A Tiered, *In Situ* Approach For Assessing Sediment Contamination

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Strengths & Limitations of Traditional Environmental Assessment Methods

- Criteria: easy, wide use, proven utility
- Biota: high certainty, long term measure/integrator, public interest
- Bioaccumulation: risk models, long term measure, wide use
- Toxicity (lab): wide use, proven utility, integrator
- TIE (lab): partitions chemicals, causality

- Criteria: single chemical, causality, extrapolation, exposure reality
- Biota: causality, indirect effects, variability, natural stressors
- Bioaccumulation: thresholds, metabolism, acclimation
- Toxicity (lab): causality, extrapolation, chronic costs, natural stressors
- TIE (lab):artifacts,insensitive

Strengths/Limitations of Non-Traditional Environmental Assessment Methods

- Habitat: essential to life, dominant stressor
- GW/SW Flow: documents exposure, compartmentalize stress
- *In situ* Toxicity and Uptake: improved exposure, compartmentalize stress, minimize artifacts
- *In situ* TIE: improved exposure, minimize artifacts, sensitive

- Habitat: non-std., receptor specific, quantification
- GW/SW Flow: non-std., logistics
- *In situ* Toxicity and Uptake: non-std., logistics, reference site, acclimation, proper deployment
- *In situ* TIE: non-std., logistics, proper deployment, screening only

Tier 1: Stress Demonstration

Site Reconnaissance

Sample Design Issues

- Bioaccumulation - *tissue design*
- PAHs - *phototox testing*
- GW/SW interactions - *piezometer design*

Exposure

reference sites vs. stressor gradient

Compartment
- Water column
- Interface (sed/water)
- Surficial sediment
- Pore water

Event
- Low flow
- High flow
- Seasonal
- Diel

Period
- 1-30 days

Physicochemical Profiles

Effects

Species
- *H. azteca*
- *D. magna*
- *C. dubia*
- *P. promelas*
- *C. tentans*
- *L. variegatus*
- etc.

Measurement Endpoints
- Survival
- Growth
- Reproduction
- Tissue

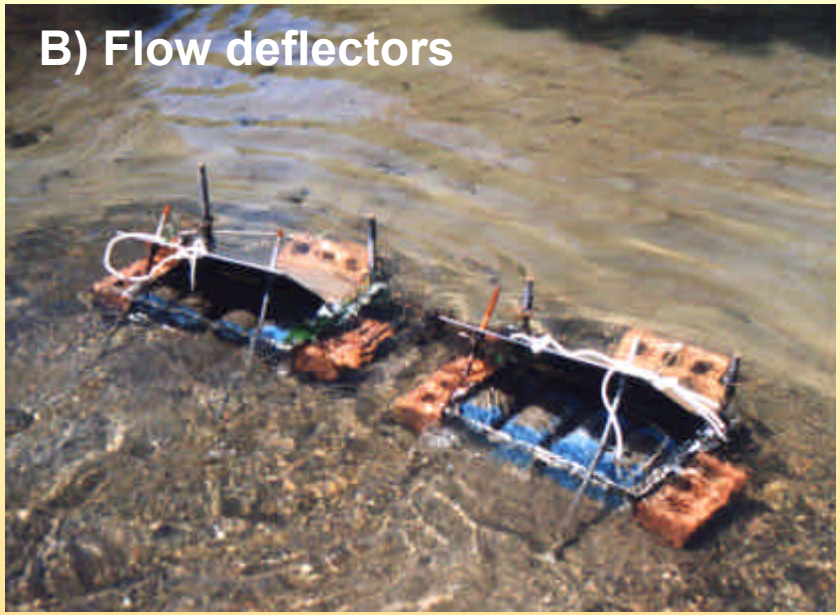
Weight of Evidence
- Lab tox testing
- Chemistry + SQGs
- Indigenous biota (structure/function *indices, genetic profiling, fish DELTs, hyporheous*)
- Habitat (*QHEI*)
- Retrospective studies

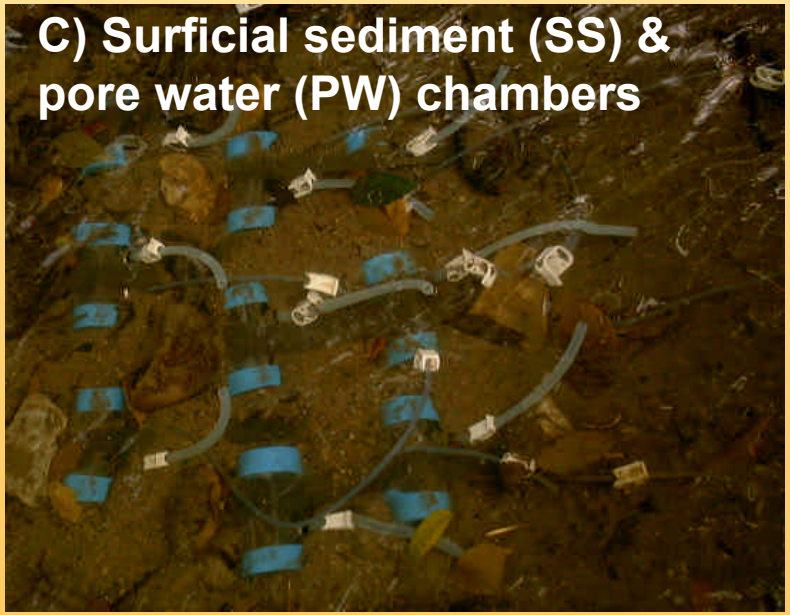
Tier 2: Stressor Class Identification

- Physical stressors (*flow, temperature, suspended solids)*
- Chemical stressors (*PAHs, nonpolars, metals, ammonia*) classes
- *In Situ* testing - *Stressor Identification Evaluations (SIE)*
- Laboratory testing - *Toxicity Identification Evaluation (TIE); Phase 1*

