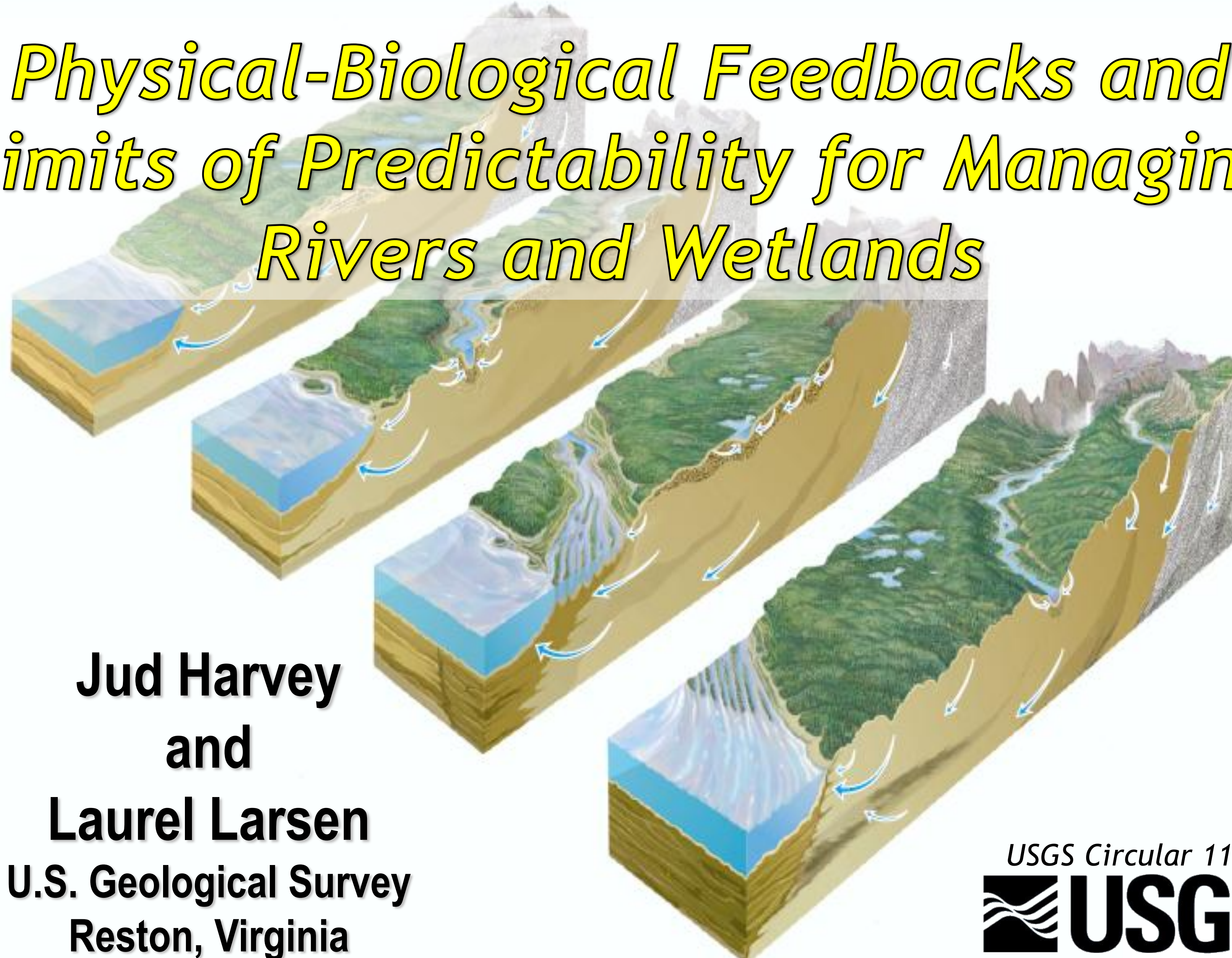
Physical-Biological Feedbacks and Limits of Predictability for Managing Rivers and Wetlands



Jud Harvey
and
Laurel Larsen
U.S. Geological Survey
Reston, Virginia

USGS Circular 1139

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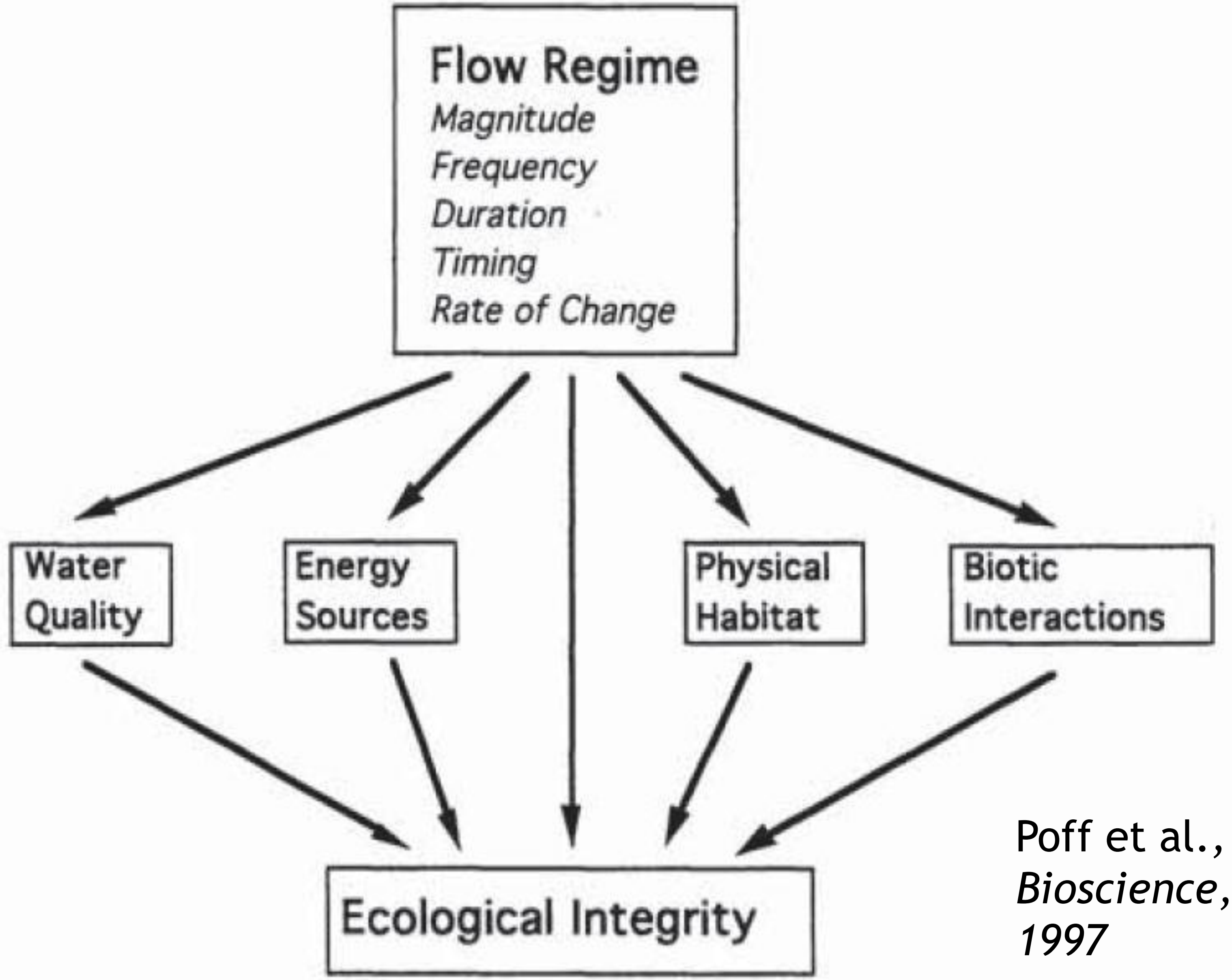
“The Natural Flow Regime”

