WATERSHED PARTNERSHIP SEMINAR

October 10 – 20, 2006
Mission Inn
Riverside, California

Dennis Bowker

Peter Goodwin
Center for Ecohydraulics Research
University of Idaho

With special thanks to:
Chris Bowles
Philip Williams and Associates
Pat Brezonik
National Science Foundation

HOW WATERSHEDS WORK

Presentation Outline

- Watershed Processes
- A Glimpse of the Future (Enabling Technologies)
  - Sensors and Sensor Networks
  - Cyber-infrastructure
  - Data Synthesis and Data Mining
  - Integrated Modeling-Monitoring (Real-time modeling)
- The Role of Models in Restoration
  - Design tool and Integration with Geomorphology
  - A Communication Tool
  - Performance Assessment and Adaptive Management
  - Current Limitations
  - Some "rules-of-thumb"
- Examples
- Questions!

Definition of a Watershed

- Websters Dictionary
  - n. a ridge or other line of separation between two river systems or drainage areas
  - the catchment area of a river system
- Catchment
  - n. the whole area from water drains to a river, lake or reservoir

Complicating factors:

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Complicating factors:
  - inter-basin transfers
  - basin interconnectivity through groundwater
  - Arroyo Seco or Los Angeles River or Los Angeles River/San Gabriel combined?

Key Watershed Functions

- Converts vertical flow of water (precipitation) to horizontal flow
- Spatially diffuse to concentrated point flow
- Provides transport pathways for: nutrients, contaminants, POPs
- Water Quality
  - transformation
  - removal
  - addition
  - storage
- Carbon cycling – source, sink or neutral

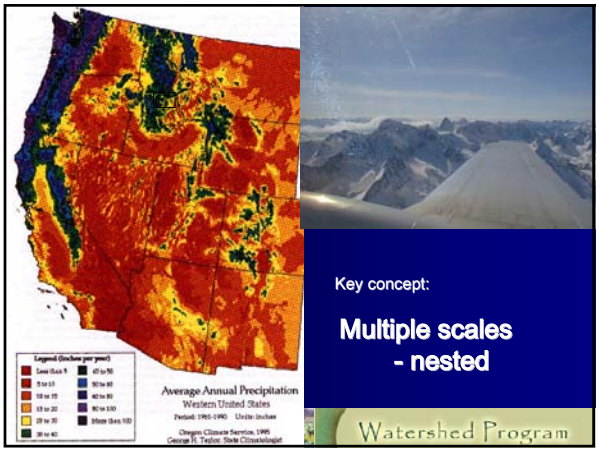
Watersheds are integrators of numerous complex processes.

Key Watershed Concepts

- Multiple scales
  - nested
- Heterogeneity – physical and biological processes
- Transport Mediums
  - air
  - surface water
  - groundwater
  - gravity
- Air flows – temperature, precipitation, pollutants, fine sediments
- Water – watershed converts vertical to horizontal

CALFED BAY-DELTA PROGRAM

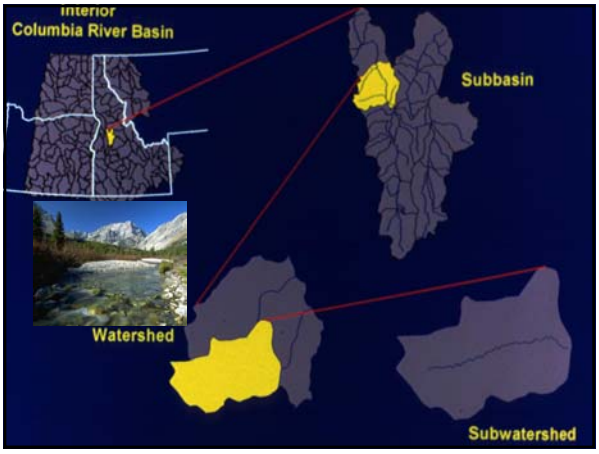
Watershed Program



Key concept:

Multiple scales
- nested

Watershed Program



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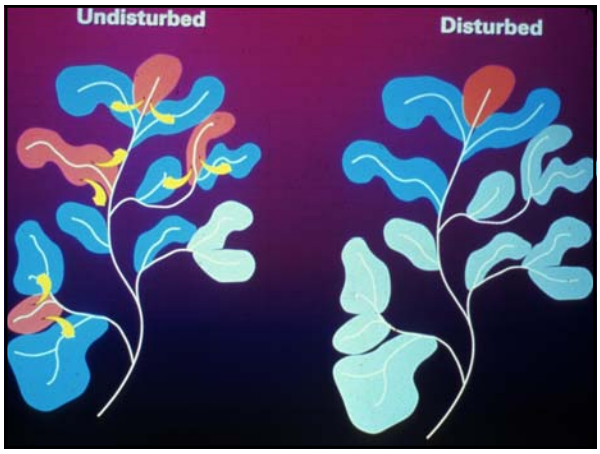
Watershed Program



