Goal 7 Modeling Review and Recommendations

Scott Wright, USGS California Water Science Center

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Outline

- **Why use models?**

- *What's behind these models?*

- **Time and space scale issues**

- *Modeling approach for the Colorado River in Grand Canyon*

- **Integration of modeling and monitoring - historical perspectives**

- *Recommendations from recent review*

- **Future directions/Proposed FY08 work**

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Why use models?

- **To make predictions that allow for the evaluation of "what if" scenarios.**

- **Accurate predictions of system response lead to more efficient resource management – i.e. there is less need for trial and error**
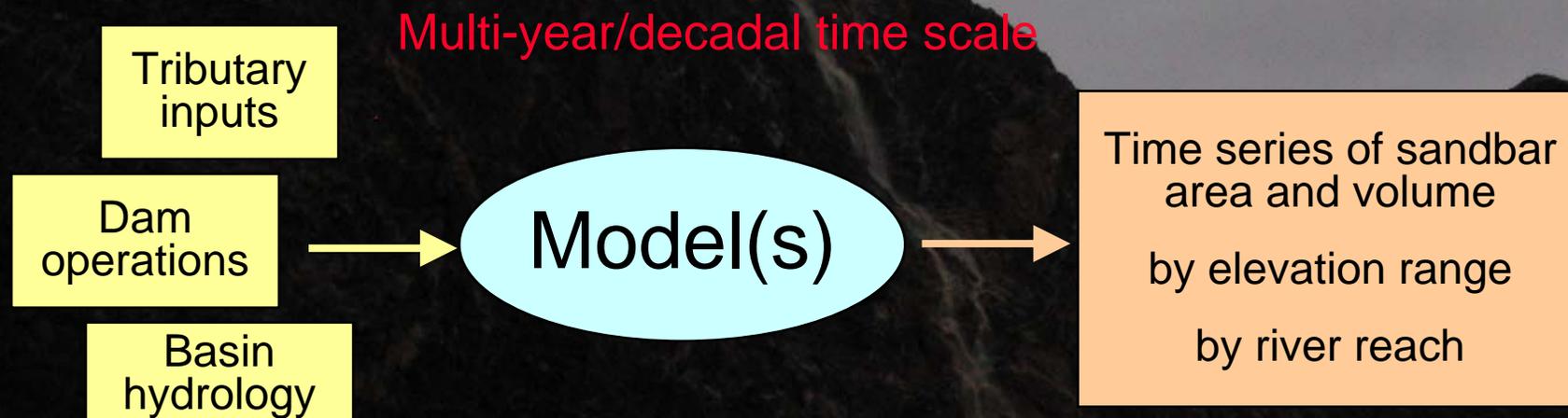
Models
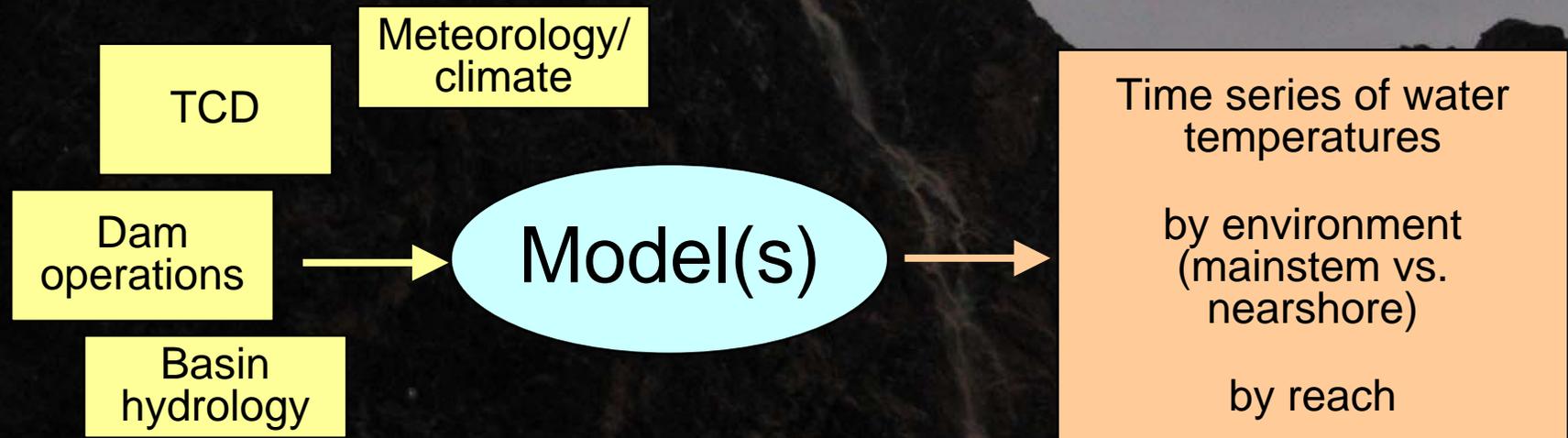
Modeling