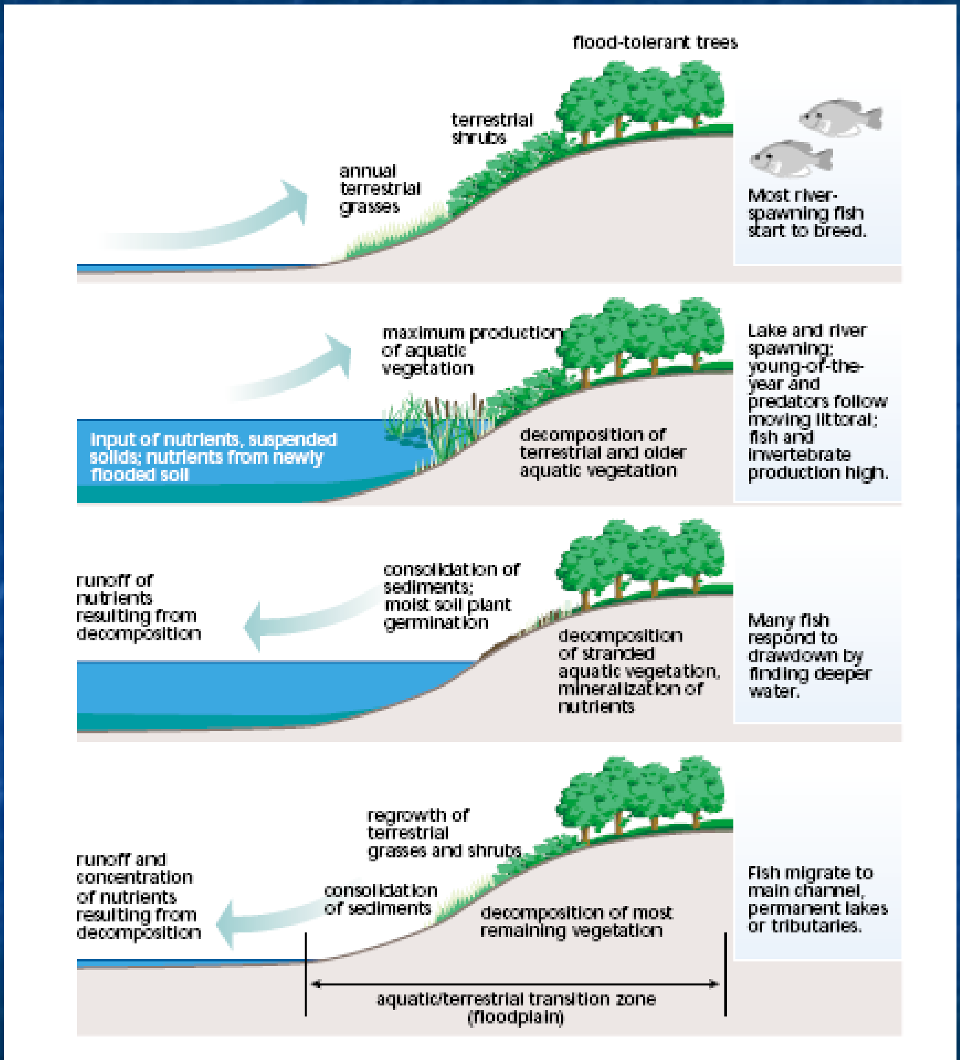


Poff et al., *Bioscience, 1997*

Four Reasons a Natural Flow Regime Matters

- creates a complex assemblage of aquatic and riparian habitats

Flood Pulse Facilitates Fish Spawning, Plant Germination, and Nutrient Exchange *Junk et al., 1989*



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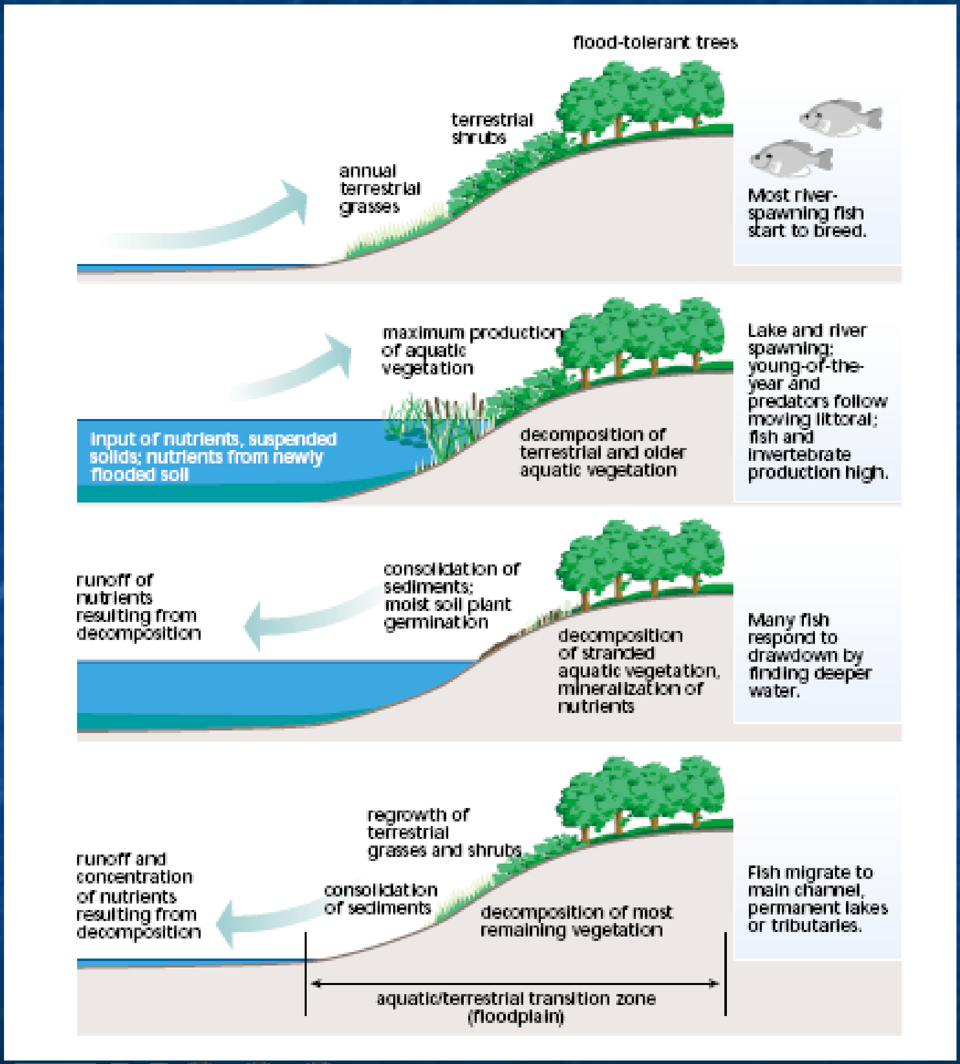
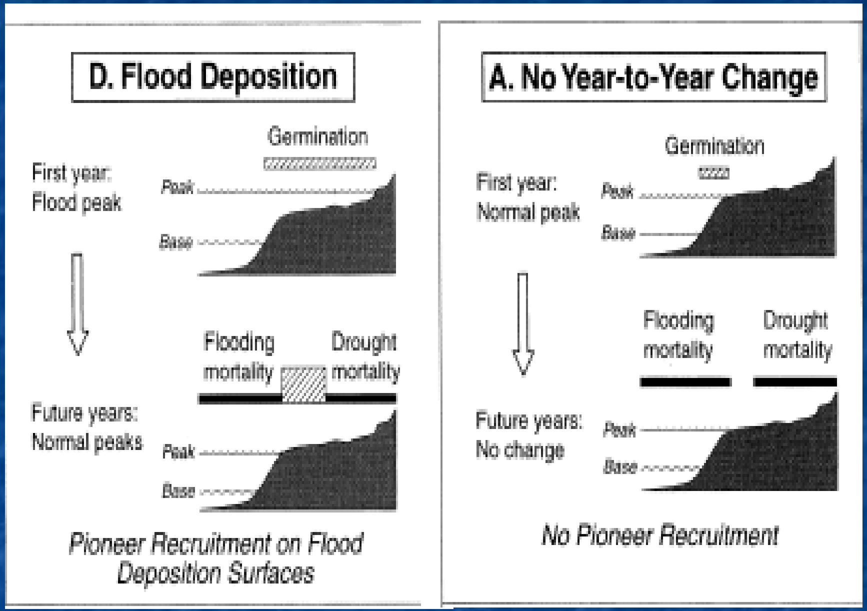
Four Reasons a Natural Flow Regime Matters

- creates a complex assemblage of aquatic and riparian habitats

- supports diverse habitat requirements for aquatic and riparian plants, macro invertebrates, amphibians, and fish while maintaining pathways of animal migration and gene flow

Flood Pulse Facilitates Fish Spawning, Plant Germination, and Nutrient Exchange *Junk et al., 1989*