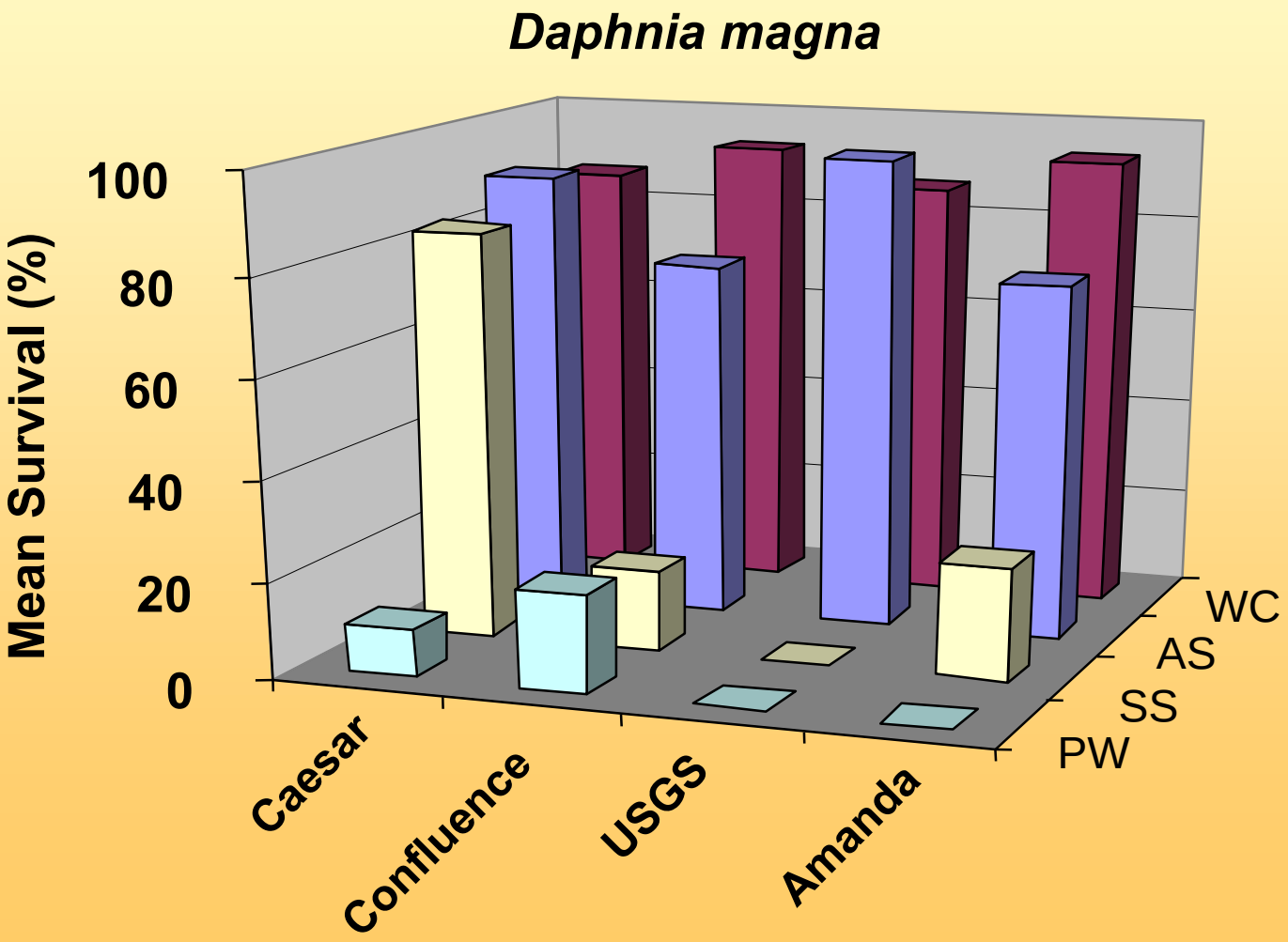
Tier 3: Stressor & Source Confirmation

In Situ Chambers (Deployed)





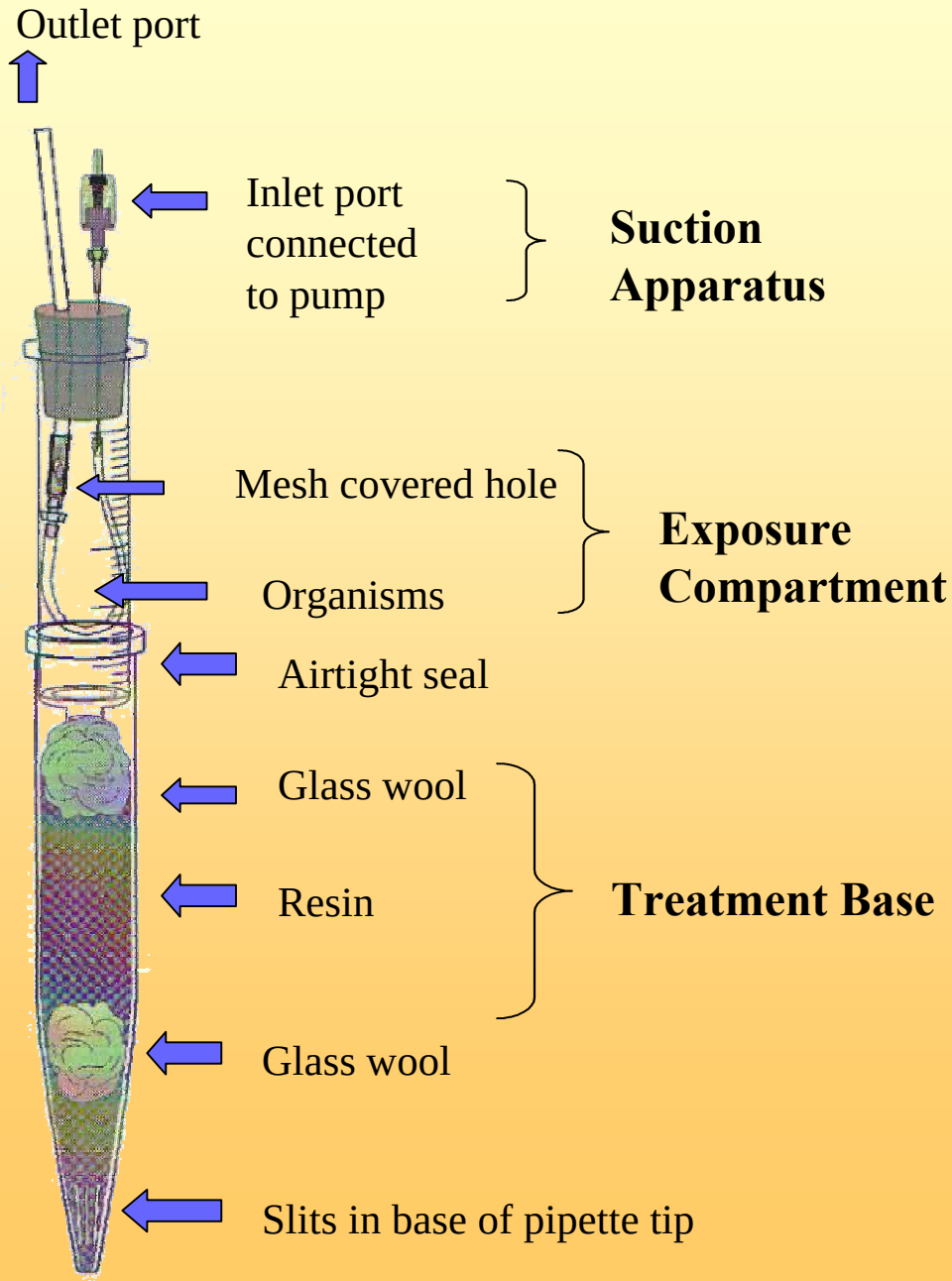
Dicks Creek 1999
72-h *In Situ* Exposure



