Approaches for Rehabilitating Regulated Gravel-bed Rivers: Progress and Challenges

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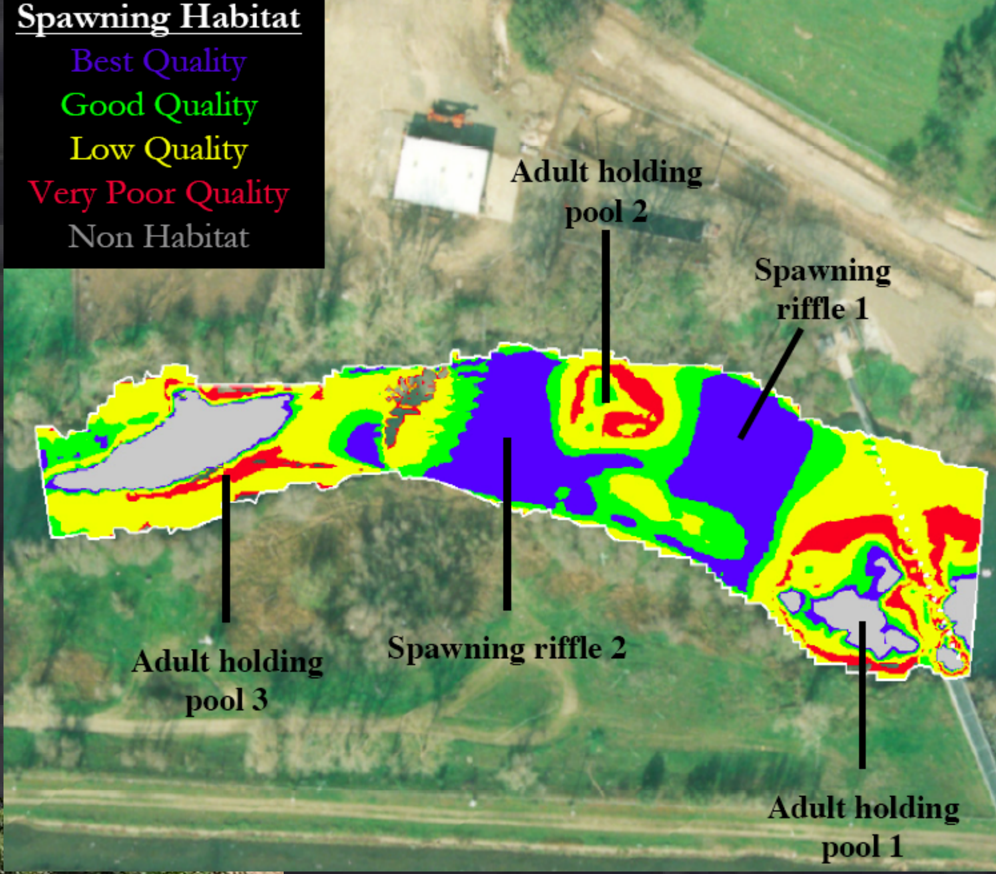
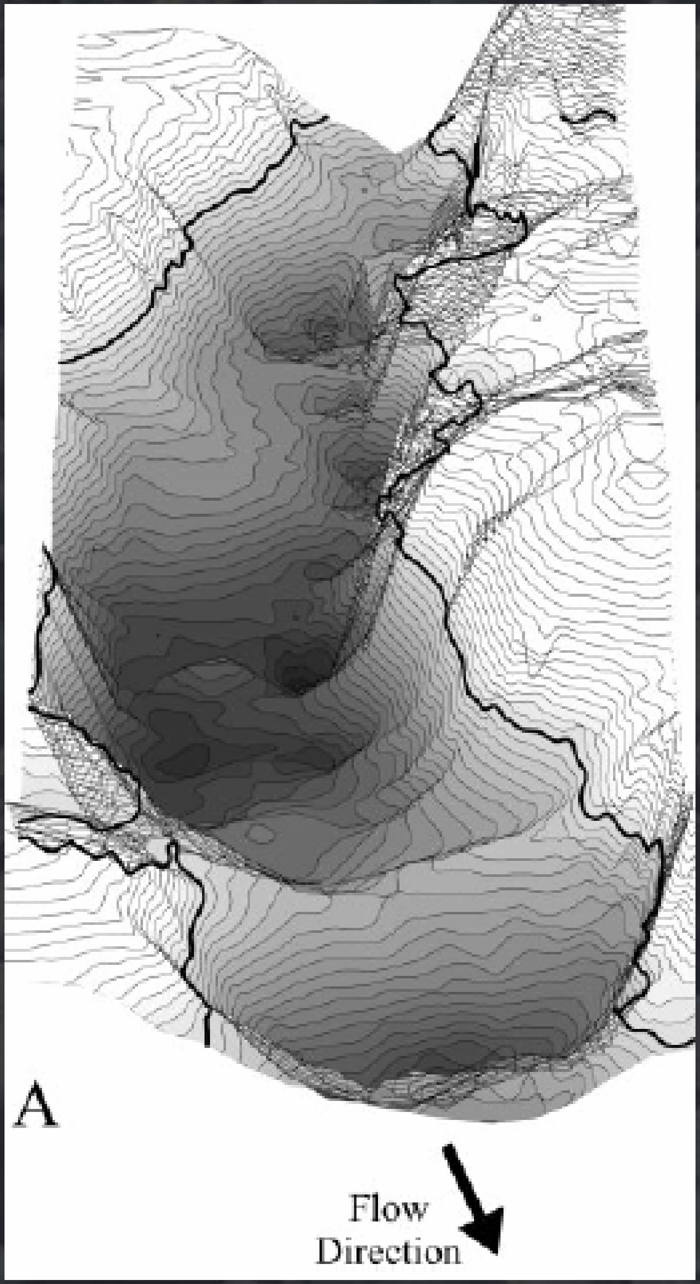
Spawning Habitat Integrated Rehabilitation Approach (SHIRA)

- *Transparent reporting*
- *Hypothesis-driven*
- *Predictive at ~1-m scale*
- *Balance Geo/Hydro/Eco*