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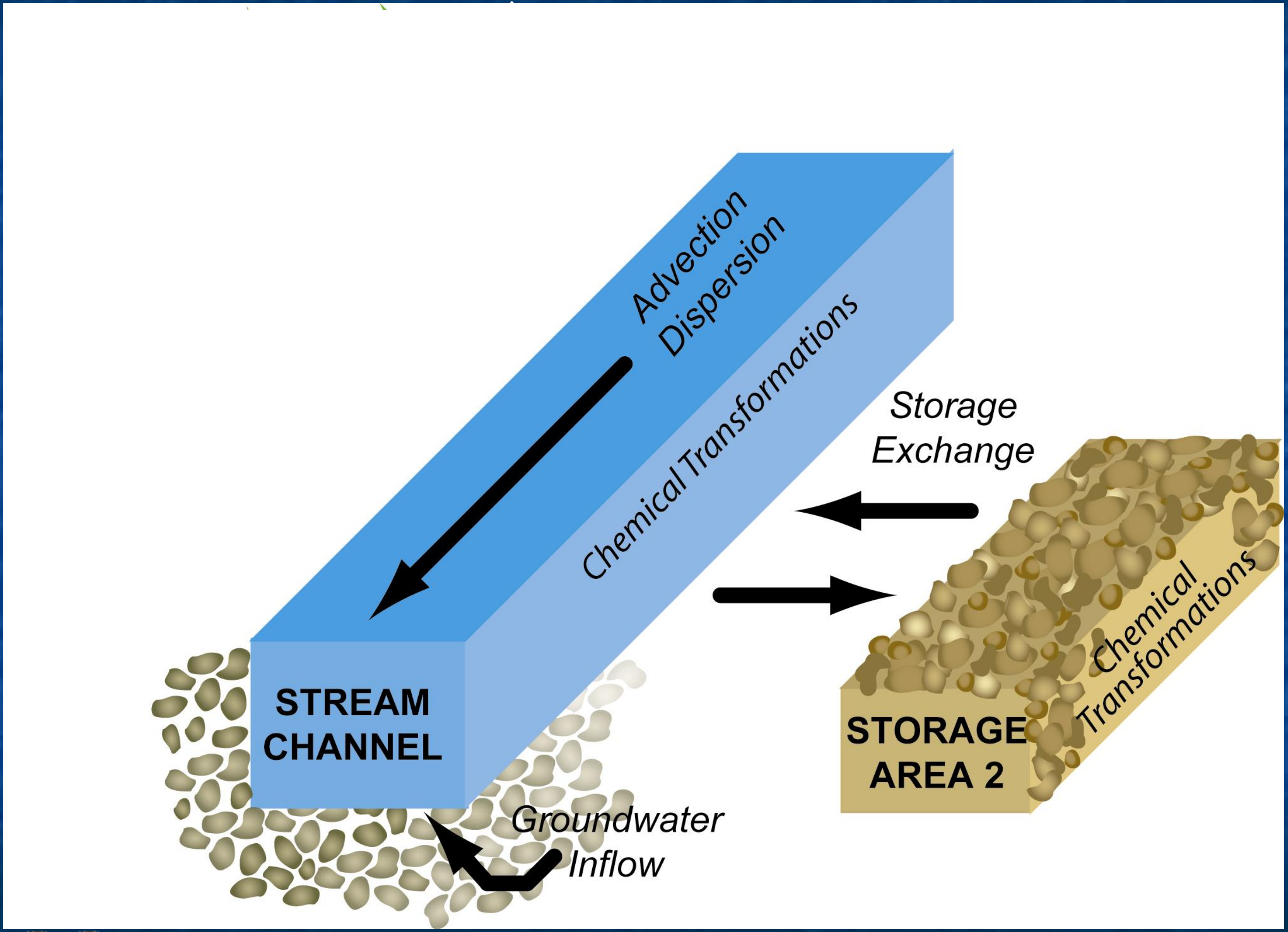
Four Reasons a Natural Flow Regime Matters

- creates a complex assemblage of aquatic and riparian habitats

- supports diverse habitat requirements for macro invertebrates, amphibians, and fish, including nursery areas, and maintains pathways of animal migration, gene flow, and biodiversity

- maintains hydrologic connectivity through the main-channel and between the main channel and off-channel environments.

Retention/Transformation Facilitated by Hydraulic Exchange with Off-Channel Areas



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Nutrient Spiraling Concept - Newbold et al., 1982, Stream Solute Workshop, 1990

Four Reasons a Natural Flow Regime Matters

- creates a complex assemblage of aquatic habitats

- supports diverse habitat requirements for macro invertebrates, amphibians, and fish, including nursery areas, and maintains pathways of animal migration, gene flow, and biodiversity

- maintains hydrologic connectivity through the main-channel and between the main channel and off-channel environments

- resupplies storage areas with labile carbon and oxygen at levels supporting decomposition, nutrient mineralization, food webs

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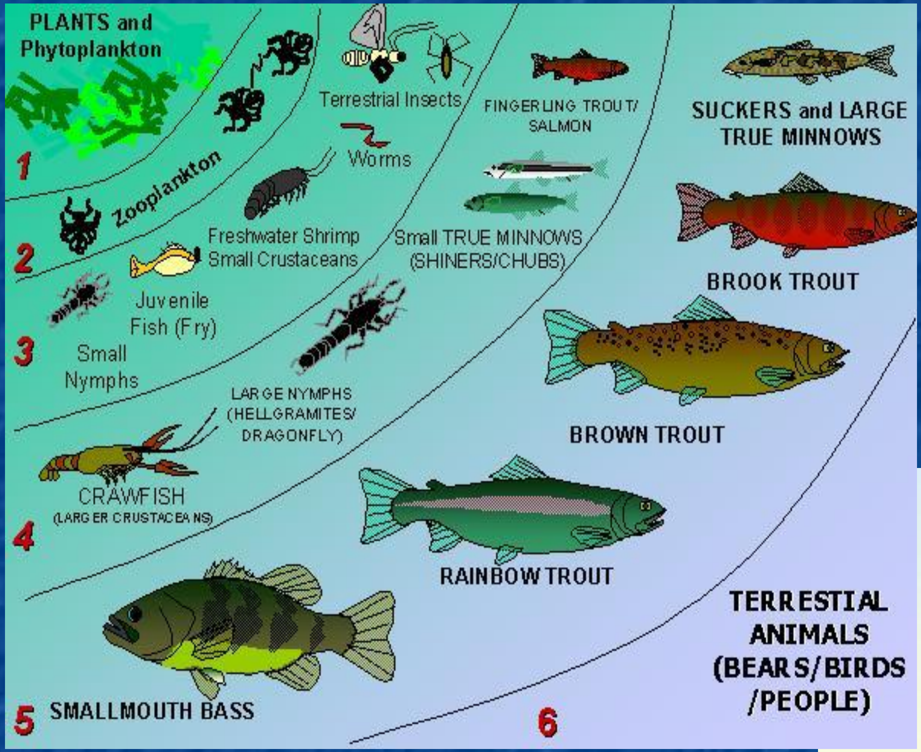
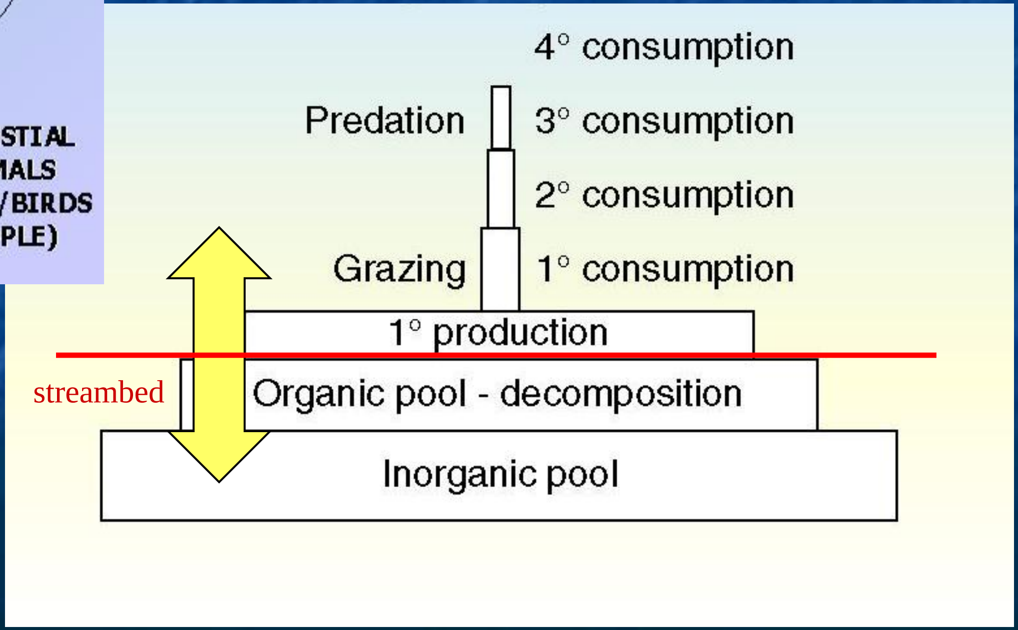
Aquatic Food Webs Depend on Groundwater-surface Water Interactions



