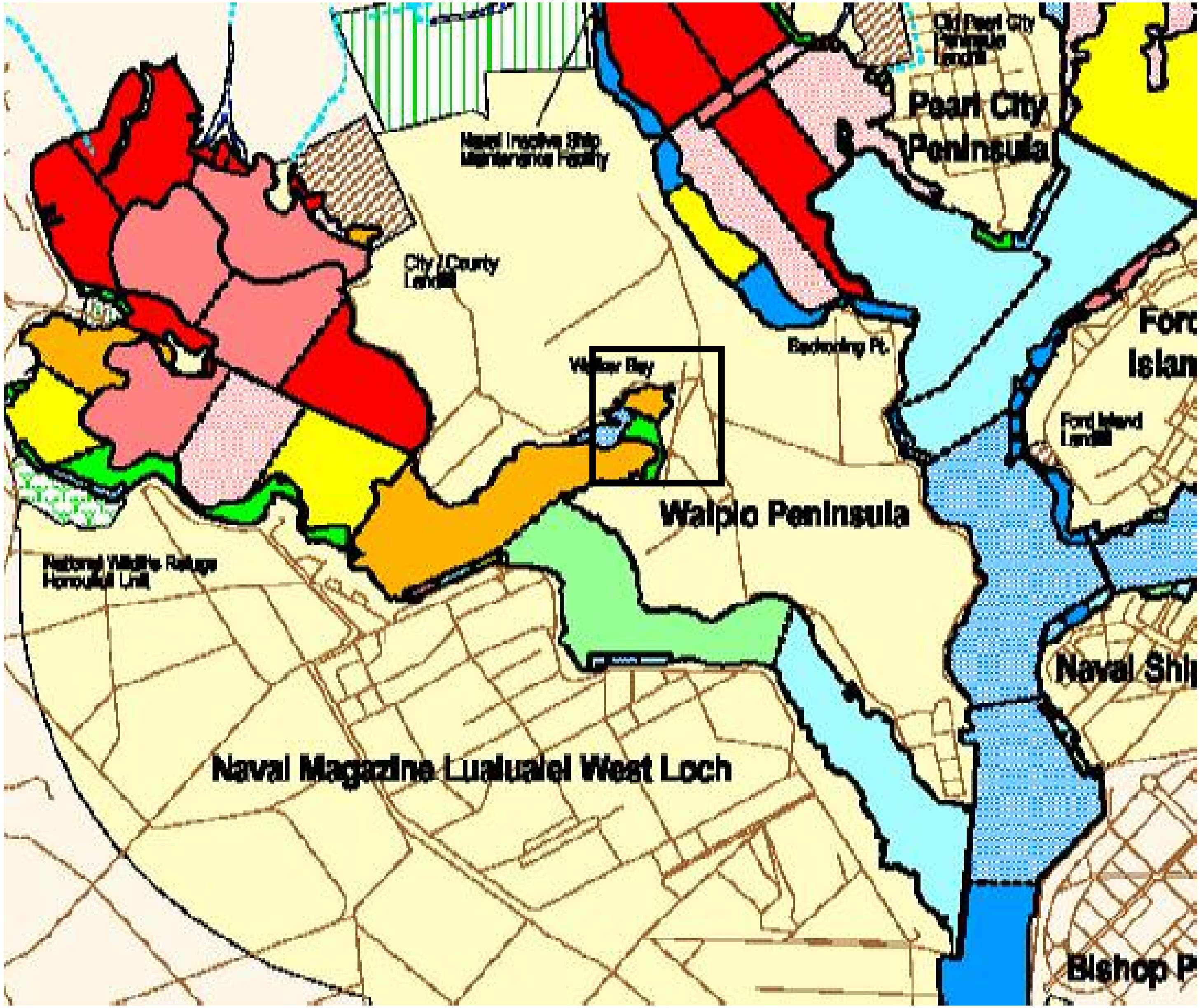
To manage Cr impact adjacent to this installation, it is clear one needs to focus on these two sites





