The Science and Practice of Restoration - Ghosts of Rivers Past, Present, and Future

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past – river “restoration”

civilization and rivers

- Mesopotamia - Tigris and Euphrates
- India - Ganges and Indus
- China – Yangtze and Yellow
- Europe – Rhine and Danube
- Sacramento – Sacramento River

goods and services of rivers

Rivers – transport water and materials across a landscape

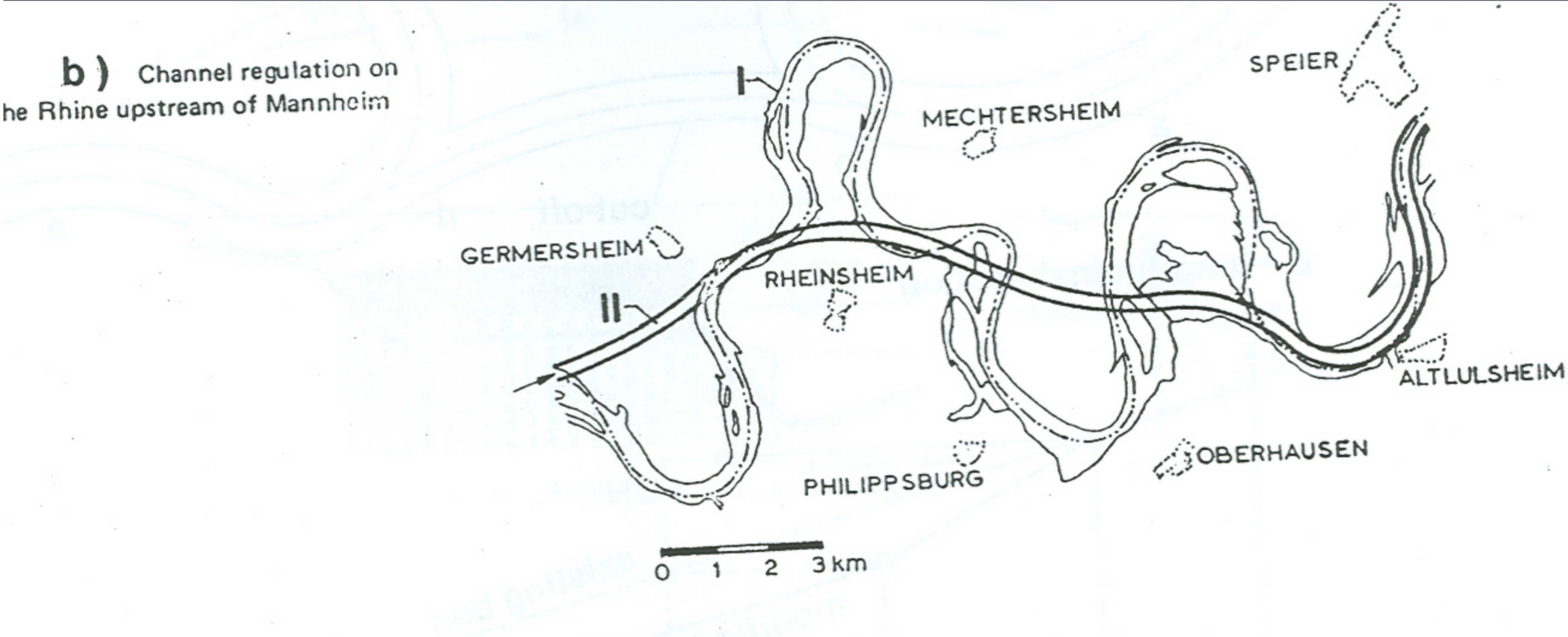
- water (agricultural, domestic, drinking)
- navigation
- power
- transportation of goods
- recreation

Agriculture accounts for nearly 70% of the water used throughout the world

disturbances and rivers

- flooding
- landslides and debris flows
- erosion and meandering

to optimize services provided by rivers and to limit disturbances, historical river engineering attempted to control rivers



Source: Yalin 1985

definitions

<u>River engineering</u>

- (Yalin 1985)– Stabilization and modification of river course, flood protection
- (Yang 1996) – “concerns itself with the transport of more or less large water masses through a landscape which it feeds or drains”

river ‘reclamation’ then and now

“the reclaiming of desert, marshy, or submerged areas or other wasteland for cultivation or other use” (circa 1936*)*

“when water is detained, infiltrated and transpired near to the where it falls, flood peaks are lowered ... high concrete walls in which they were confined can be replaced by vegetated embankments. Water quality is improved and wildlife returns to the river.” (circa 2007*)*

river engineering => river restoration

to improve the integrated ecological, economic, physical, and social conditions of a river *system*

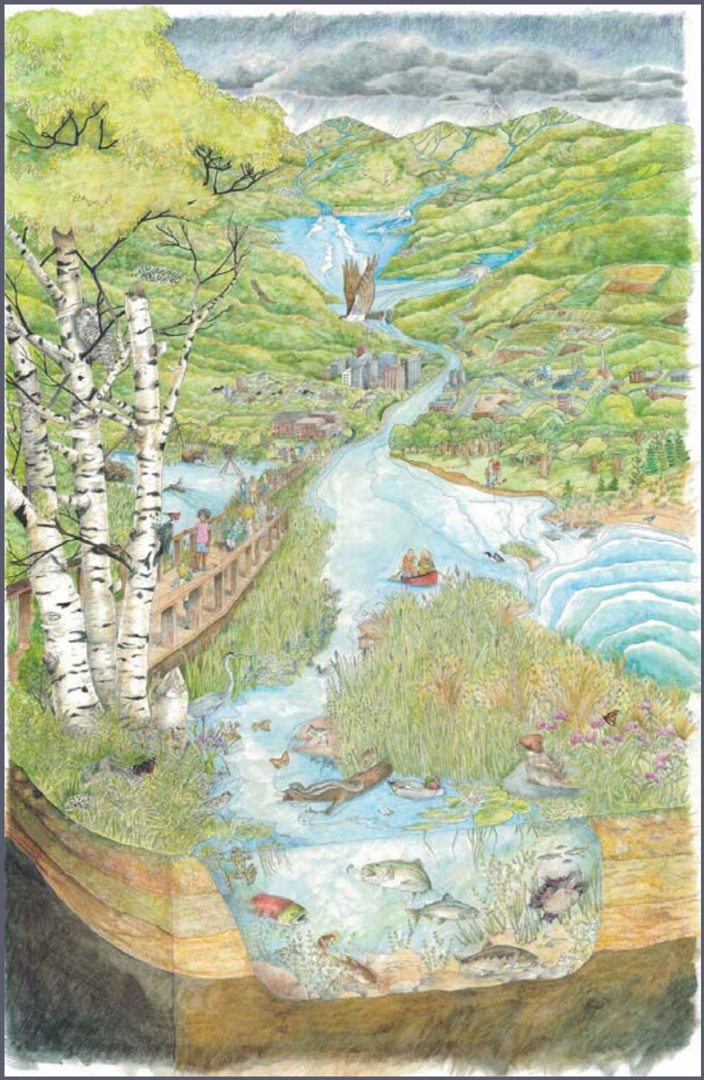


Image: canadian wildlife federation 2007

more definitions

Restoration, Rehabilitation, Reconfiguration, Reconstruction

- an attempt to return an ecosystem to its *historic*, predegradation trajectory (Society for Ecological Restoration 2002)

- return of a degraded stream ecosystem to a close approximation of its remaining natural potential (USEPA 2000)

Implications - In $$? In recovery?

present - river restoration

the most commonly stated goals for river restoration in the United States (Bernhardt et al. 2005):