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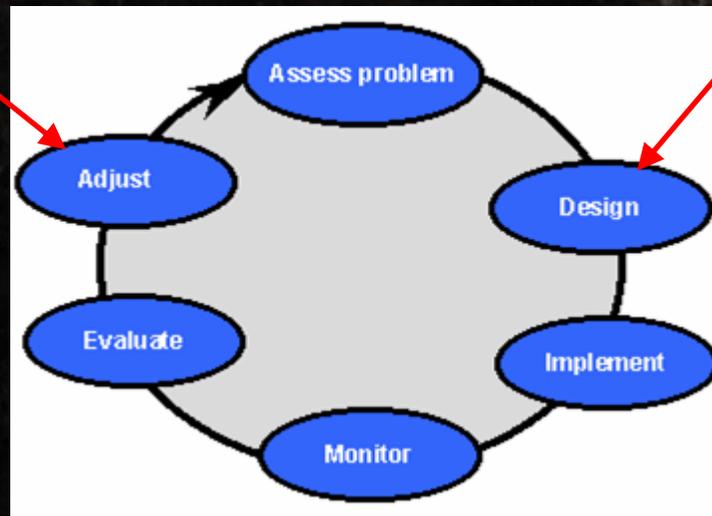
Why use models in Grand Canyon?

Is there a 'Flow-Only' operation that will restore and maintain sandbar habitats over decadal time scales? If yes, then what is that operation?

Multi-year/decadal time scale

Tributary inputs

Dam operations → Model(s) → Time series of sandbar area and volume

by elevation range

by river reach

Basin hydrology

This should be the ultimate goal – but it is ambitious and must be pursued incrementally – may require a suite of models of various scales

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Why use models in Grand Canyon?

How do dam operations, hydrology, and meteorology interact to determine mainstem and nearshore water temperatures throughout the CRE?

TCD

Meteorology/ climate

Dam operations

Basin hydrology

Model(s)

Time series of water temperatures

by environment (mainstem vs. nearshore)

by reach

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What's in these models?

Models attempt to reproduce known physical laws

Flow - momentum and mass conservation:

$$\frac{\partial \overline{u}_i}{\partial t} + \overline{u}_j \frac{\partial \overline{u}_i}{\partial x_j} = -\frac{1}{\rho}\frac{\partial \overline{p}}{\partial x_i} + \frac{1}{\rho}\frac{\partial \overline{\tau}_{vij}}{\partial x_j} + \frac{1}{\rho}\frac{\partial \tau_{Rij}}{\partial x_j} + g_i$$
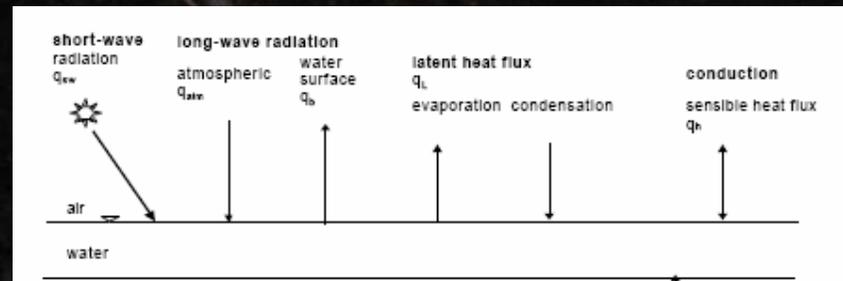
Sediment – mass conservation:

Change in land surface elevation with time →

$$\frac{\partial \eta}{\partial t} \propto \frac{\partial Q_s}{\partial x}$$

← Divergence in sediment flux

Temperature – heat balance:

