Physical Models and Critical Uncertainties in Restoration Design

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Toward a (more ambitious) experimental approach to river restoration

Take Home Messages

- Large knowledge gaps exist
- “Restoration Science” = Marriage of practical needs and basic science
- Experimental Approach Needed
  - Field projects often uncontrolled experiments
  - Lab experiments can play key role
  - Large scale field experiments needed too
- CBDA can make it happen

Episodic Sediment Supply

- Natural sediment supply is episodic
  - Debris flows, landslides, bank failures…
  - “Natural gravel augmentation”
  - Water and sediment supply: different distributions

How do channels respond to pulses of elevated sediment supply?

- **Fining**
- **Aggradation**
- **Filling of pools - smoothing of bed**
- **Increased patchiness**

Tom Lisle, Yantao Cui, and others…

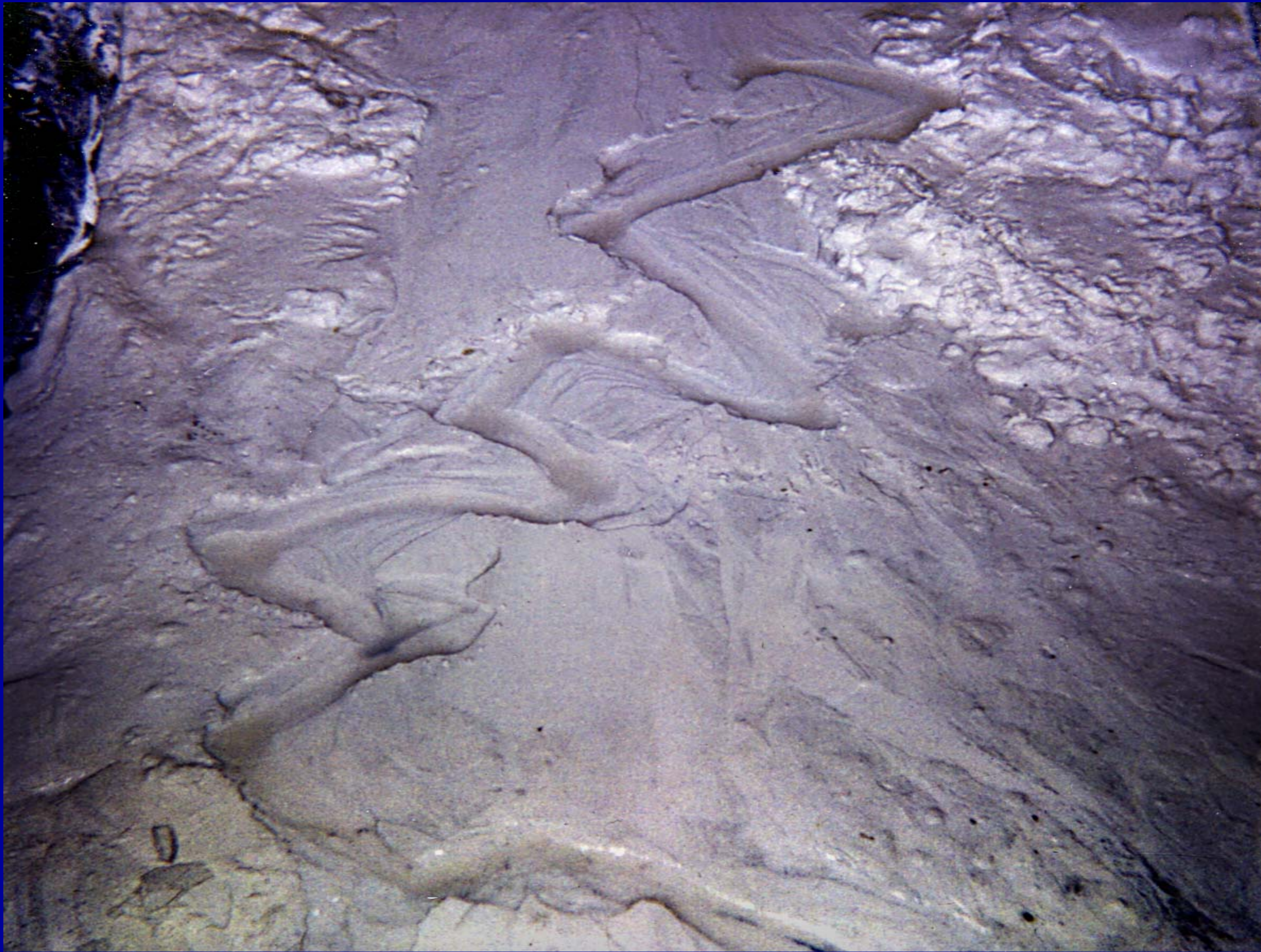
Challenge is to predict spatial and temporal extent of change

Armor mobilization by fine sediment

- Sand added to gravel increases gravel mobility
- Field and Laboratory evidence
- Due to
  - smoothing of bed?
  - Scour-ability of interstitial fines?
- Could fine *gravel* pulses also break up armor?