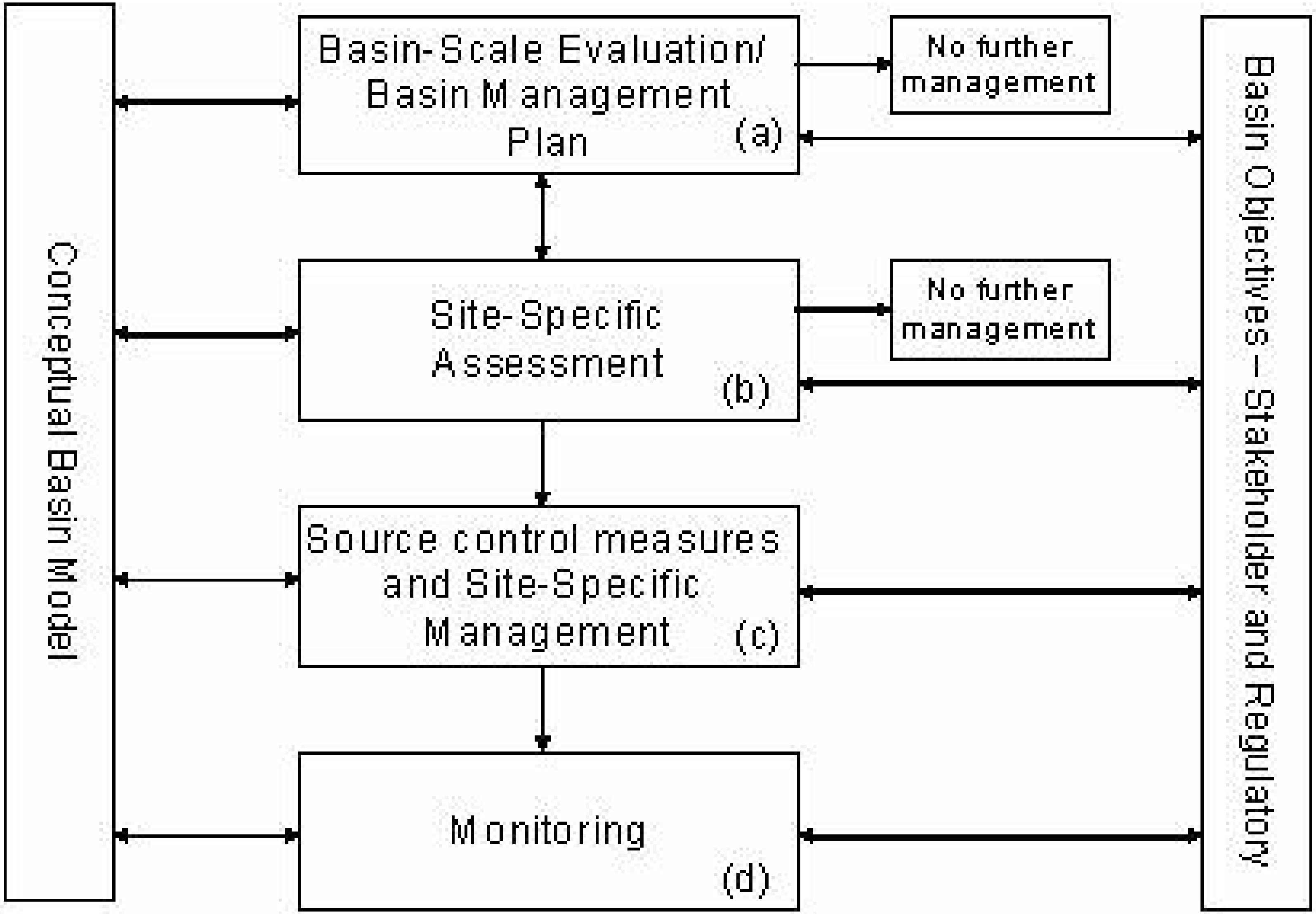
*Tan areas are land, coloured areas are harbour sediments

However, management of those sites alone probably won’t make much difference in the long run – recontamination will occur



Nonetheless, whether we’re dredging or cleaning up, we are seldom tasked to look outside our own “fence line” and thus these data are often not available