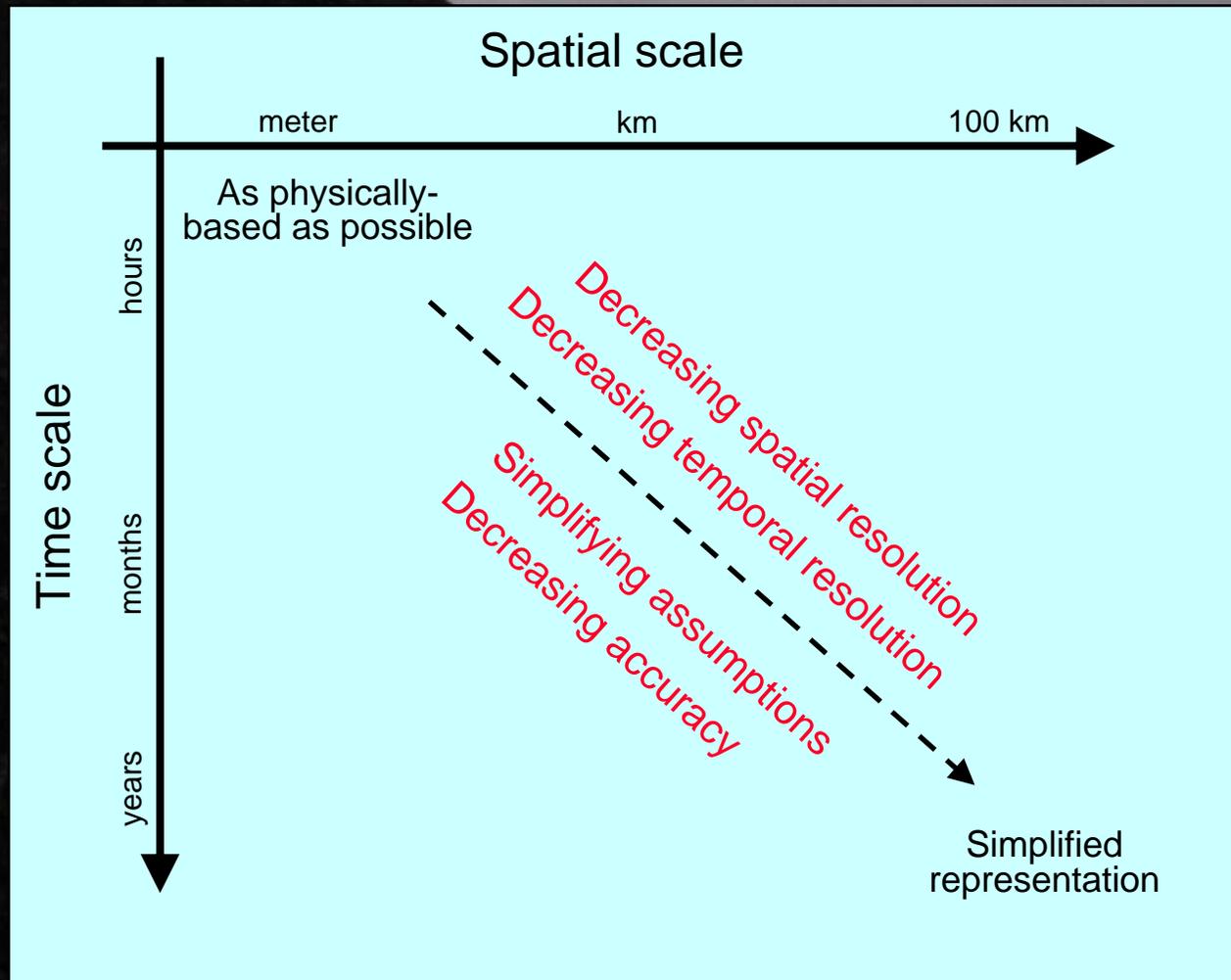Equations are linearized and solved numerically by "stepping" in space and time