Lateral effects (“the missing dimension”?)

- Predictive models now 1-D, reach avg.
- 2-D modeling not yet practical at large temporal and spatial scales
- Channel response inherently 2-D (at least)
  - Patchiness and sediment transport
  - Roughness (LWD, Boulders, Bars…)



Scaling Channels Down Below Dams (the ‘mini-me hypothesis)

- Size channel to post-dam flow regime
- Restore active geomorphic processes
- Can it be done?
- Under what circumstances?
- Basic questions:
  - What controls channel width?
  - What is threshold for lateral migration?

“Restoration Science”

- Urgent applied problems push envelope of basic science (e.g. G. K. Gilbert)
- Multi- and Inter-Disciplinary
- Publicly accountable / Short time-line
- Advanced needs:
  - – Complex interactions
  - – Diagnostic models
  - – Predictive models
- NSF: “Land-use dynamics” program

Creating New Knowledge

- Field observation and experimentation
- Theoretical models
- Numerical simulation
- Laboratory experimentation

Limits to Project-Based Learning

- Many variables manipulated simultaneously
  - cause and effect difficult to discern
- Long time required for results
  - Especially below dams…
- $$ Expensive $$
- Risk of “failure”
  - Disincentive to experimental approach

Advantages of Physical Modeling

- **Focus on one variable at a time**
  - **(hold others constant)**
- **Satisfy assumptions of model**
- **Vary variables through wide range**
- **Make detailed and thorough measurements**

Efficient way to test hypotheses and gain new insight

Physical Modeling: Challenges and Limitations

- Scaling down in space and time
  - (there are limits!)
- Difficult to reproduce long time-scale phenomena
  - (same is true in the field)
- Difficult to include biologic influences

Scaling between Field and Laboratory

Principle: Keep ratio of forces equal

Water motion - “Froude Number”

Ratio of Turbulence to Gravity

Sediment motion - “Shields Number”

Ratio of Fluid Drag to Particle Weight

Water-sediment - “Particle Reynolds Number”

Ratio of Turbulence to Viscosity

Applying Experimental Results

- Development and Calibration of Numerical Models
- Focused hypotheses for field tests
- Scaling relations for designing channels
- Scaled models of specific designs

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Physical Modeling Experiments to Guide River Restoration Projects