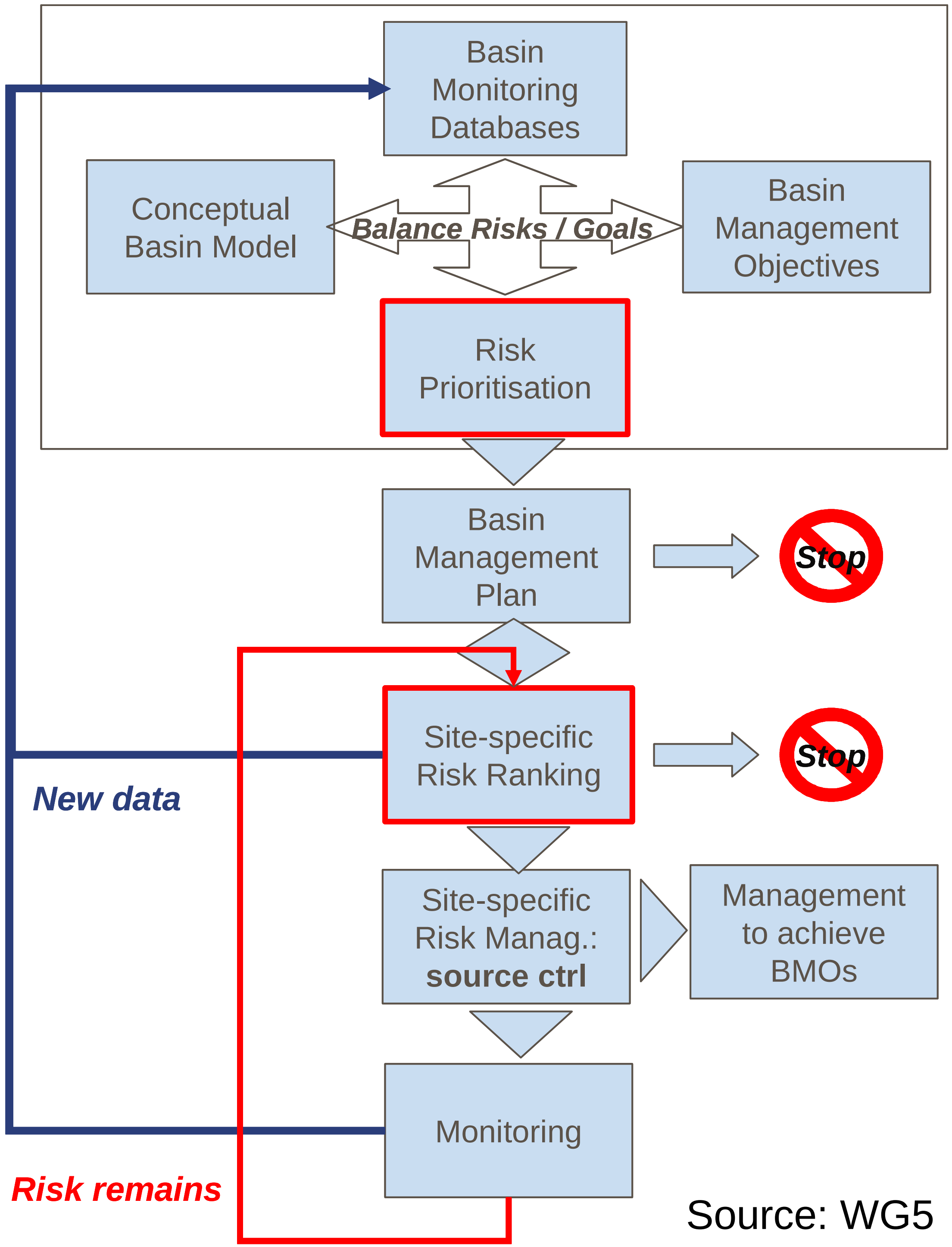
There is now recognition that sustainable risk management implies assessment at the basin-scale, managed at the site-specific scale



This can be viewed as a ***second*** revolution of scale

Source: WG5

- A basin-scale risk management framework should be comprised of two principal levels of decision making
- basin-scale evaluation (**risk prioritisation** of sites for further evaluation and/or management) and
- an assessment of specific sites for risks and management options (**site-specific risk ranking and management**).