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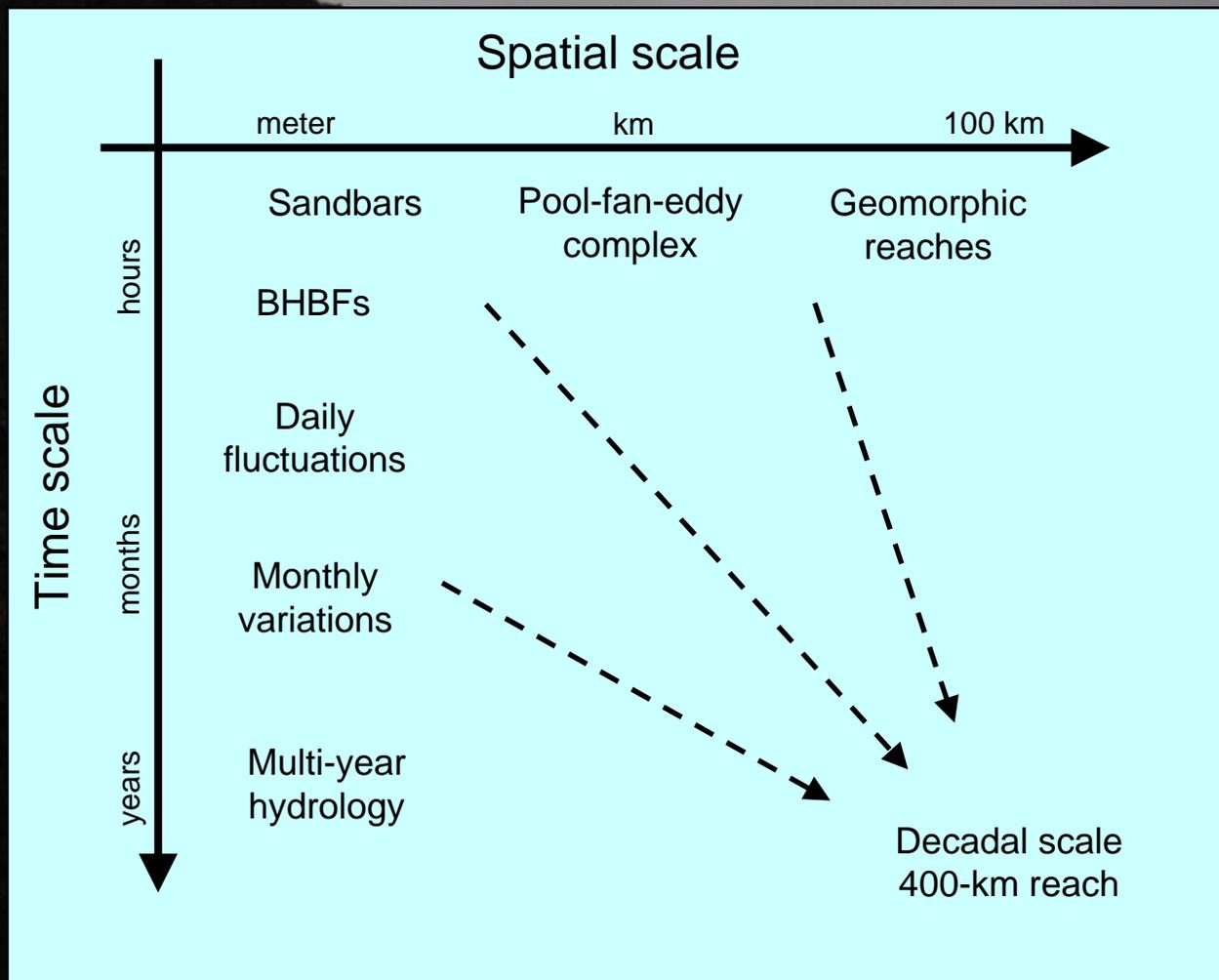$$\frac{\partial f}{\partial t} \rightarrow \frac{f^{t2} - f^{t1}}{dt} \qquad \frac{\partial f}{\partial x} \rightarrow \frac{f_{x2} - f_{x1}}{dx}$$

Scale is a major issue in modeling

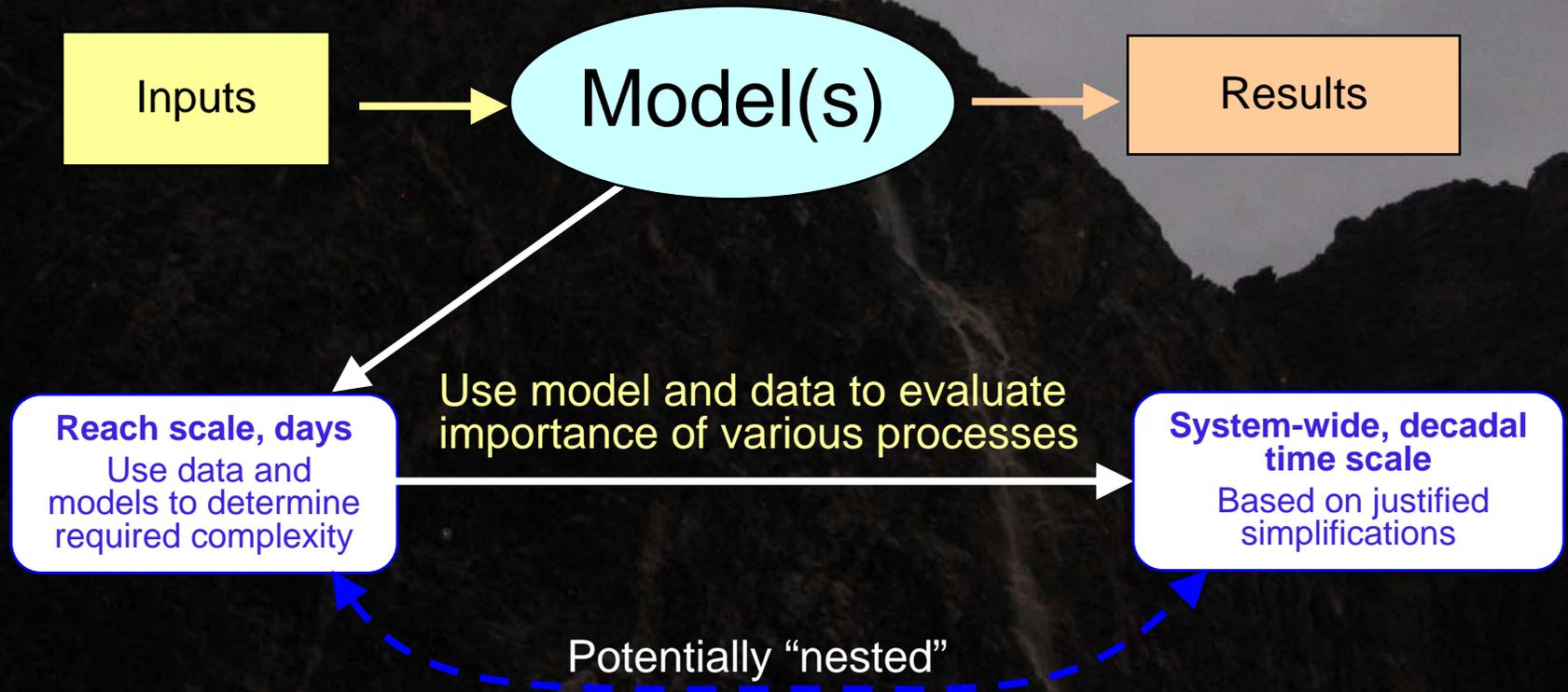The type of model used is dependent on the scale of interest