- enhance water quality
- manage riparian zones
- improve in-stream habitat
- fish passage
- bank stabilization

current approaches to restoration

► environmental flows
► channel reconfiguration
► dam/barrier removal

restoration in california

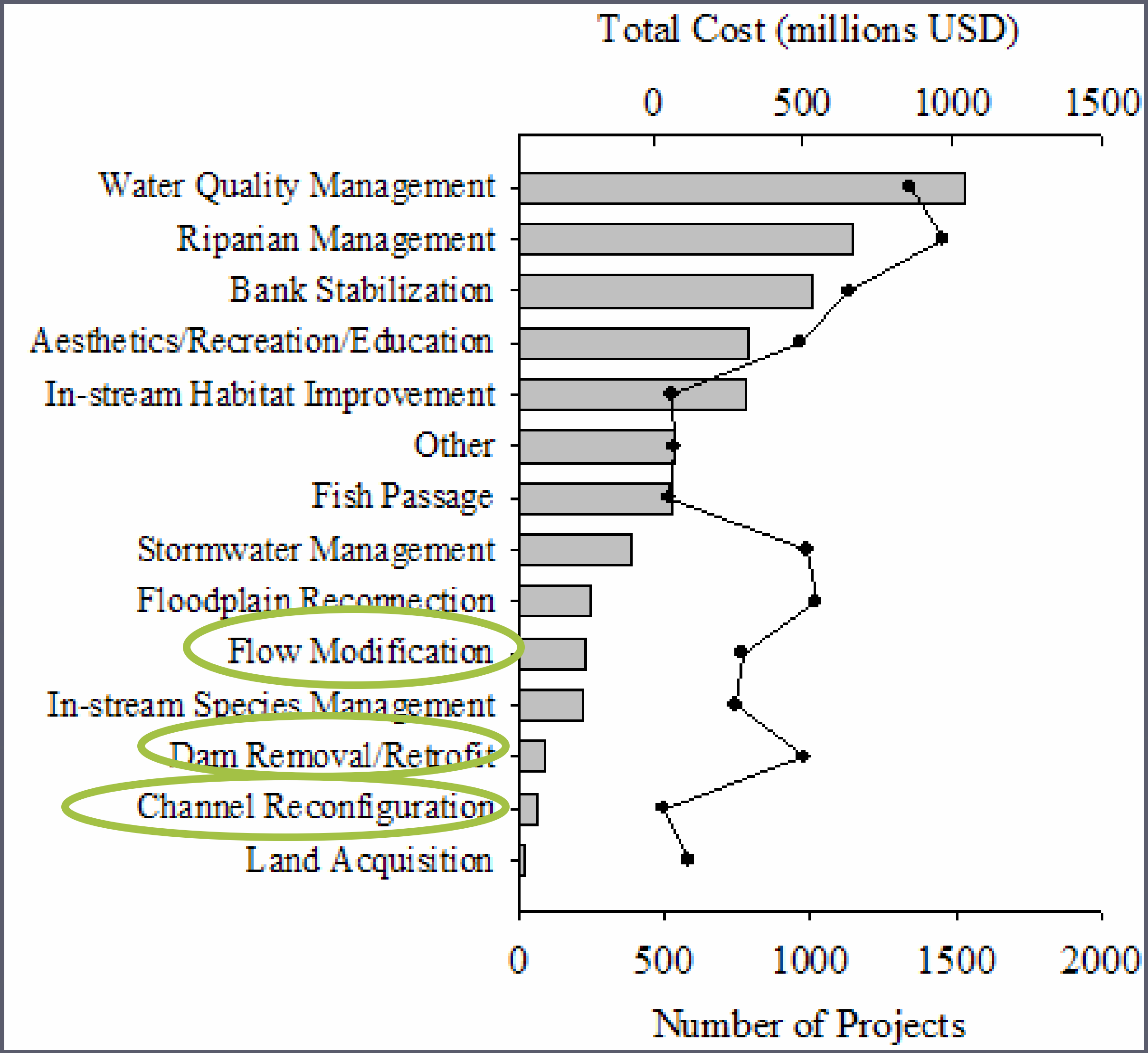


figure: NRRSS (2005) – see www.restoringrivers.org for detailed report

environmental flows

channel reconfiguration

dam removal

definitions

Environmental (instream, experimental) flows

- Reoperation of water infrastructure to provide the “acceptable balance between a desired ecosystem condition and other social and economic needs for water” (IUCN 2003) Water for everyone!?
- in practice
  - transports and resorts sediment, resets habitats, filters exotics
  - requires the integration of engineering, law, ecology, economy, hydrology, political science and communication.
  - requires negotiations between stakeholders over competing water uses
- tends to frame river within context of watershed

prescription development - past, present, and future?

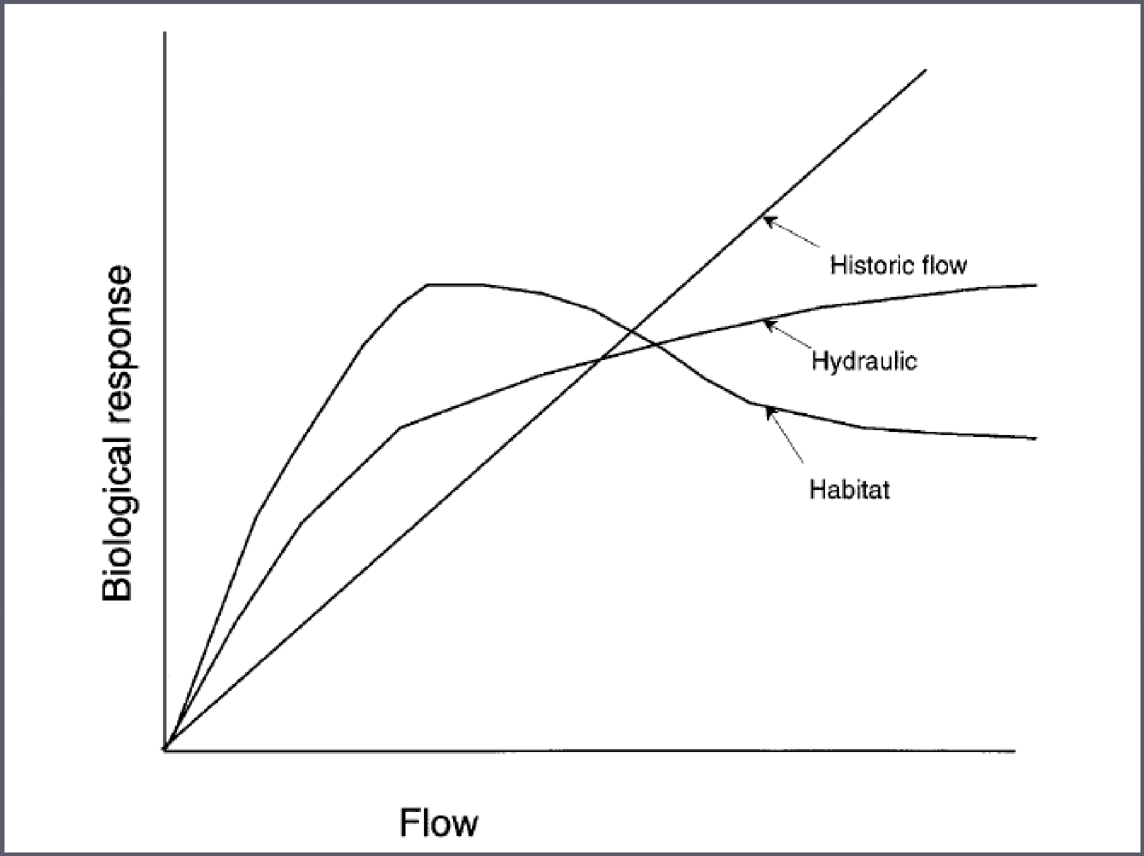


Image: Jowett (1997)

- Conflicts between recommendations?
- Goal of non-degradation of all instream resources

Upper Willamette River, Oregon - past, present, and future

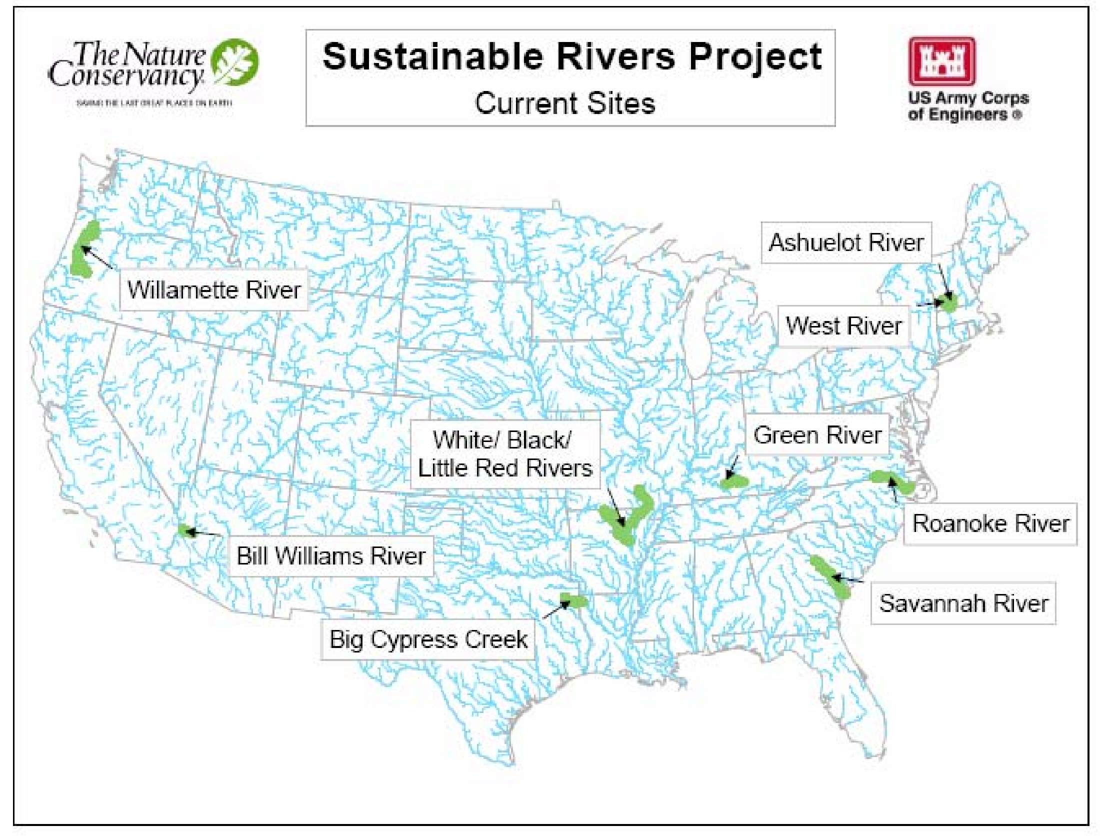
Chinook populations

past (1900) ~300,000
present (2005) ~50,000
future ???