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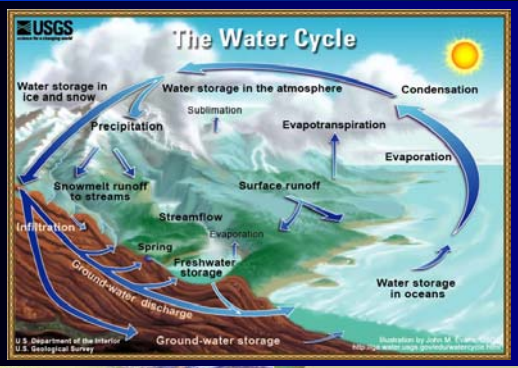
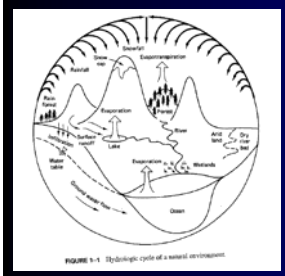
Water Cycle



Effects of Anthropogenic Disturbance



McCuen, 1998

One estimate of global water distribution

Water source	Water volume, in cubic miles	Water volume, in cubic kilometers	Percent of total freshwater	Percent of total water
Streamflow in rivers	509	2,120	0.006%	0.0002%
Total global freshwater	8,404,000	35,030,000	2.5%	--
Total global water	332,500,000	1,386,000,000	--	--

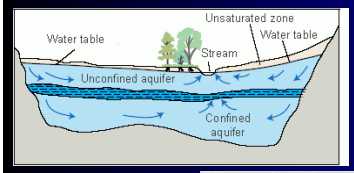
Source: Gleick, P. H., 1996: Water resources. In Encyclopedia of Climate and Weather, ed. by S. H. Schneider, Oxford University Press, New York, vol. 2, pp.817-823.

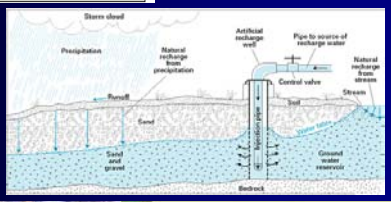
	Intensity inches/hour (cm/hour)	Median diameter (millimeters)	Velocity of fall feet/second (meters/second)	Drops per second per square foot (square meter)
Fog	0.005 (0.013)	0.01	0.01 (0.003)	6,264,000 (67,425,000)
Mist	.002 (.005)	.1	.7 (.21)	2,510 (27,000)
Drizzle	.01 (.025)	.96	13.5 (4.1)	14(151)
Light rain	.04 (1.02)	1.24	15.7 (4.8)	26 (280)
Moderate rain	.15 (.38)	1.60	18.7 (5.7)	46 (495)
Heavy rain	.60 (1.52)	2.05	22.0 (76.)	46 (495)
Excessive rain	1.60 (4.06)	2.40	24.0 (7.3)	76 (818)
Cloudburst	4.00 (10.2)	2.85	25.9 (7.9)	113 (1,220)

Source: Lull, H.W., 1959, Soil Compaction on Forest and Range Lands, U.S. Dept. of Agriculture, Forestry Service, Misc. Publication No.768

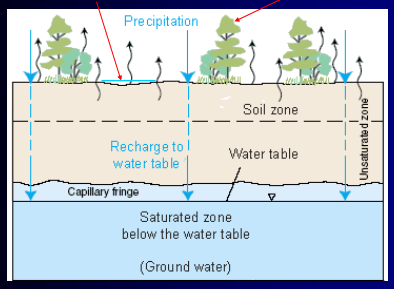
http://ga.water.usgs.gov/edu/watercyclehi.html

The Classic Approach





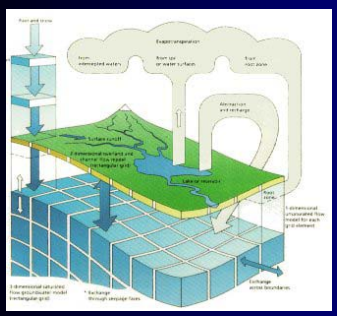
The Classic Approach



Balance available to runoff as sheet flow

Runoff depends on many factors including antecedent conditions

Classic Approach



Example: MIKE SHE

But currently subject of considerable research

'Old water paradox'