6 gravel experiments
2 technical reports
5 journal articles

Presentation Outline

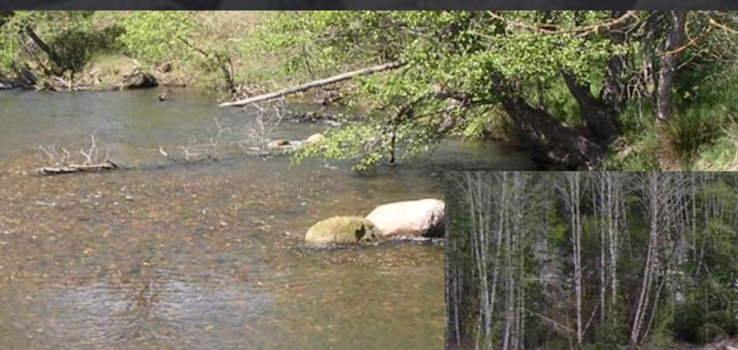


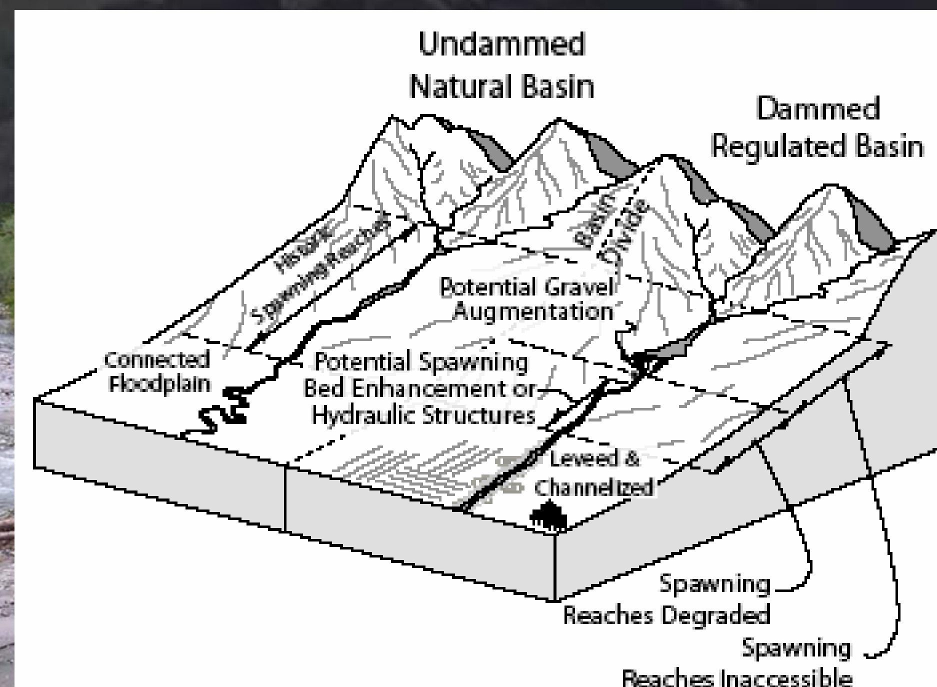
·Overview of existing river rehabilitation approaches as a function of spatial scale.
(hypotheses, challenges, prospects)

·Illustration of transparent, hypothesis-driven, predictive, adaptive-management experiment regarding gravel addition.
(emphasis on <1-m scale that rocks and fish experience the river)

Spatial Scales of River Rehabilitation

Hydraulic Unit Microhabitat (10^{-1}-10^{0} Channel Widths)	Geomorphic Unit Mesohabitat (10^{1} Channel Widths)	Reach Unit (10^{2}-10^{3} Channel Widths)
Provide higher quality habitat for existing populations	*Provide greater quantity of habitat to increase population size*	*Provide a mechanism for self-sustainability of the river system*





What should be the balance of efforts at different scales?

Reach Scale

Are Biological Solutions Working?

Fish hatcheries- genetic drift?

"Recent work has indicated that a ***natural flow regime*** is one of the most important factors in maintaining native CA stream fish communities." -Brown, 2000

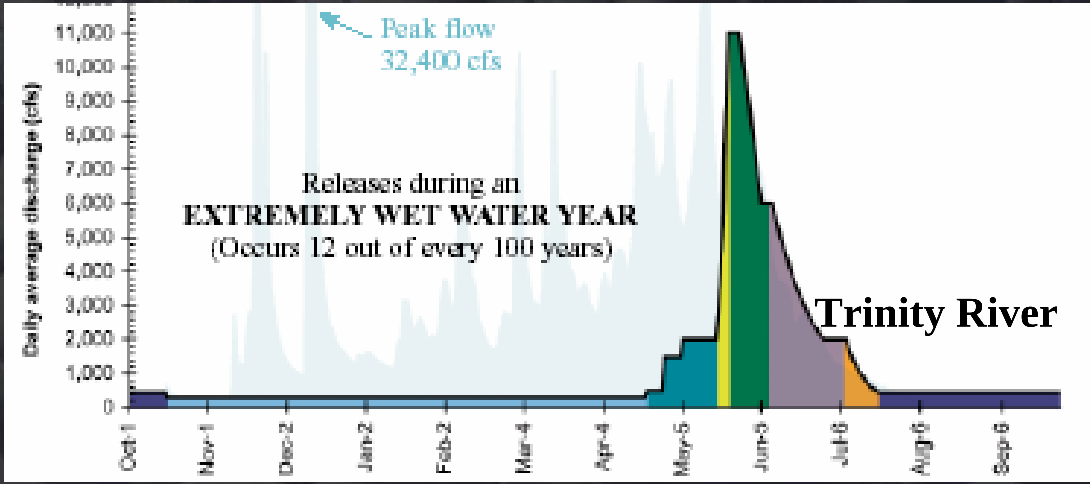
"Ecological and genetic diversity help stabilize salmon production. And when production is based on a few large hatchery programs, both the genetic and ecological diversity is reduced. The result is salmon production is much more vulnerable to productivity cycles and human impacts." -James Lichatowich

Reach Scale

"Let 'Er Rip" Hypothesis

If we 1) add coarse sediment and/or water at the top of regulated reaches and 2) remove floodplain barriers, then the river will naturally restore itself to a self-sustainable size.

designed levee breach



Flow re-regulation

Gravel addition

Reach Scale

Conceptual and Practical Challenges

·Trajectory of dynamic systems is strongly sensitive to initial state!

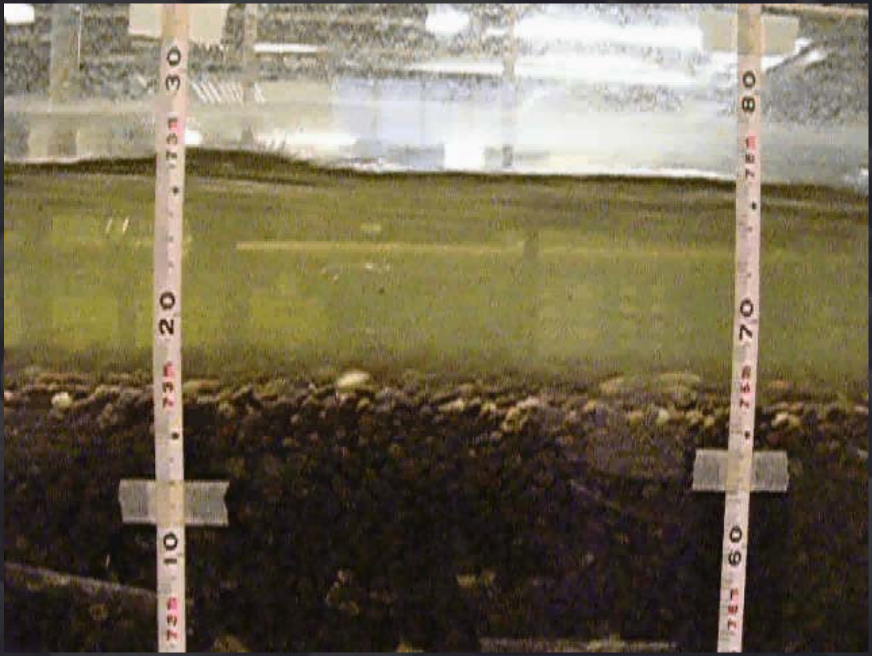
·How long will this take?