Sediment PCBs (µg/kg, DW)

Site	Tot PCB	Tot DL-PCB
Caesar	0	0
Confluence	11	1
USGS	409	15
Amanda	629	29

In Situ TIE Chamber



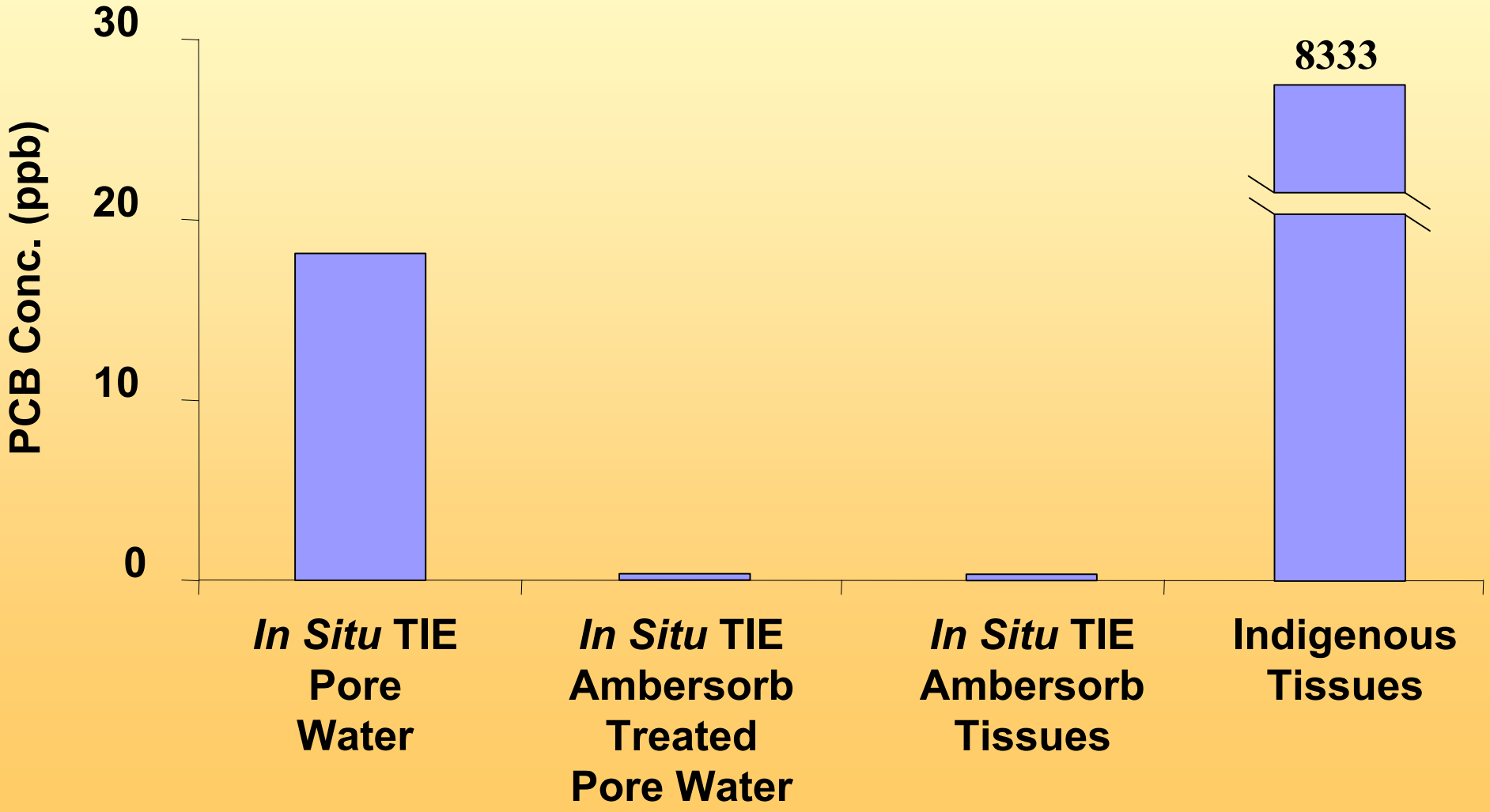
Resins Used:

Zeolite - NH_3

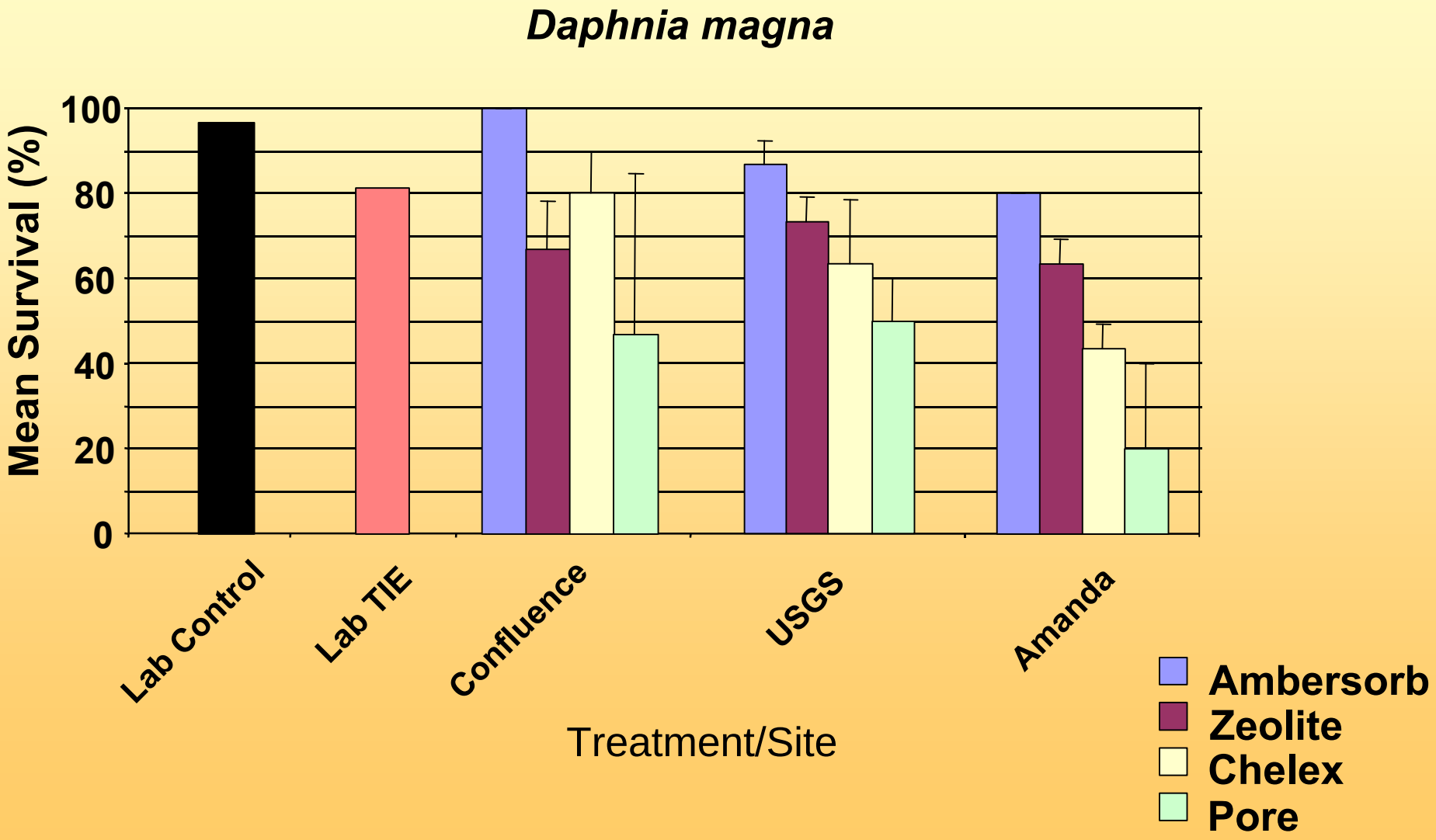
Chelex - Metals

Ambersorb - Non-polars

Dicks Creek 1998
L. variegatus tissues



Dicks Creek 1999: 24-h *In Situ* TIE



Sediment Toxicity Assessment and GW-SW Interactions

- GW-SW interactions in relation to sediment toxicity new area of research

- GSI issues exist at numerous sites:
  - 75% all RCRA/Superfund w/in 1/2 mile of surface water
  - 51% NPL sites with surface water contaminated (most via groundwater transport)
  - observed at all sites we have studied

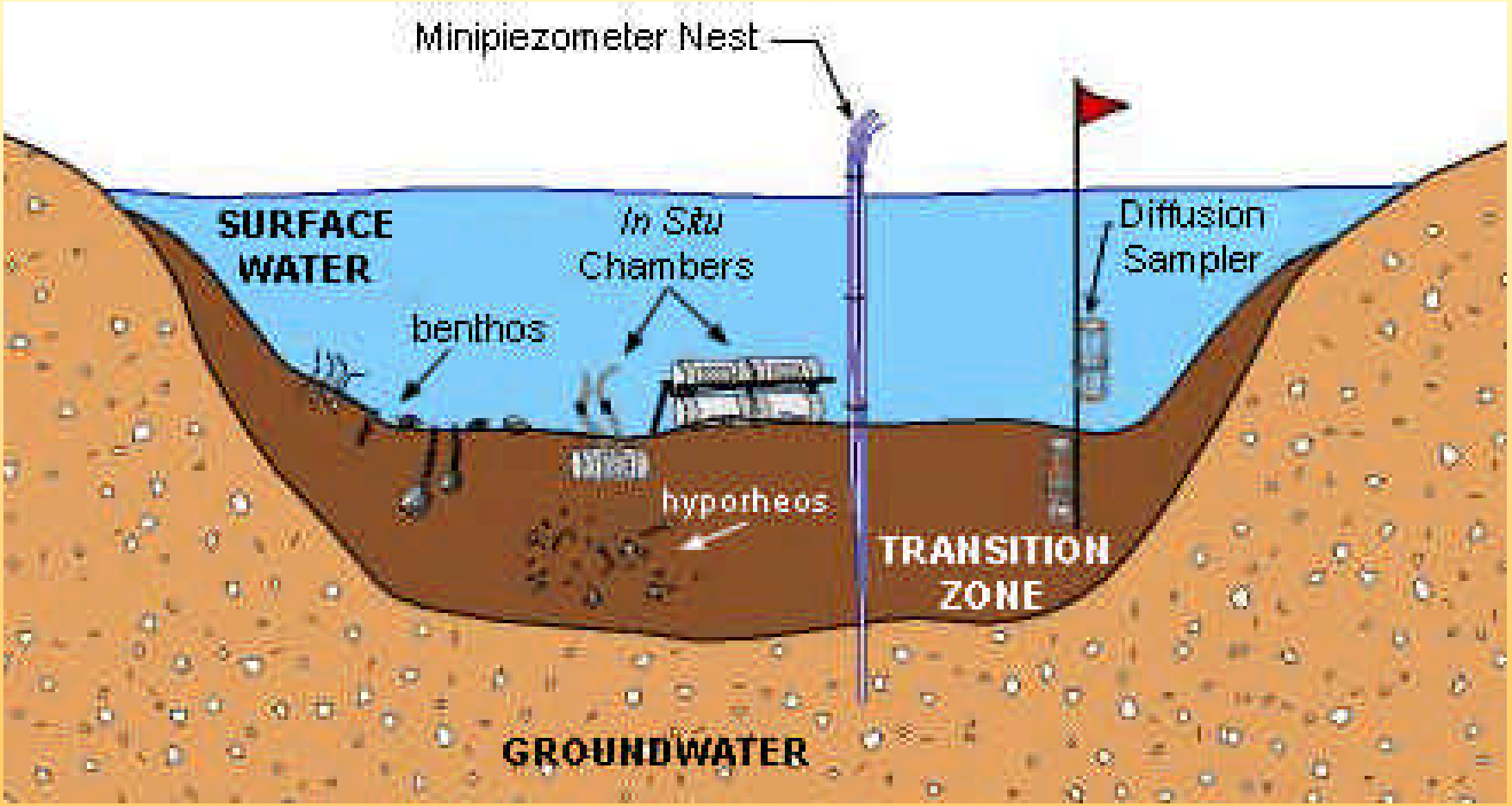
Sediment Toxicity Assessment and GW-SW Interactions

- Interdisciplinary approach (hydro/eco/chem/tox) essential to assess fate dynamics (exposure) and resulting biological effects
  - GW, SW, sediments often evaluated by separate groups
- Ecological Risk Assessment process dictates characterization of exposure vs. effects to characterize risk . Without knowledge of GSI this process prone to error...
  - Increasing concern by USEPA and risk assessors

GW-SW Interactions and Contaminated Sediments: Potential Effects

- Influence *in situ* exposure of biota:
  - Upwelling: Benthos, SW biota (GW and/or sed contam)
  - Downwelling: Benthic, hyporheic, phreatic (SW and/or sed contam)
- Transition zone serves important ecosystem functions; may be sensitive to perturbation