Aquatic Food Webs

Trophic Pyramid



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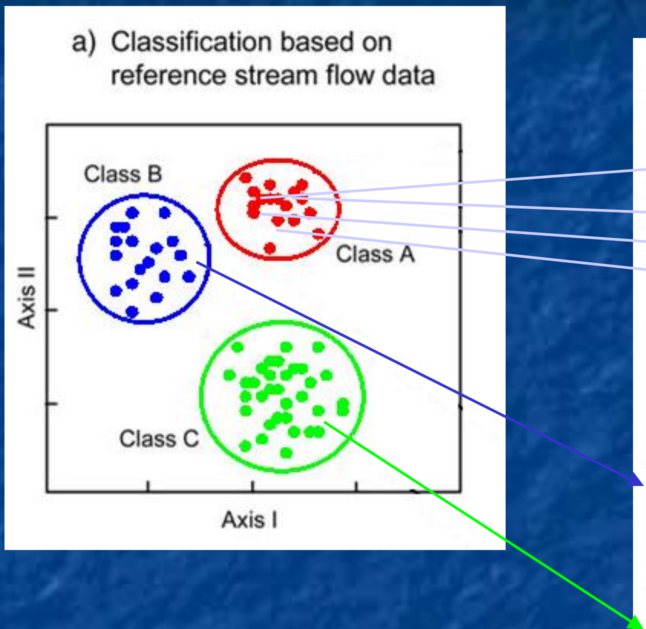
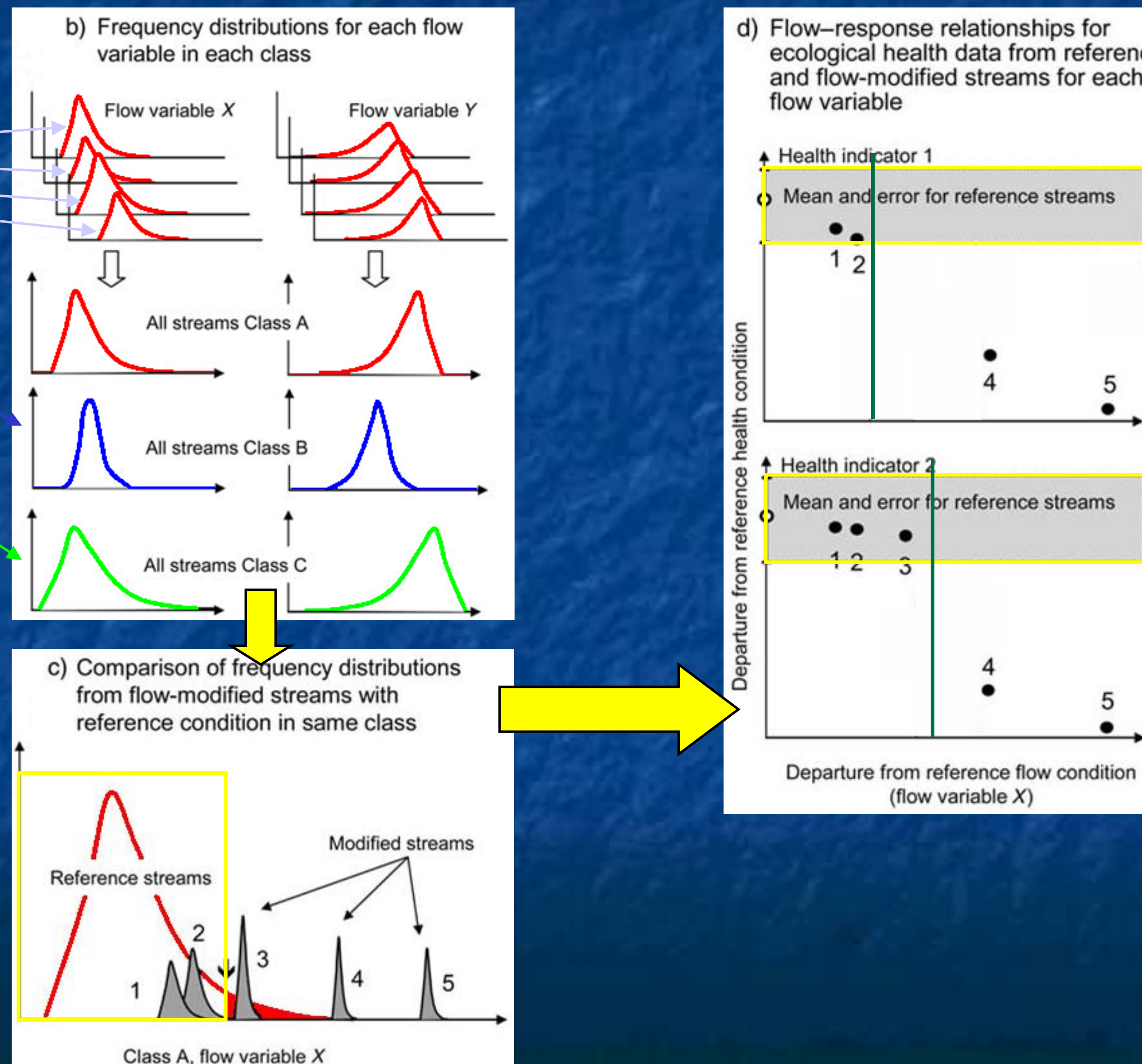
Statistical Approach to Define Ecological Limits of Hydrologic Alteration - E.L.O.H.A.





Arthington et al., Freshwater Biology, 2007

also see Poff et al., Freshwater Biology, 2008

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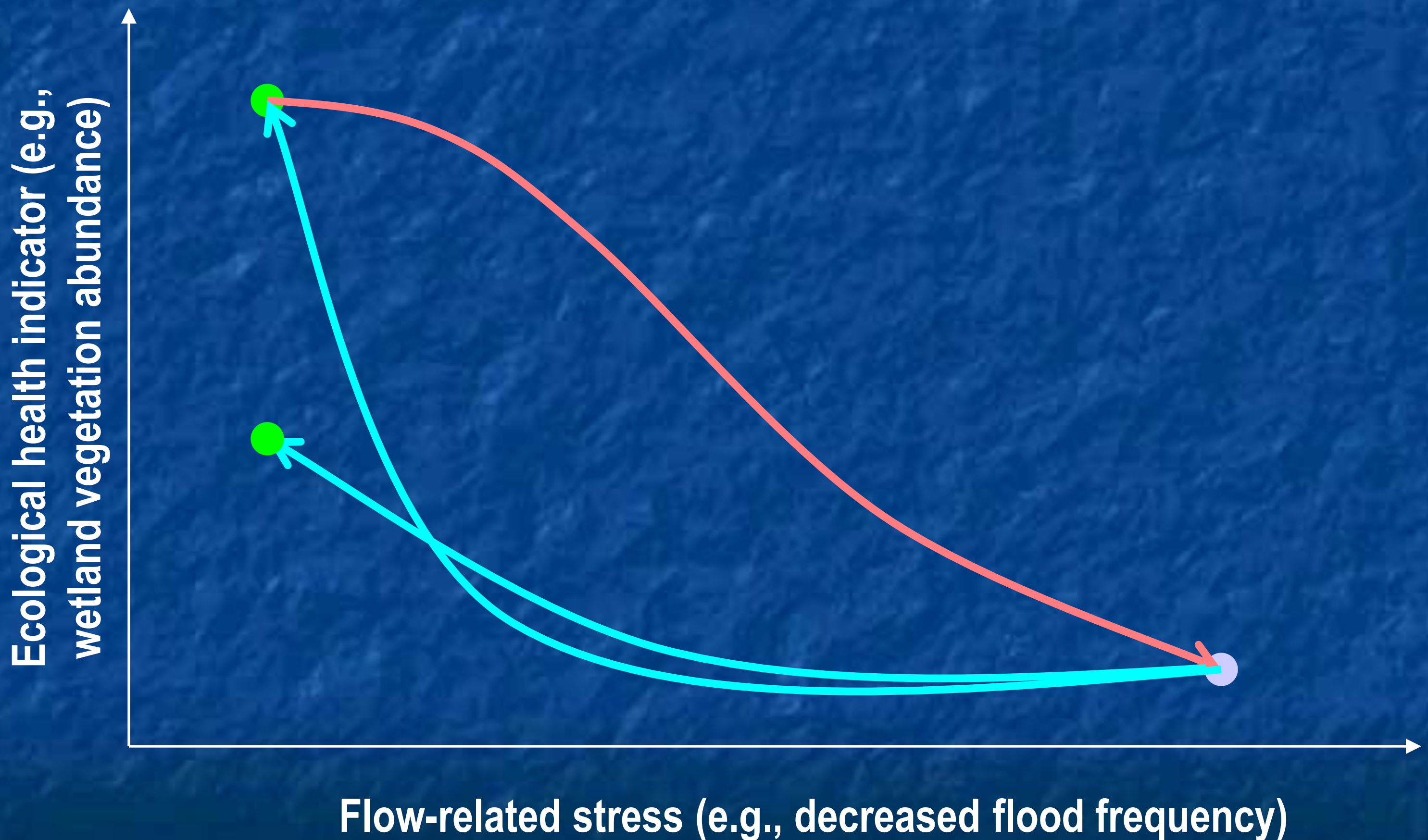
Physical and Biological Process Feedbacks Not Considered in ELOHA