Kirchner

Dry Creek Experimental Watershed

Plot/Point Scale

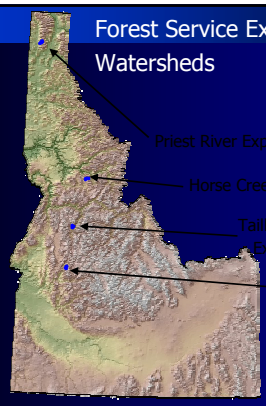
Headwater Scale

Large Watershed Scale

- 7 stream gauging stations
- 3 weather stations

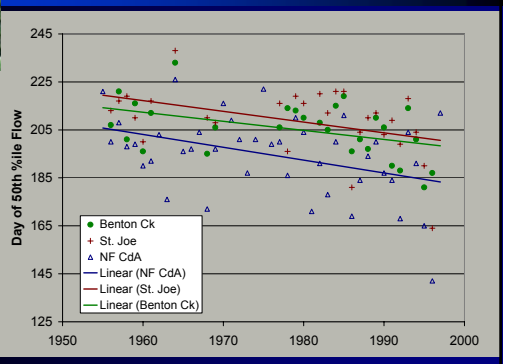
- 27 km^2 at the urban/wildland interface
- Representative semi-arid mountain front environments
- Jim McNamara – Boise State

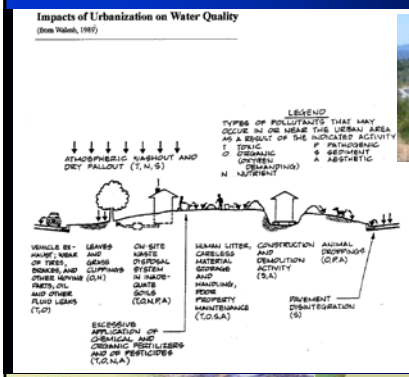
Forest Service Experimental Watersheds



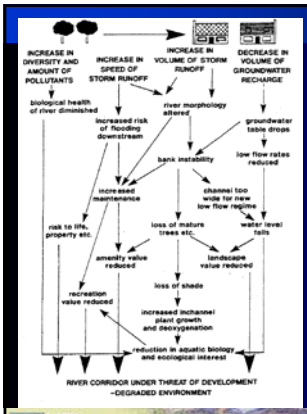
Is Climate Change Real?

Charlie Luce





Point Source



Anthropogenic disturbance in watersheds

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Erosion caused by surface runoff

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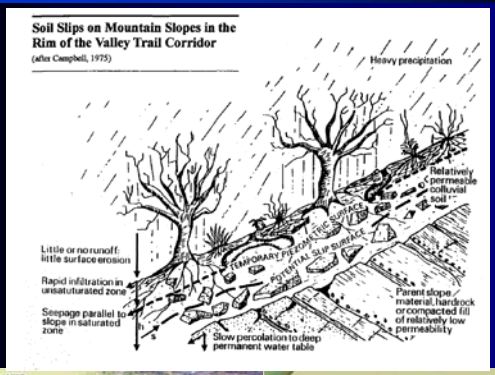
The Classic Approach



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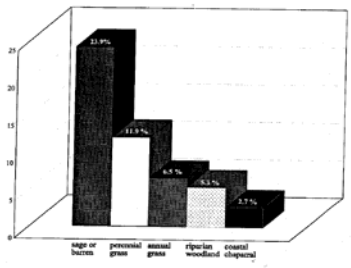
River and Stream Characteristics

Courtesy: Janine Castro

Percentage of Habitat Area with Soil Slips
(after Bailey and Rice, 1969)



Stream ecosystem response to perturbations - *FIRE*

Stream ecosystem response to perturbations - DAMS

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River and Stream Characteristics

Source: CALFED, 2000

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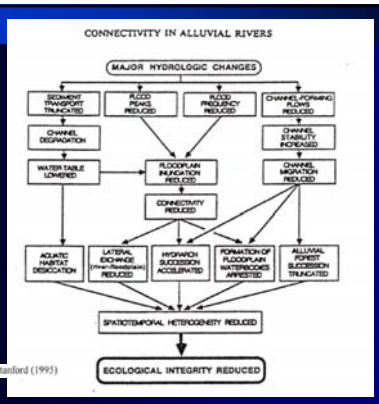

Source: Ward and Stanford (1995)