Integrated *In Situ* Assessment Design



Mini-Piezometers

- Measure hydraulic head (Δh) and vertical hydraulic gradient to detect up- and downwelling zones
- Withdrawal of pore water from desired depths within stream bed for chemical profiling
- Can be used for repeated measures

Piezometer Installation & Reading

Manometer

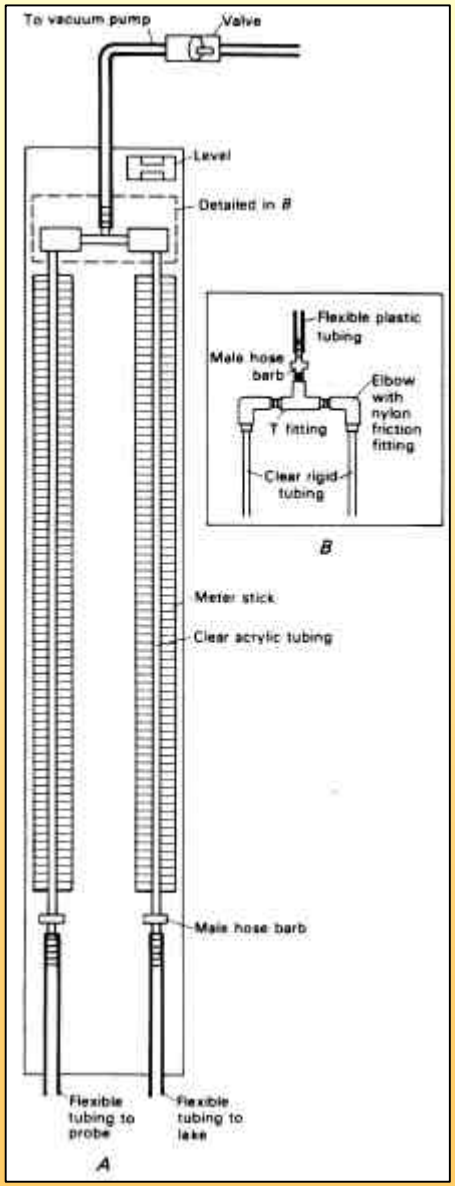


Diagram from Winter et al. (1988)

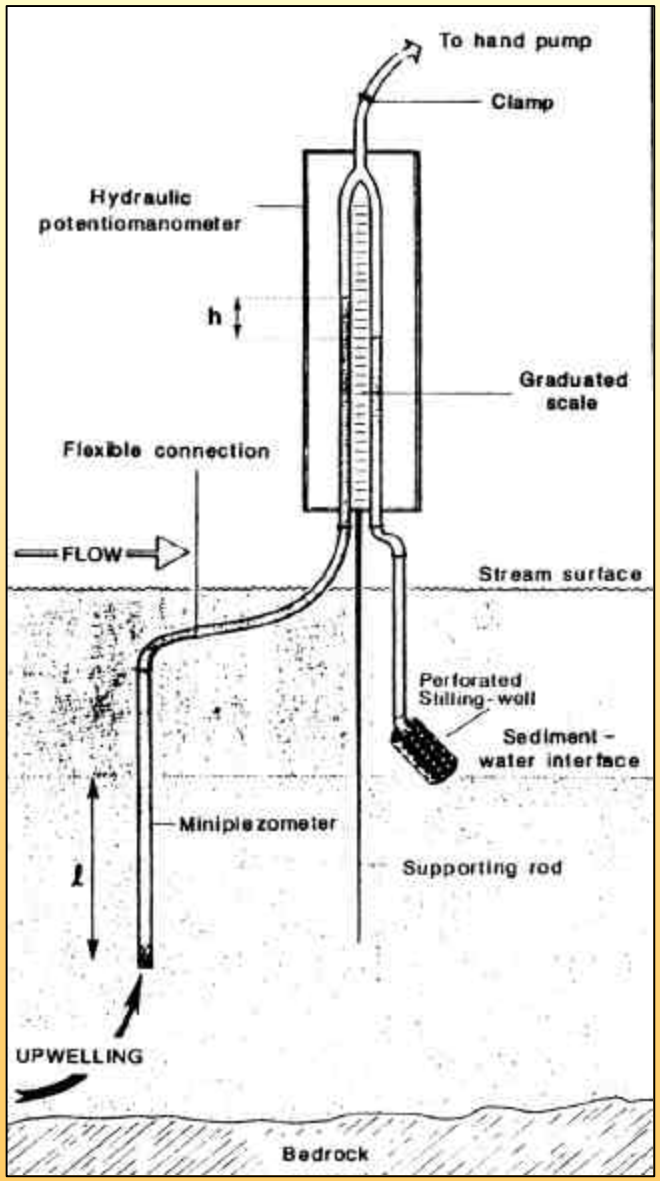
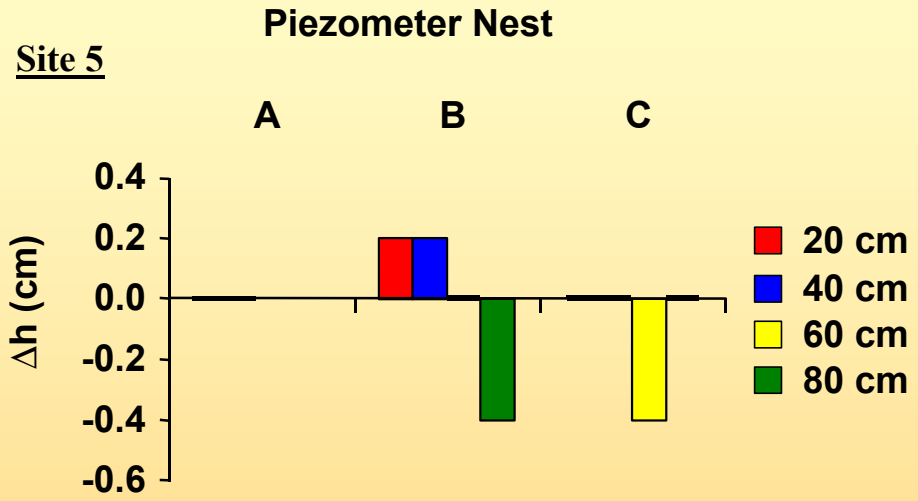
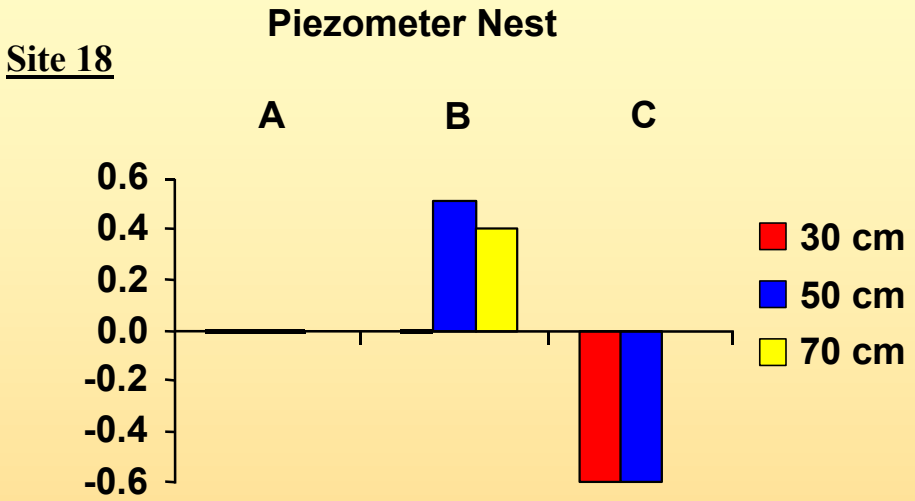