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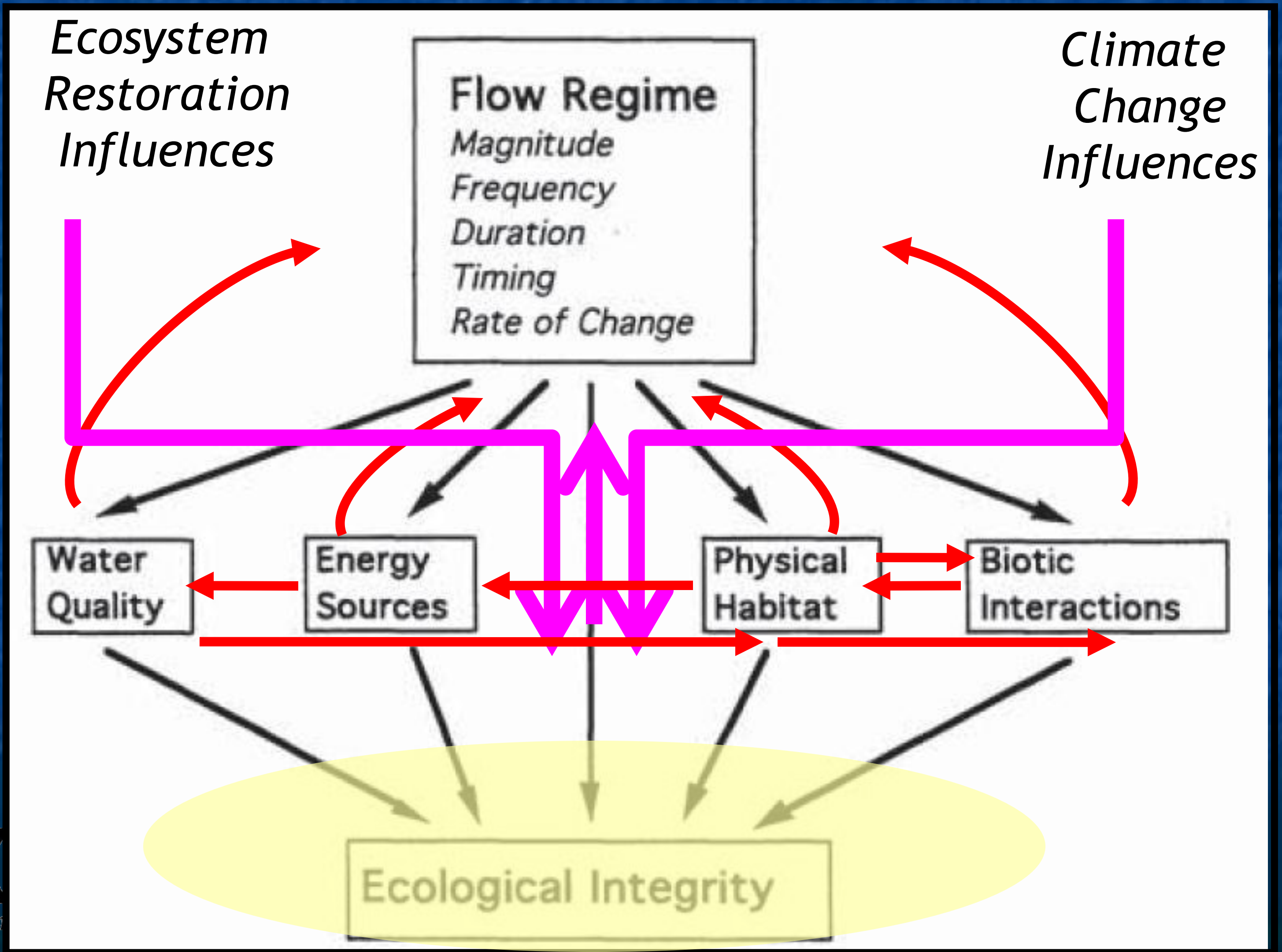
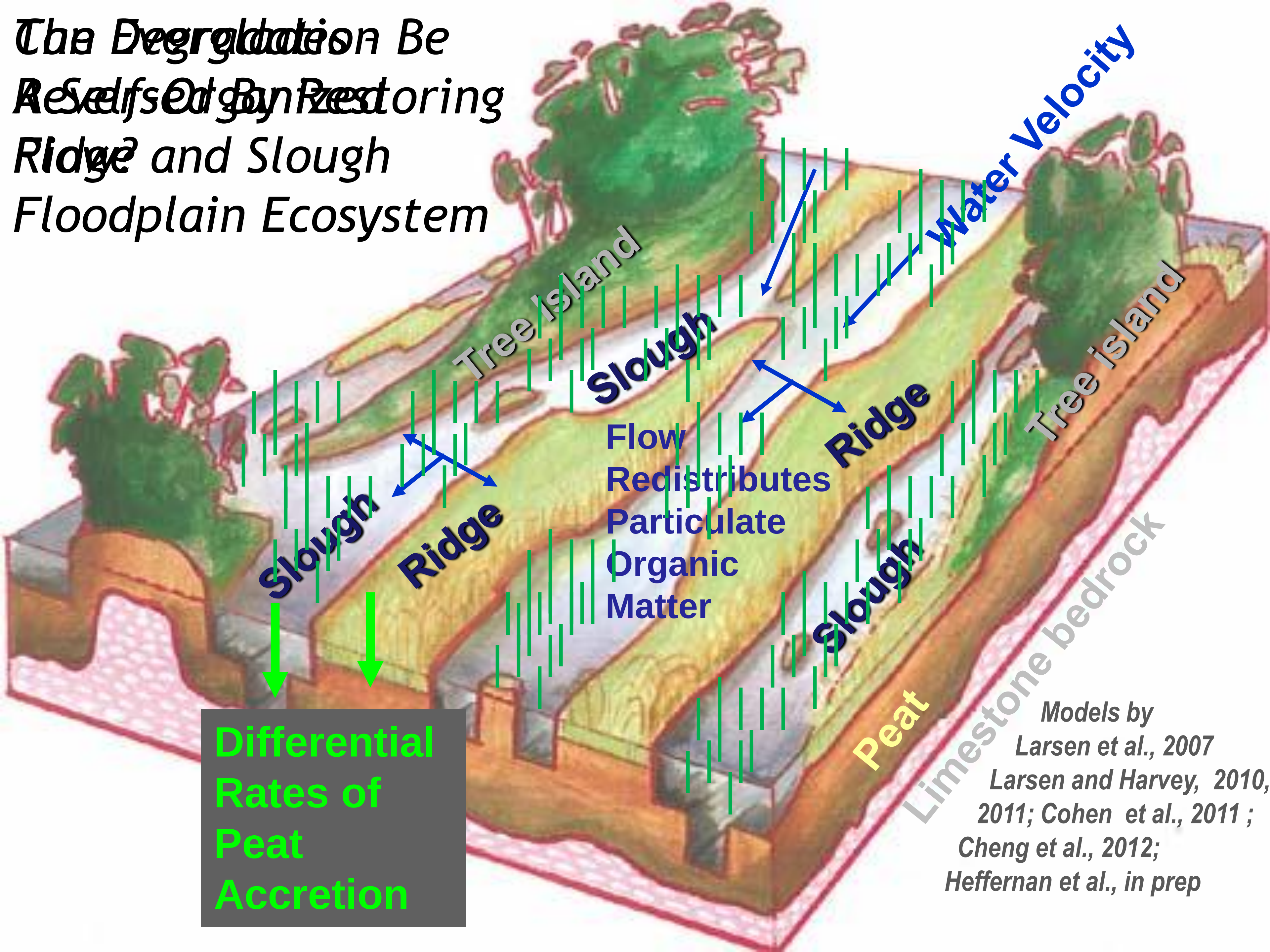
“The Natural Flow Regime - Updated”

by incorporating feedback interactions between fluvial, biological, and geomorphic processes



Can Degradation Be Reversed by Restoring Ridge and Slough Floodplain Ecosystem

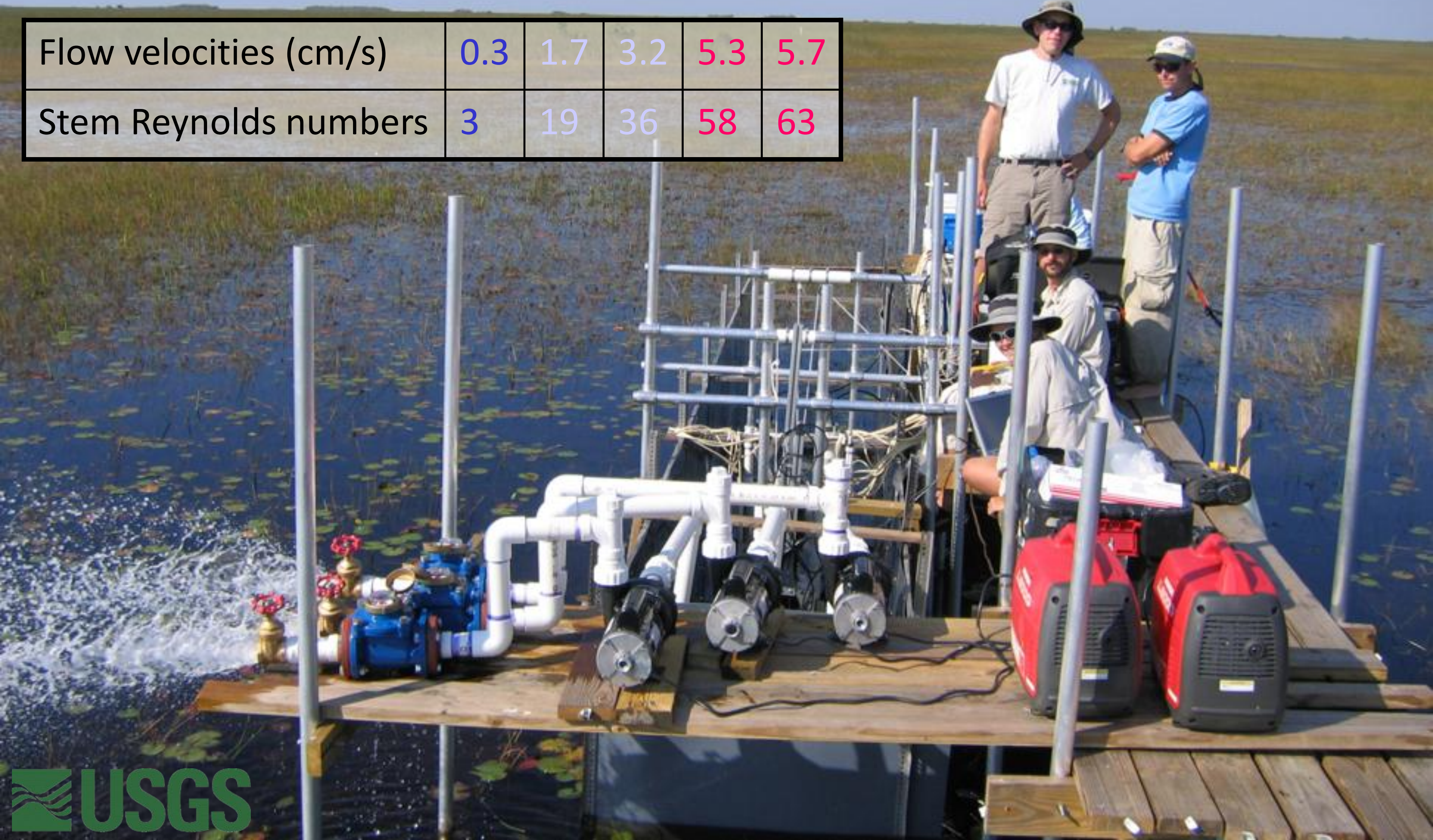
The Everglades: A Self-Organized Ridge?