Steelhead populations

past (1900) ~200,000
present (2005) ~5,000
future ???

TNC/USACE – Sustainable Rivers



- developed and tested a process for identifying and refining environmental flow objectives (Richter et. al. 2006)
- implementing recommendations as possible
- project could result in reoperation of up to 13 dams

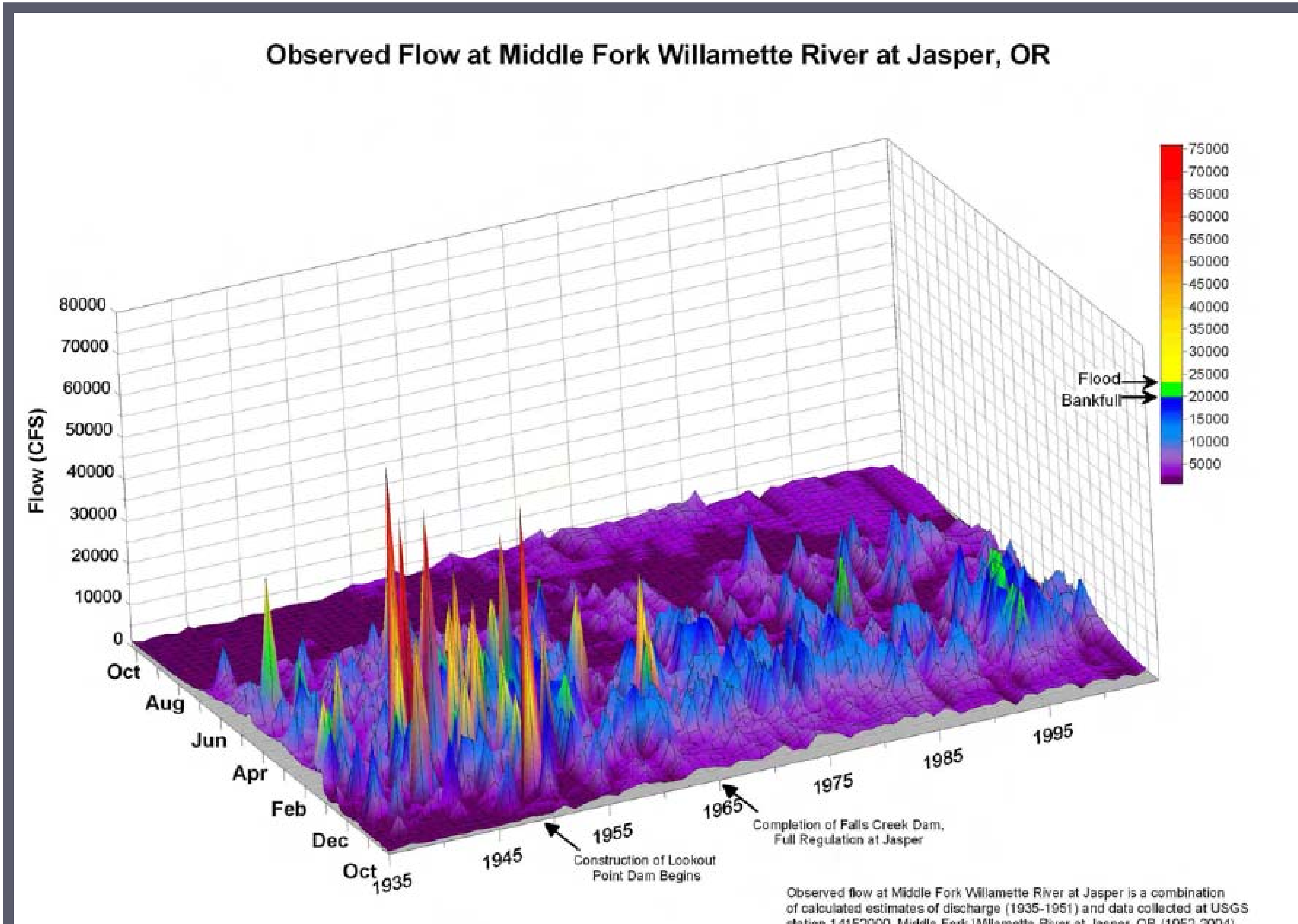


Image: Gregory et al. (2007)

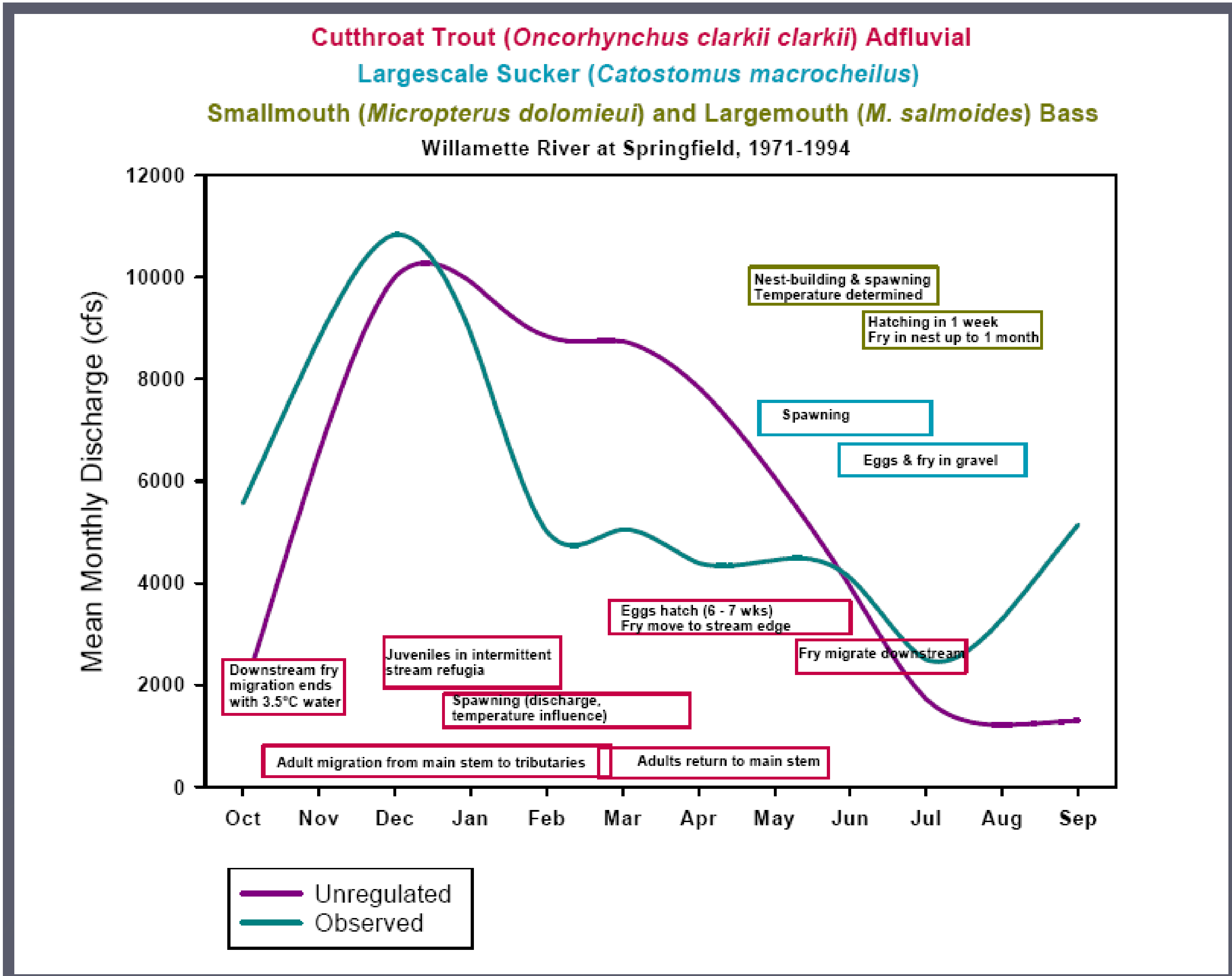
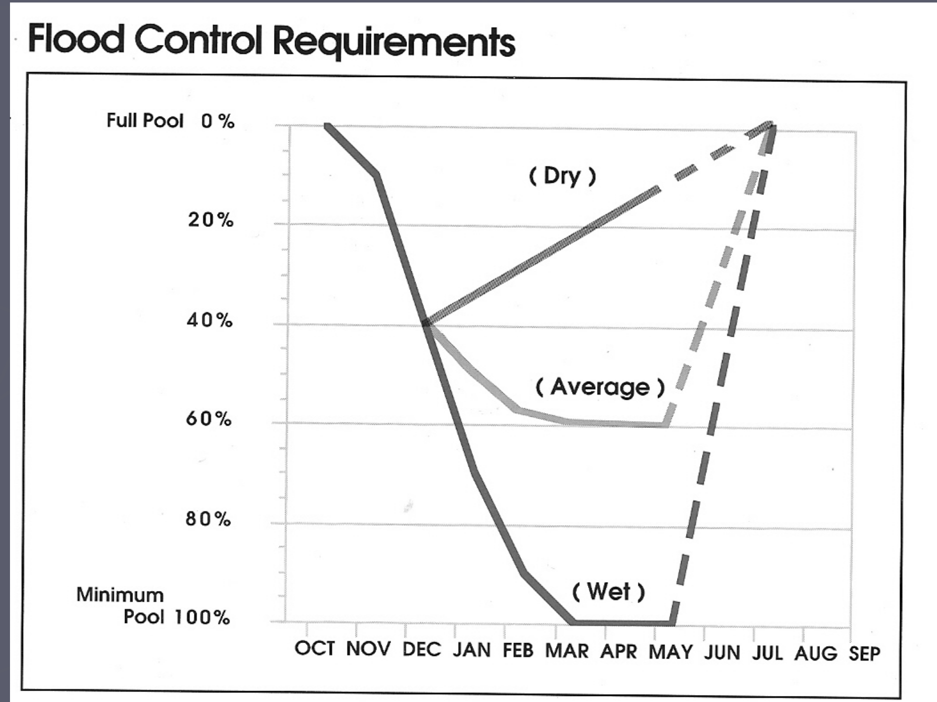