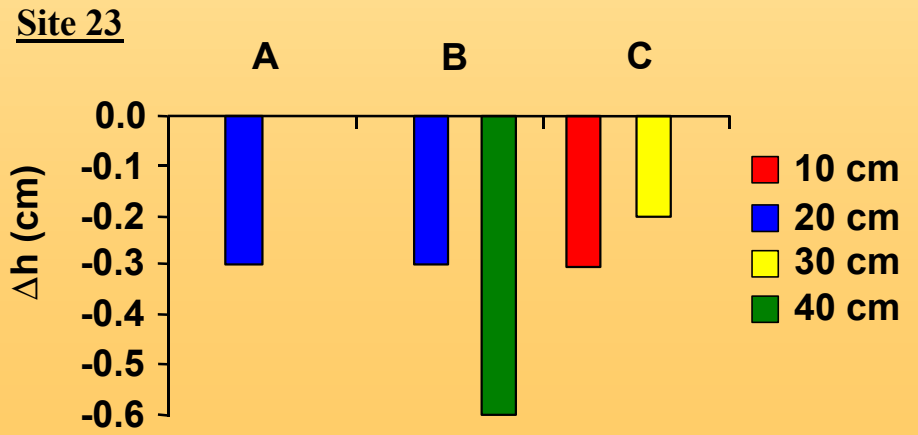
Diagram from Boulton (1993)