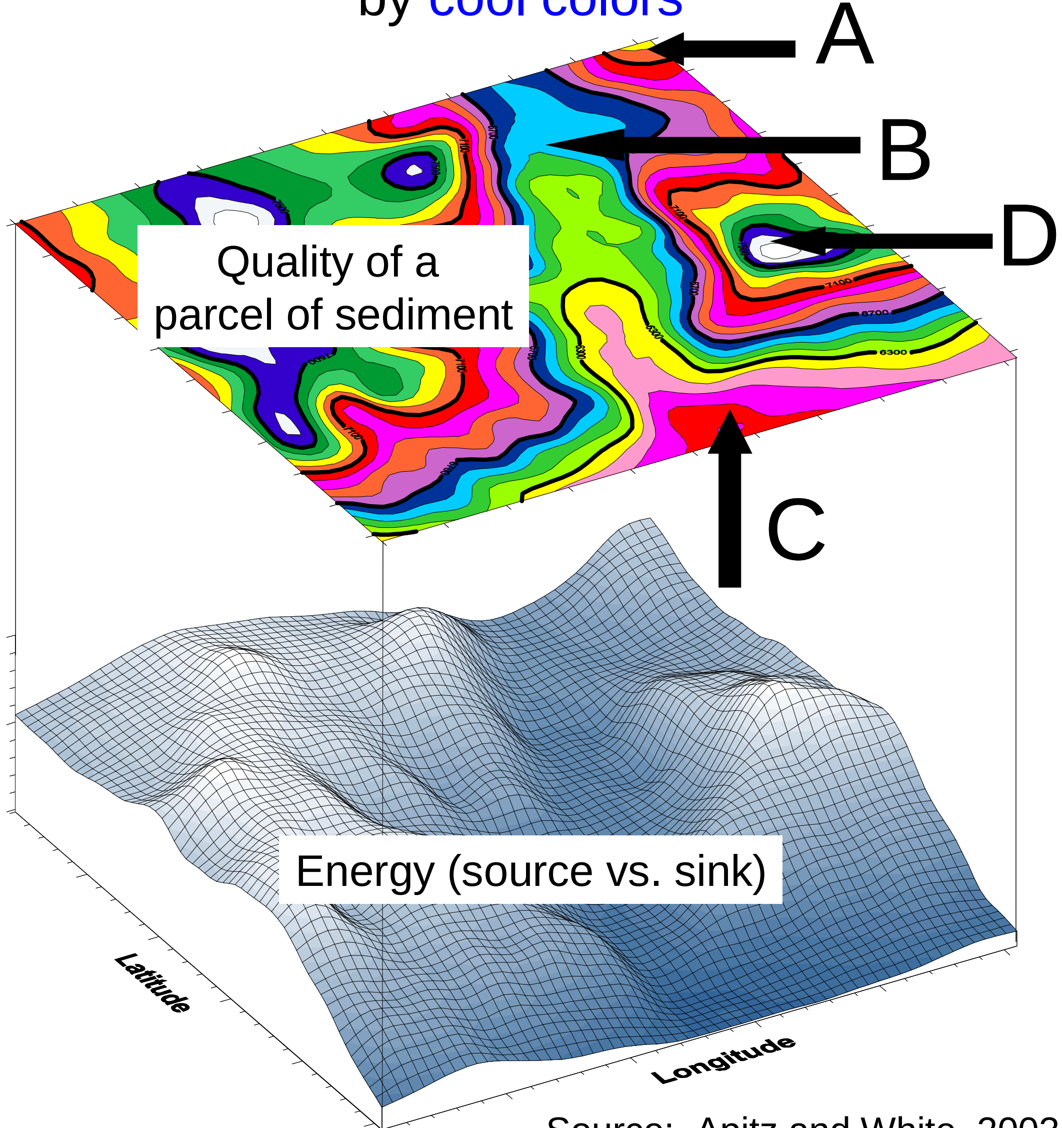
Source: WG5

Basin-scale management requires conceptual basin models

- Management of risk in a river basin demands that sediment risk management should be closely linked with the assessment and management of these other media
  - Because of the complexity of these interactions, conceptual models are required to identify, quantify and communicate the links between these processes and media
- An understanding of the particle and contaminant flows and interactions within a river basin should inform basin-scale evaluation
  - This can be termed a Conceptual Basin Model (CBM)
  - Inasmuch as it describes how materials move and interact between sites and media, it leads to increased knowledge about the river basin system and also serves as an important communication tool