Image: Gregory et al. (2007)

flow prescriptions

- low flows (seasonal, annual and extreme low flows)
- high flow pulses (up to bankfull discharge)
- small floods (overbank flows, approximately 2- to 10-year return period)
- large floods (floodplain maintenance flows, > approximately 10-year return period)



The storage reservation diagram is one of the tools operators use to assure there is adequate flood control space in each reservoir. The diagram shown here specifies the amount of storage required to protect against a range of runoff forecasts, from a dry to a wet year.

environmental flows – Owen's River

"probably the most significant river restoration project in at least the Western United States, if not the entire country."*

- 65 miles of multi-purpose, river restoration –
  - allow some habitats to regenerate
  - seasonal water surges will push seeds beyond riverbanks
  - relieve tensions with Owen's valley
  - Owen's lake - "possibly the greatest or most intense human-disturbed dust source on Earth." (USGS)

*Nahai, Department of Water and Power

Photo: Daniel Mayer

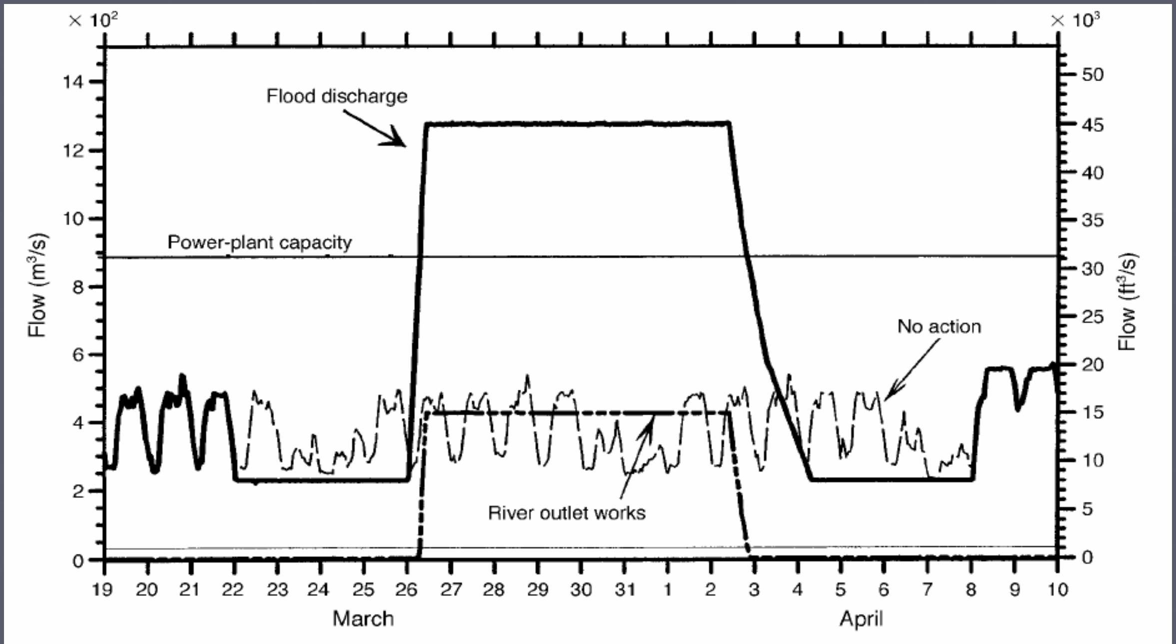
Photo: Don Kelsen

“experimental” flows – Colorado River

<u>1996 controlled flood experiment</u> (Patten et al. 2001)

- to test the hypothesis that controlled floods can improve sediment deposition patterns and alter important ecological attributes of the river ecosystem without negatively affecting other canyon resources

- learn more about river processes, both biotic and abiotic, during a flood event.



flood magnitude - < 1.25-yr recurrence, and only *10%* of the predam spring snowmelt floods

(Schmidt et al. 2001)

experimental flood – Colorado River

the lasting effect of this flood varied among different small-scale fluvial environments. (Schmidt et al. 2001)

Beneficial results:

- reworking fine but not coarse deposits
- Scoured return-current channels - important nursery habitats for the native fishery when baseflows are low
- Temporarily increased number and area of backwaters
- Fluvial marshes scoured
- Temporary inundation of riparian shrubs

Image: USGS (2005)

issues in flow recommendations

- Beecher (1990) stated that instream flow management should have clear, measurable goals, and that failure to do this would lead to controversy and achieve vague results.
- tendency to ignore natural complexity of hydrograph for prescriptive, operational, and simplified "rules" to address pressing river management issues (Arthington et al. 2006)
- prioritization of protected resource –
  - which resources and at what level?
  - who decides resource and level?
  - how is measurement of resource recovery operationalized?

performance evaluation of flow recommendations

- educated trial and error – large environmental experiments
- long term effects difficult to predict
- confounding effects of multiple releases