Canyon geomorphology - range in scales

Modeling Approach for Grand Canyon

Inputs → Model(s) → Results

Reach scale, days
Use data and models to determine required complexity

Use model and data to evaluate importance of various processes →

System-wide, decadal time scale
Based on justified simplifications

Potentially "nested"

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Canyon sediment modeling timeline

1960 GCD 1970 1980 1990 2000

Laursen – computed post-dam transport rates; not really a "model"

Randle and Pemberton – 1D, steady flow, no eddies, system-wide, month-to-year time scale

Wiele and others – 2D, steady flow, km-scale reaches with eddies, day-to-week time scale

Topping – Paria River model

Wiele and others – 1D, unsteady flow, 100 km scale with eddies, week-to-month time scale

Schmeeckle and others – 3D, unsteady flow, km scale reaches with eddies, hours-to-day time scale
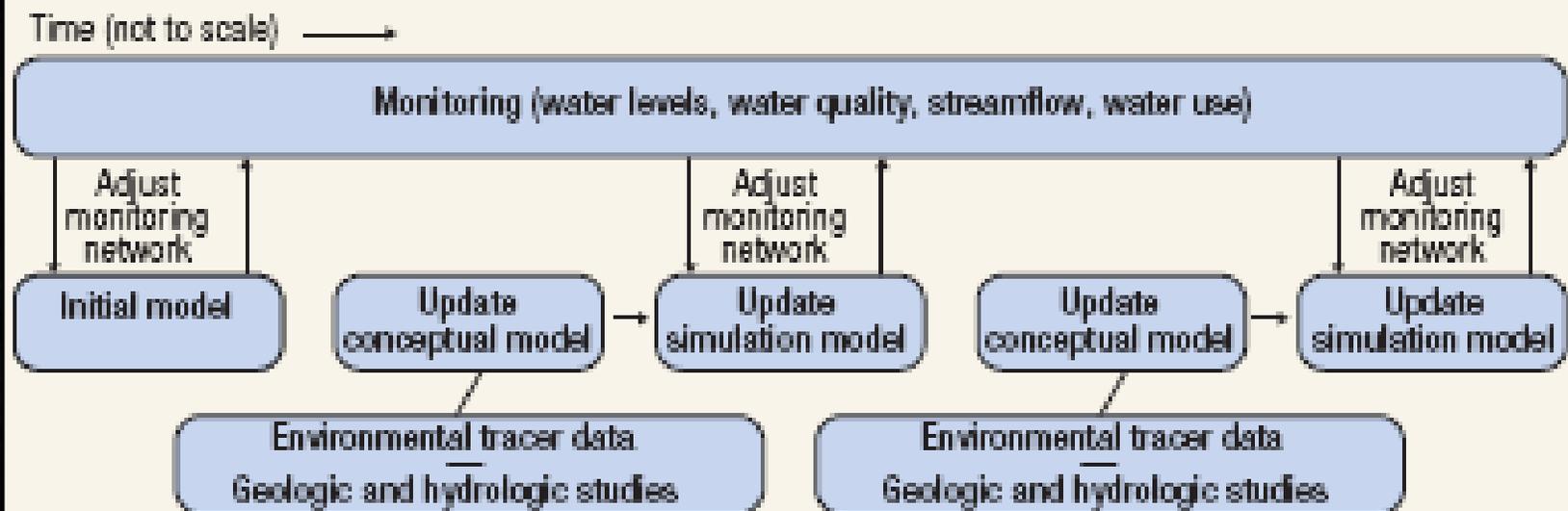
Sediment modeling external review