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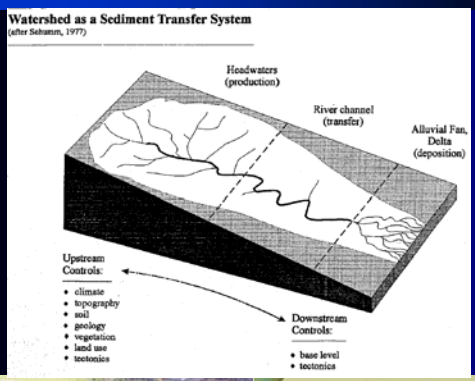
Movement of Sediment



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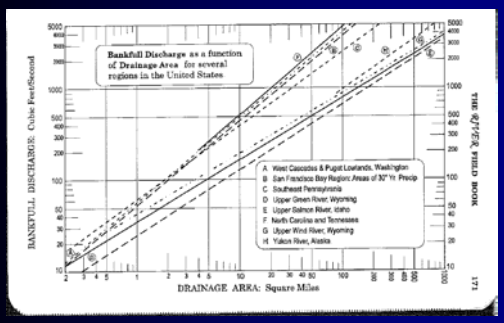

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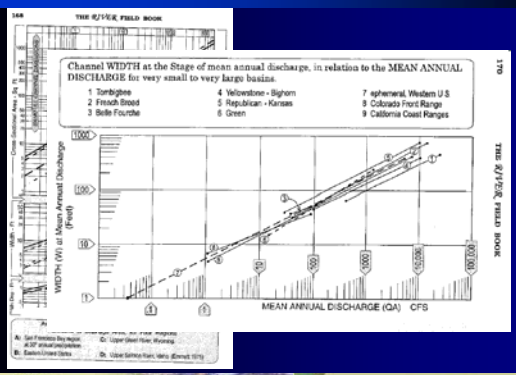

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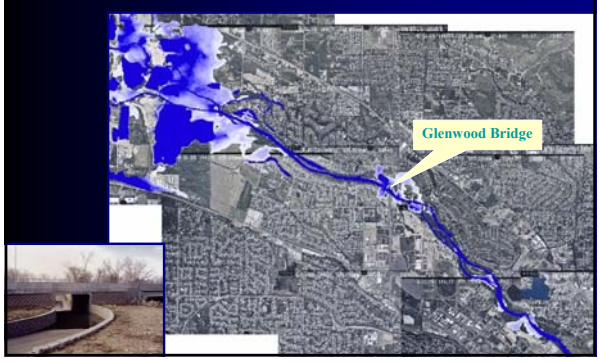
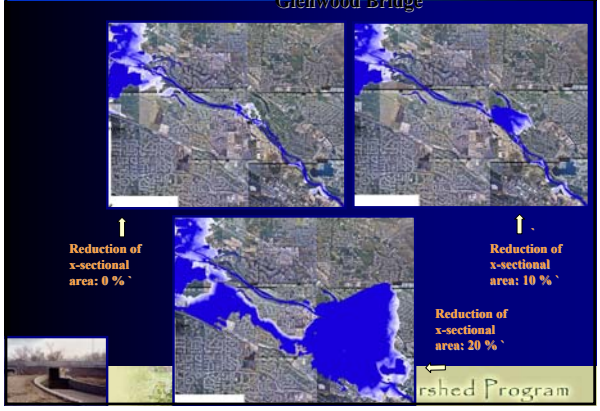
2-D Flood Animation: Impact of the Accumulation of Debris in Glenwood Bridge



Impact of the Accumulation of Debris in Glenwood Bridge



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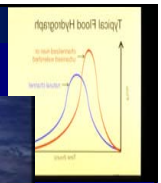
Vegetation Management

Example of Wildcat Creek

- Year of vegetation removal, n=0.038
- One year following vegetation removal, n=0.045
- Three years following vegetation removal, n=0.078
- Ten years following vegetation removal, n= 0.048
- Other examples: San Lorenzo River, Paharo River

Watershed Linkages



Hydrographs

Program

ASCE Professional Code of Ethics

Fundamental Canons

Engineers shall hold paramount the safety, health and welfare of the public and shall strive to comply with the principles of sustainable development in the performance of their professional duties.

Guidelines to Practice Under the Fundamental Canons of Ethics

CANON 1.

- Engineers shall hold paramount the safety, health and welfare of the public and shall strive to comply with the principles of sustainable development in the performance of their professional duties.
- Engineers should seek opportunities to be of constructive service in civic affairs and work for the advancement of the safety, health and well-being of their communities, and the protection of the environment through the practice of sustainable development.
- Engineers should be committed to improving the environment by adherence to the principles of sustainable development so as to enhance the quality of life of the general public.