·Can biota survive the massive disturbance?

How do you get 10^4-10^5 tons of gravel into a river?

Is this like our CA rivers?

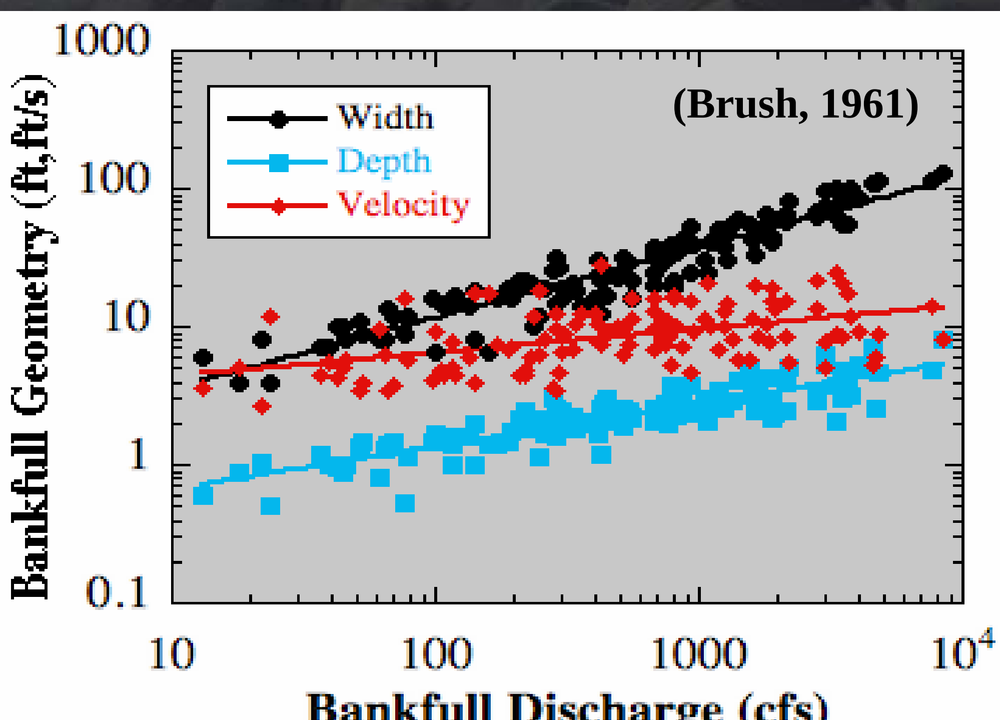
gravel peppering at high flow



Geomorphic Scale

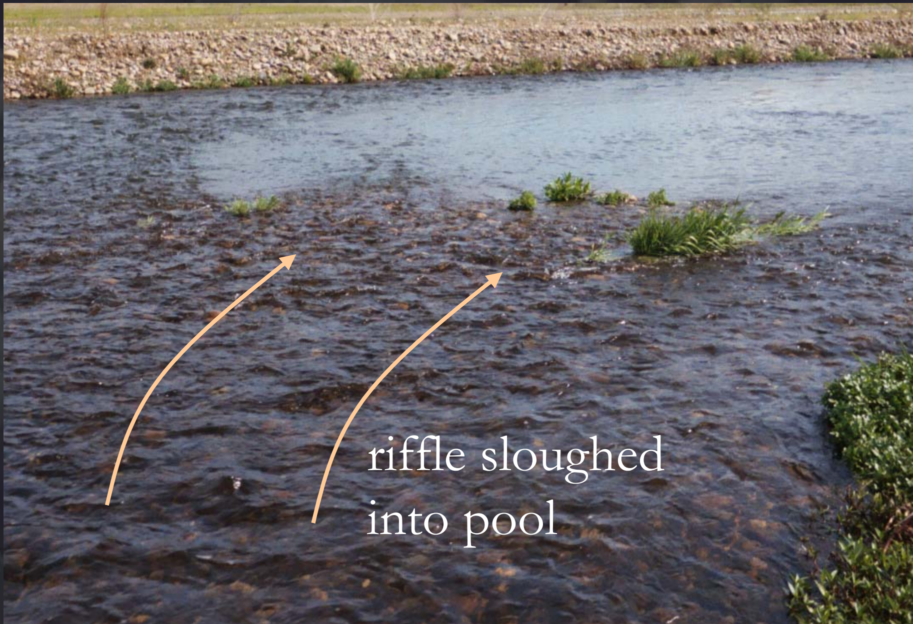
"Size Channel to Flow" Hypothesis

If we build channel geometry to carry "bankful discharge" AND if flow and sediment inputs are re-regulated, then the channel will be self-maintaining.