Collaborators

- Stillwater Sciences
- U.C. Berkeley
- San Francisco State

- SAFL (U. Minn)
- NCED

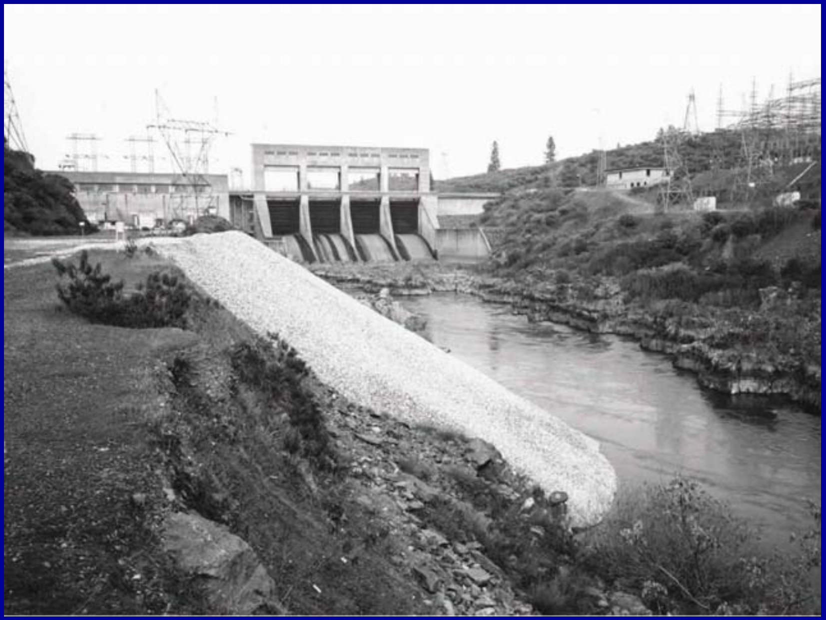
Restoration Strategies

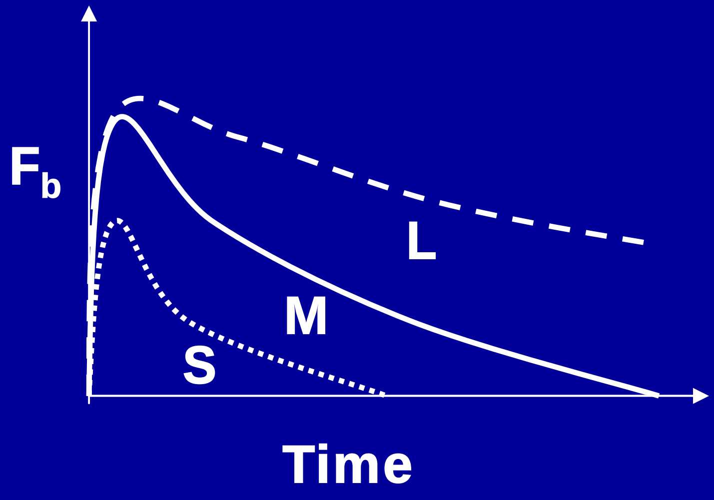
- Gravel Augmentation
- Dam Removal
- Channel and Floodplain Reconstruction

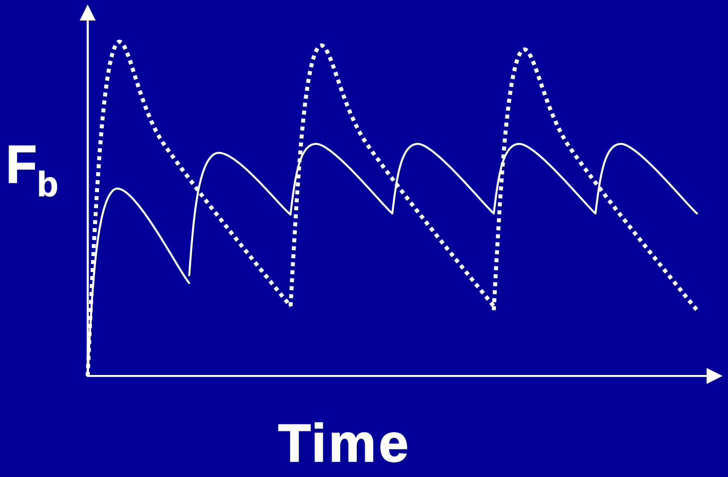
Richmond Field Station
Restoration Geomorphology Laboratory