environmental flows

channel reconfiguration

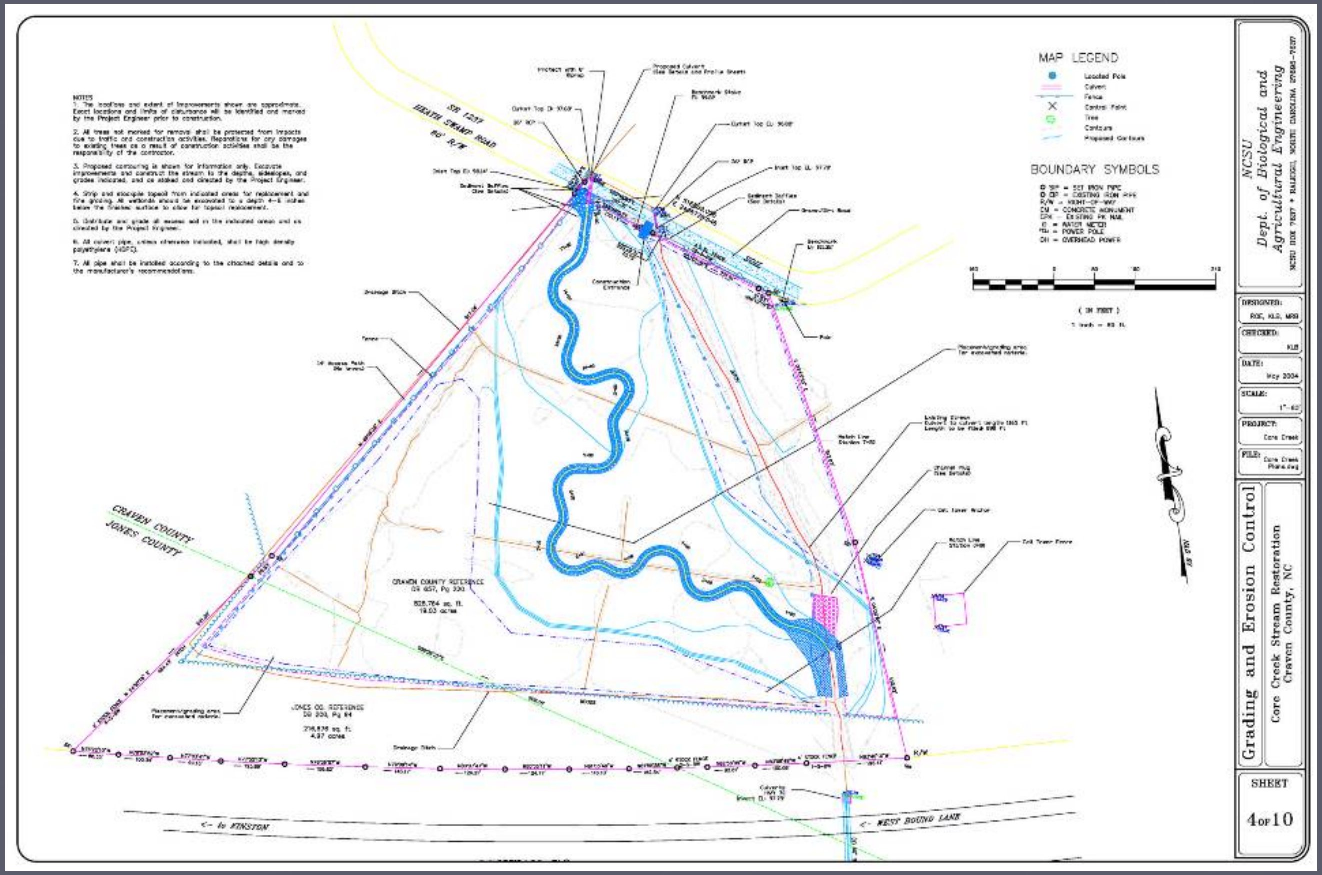
dam/barrier removal

channel reconfiguration

channel reconfiguration

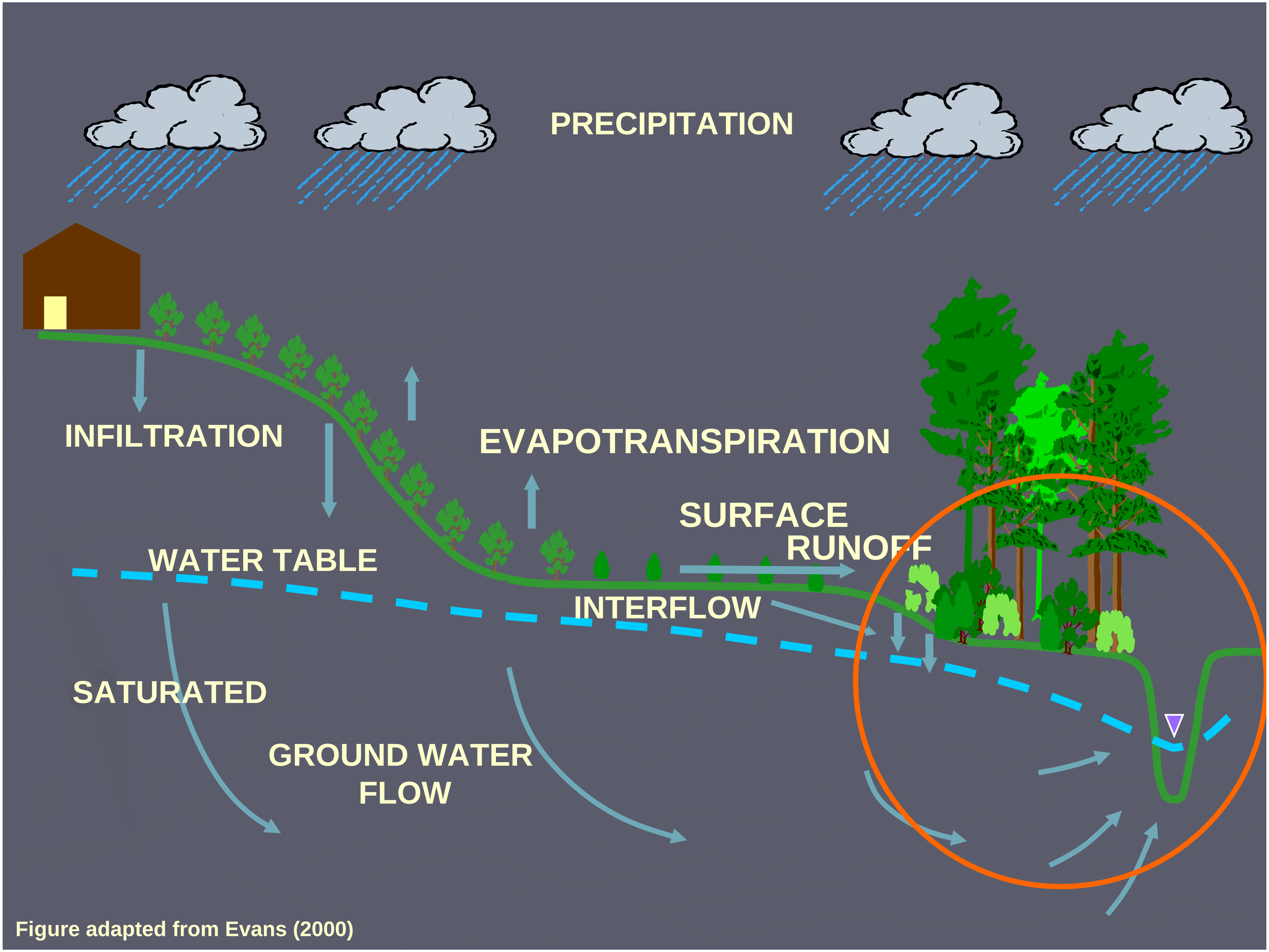
channel reconfiguration

"natural channel design"



natural channel design – the right direction

- generally focus on returning channels to more natural, “stable” morphological condition
  - as indicated by reference reaches or historical sediment and hydrology
  - dependent on design methodology and stakeholder interests


PRECIPITATION
INFILTRATION
EVAPOTRANSPIRATION
SURFACE
RUNOFF
WATER TABLE
INTERFLOW
SATURATED
GROUND WATER
FLOW
Figure adapted from Evans (2000)

river networks and scale

rivers transport the flow, sediment, and other materials *from the watershed*

towards a more “stable” condition – past, present, and future

- historical
- current reference
  - changing landscape and climate?
  - operationally, where the water, habitat, and biota are exposed to the lowest level of anthropogenic stressors (Stoddard et al. 2006).
- future condition
  - wide margins of ‘error’ for adaptability in extreme and uncertain atmospheric and regulatory climates
  - “passive” restoration
  - with integrative, watershed management, patience is a virtue

performance evaluation

- only 10% of projects reporting monitoring (Bernhardt et al. 2005)
- missed opportunities - large environmental experiments
- bio-monitoring is difficult, expensive
- “stable” pattern, profile, and dimension enough?