Geomorphic Scale

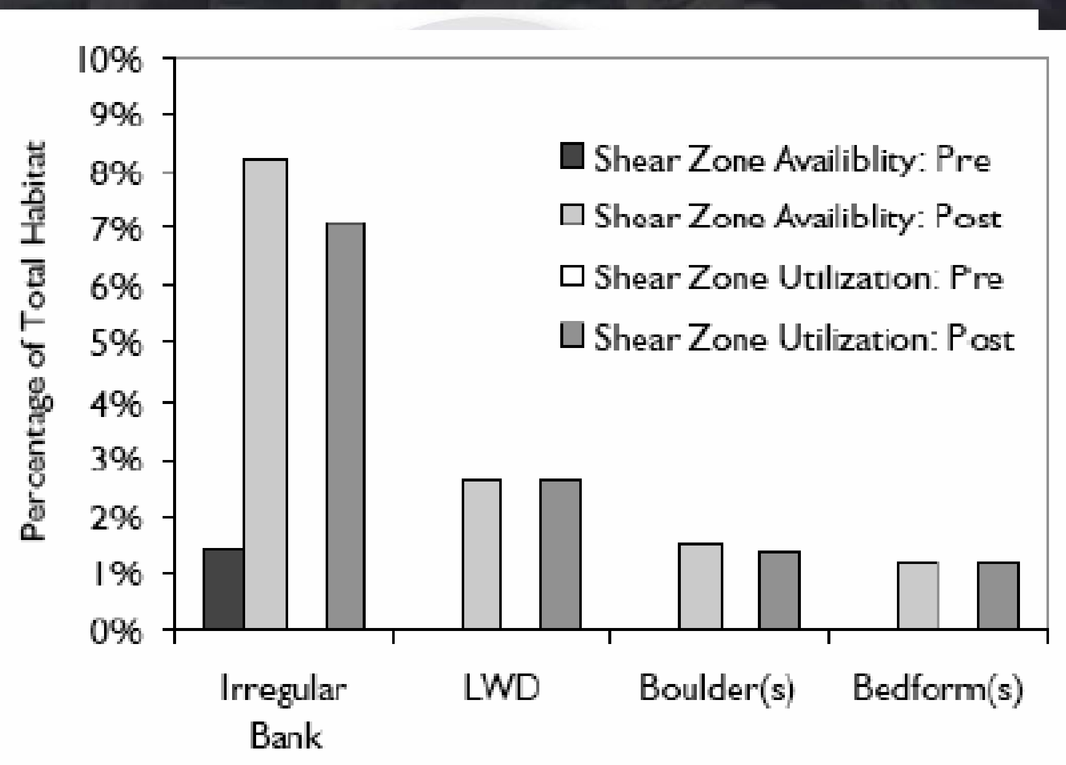
Prescriptive Design Failures



Hydraulic Scale

"Sustain the Wild Biota" Hypothesis

If we place gravel, boulders, and LWD to create heterogeneous habitats for ***indicator*** *species whose needs reflect those of the community, then we can restore local river processes and sustain existing populations.*

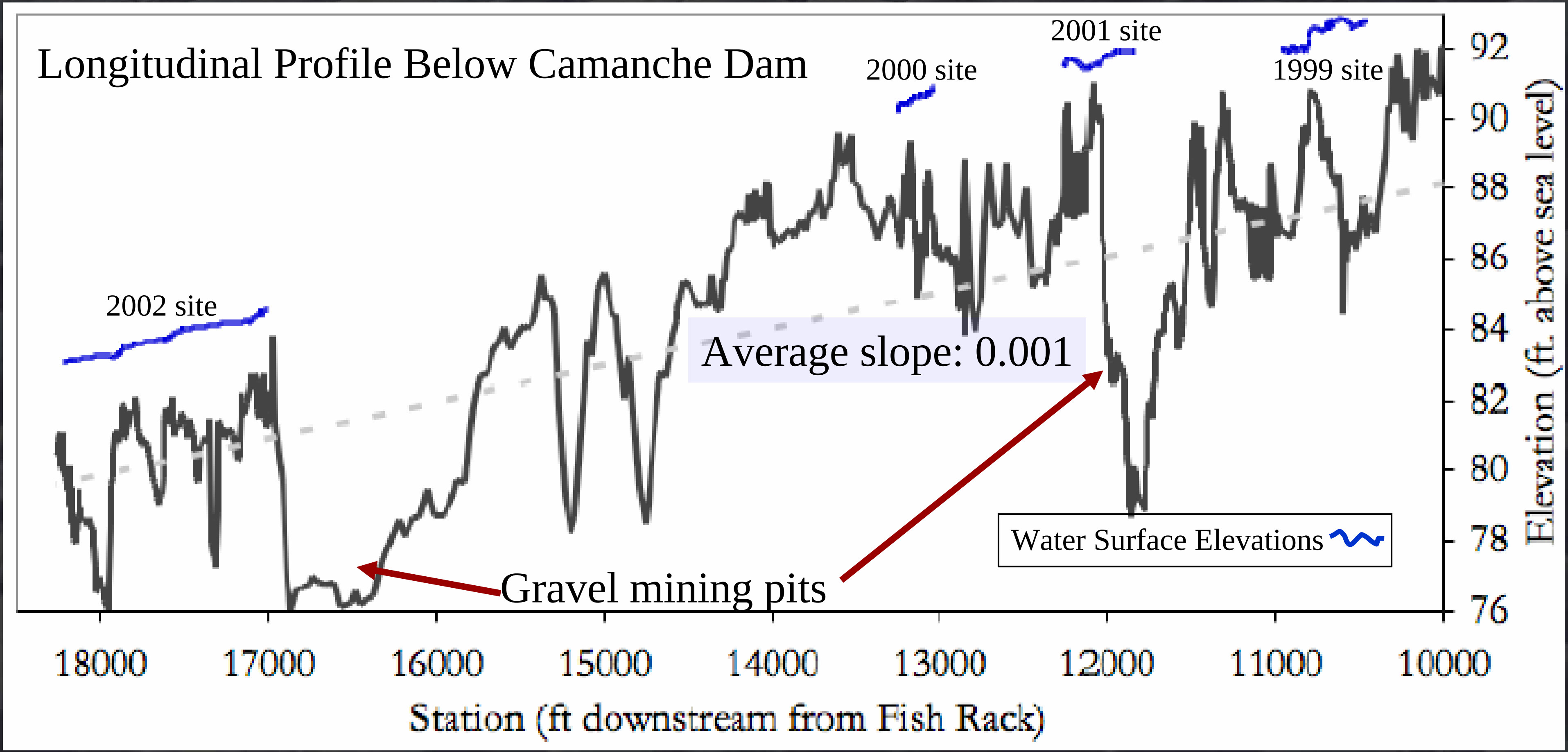


Mokelumne River (Lodi, CA)

Hydraulic Scale

Where Should Gravel Be Added?

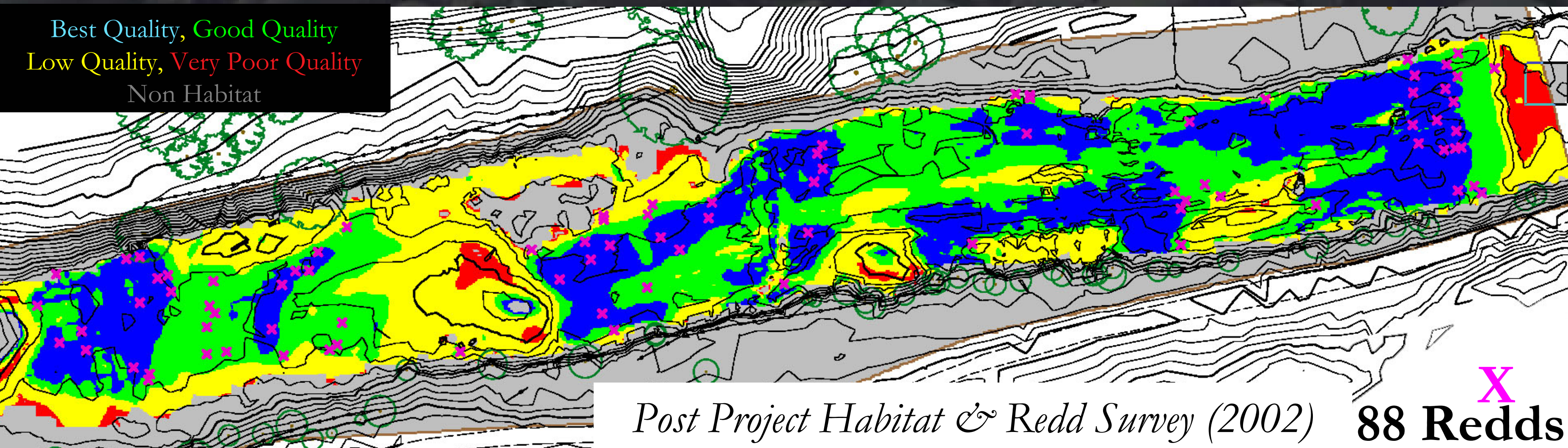
Fill in mining holes? Top off riffles? Change slope?