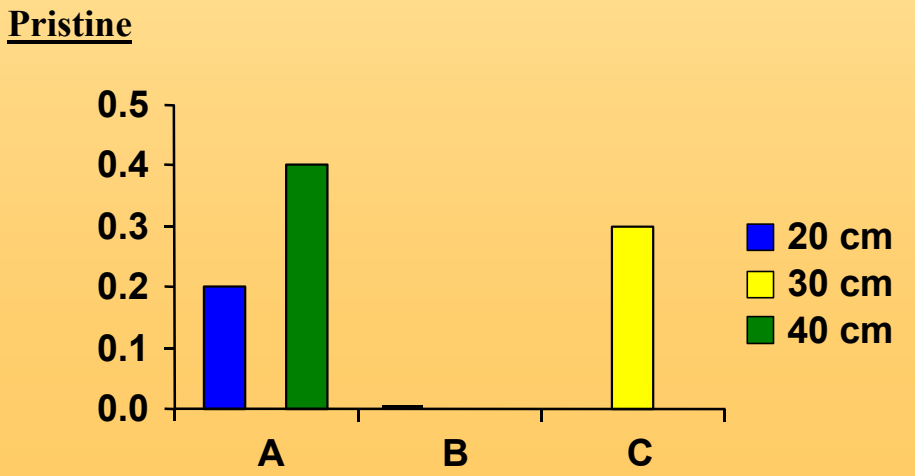
$$VHG = \frac{\Delta h}{\Delta l}$$

Maine 1999: Hydraulic Heads



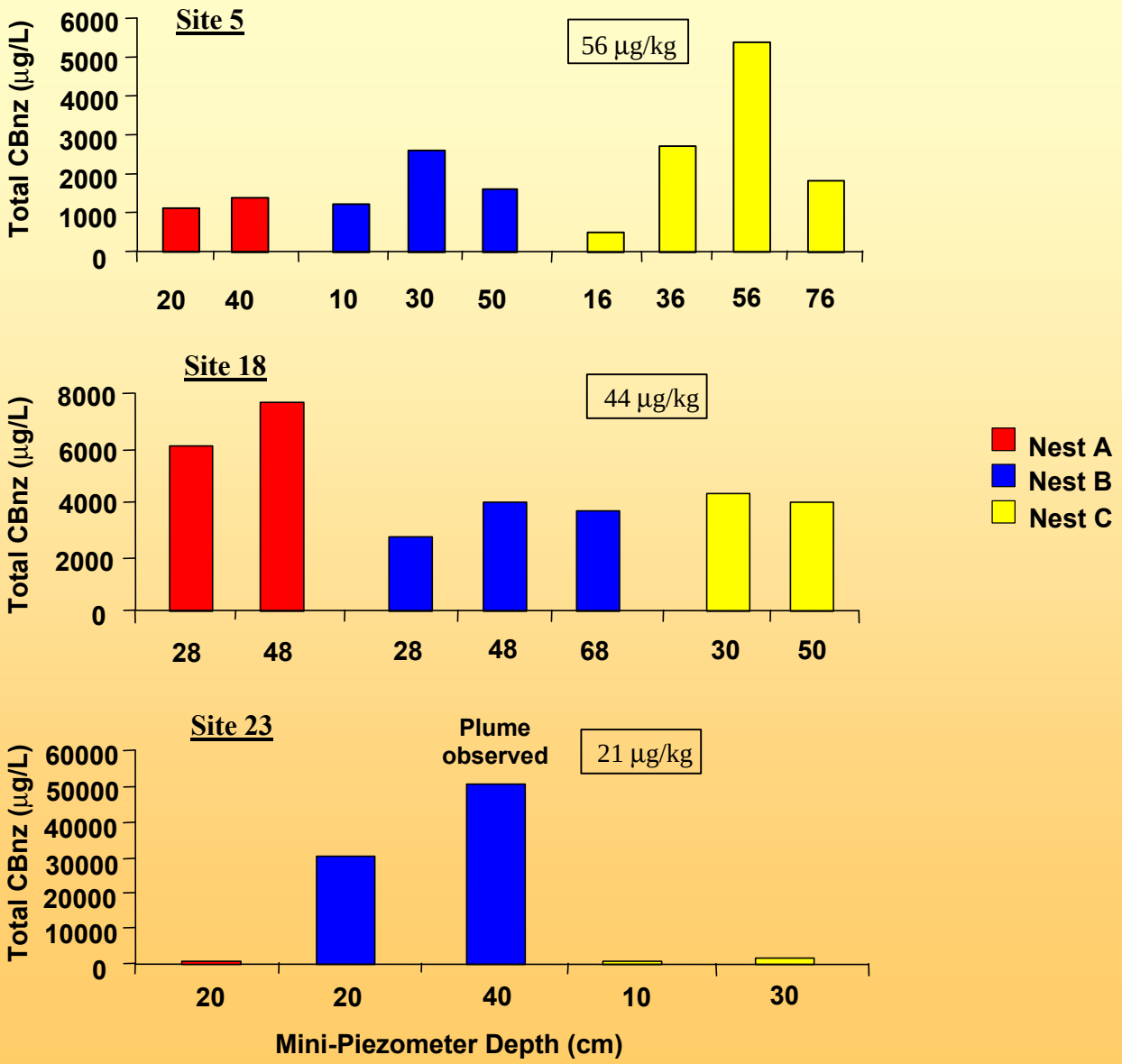






(Greenberg, M.S. et al. *Environ. Toxicol. Chem.* 21(2):289-297, 2002)

Total Chlorobenzenes in Pore Water



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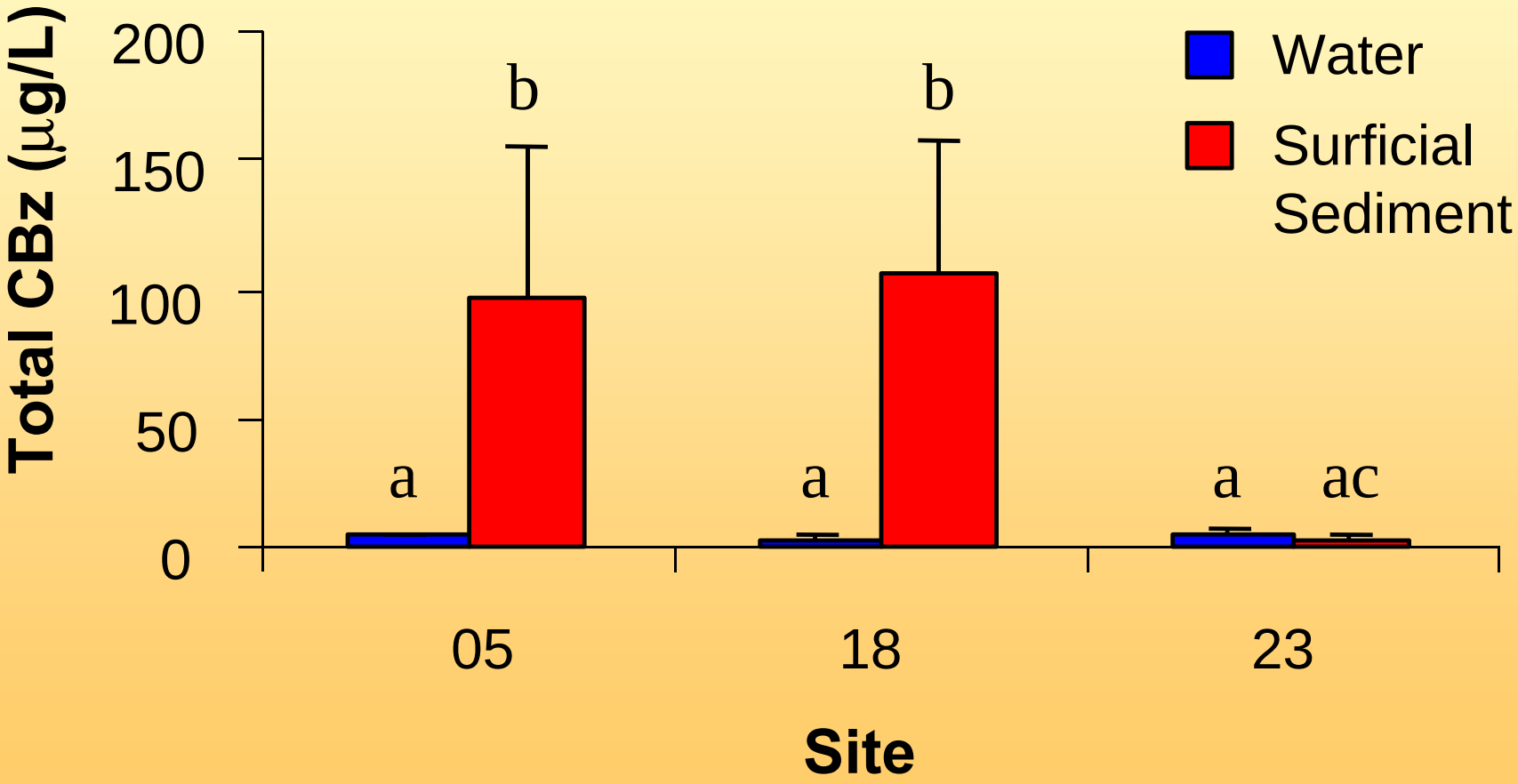
Total Chlorinated Benzene Exposure Levels Within *In Situ* Chambers