Sediment Review Panel Recommendations

❖ The modeling program needs better integration with the monitoring program – formulate an integrated research plan

❖ It is time to update the Wiele 2D model as major advances have been made in multi-dimensional modeling over the past 10 years a lots of new data are available; evaluate readily available modeling packages (such as Delft3D) and available data

❖ Wiele 1D model is a step forward but more work is necessary to evaluate its predictive capabilities – continue to improve upon this model based on updated MD model

❖ Continue efforts by Arizona State University (Mark Schmeeckle's group) to model sandbar stability (i.e. mass failures due to bank collapse), including laboratory experiments
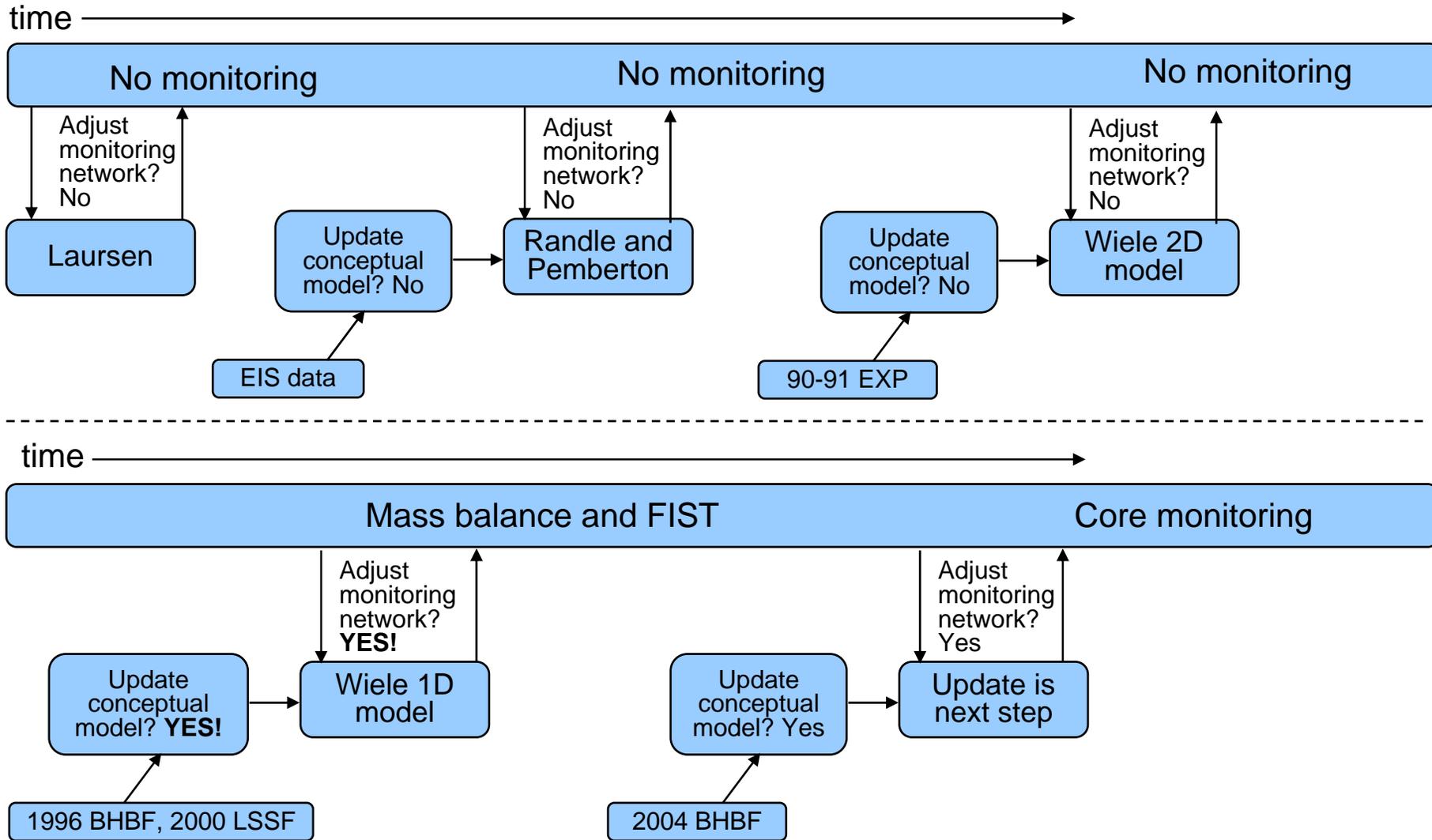
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Linking modeling and monitoring

Modeling should be conducted in parallel with monitoring and experiments

"Integrated approach to modeling and modeling", from Alley, 2006

Time (not to scale) →

Monitoring (water levels, water quality, streamflow, water use)

Adjust monitoring network | Adjust monitoring network | Adjust monitoring network

Initial model | Update conceptual model → Update simulation model | Update conceptual model → Update simulation model

Environmental tracer data — Geologic and hydrologic studies | Environmental tracer data — Geologic and hydrologic studies

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Have modeling and monitoring been linked?