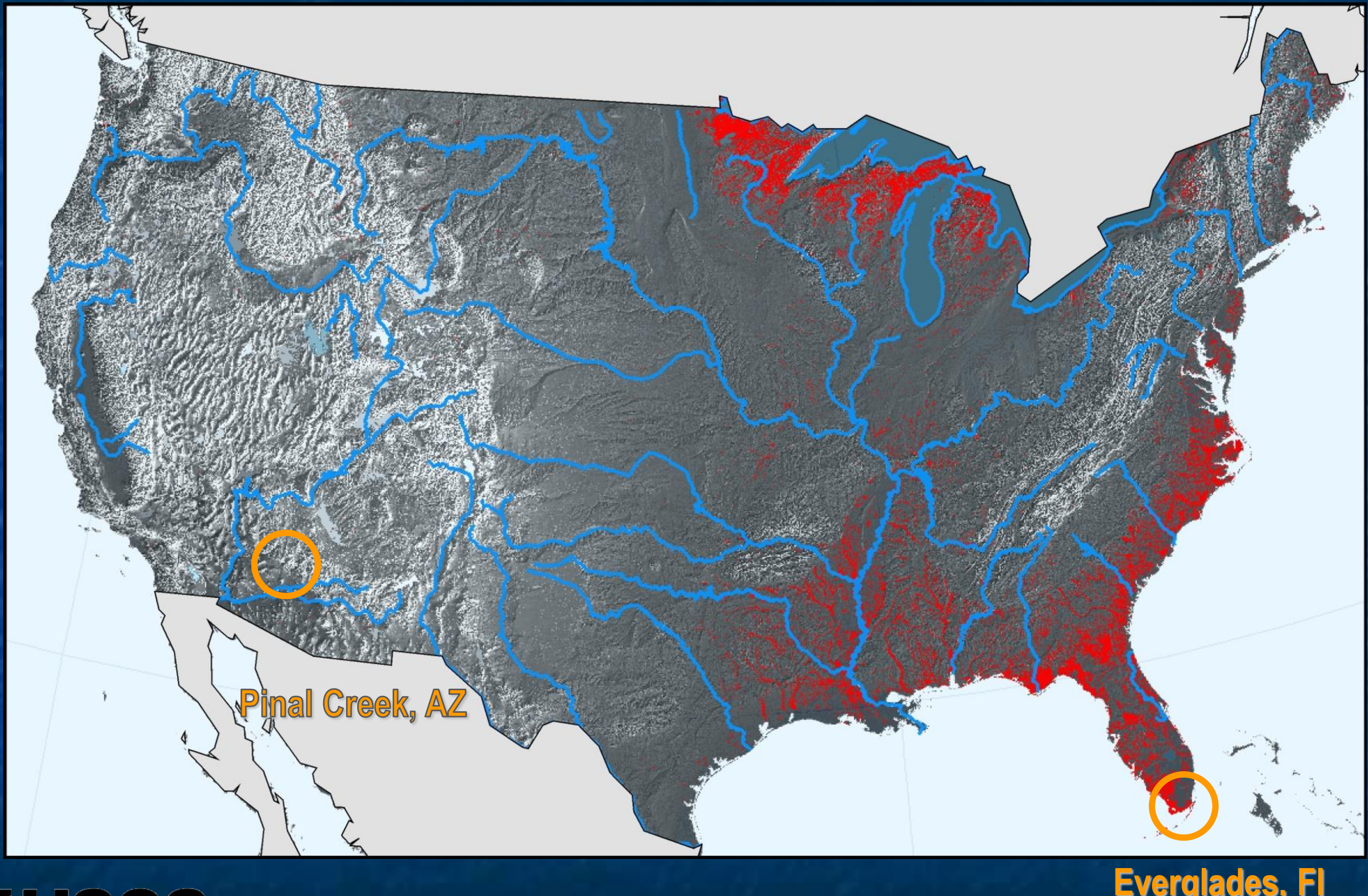
Stepwise Increase in Velocities o Historic Pre-drainage Levels in Experimental Flume

Harvey et al., Geomorphology, 2011

Flow velocities (cm/s)	0.3	1.7	3.2	5.3	5.7
Stem Reynolds numbers	3	19	36	58	63



Semi-arid Headwater Stream



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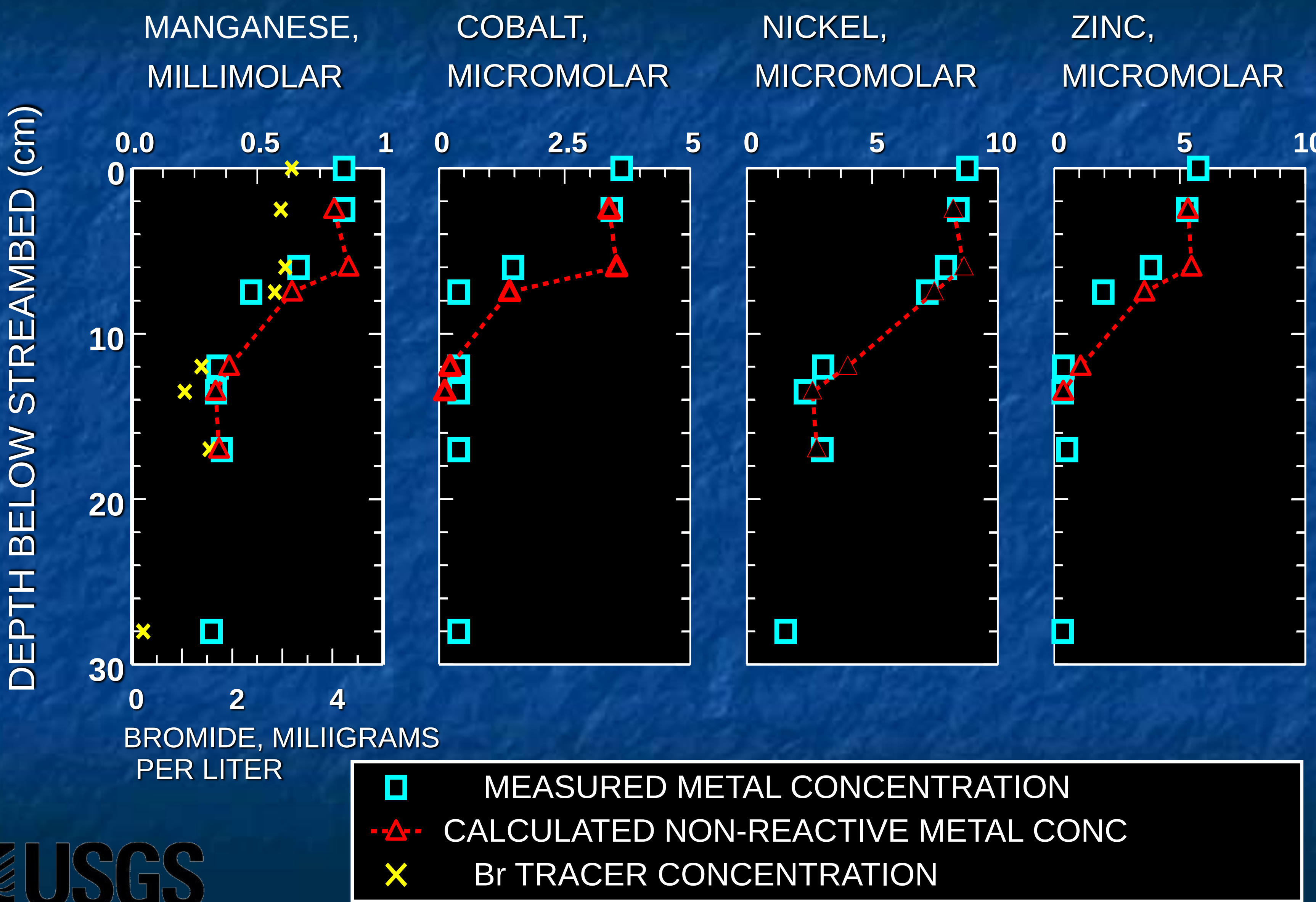
Removal of Metals in Hyporheic Zone of Pinal Creek, AZ