How long will it last???

Hydraulic Scale

Why bother with one needle in the haystack?



DOES

=

?

Adaptive Management Experiments

Transparent, hypothesis-driven, predictive/testable

Design objective

Spawning-riffle habitat should be geomorphically sustainable.

An example design hypothesis

Although riffles scour naturally occurs at high Q, there should be very limited riffle scour at very low spawning Q.

How to include hypothesis in design

Design riffle with appropriate slope and with divergent flow streamlines.

How to test design hypothesis

Make quantitative predictions using XS-based and 2D-based equations.
Monitor site changes using a sediment budget and sediment tracers;
Compare observations against predictions.

1999 Baseline Gravel Placement Site

***Ad hoc* contouring by biologist based on local experience**

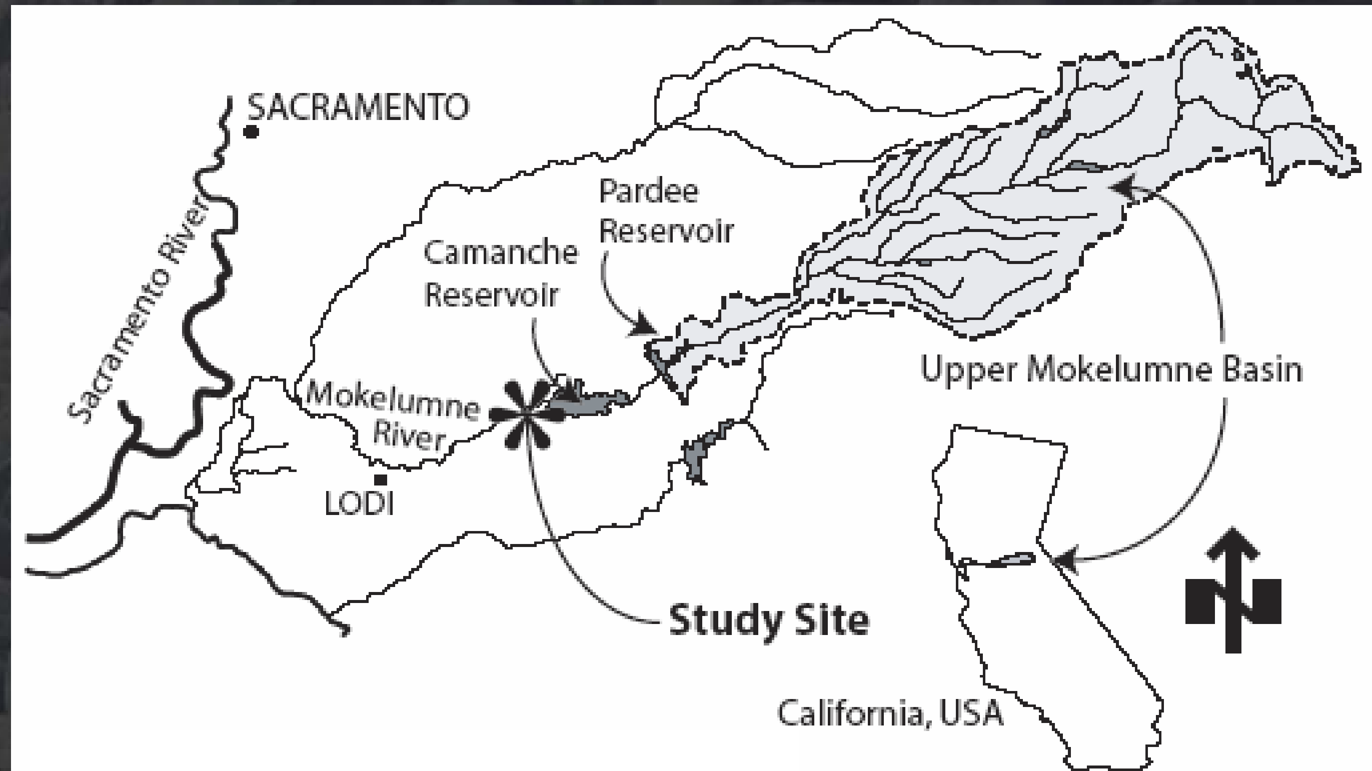