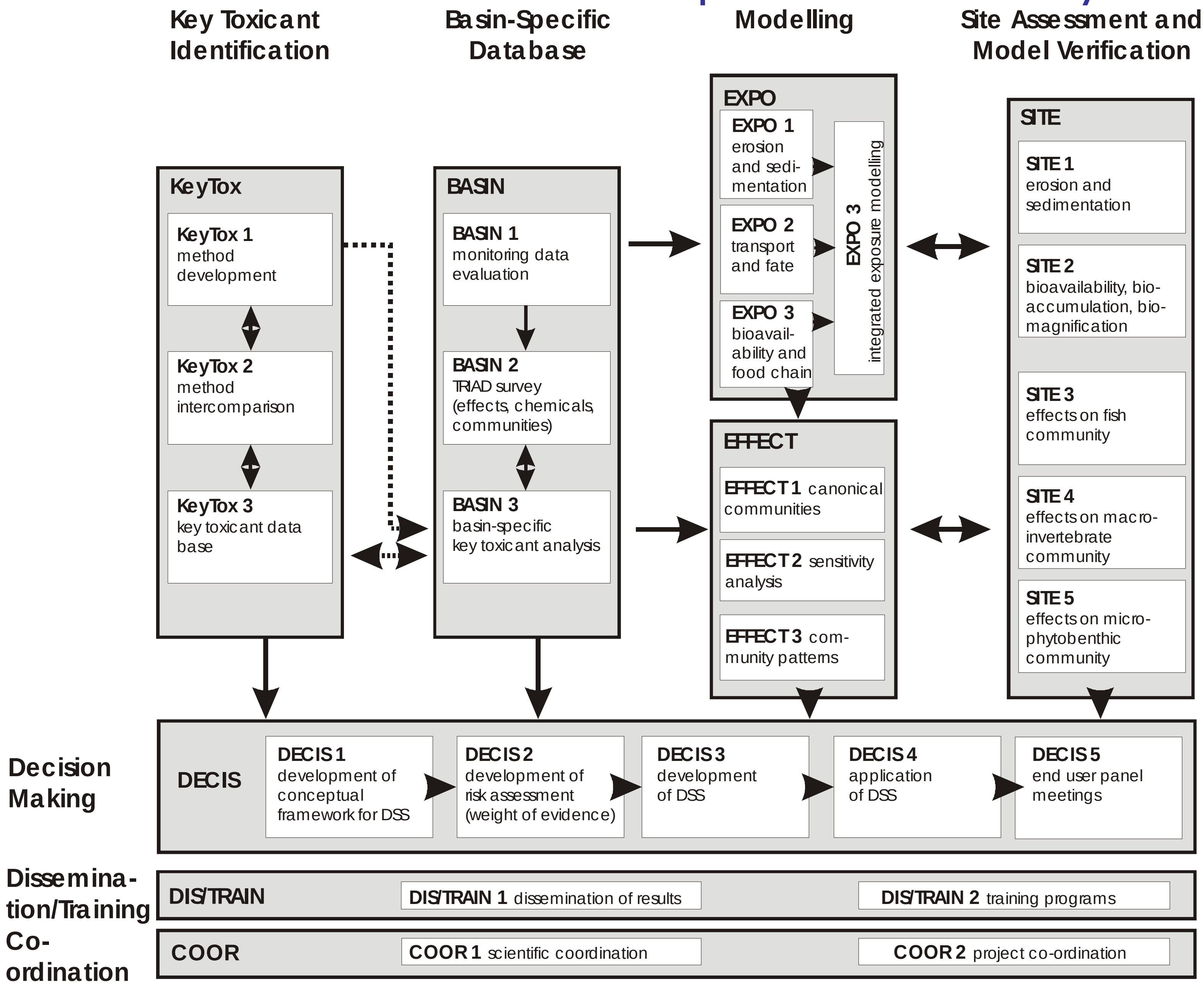
- It is the relationship between hydro-dynamically connected sediments, in terms of quality, quantity and energy, that defines their relative risk, and their risk priority in a risk management strategy
- A conceptual projection of sediment energy (source vs sink) and quality using data from a CBM can be used to inform Risk Prioritisation
- In this example, sediment A is of poorer quality than, and is upstream of, B, thus its risk is higher than sediment C, which is downstream from cleaner sediment D, although A and C are of similar quality

potential sediment (e.g. soil) is included. In colored scale, poorer quality is indicated by warm colors, better quality by cool colors