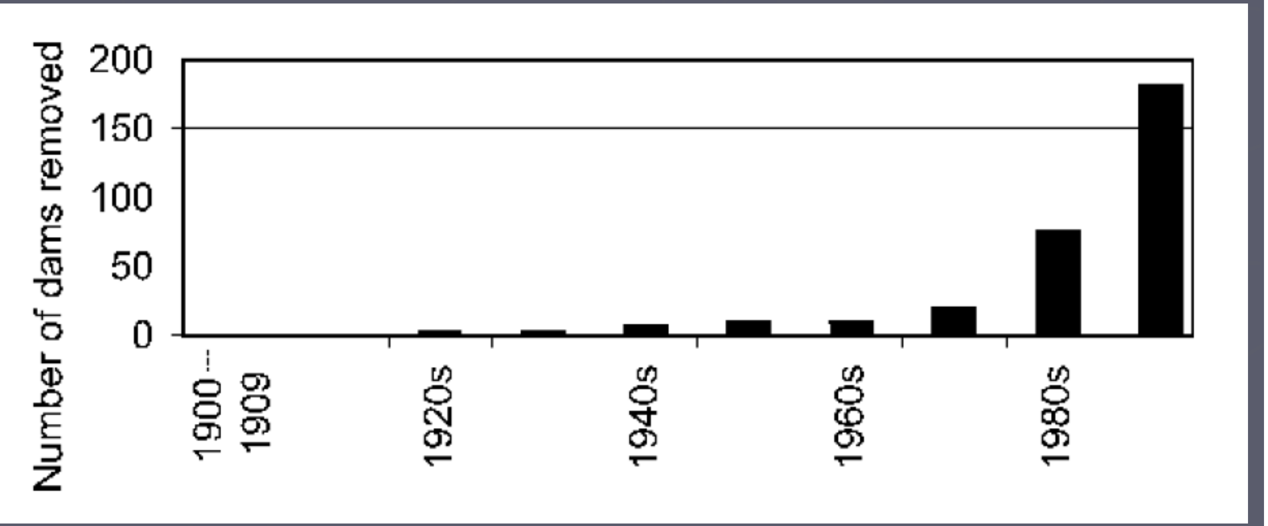
environmental flows

channel reconfiguration

dam removal

why dam removal?

- Federal Energy Resource Commission (FERC) relicensing hydropower projects at expiration of 30,50 year licenses
- 85% of dams in the US will reach the end of their working life by the 2020 (FEMA 1999)



(Heinz Center 2002)

- bonytail
- chub, thicktail **(EXTINCT)**
- goby, tidewater
- pupfish, Cottonball Marsh
- pupfish, desert
- pupfish, owens
- pupfish, tecopa **(EXTINCT)**
- salmon, chinook - California coastal ESU*
- salmon, spring-run chinook
- salmon, winter-run chinook
- salmon, coho - Central California ESU*
- salmon, coho - So. Oregon/No. California ESU*
- sculpin, rough
- smelt, delta
- splittail, Sacramento
- squawfish, Colorado (=Colorado pikeminnow)
- steelhead - Northern California ESU*
- steelhead - Central California Coast ESU*
- steelhead - South/Central California Coast ESU*
- steelhead - Southern California ESU*
- steelhead - Central Valley ESU*
- stickleback, unarmored threespine
- sucker, Lost River
- sucker, Modoc
- sucker, razorback
- sucker, santa Ana
- sucker, shortnose
- trout, Bull
- trout, Lahontan cutthroat
- trout, Little Kern golden
- trout, Paiute cutthroat
- tui chub, Cowhead Lake
- tui chub, Mohave
- tui chub, Owens

why dam removal?

Environmental governance changes - restoring continuums and reconnecting threatened and endangered fish to habitats upstream

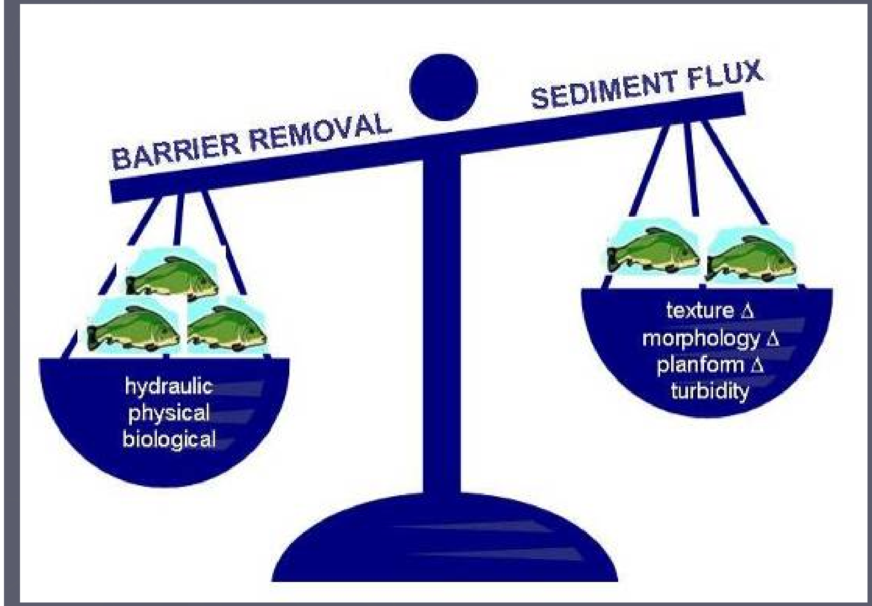
source: California Dept. of Fish and Game (2006)

dam removal as restoration

<u>restoration is:</u>

- reconnecting habitats and material transport
- releasing 18 M yds3 of sediment?

uncertainty about dam removal



geomorphic processes

biological responses

socio-economic issues

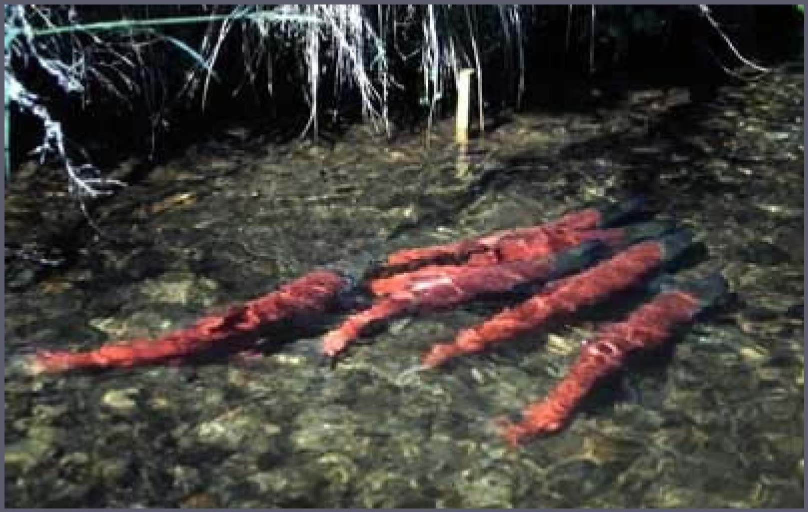
uncertainty in sediment effects

- When will the sediment be eroded downstream?
- Where will it go and how deep will it be?
- To what extent do fine sediment intrude interstitial gravels (spawning habitat) downstream?
- How does deposition affect flooding?
- How does the river channel change over space and time?

uncertainty in physical-biological links

- when and how many more fish?
- short-term vs. long term effects of sediment and barrier?
- food web interactions?

?



uncertainty in socio-economics

Health and Social Well-Being Impacts	Quality of the Living Environment (Livability) Impacts	Economic Impacts and Material Well-Being Impacts	Cultural Impacts	Family and Community Impacts	Institutional, Legal, Political, and Equity Impacts
Uncertainty – being unsure about the effects or meaning of the dam removal	Perceived and actual quality of the living environment	Standard/Cost of living	Cultural integrity – degree to which local culture is respected and likely to persist	Changes in social networks	Workload and viability agencies – capacity of formal institutions to handle additional workload generated by dam removal
Feelings about the removal that may result in formation of interest groups	Leisure and recreational activities and opportunities	Access to public goods/services	Experience of being culturally marginalized – e.g., structural exclusion of certain groups	Changes in demographic structure of the community	Changes in land ownerships, tenure, or legal rights
Annoyance – experiences due to disruption of life	Aesthetic qualities	Property values – real estate sales	Loss of cultural or natural heritage –areas of cultural or recreational value	Community identification and connection – sense of belonging, attachment to place	Participation in decision-making
Dissatisfaction – due to failure of removal to deliver promised benefits	Environmental quality and amenity value – the non-market, non-consumptive aesthetic and moral value subscribed to dam removal site	Occupational status and type of employment - temporary local jobs generated by the project		Perceived and actual community cohesion	Access to and utilization of legal procedures and advice throughout project

reducing uncertainty – small dam removal

field and modeling studies at OSU

- methodology –develop and test methods of detectible effects vs. measurement errors?
- predictability – how do relationships between valley network and dam characteristics influence and scale with channel responses?
- recover – for how long (space and time) is the sediment signal of dam removal detectable downstream?