330 cfs example

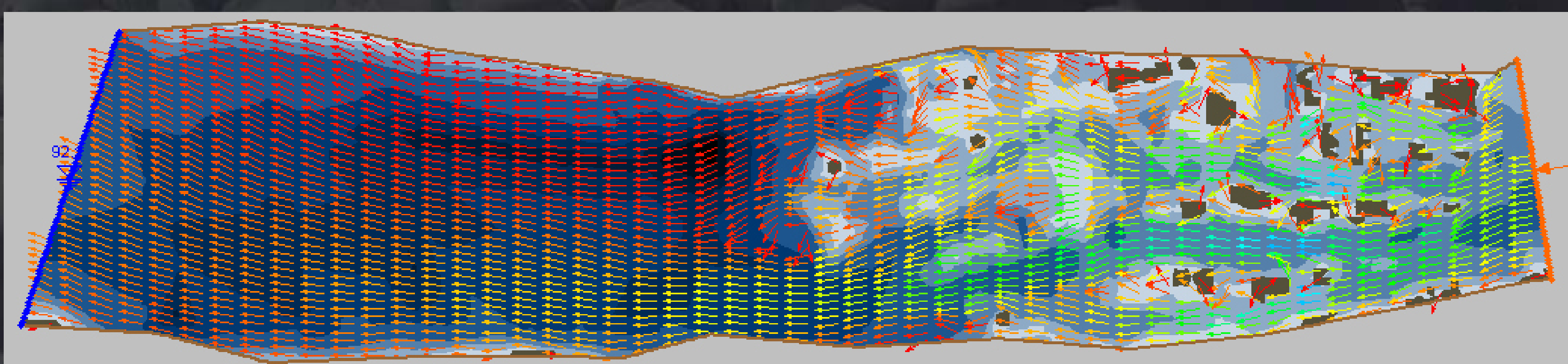
Depth

darker=deeper

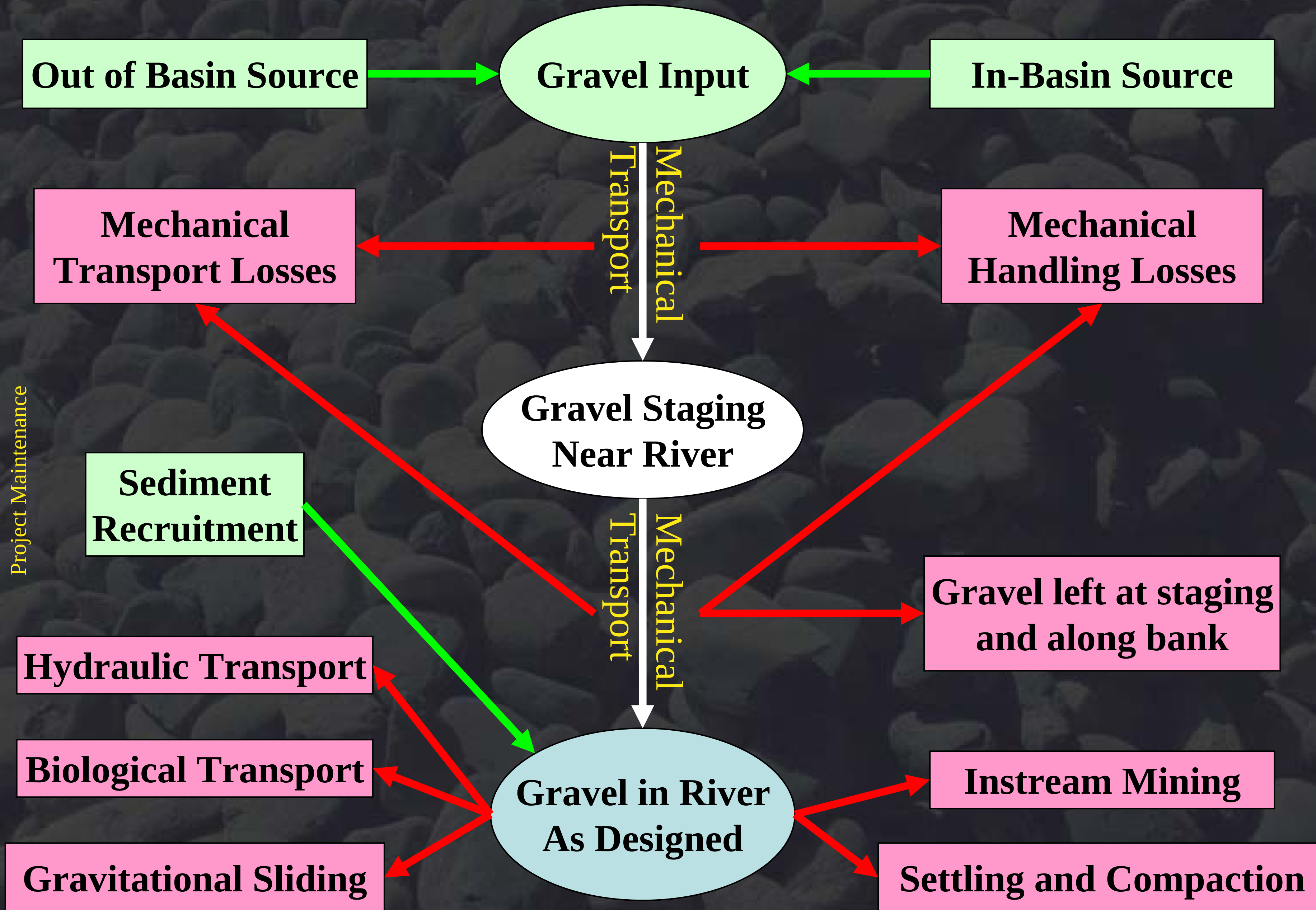
Velocity

blue=fast;red=slow





Gravel Placement Sediment Budget



Flow-based Scour Prediction

Cross-section averages

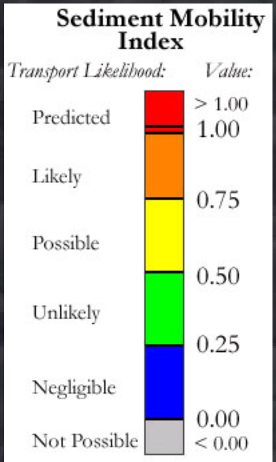
For a given XS and time period, can the flow scour the riffle?

				Number of Days ≥ Qcrit		
Time period	No of days	Site	Peak Flow (m^3 sec^{-1})	25mm D_{10}	48mm D_{50}	81mm D_{90}
23 May 2003 to 10 June 2003	19	1999 (A)	56.7	1 (5%)	0	0
1 Sept 2002 to 23 May 2003	266	1999 (A)	12.5	0	0	0
1 Sept 2001 to 30 Aug 2002	364	1999 (A)	15.9	1(>1%)	0	0
1 Sept 2000 to 30 Aug 2001	364	1999 (A)	13.4	6(2%)	0	0
1 Sept 1999 to 30 Aug. 2000	364	1999 (A)	70.0	30(8%)	0	0

For 330 cfs (9.34 cms) spawning Q, ZERO scour is predicted for all sizes.

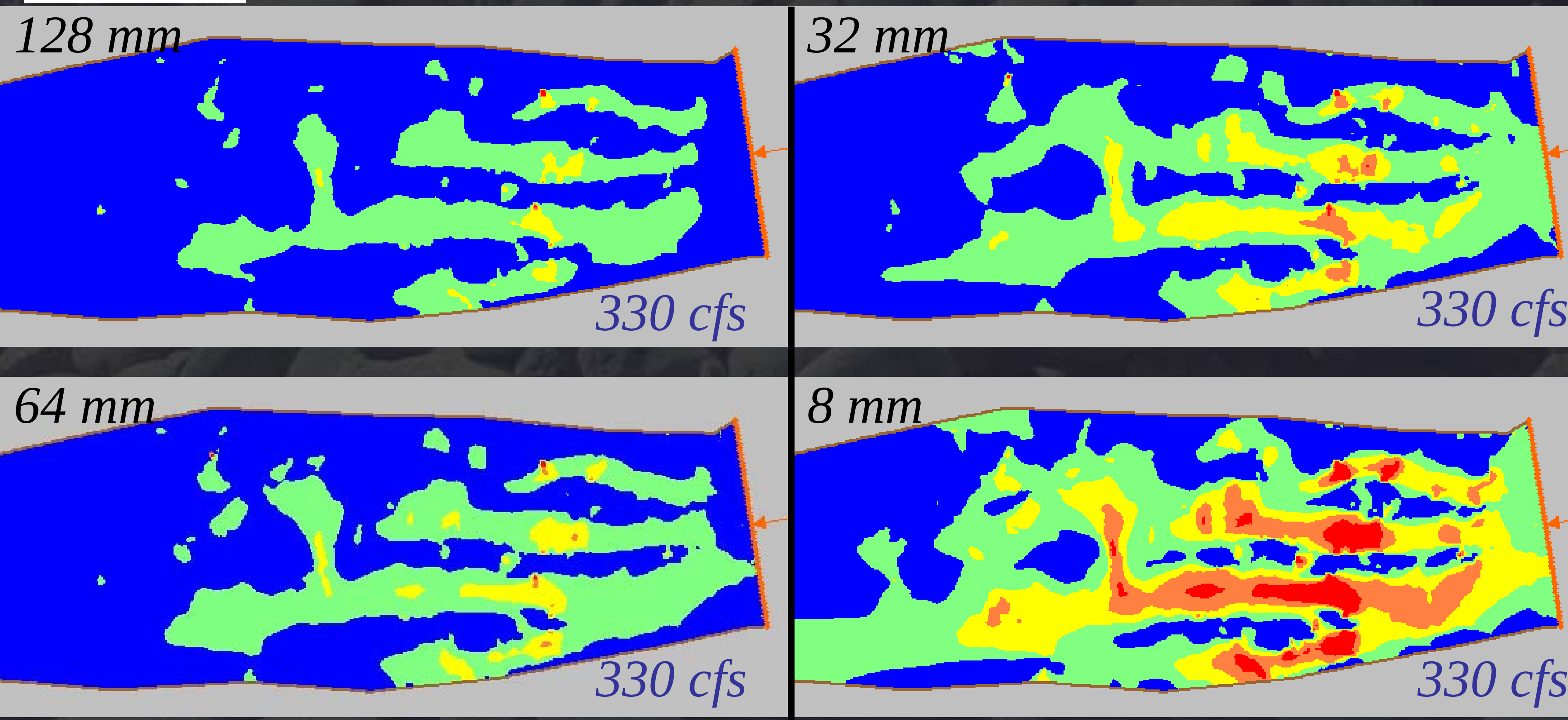
2D Scour Prediction (~ 1 m)