Delft3D modeling package

- ## Off-the-shelf package lots to offer:

  - 2D and 3D options for flow and transport
  - **Sediment transport with multiple grain-sizes, bed sorting, and bed layering history (i.e. stratigraphy)**
  - Water temperature in 3D with full surface heat energy balance (also many other WQ constituents)
  - **Current cooperative agreement with USGS, licensing and technical support**
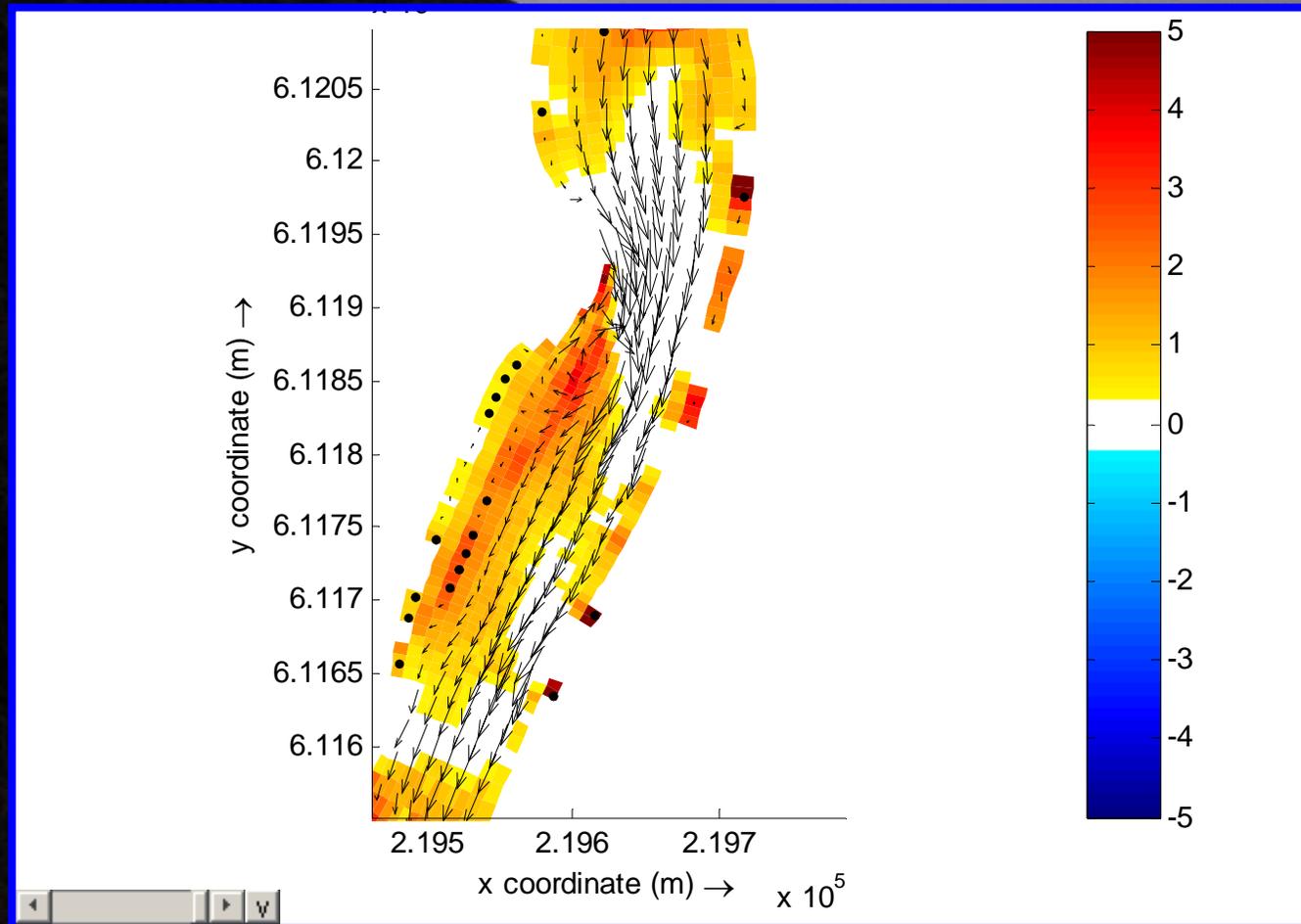 - Fully documented with many applications around the world