A work in progress…

Gravel Augmentation Hypotheses



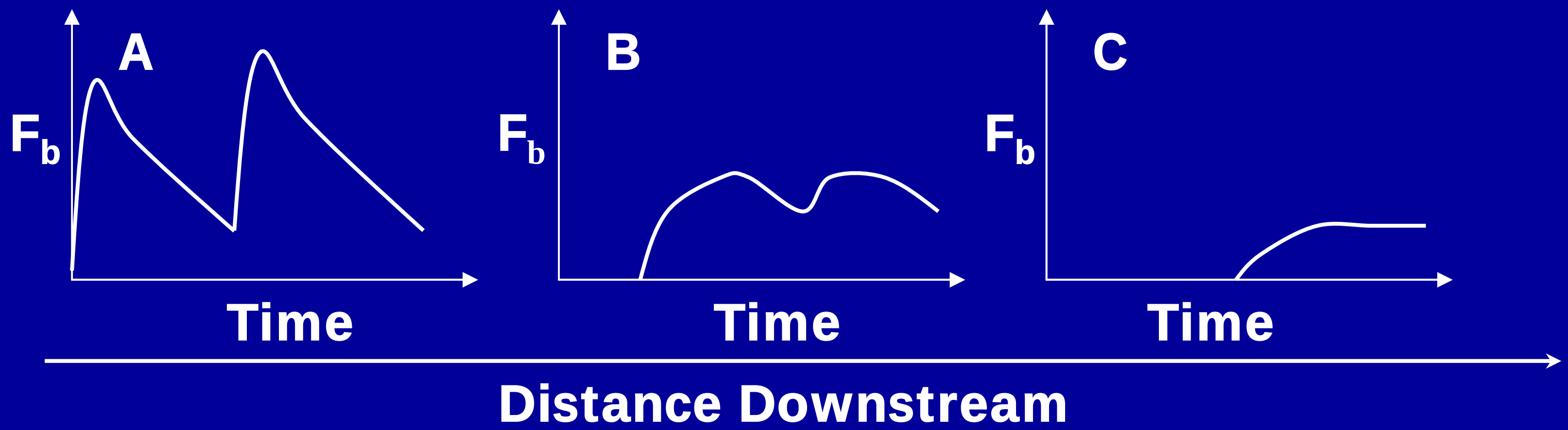




F_b = Fraction of bed in desired bed surface size class

Gravel Augmentation Hypotheses

Downstream Effects



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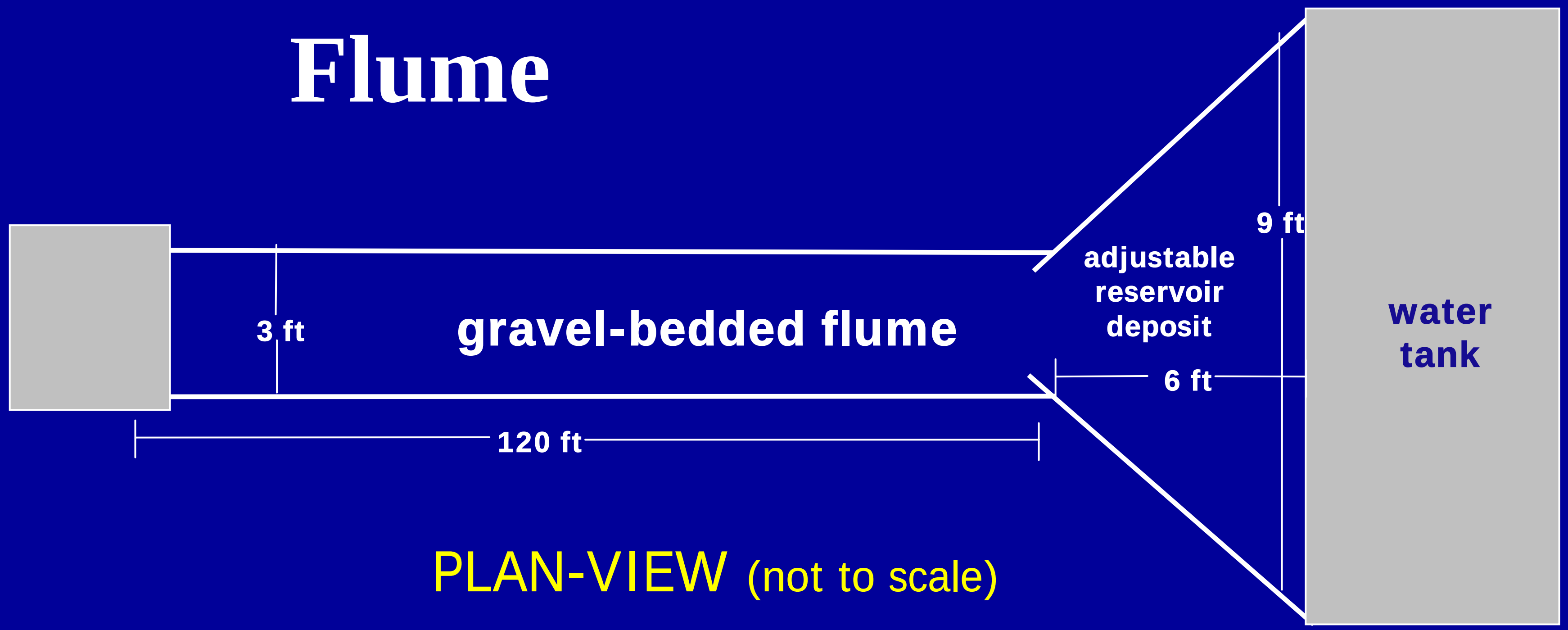
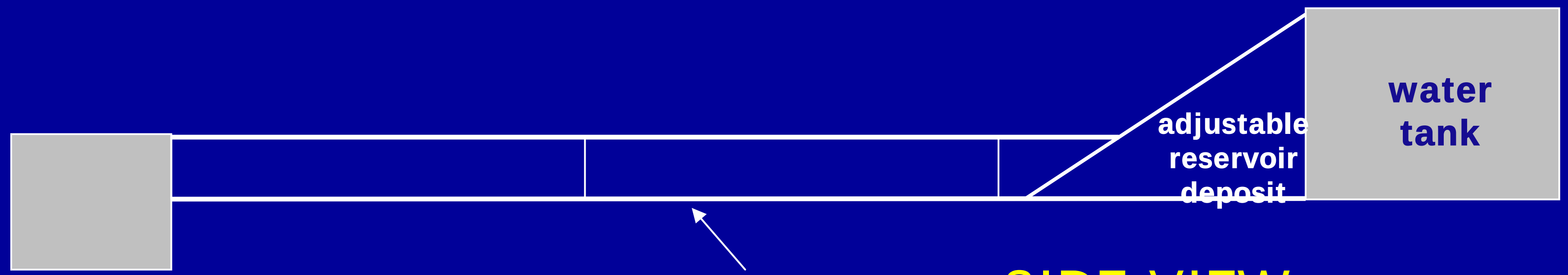
Dam Removal Flume