grain-size dependent



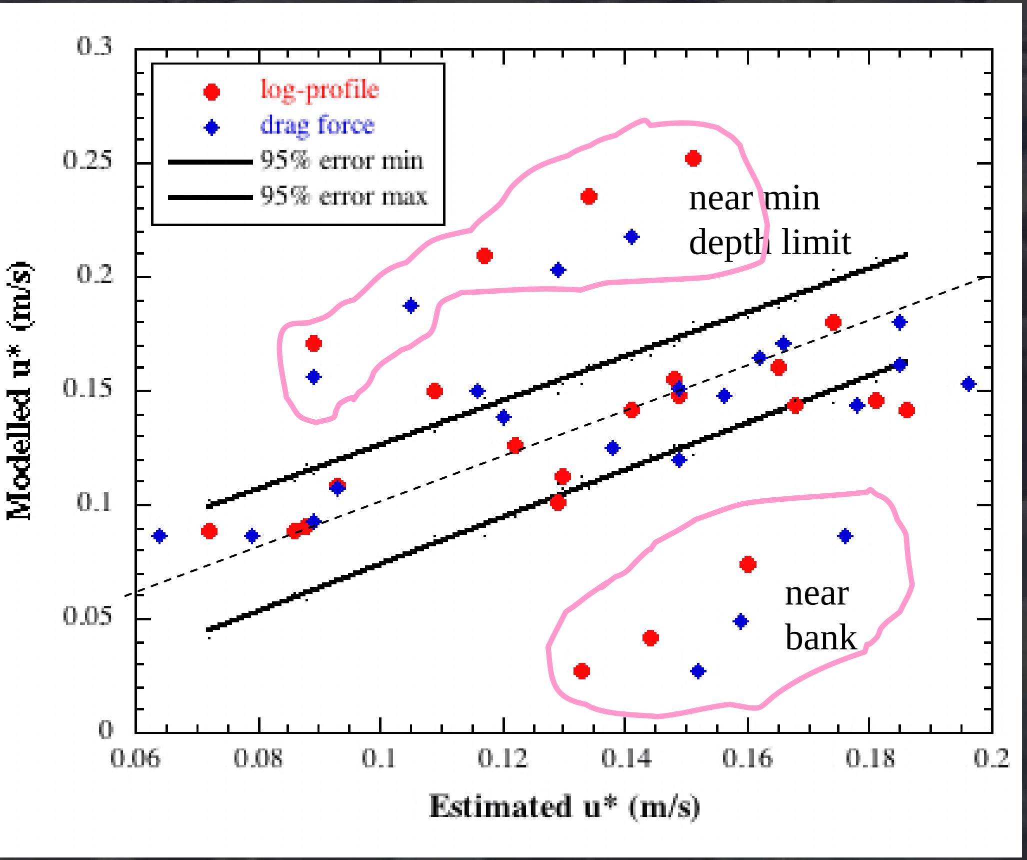
$$SMI = \frac{\bar{u}_{actual}}{\bar{u}_{critical}}$$

$$\bar{U}_{critical} = \sqrt{\frac{\tau_{critical}}{\rho_{H_2O}}} \cdot 5.75 \cdot \log\left(\frac{12.2 \cdot D}{d_{50}}\right)$$