Enhanced Metal Uptake in Hyporheic Zone



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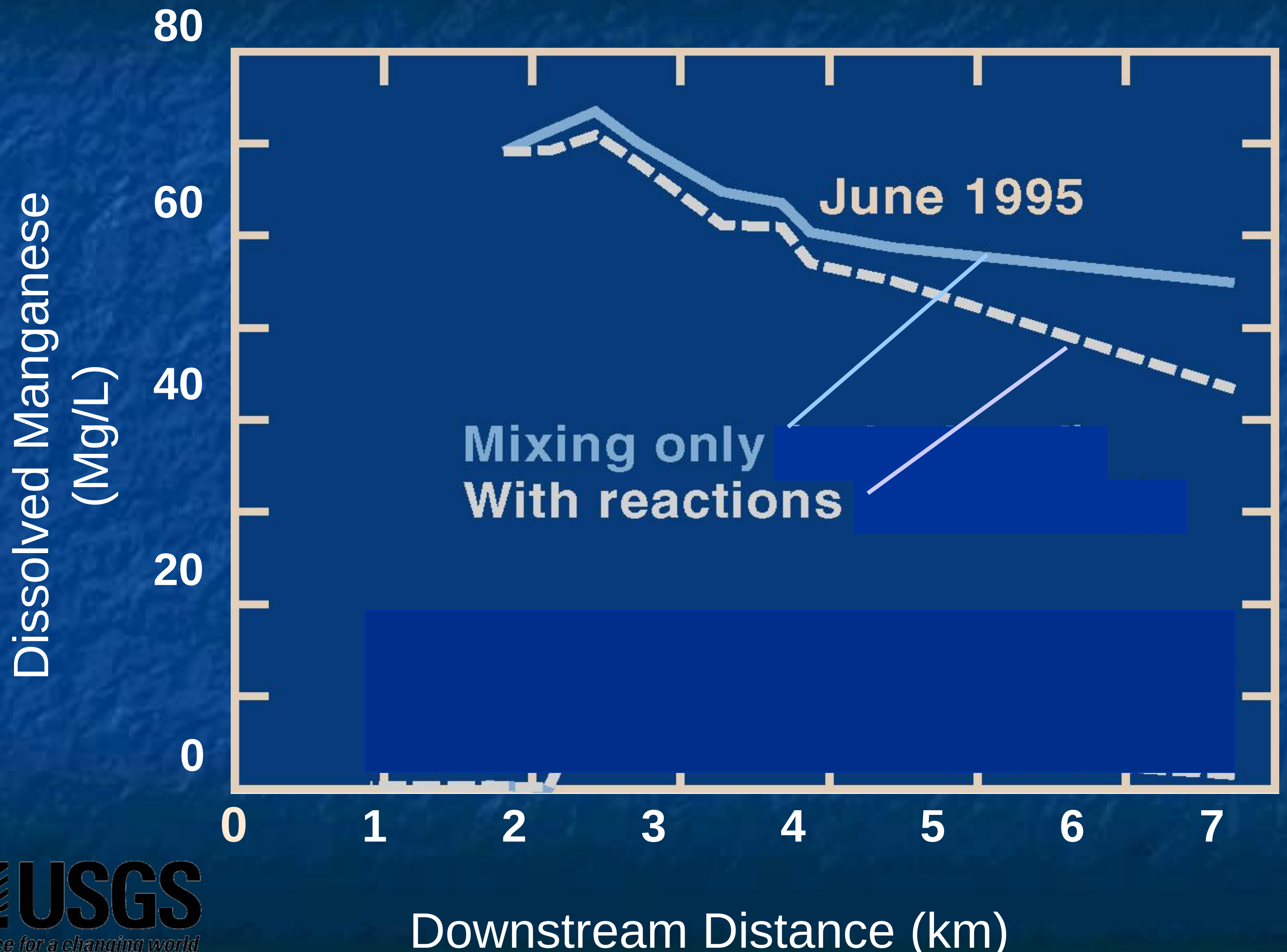
Fuller and Harvey, ES&T, 2000

Removal of Metals Increased Over Five-Year Period



Biophysical Feedbacks Created an Alternative Stable Stream Type

Flow-related stress (decreased flood frequency)

1995 → 1999

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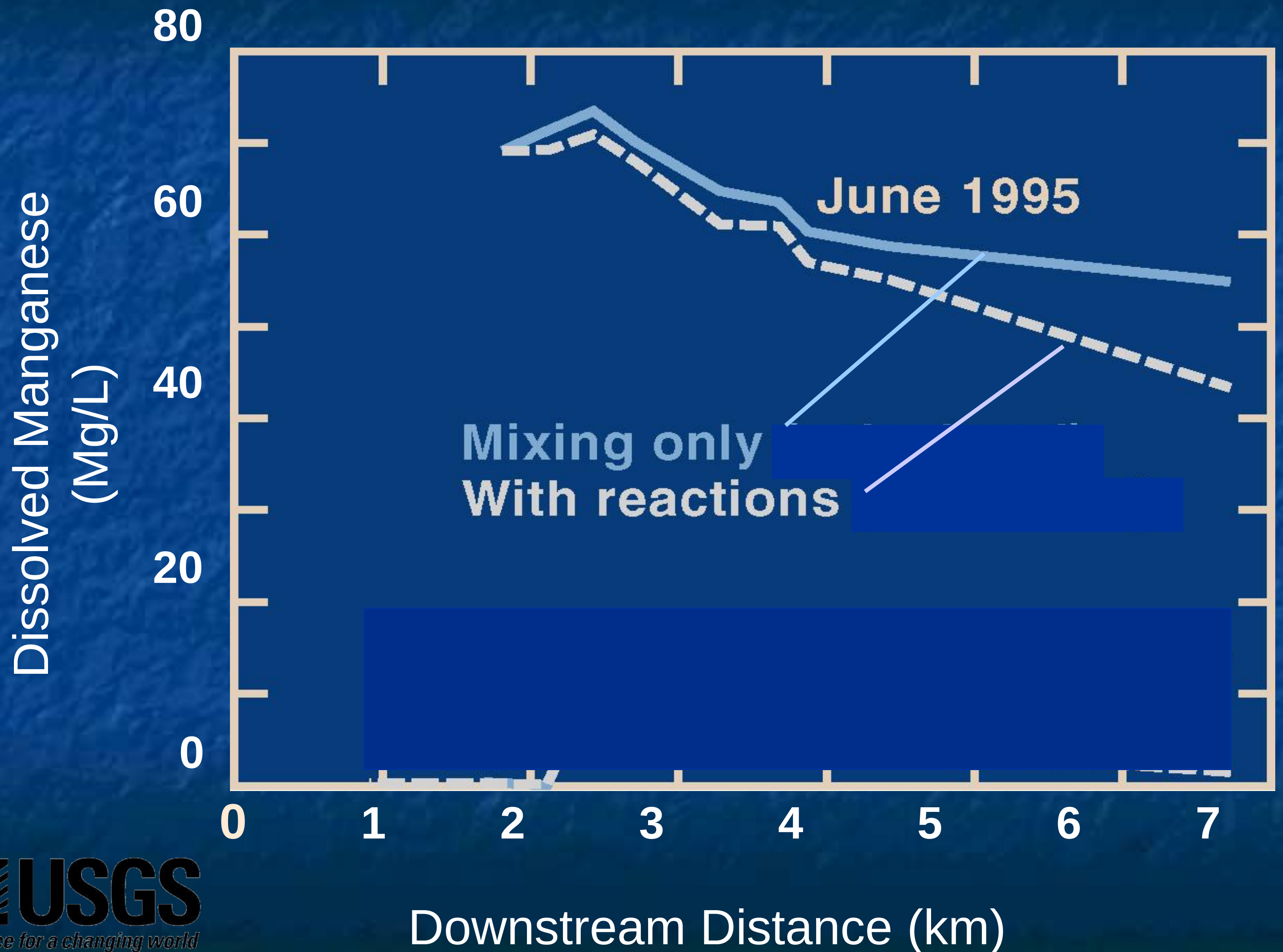
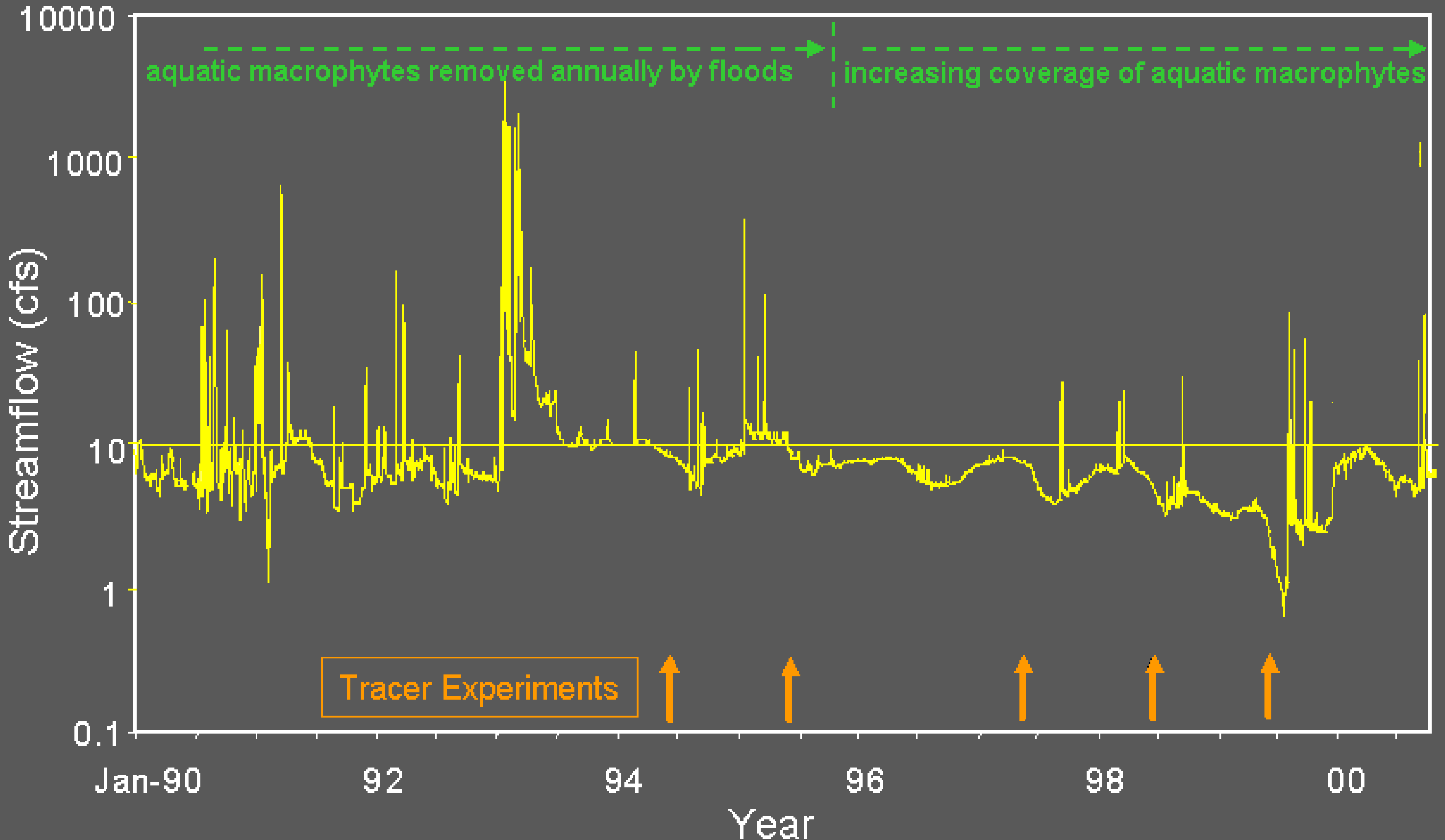
Removal of Metals Increased Over Five-Year Period