Source: Apitz and White, 2003

FP6-funded ModelKey Program has adopted a Basin Scale and then Site-Specific Hierarchy



Source: Werner Brack

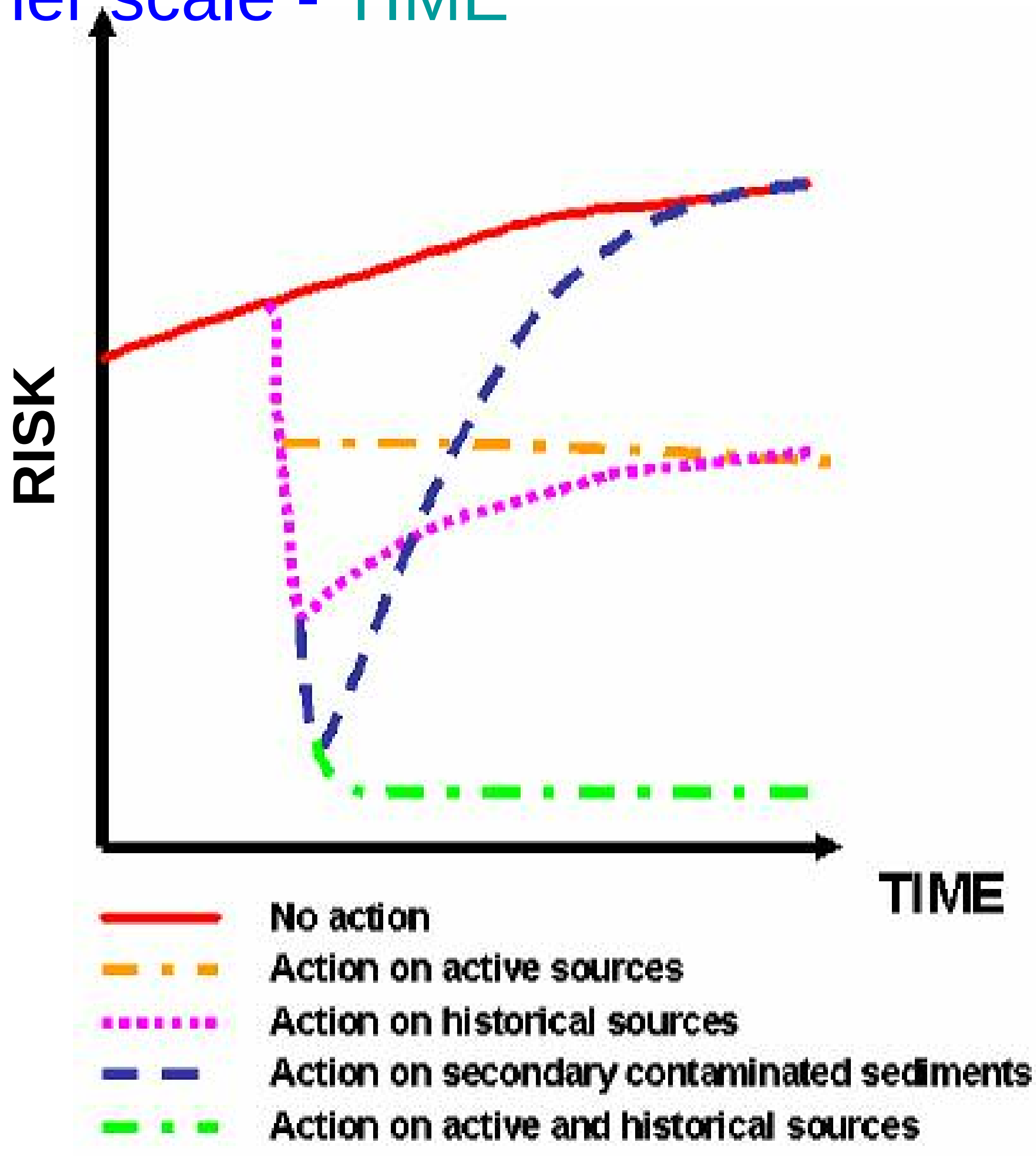
Clearly, we have been, and continue to, reduce contaminant inputs into the system