Negligible Unlikely Possible Likely Predicted

Obs vs Pred
Shear Stress Pattern



Unsorted

64-128 mm

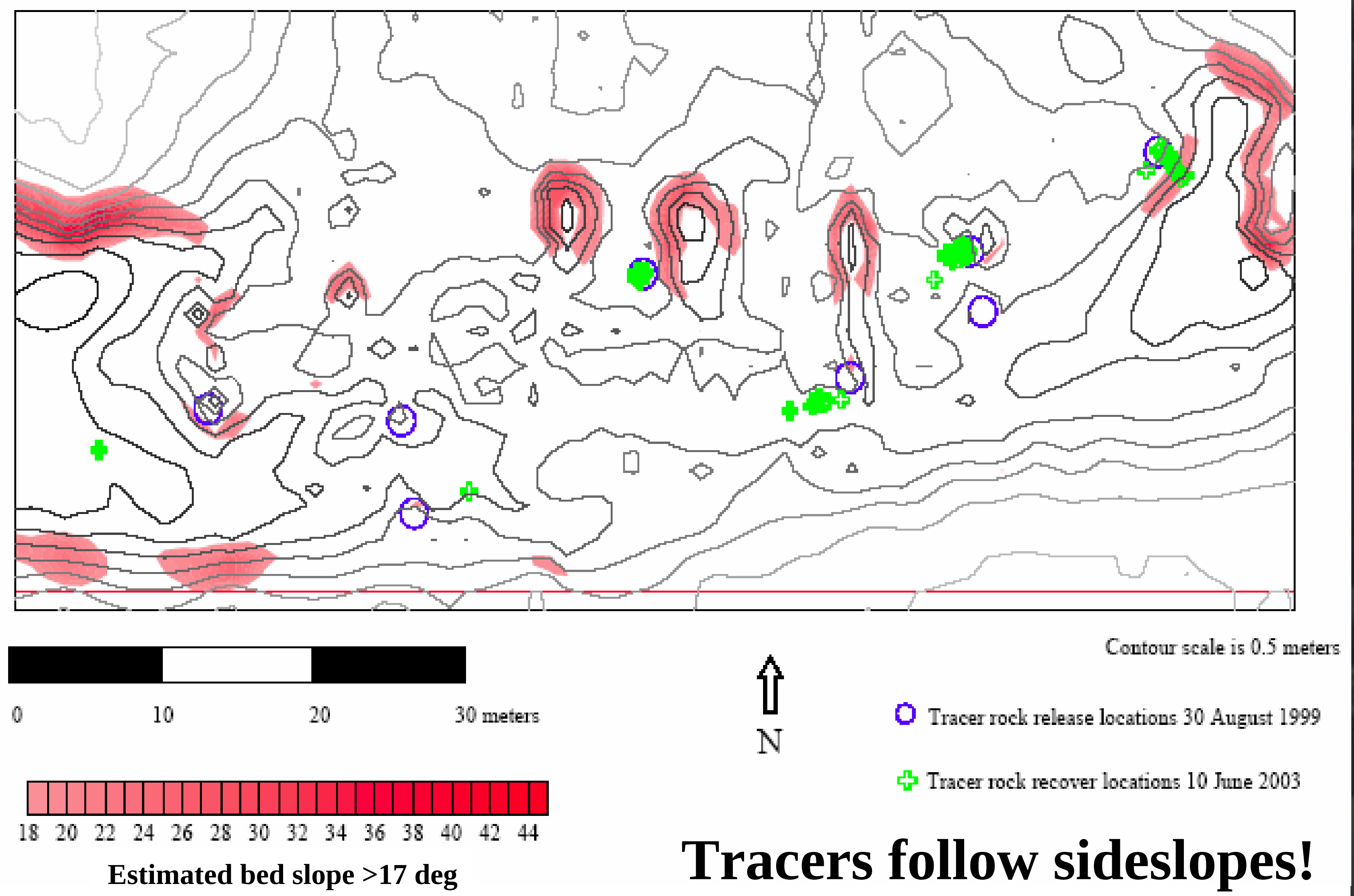
32-64 mm

8-32 mm

56 % of predictions within 95% confidence.

Others in poorly refined model mesh areas.

Slope Stability Analysis



Tracers follow sideslopes!

DEM Analysis

Raw Volume Changes (% of total input)

Year 1 = -20%

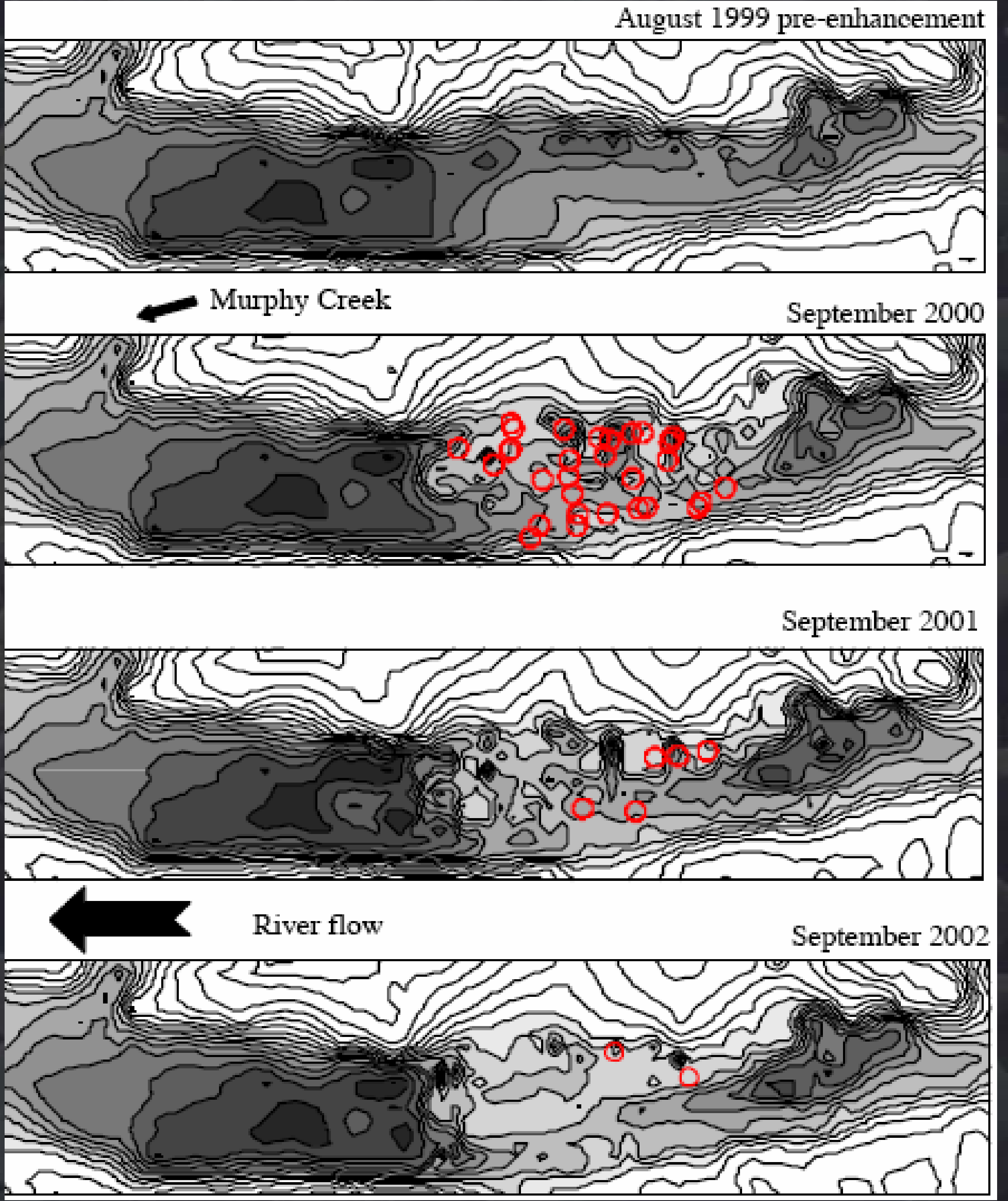
Year 2 = -16%

Year 3 = -6%

Year 4 = -8%

Summary
50% volume decrease

1/2 due to settling and compaction



Hydraulic Unit Reality Drives Outcome

Rivers show greater sub-reach diversity than "advertised"

"How many channel widths is that riffle spacing "supposed to be?"

"But according to my reference reach this bar doesn't belong here."

Conclusions

CALFED needs to identify existing approaches and organize them into a scale-dependent framework to enable meaningful comparisons.

Then, approaches need to use predictive, mechanistic tools to develop and test hypotheses

Many practical realities are being ignored- do we even know what the right questions are???