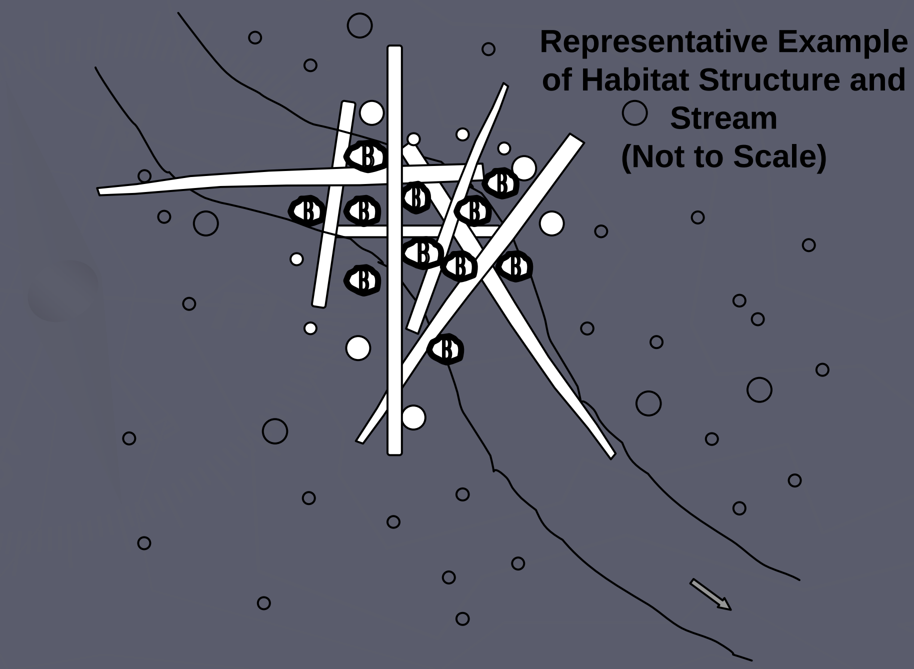
reducing uncertainty – effects of "intervention"

field and modeling studies on Coal Creek dam

Height: 27'

Constructed: 1950s

Removed: 2007



future – river restoration

the future of river management

1. Beyond band-aids
2. Learning from environmental experiments
3. Embracing an uncertain climate

Image: WWF (2007)

(1) beyond band-aids

Are restoration activities patching symptoms or addressing sources?

Are patches the silver bullet to ecological recovery?

?

band-aids for...

reaches with:

- distinct and clear impact sources
- few other factors limiting recovery
- numerous benefits and stakeholders
- hypothesis testing at short time and spatial scales
- public participation and engagement

may need a full body cast...

watershed-ecosystem restoration of:

- hydrology
  - Magnitude
  - Frequency
  - Timing
  - Duration
  - rate of change
  - predictability of flow events
- materials
  - Sediment
  - Wood
  - Organisms
  - Nutrients, metals, hydrocarbons
  - Organic matter

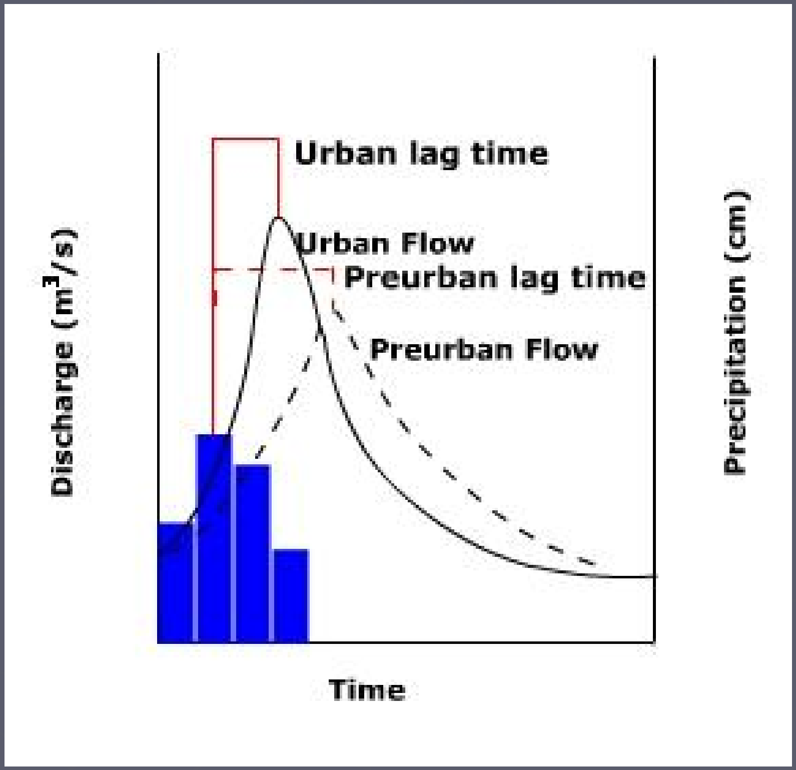


figure: www.uwsp.edu

watershed-reach interactions

(2) Learning from environmental experiments

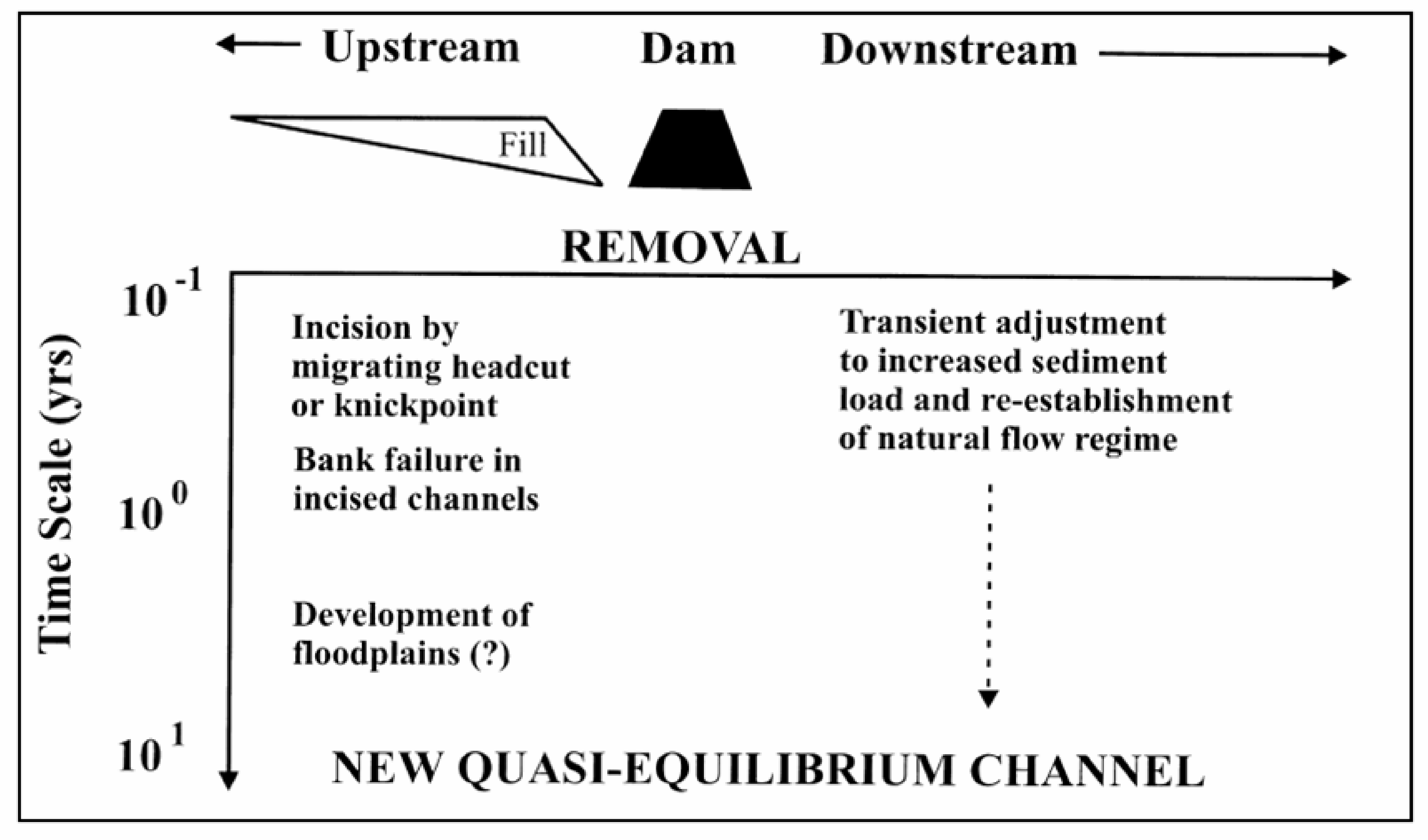
Advantages

- broad scale trend development
- validation of conceptual and numerical models
- identification of dominant processes and scales
- real-world examples and observations

Disadvantages

- uncontrolled – challenges in hypothesis testing
- spatial and time frames for expectations and recovery are unpredictable
- risk – of wasting money, damaging infrastructure, being wrong...

large scale experiments



Hart et al. (2002)

(3) embracing an uncertain climate

future of river mgmt?

WGI – summary for policy makers

- "the likely amount of temperature and sea level rise varies greatly depending on the fossil intensity of human activity during the next century"

future of river mgmt?