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NSF-ENG working definition of CI:

Cyberinfrastructure is a national network of resources that:

- provides broad and easy access to shared and maintained repositories for data, models, and tools.
- includes connectivity with shared facilities for experimentation and computation.
- enables reliable visualization and information extraction from multimedia data resources and libraries.
- supports real-time data flows and distributed collaboration.
- ensures that applications and domain communities can form and grow, and that efforts develop with interoperability.

Drexel

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3rd NSF-ENG
Cyberinfrastructure Workshop
April 22-23 Drexel University

For workshop report and additional information visit website

http://thor.cae.drexel.edu/~workshop

Ppts and presentations are posted

M. Piasecki, June 2004

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Sensors and Sensor Networks

Sensors for Environmental Observatories
NSF Workshop: November 2004
University of Washington

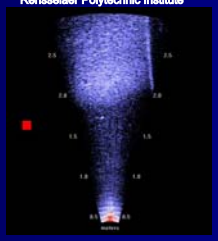
Final Report December 2005

Objectives:

- Map out strategies to ensure sensor technologies are developed for long-term autonomous deployment;
- Build a sensor capacity for the environmental observational networks for the high priority parameters identified within research community reports;
- Build a multidisciplinary community of researchers who will help interested federal agencies develop research plans that meet these needs; and
- Provide community guidance to help shape future NSF program announcements in this area.

www.wtec.org/seo

Co-chaired by:
Peter Arzberger
University of California at San Diego
James Bonner
Texas A&M University
David Fries
University of South Florida
Arthur Sanderson
Rensselaer Polytechnic Institute



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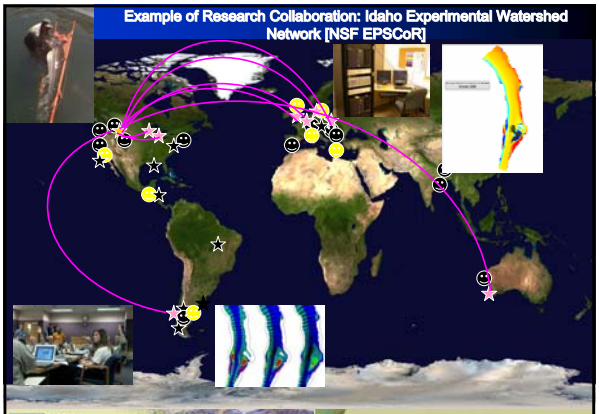
Example of Research Collaboration: Idaho Experimental Watershed Network [NSF EPSCoR]



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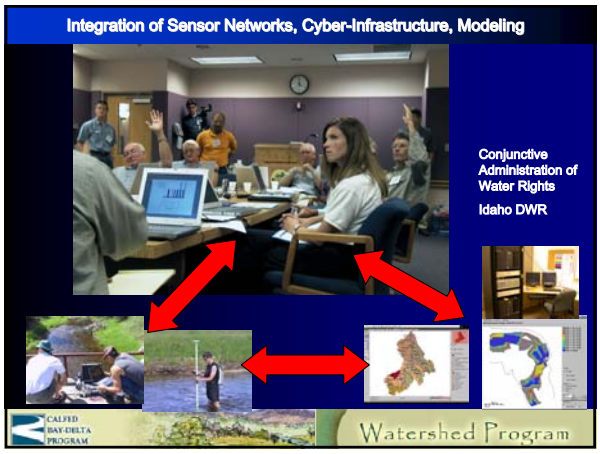
Integration of Sensor Networks, Cyber-Infrastructure, Modeling



Trends in Community Science

- Environmental Observatories
  - LTER
  - NEON
  - Hydrological Observatories (CUASHI)
  - OOI
  - CLEANER
  - NEES

  EU Initiatives such as TWINBAS and TWINLATIN
- Common features
  - Driven by scientific and engineering communities
  - Cyber-infrastructure emphasis
  - Inclusive
  - Grand Challenges
  - Sensor and Sensor Networks
  - Paradigm shift in simulation models

    Closure relations, calibration, data mining

    Data Driven Models

CLEANER
Collaborative Large-scale Engineering Analysis Network for Environmental Research

CUAHSI

CLEANER-Hydrologic Observatories:

An MREFC initiative in NSF's Engineering and Geosciences Directorates

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Who is CUAHSI?