- However, deposited sediments reflect the history of past and present point and diffuse pollution
- These sediments are amenable to erosion and further transport downstream
- Furthermore, point and diffuse sources of sediment, both contaminated and uncontaminated, continue to enter the system from
  - ongoing agricultural and industrial practices
  - catastrophic spills and accidents
  - changes in erosional and depositional patterns due to climate change and anthropogenic activities

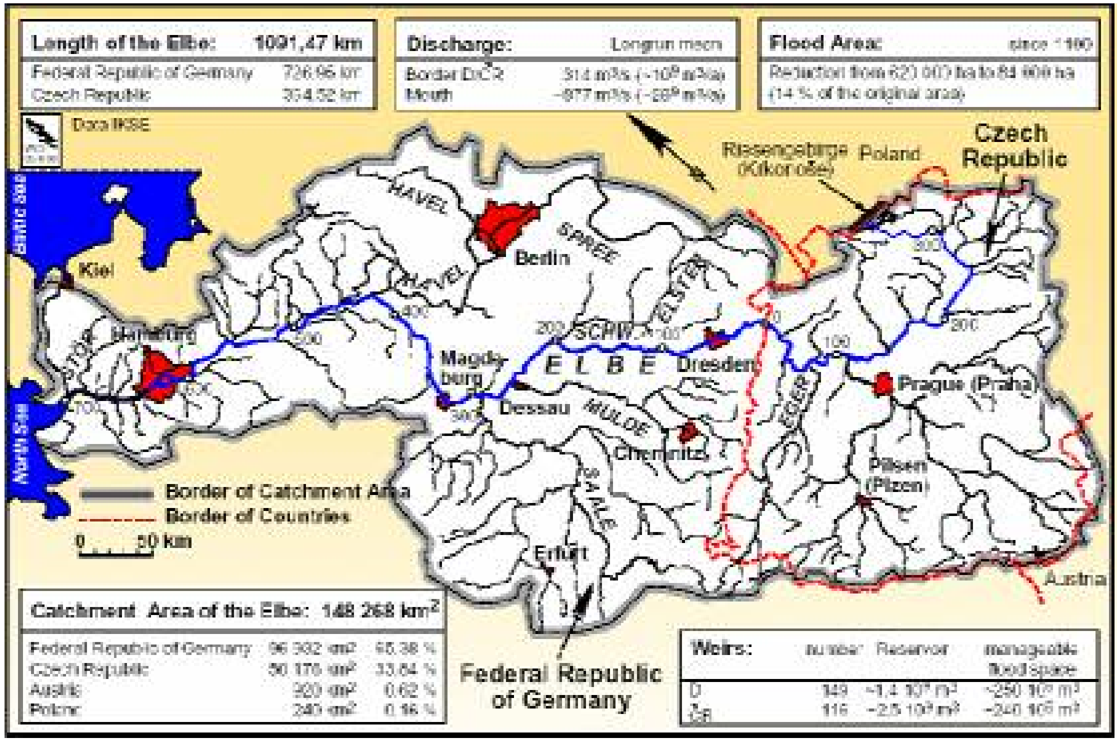
These are not transient problems that will soon cease to clutter “normal” sediment management. Rather, we need to re-think the links between our goals and activities, over time