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Delft3D initial evaluations

Eminence backwater temperature model

Example for illustrative purposes only
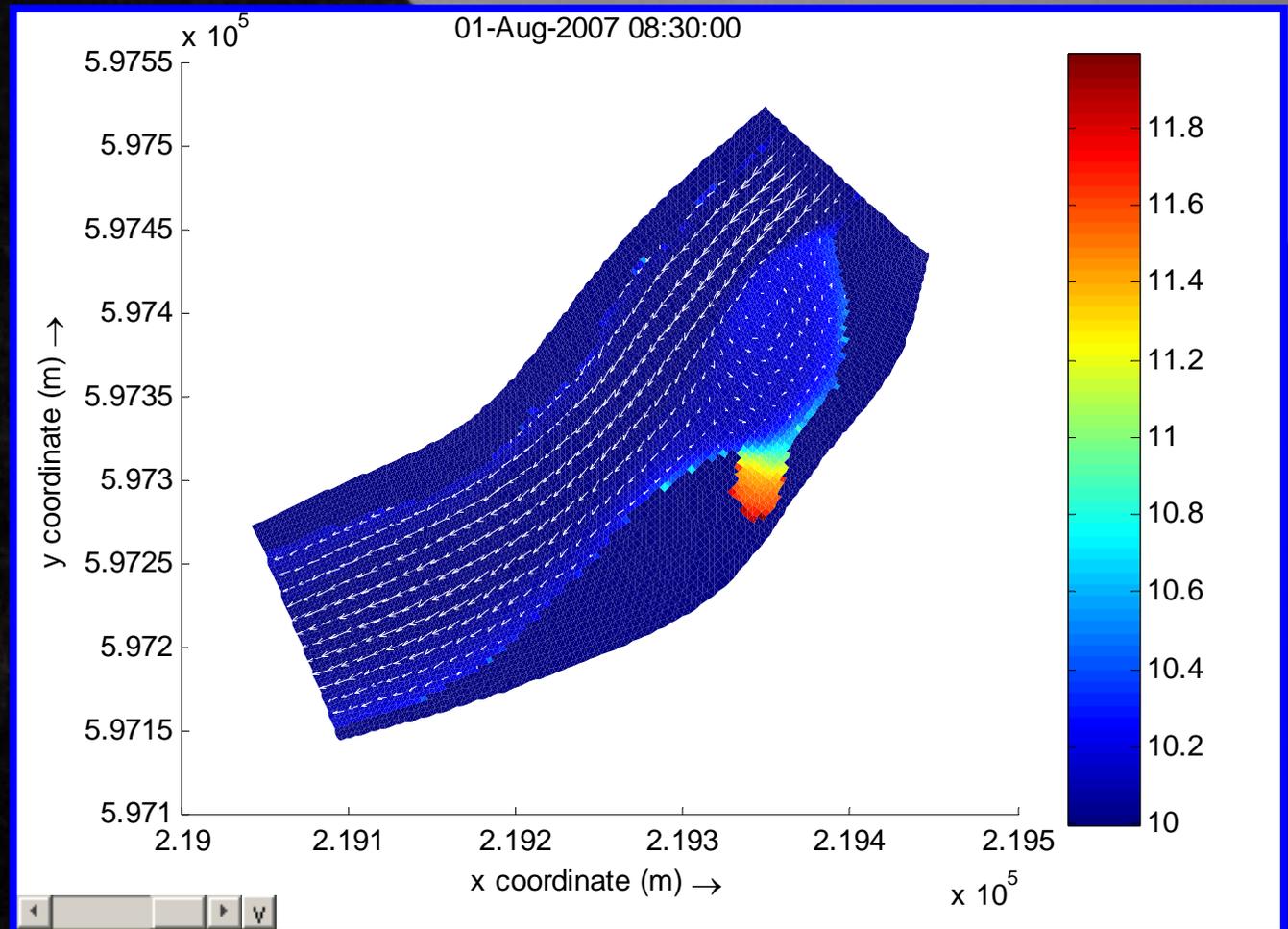
Delft3D initial evaluations

30-mile eddy deposition during high flow

Example for illustrative purposes only

Proposed FY08 activities

❖ Develop multi-dimensional models (Delft3D) of flow, temperature, and sediment transport for reaches with available topography/bathymetry (FIST reaches). Principal Investigators – Scott Wright and David Topping; requested budget: $135,000 (additional funds being requested from BoR for support of Craig Anderson of GCMRC)

❖ Continue efforts to model sandbar mass failure/stability, including laboratory experiments at ASU. Principal Investigator – Mark Schmeeckle; requested budget: $55,000.

❖ Continue efforts to understand the relationships between flow, bed sediment grain-size, and suspended-sediment grain-size. Continue to pursue the potential for a model that relies on "shifting rating curves". Principal Investigator – David Rubin; requested budget: $30,000

Total budget request: $220,000
Currently in FY08 budget: $117,000
Additional funding needed: $103,000

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Questions?

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