- A consortium of 90 research universities and 1 affiliate member
- Incorporated June, 2001 as a non-profit corporation in Washington, DC

Jon Duncan

CUASHI, June 2004

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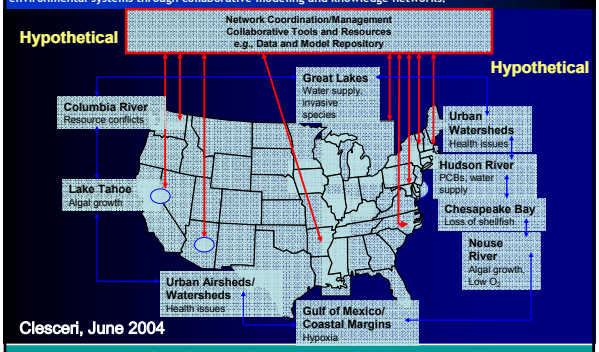
Key Focus: fundamental understanding of adaptive dynamic management of human-dominated complex environmental systems through collaborative modeling and knowledge networks.



Clesceri, June 2004

CLEANER Network and Examples of Stressed Environmental Systems

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Hypothetical

The WaterS Network will:

1. Consist of

(a) teams of ***investigators*** studying human-stressed landscapes, with an emphasis on water problems and questions;
(b) a national network of ***interacting field sites***;
(c) ***specialized support*** personnel, facilities, and technology; and
(d) ***integrative cyberinfrastructure*** to provide a shared-use network as the framework for collaborative analysis

2. Transform environmental engineering and hydrologic science research and education by:

(i) providing *advanced* sensor systems for data collection and state-of-the-art informatics tools for data mining, analysis, visualization, and modeling of large-scale environmental issues; and
(ii) engaging academics and others in collaborative and interdisciplinary studies of real-world problems

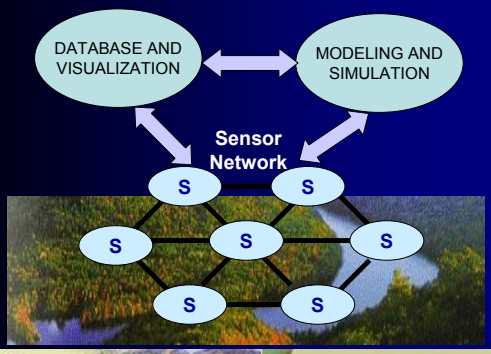
3. Enable more effective adaptive-management of human-dominated, environments based on observations, experimentation, modeling, engineering analysis, and design

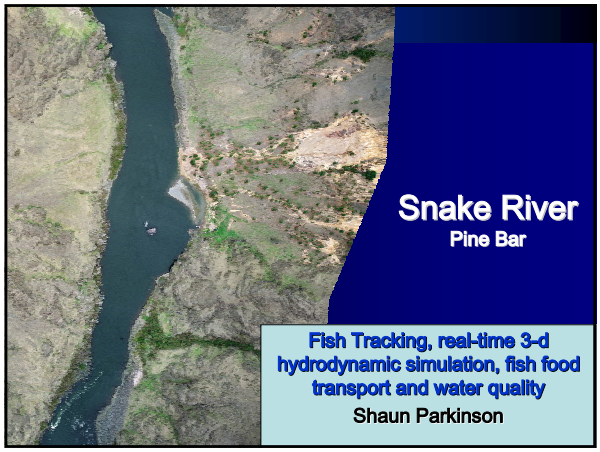
Waters Network: CUASHI-CLEANER

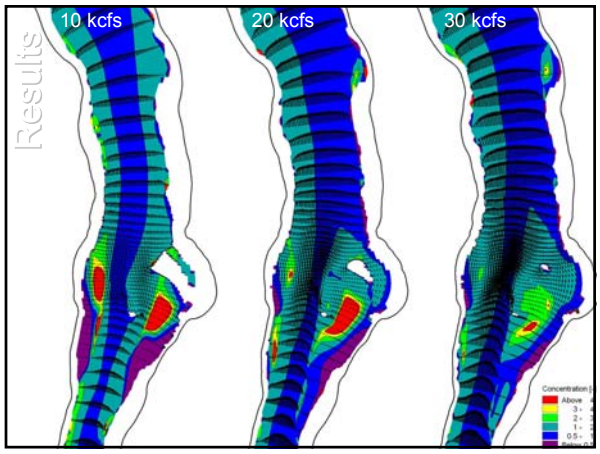
Dramatically advance our understanding of the nation's water resources and provide a scientific basis for sustainable use through:

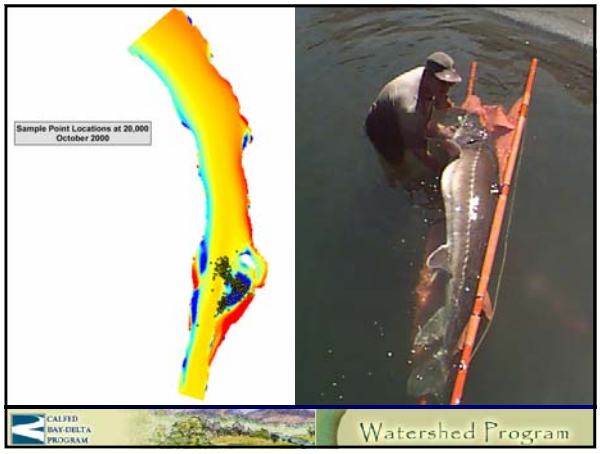
- Forecasting how human changes in landscapes (land use/cover) affect water availability and variability, including floods and droughts
- Developing technologies and strategies to provide safe drinking water for all citizens
- Keeping nutrients and other agricultural chemicals on the farm and out of our waterways
- Designing cost-effective solutions to the nation's urban storm-water problems
- Restoring and enhancing the quality and ecological integrity of the nation's lakes, rivers, and wetlands

Adaptive Dynamic Management: Core of EOs




Snake River
Pine Bar
Fish Tracking, real-time 3-d hydrodynamic simulation, fish food transport and water quality
Shaun Parkinson


Results
10 kcfs
20 kcfs
30 kcfs


Sample Point Locations at 20,000
October 2000
CALFED BAY-DELTA PROGRAM
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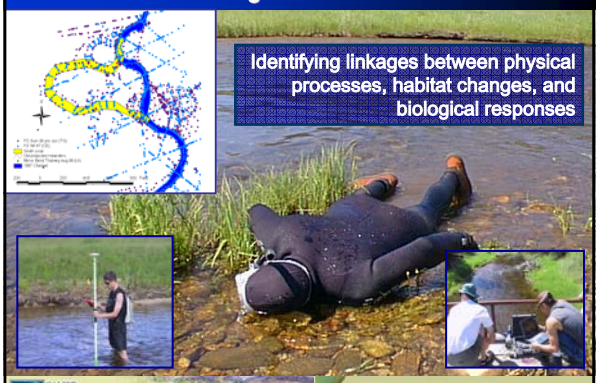
Why Use Models?

- Are we worsening flood or scour risk upstream or downstream?
- What is the inundation depth, duration and frequency on floodplains?
- What is the risk of stranding fish?
- What is the rate of change of flood elevation (e.g Cottonwood recruitment) ?
- Will my river continue to incise?
- How will the site evolve over time and how fast (limitations on rates of bank erosion)?
- How will the substrate change?
- How will the geomorphic characteristics change?
- Performance Assessment

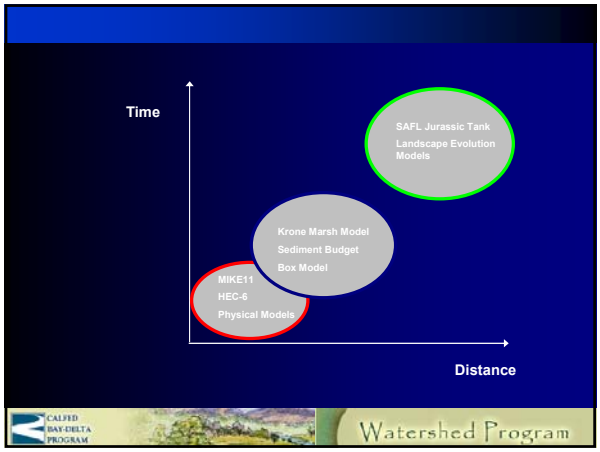
Monitoring and Evaluation



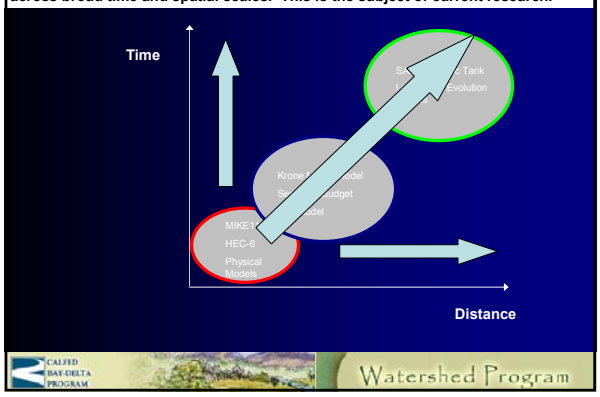
Challenges of ecological restoration monitoring