PLAN-VIEW (not to scale)

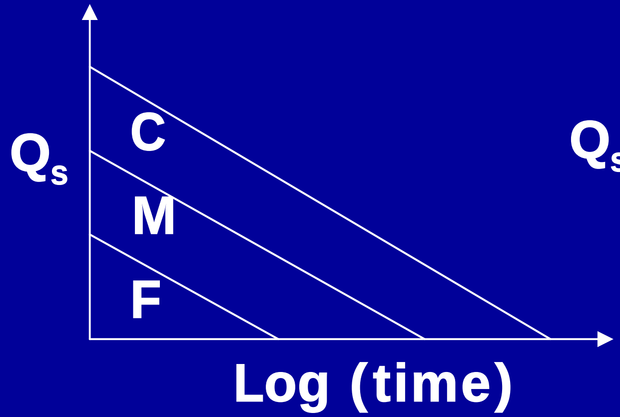


SIDE-VIEW (not to scale)

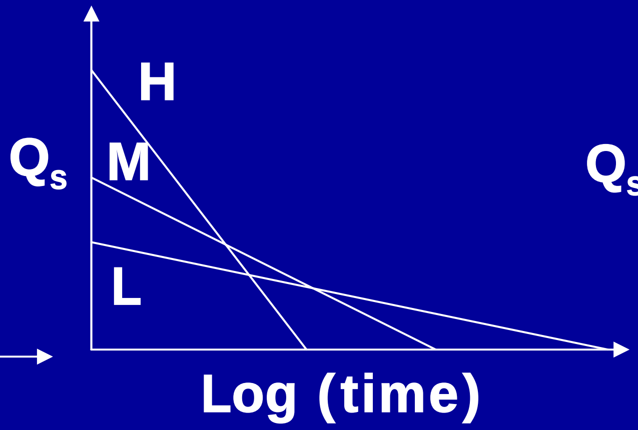
Dam Removal

Hypotheses

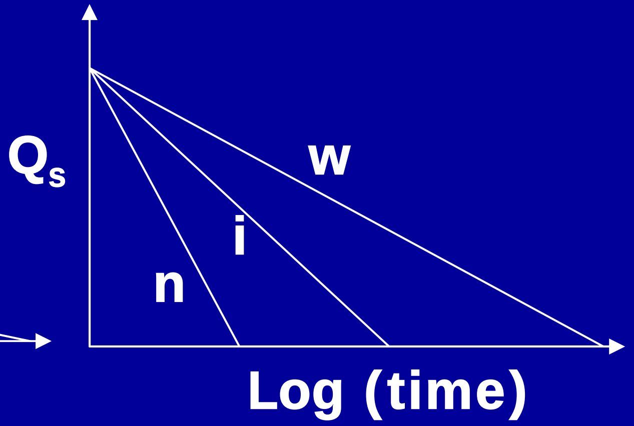
Grain Size



Hydrograph



Reservoir Geometry



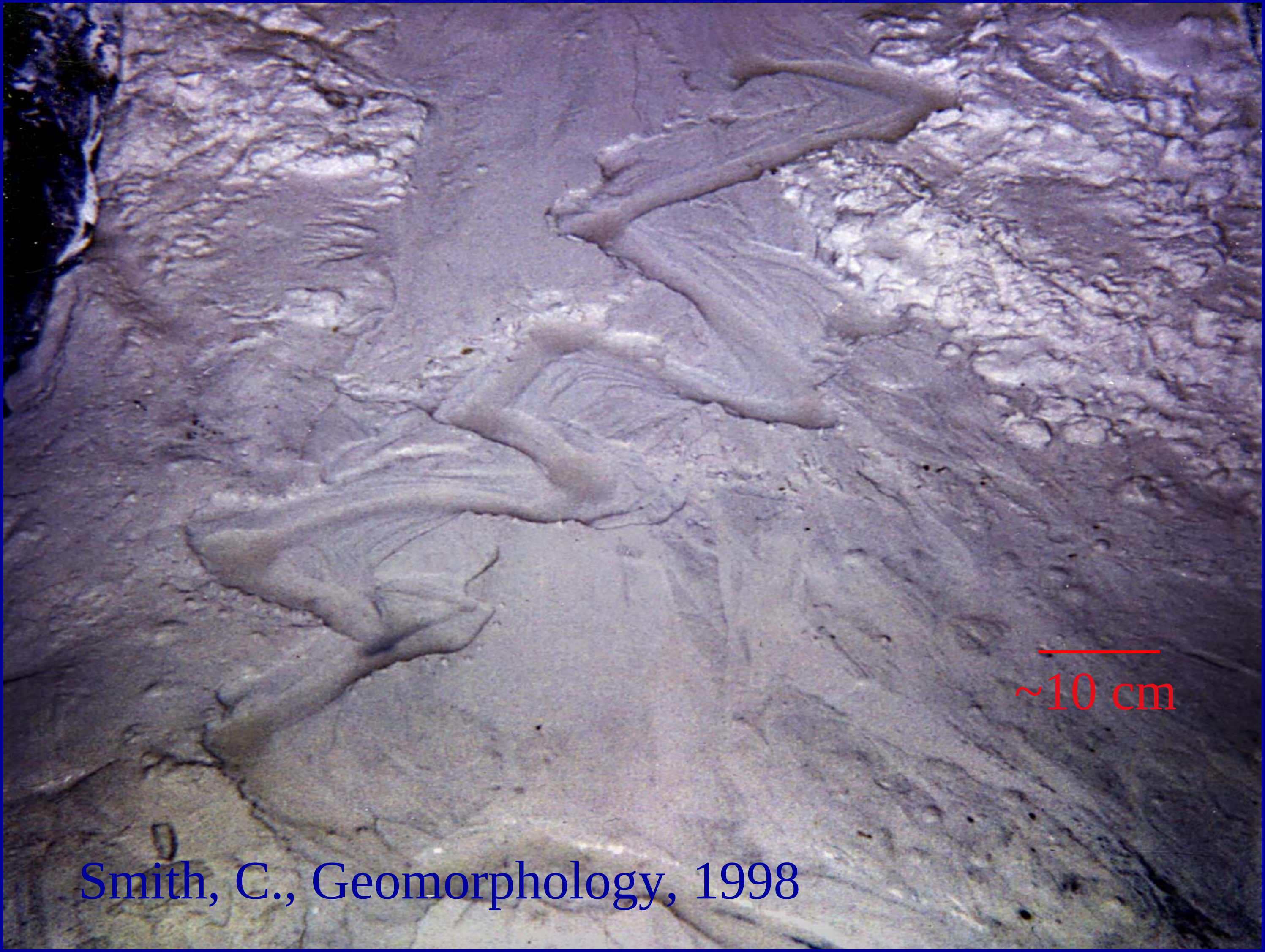
Channel And Floodplain Reconstruction

Beyond "Bankfull" Hydraulic Geometry

What is influence of:

- flood flows (beyond 2-yr)
- sediment supply rate
- grain size distribution
- vegetation

Charles Smith's "Micro-Me" Meandering Channel



Michal Tal's
Vegetation-Controlled Channel

Restoration Paradigms

- **Business**
  - **"Product" delivery**
- **Regulatory**
  - **Law enforcement**
- **Scientific**
  - **Create new knowledge**

CBDA has opportunity to lead paradigm shift

Large Scale Field Experiments

- Coordinated project designs
  - To test specific hypotheses
  - Within a basin or across basins
- Advantages
  - Field confirmation of predictive models
- Disadvantages
  - Some projects would 'fail'

Experimental Reference Site(s)

- One central location for many to work
- Comprehensive data base, measurements
- Long-term study
- Collaborations focused on hydro-geo-bio linkages
- Test of models: what if we did everything we could… would ecosystem recover?

Other ways CBDA could lead

- Solicit proposals to test specific hypotheses
- Build data base on monitoring results
  - Accessible, searchable, required of recipients
- Endowment fund for long-term monitoring
- Institutionalize ongoing peer review

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