WGII - Impacts, Adaptation and Vulnerability

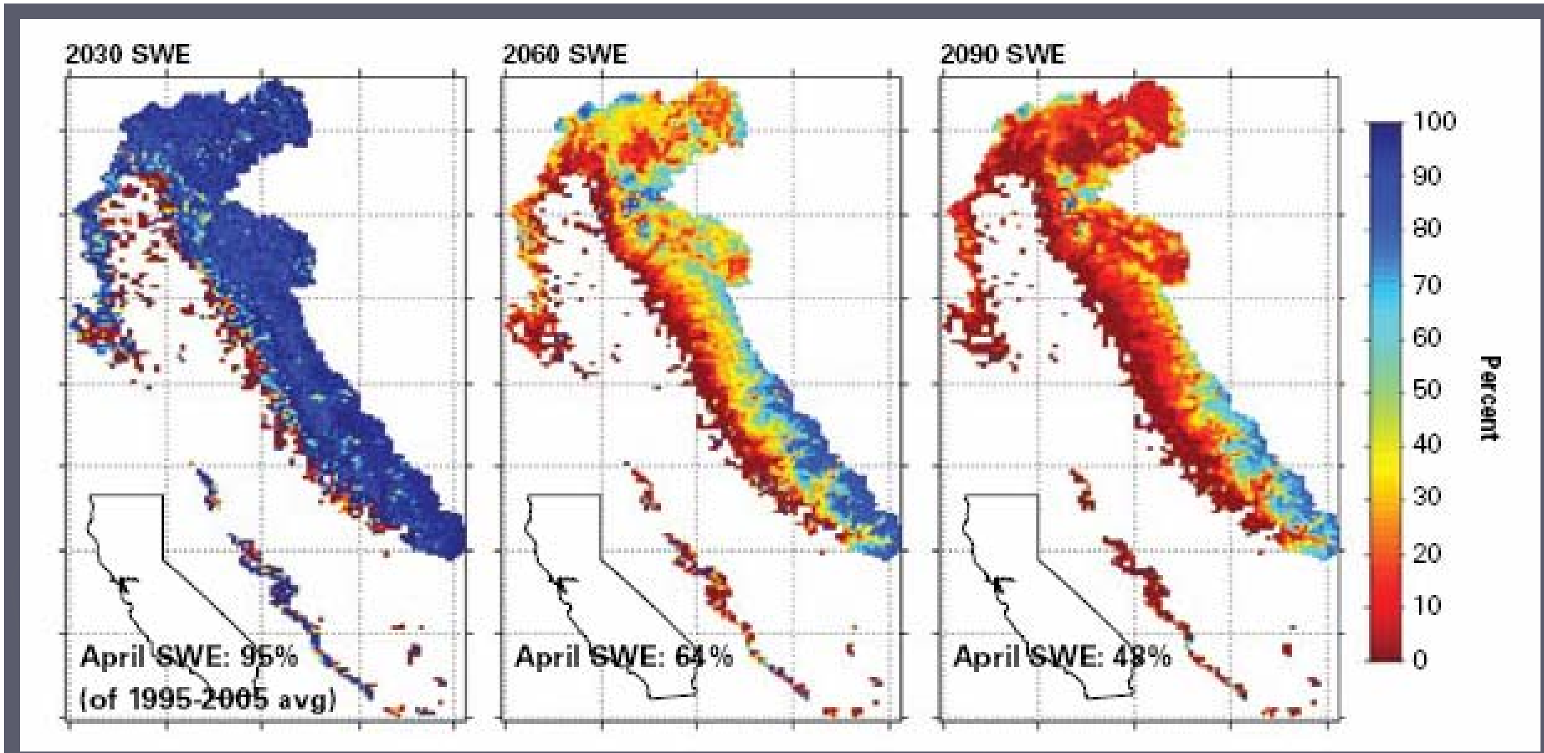
Fresh water resources and their management

- Drought-affected areas will likely increase in extent.
- Heavy precipitation events, which are very likely to increase in frequency, will augment flood risk

climate, energy, and water – California (pop=36M)

- by 2020, CA will experience water shortages of 2.4 million acre-feet
- “Climate change has the potential of affecting ... water supply, hydroelectric power, sea level rise, more intense precipitation events, water use, and a number of miscellaneous items which include water temperature changes.”*

*Maurice Roos, California’s state hydrologist - NRDC (2007)

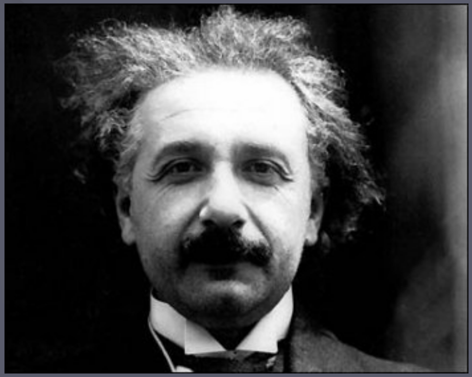


Source: Knowles and Cayan (2002)

Schwarzenegger pushes 2008 ballot measure for $4.5B in bonds for new water storage in California
(*NY times*, 04.04.07)

history repeating itself?

- HISTORY, n. an account mostly false, of events mostly unimportant, which are brought about by rulers mostly knaves, and soldiers mostly fools. (Ambrose Bierce)



- No problem can be solved from the same level of consciousness that created it. (Albert Einstein)

closing thoughts

the river why

with so much uncertainty in river restoration...

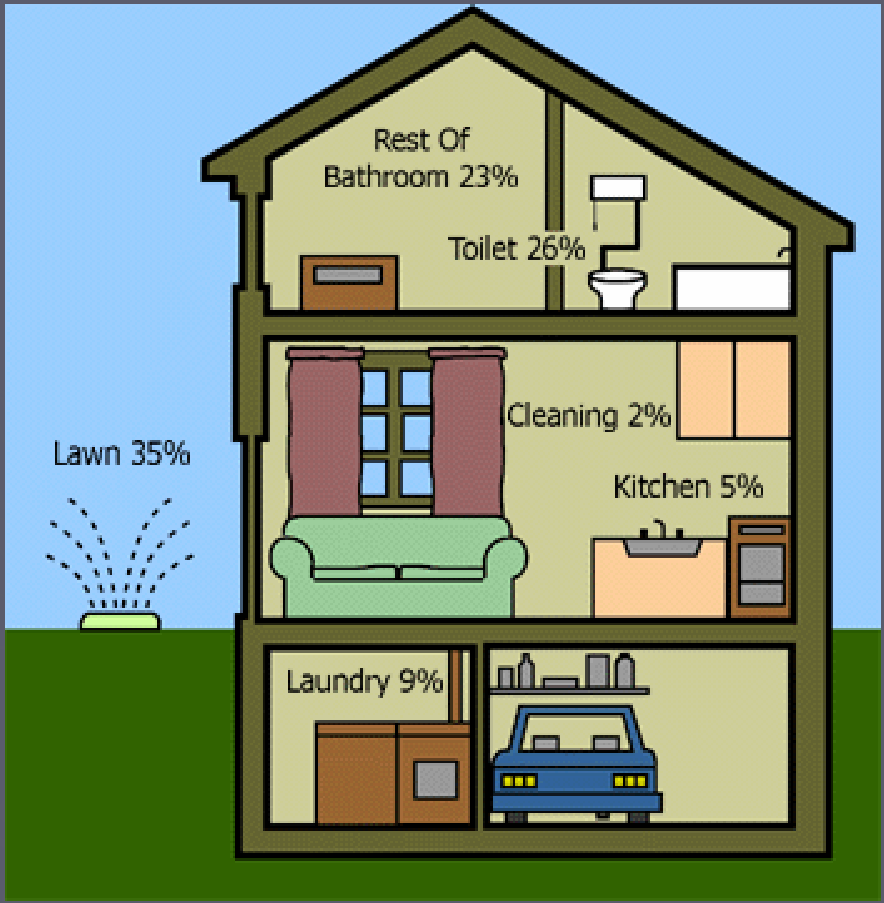
- complex network interactions
- large environmental experiments
- future climate conditions

why not conservation?

conservation of river ecosystems

Images: wikipedia

water quantity conservation



www.texasep.org/index.html

the "do nothing" option – no longer an option

source: USGS 2004

visions of future rivers

- put conservation first.
- put integrated watershed management first.
- put sustainable, educational, and informative restoration first.

demonstrated success – Yolo Bypass

Integrated flood management:

- Flood control
- Habitat for native fish and migratory birds
- Agricultural production

image: WCD (2007)

questions?

Photograph: Russell Lee (1941)

"Thousands have lived without love, not one without water."
-- W. H. Auden