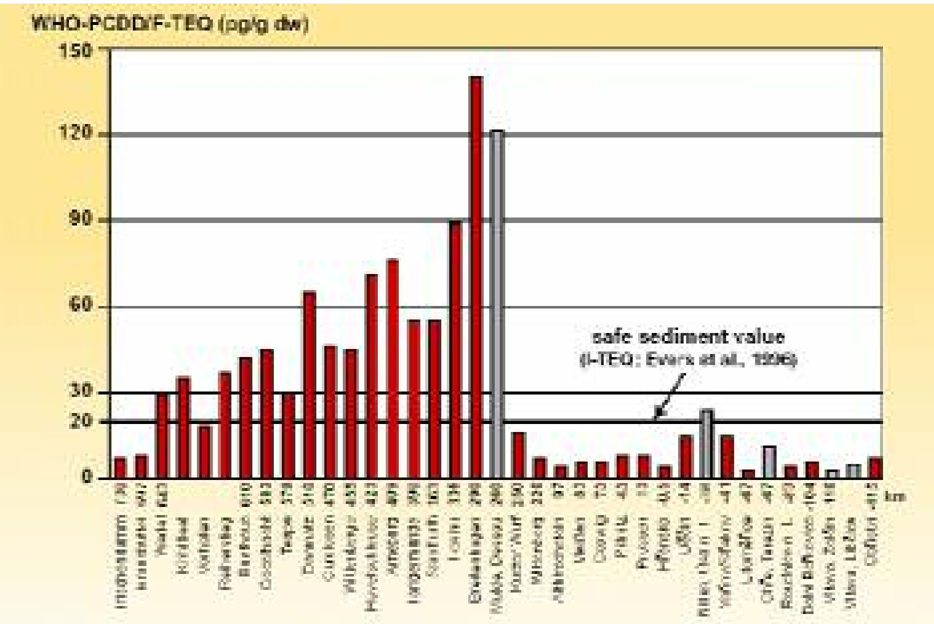
Risk management also requires a careful consideration in another scale - TIME

- Contamination (and thus risk) can result many types of sources
- Unless all these risk sources are managed, risks will continue and spread
- We must, then, project risk over time under various scenarios (using CBMs)
- We must consider the implications of these trends on our management strategies, but also on our criteria and standards



Source: Claudio Carlon





Concentrations of PCDD/F in sediment samples from the river Elbe and the mouths of its tributaries (September 2002)

River Elbe: Cross-border and cross-generational Risk Management*

- Hamburg Harbour spends millions annually treating DM contaminated upstream
- Major impacts are metals from historical mining sites (300) in Czech Republic and organics (dioxins) from former East Germany
- They wanted to know which source should be managed, or if they should continue to treat downstream

*Discussed by WG5 as a conceptual case study at the 2nd SedNet conference

One Conceptual Approach - **River Basin Management**

- Develop a Conceptual Basin Model for the Elbe
- Carry out a whole basin risk allocation, examining the relative contributions of various contaminant sources and types to cumulative risk
  - e.g. do 15% of sources cause 90 % of risk? Will removal of metals reduce risk, or is risk dominated by organics?
  - Note that many sources in this basin are not sediment (yet)
- Develop a prioritisation of sites - which should be managed first and where to allocate resources (Basin Management Plan)
  - Taking into account the above results, public evaluation and cost-benefit analyses:
- Select site-specific management options – which may be financed by an "Elbe River Fund" – many of these may not be sediment-specific
- It is possible that Hamburg Harbour funds are better spent in the Czech Republic
- It is possible that downstream sediments are being held to a standard not achievable for decades – impacts of decisions *over time* must be evaluated

Where are we that we weren't ten years ago?

- We have come very far
  - It is generally accepted that we can only manage risks in sediments if we understand the dynamics of contaminant behaviour
    - Extensive research has supported these goals
  - It is beginning to be accepted that sediment quality and quantity issues cannot be addressed in isolation
    - There are many types of risk, and sites and media interact
  - It is now also generally accepted that we cannot sustainably manage sediments site-by-site but must manage risk in basins
    - We have begun to develop conceptual approaches to this problem
    - National and international networks have been established

Where do we still need to go?

- While we have conceptual approaches to basin-scale management we still lack
  - Joined-up policies
  - Uniform datasets
  - Modelling tools
- We must stop separating
  - Dredging and cleanup
  - Sediments, soils and waters
- Agricultural and industrial policy, global change, and changing priorities will all affect whether we can achieve our environmental and economic goals

WFD mandates a more joined-up approach

- We must move
  - from incremental change in sediment management strategies (“evolution”)
  - to a “revolution” in which we understand how particles and contaminants move
    - from the micro- to the macro-scale
    - from source to sink
    - historically and into the future…

In order to ***sustainably*** manage risk to both the environment and our socioeconomic goals