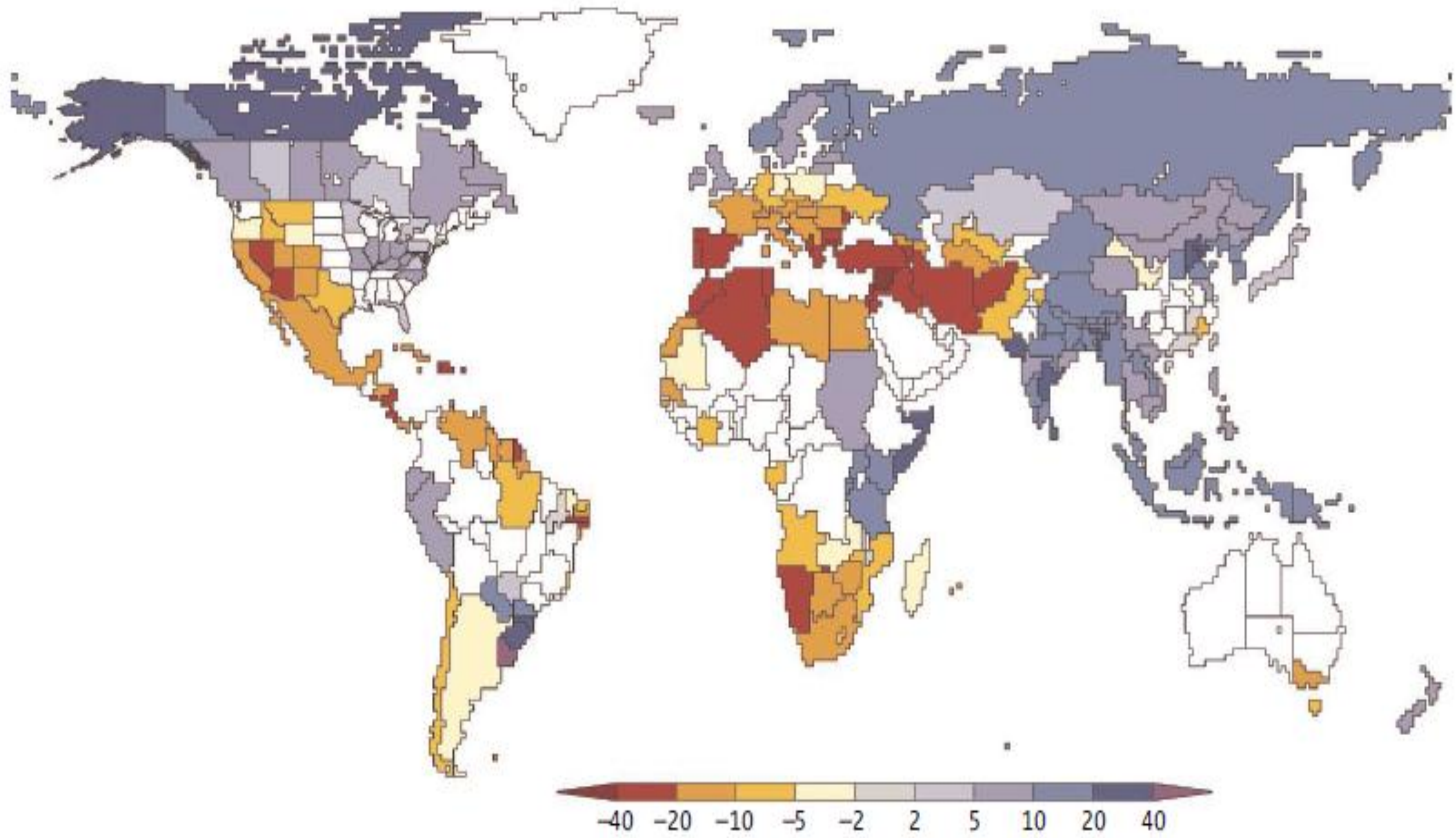


Climate-driven Decrease in Summer Monsoon Floods



Harvey, Conklin, and Koelsch, *AWR*, 2003

Sustainable Management of Water Resources



Human influences. Dramatic changes in runoff volume from ice-free land are projected in many parts of the world by the middle of the 21st century (relative to historical conditions from the 1900 to 1970 period). Color denotes percentage change (median value

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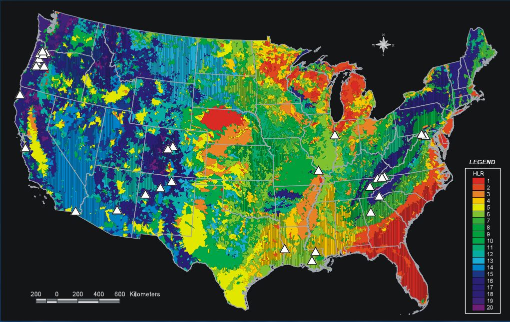
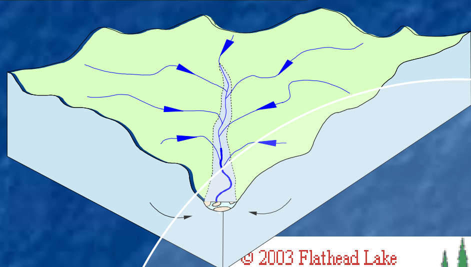
Milly et al., "Stationarity is dead: Whither water management?" *Science,* 2008

Multiple Scales

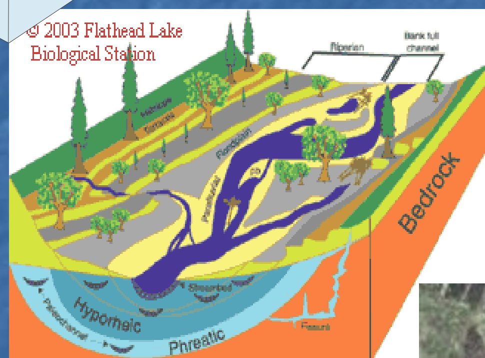


Regional-National Modeling



Watershed Monitoring and Modeling

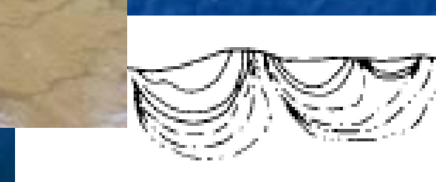
River Reach Monitoring and Modeling



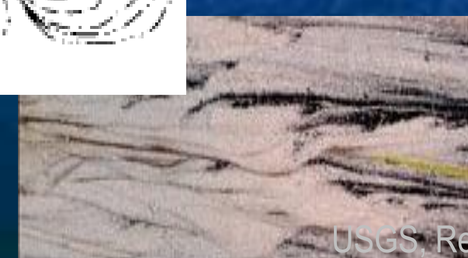
Stream Tracer Experiments

Fine-scale Field Measurements

Computational Modeling



Laboratory Flumes



Cumulative Effects

Hydroecological Perspective

Controlling Processes

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