- Spatially-sparse, short-duration data sets
- Little or no pre-restoration data
- Detectable change from restoration is a small percentage of diurnal, seasonal, or inter-annual variability
- Effects occur at multiple spatial and temporal scales
- Individual restoration actions may have cumulative responses that are less predictable

Restoration goal	Typical restoration activity	Individual physical responses			Cumulative responses	
		Shear stress	Particle size	Thermal gain	Physical	Biological
"Restore channel geometry"	Reduce w/d	+	+	-	?	?
"Restore channel slope and sinuosity"	Increase length	-	-	+		



Model formulations, cumulative uncertainties in extending short time step models over long durations and computational limitations currently preclude extending across broad time and spatial scales. This is the subject of current research.



The Modeling Process

- Simulation - process to get the results
- Calibration - user compares the results of simulation with the real measurements and by the changing model parameters to try to get the best agreement. During the calibration the user of model should find the sensitivity of model on the numerical and empirical parameters but also on the input data. For mathematical models the calibration is a very important procedure. Without it the model cannot be used for prediction and evaluation of the project.
- Verification and validation - Verification is the second stage of calibration. The already calibrated model is used to simulated the different time event. If the calibration is well done the model have a similar result to the calibration period.

The accuracy of simulation depends on three factors:

1) accuracy of input data

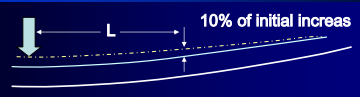
2) effectiveness of model parameters evaluation

3) inherent errors in the model

Model selection

- Question to be answered
- Quality of input data
- Quality of calibration data (response variables)
- Required accuracy
- Spatial scale of problem
- Budget

Characteristic Backwater Length



h = bankfull depth

$$L \sim \frac{h}{2S_o}$$

Reference:
P.G. Samuels, 1989. (December)
Procs of ICE. Research and Theory pp. 571-582

ASSESSMENT ⟷ MODEL

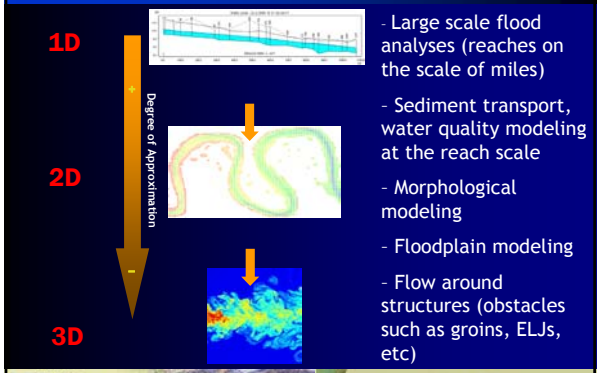
Significance Magnitude/Trend

Data To Knowledge

- MODEL - discipline knowledge
- ASSESSMENT

  Integration knowledge across relevant disciplines.
  Communication tool.
  Integrates local community.

WHICH DIMENSION FOR WHICH JOB?



- Large scale flood analyses (reaches on the scale of miles)
- Sediment transport, water quality modeling at the reach scale
- Morphological modeling
- Floodplain modeling
- Flow around structures (obstacles such as groins, ELJs, etc)

WHICH DIMENSION FOR WHICH JOB?

Choose the most appropriate tool to answer the questions...

DATA REQUIREMENTS

- Availability of data important in selection of model
- No point applying complex 3D if only cross section information is spaced at one mile intervals and is 10 years old!
- Should be sufficient data to:
  1. Understand recent historic evolution of channel
  2. Calibrate model based on recent hydrologic event
  3. Validate performance of model based on independent hydrologic event
  4. Verify predictions of model using post project data
  5. Confirm long term viability of project by establishing long term monitoring program

THE PROCESS OF MODELING

1. Model specification
2. Data assembly and verification
3. Model building
4. Model calibration and validation
5. Sensitivity testing
6. Model application to generate the required outputs

And Remember…

"All models are wrong; some are useful."
W. Edwards Deming

"It is better to be roughly right than precisely wrong."
John Maynard Keynes

Thank you for Your Attention

Conclusions

- A better way of integrating Science, Engineering and Policy
- Conceptual Models of Processes – mature but subject of research
- In future, broader issues such as pathogens, POPs, ecological integrity, climate change, carbon in our future planning as more is known.
- New sensor technologies will result in a major step forward in data-driven models
- Opportunities to leverage partnerships with the academic community (Community Science)

Water is the most critical resource issue of our lifetime and our children's lifetime. The health of our waters is the principal measure of how we live on the land"

— Luna Leopold