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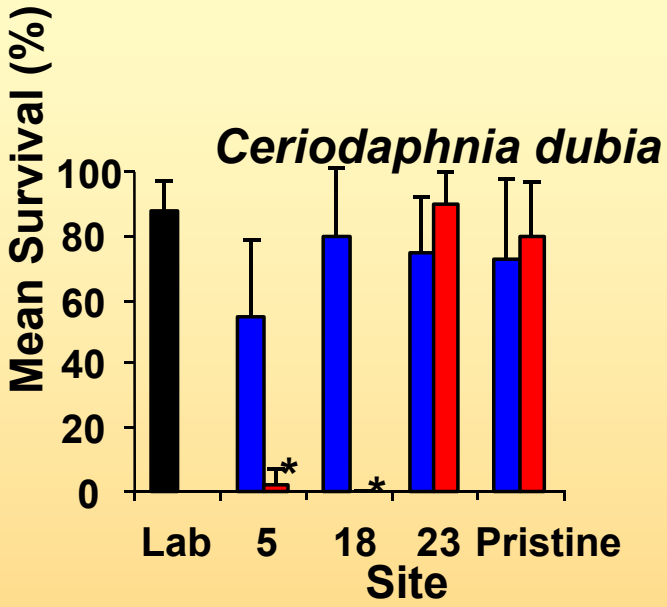
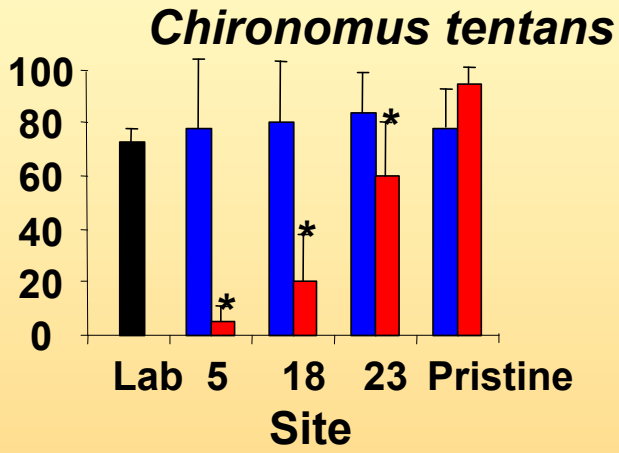
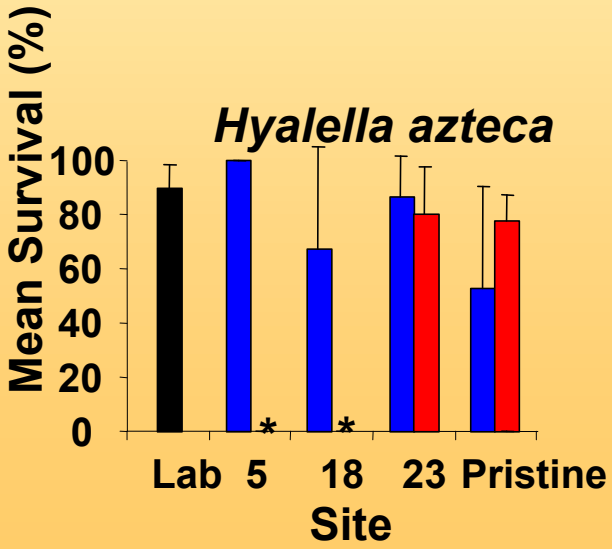
96-h Low Flow *In Situ* Exposure Maine Chlorobenzene Study







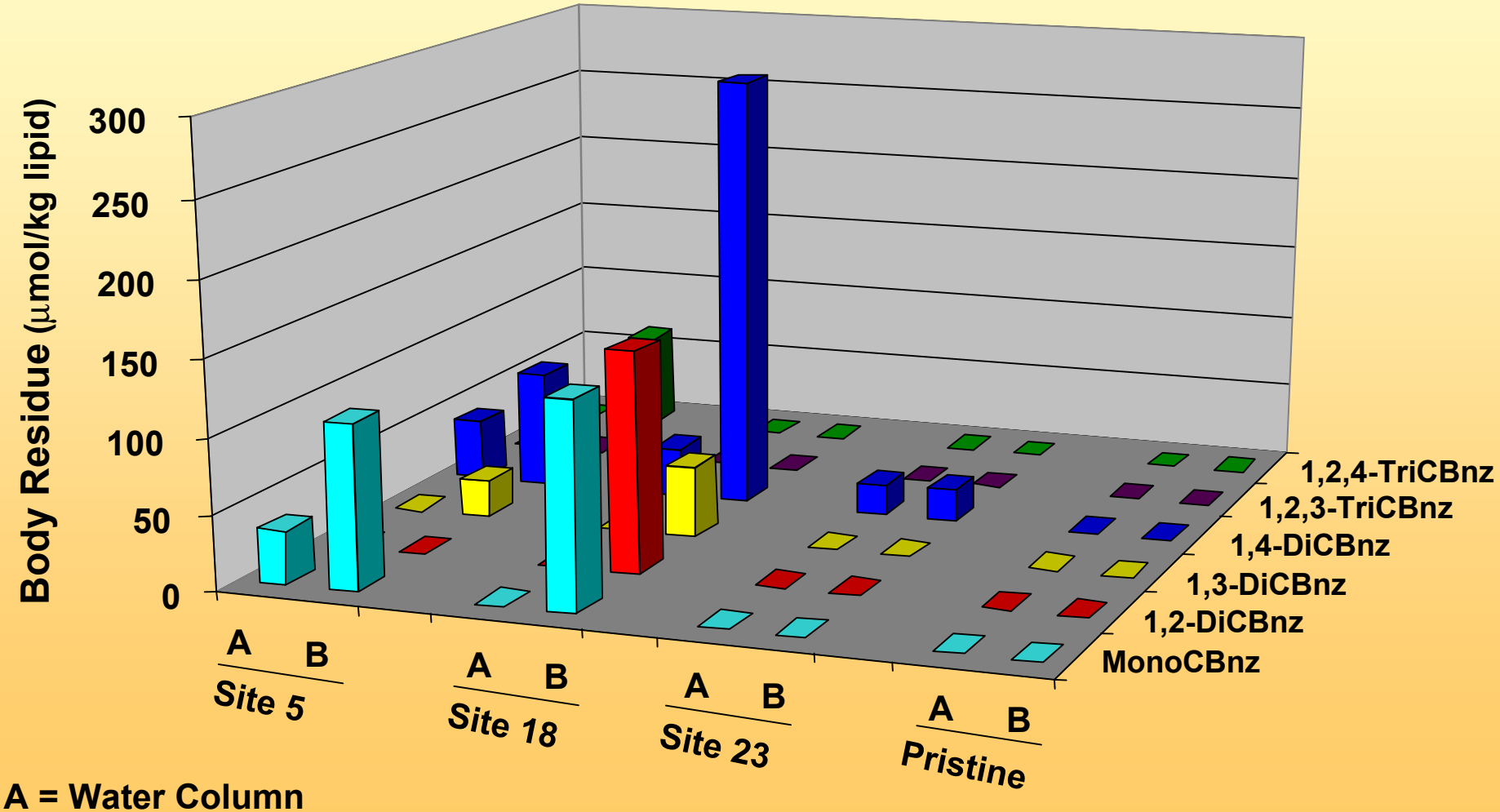
Water

Surficial Sediment

*Significantly different from field reference site, Pristine ($p < 0.05$)

(Greenberg, M.S. et al. *Environ. Toxicol. Chem.* 21(2):289-297, 2002)

96-h *In Situ* Bioaccumulation *L. variegatus*, Maine Chlorobenzene Study



A = Water Column
B = Surficial Sediments

(Greenberg, M.S. et al. *Environ. Toxicol. Chem.* 21(2):289-297, 2002)

Conclusions

- Mini-piezometer data provide a unique *in situ* characterization approach--must document GW-SW conditions
- Data from mini-piezometers improved interpretation of exposure-effects relationships
- Downwelling was shown to reduce exposure in one system while it potentially exposed organisms to SW contamination in another

Conclusions

- *In situ* TIEs more sensitive than laboratory
- Integrated approaches are essential in a holistic assessment of sediment toxicity