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Managing Water in the West

Subcommittee on Sedimentation Draft Sediment Analysis Guidelines for Dam Removal

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U.S. Department of the Interior
Bureau of Reclamation

Sedimentation and River Hydraulics Group

Acknowledgments

- Subcommittee on Sedimentation Member Organizations
- American Rivers
- California Department of Fish & Game
- Michigan Department of Environmental Quality
- Pennsylvania Fish and Boat Commission

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Acknowledgments (continued)

- Universities
  - U of Mississippi
  - Oregon State U
  - U of Montana
  - U of South Carolina
  - U of Virginia
  - National Center for Earth-Surface Dynamics
- Consultants
  - Inter-Fluve
  - Milone & MacBroom
  - Princeton Hydro
  - Stillwater Science
  - West Consultants

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Secretary of the Interior

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Assistant Secretary for Water and Science

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Advisory Committee on Water Information

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Subcommittee on Sedimentation (SOS)

Subcommittee on Sedimentation (SOS) Purpose

- **Promote collaboration on:**
  - **sediment issues**
  - **advances in information gathering, storing, and sharing**
  - **decision making about natural resources management and environmental protection**

http://acwi.gov/sos/

Subcommittee on Sedimentation Members

- Agricultural Research Service
- American Society of Civil Engineers
- Bureau of Land Management
- Bureau of Reclamation
- Colorado Water Resources Research Institute
- Federal Highway Administration
- National Center for Earth-surface Dynamics
- National Marine Fishery Service
- National Park Service
- National Resources Conservation Service
- Office of Surface Mining
- Universities Council on Water Resources
- U.S. Army Corps of Engineers
- U.S. Environmental Protection Agency
- U.S. Forest Service
- U.S. Geological Survey

There are nearly 82,700 major dams in the United States (National Inventory of Dams, 2009)

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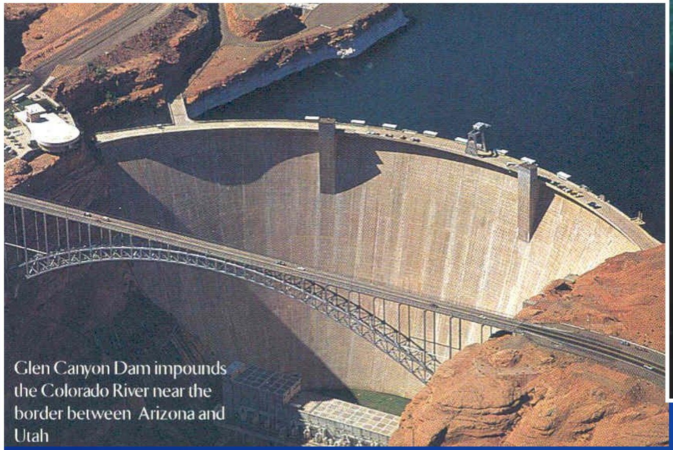
Dams come in a variety of sizes, they serve a variety of purposes, and they have a variety of environmental effects.


Glen Canyon Dam impounds the Colorado River near the border between Arizona and Utah

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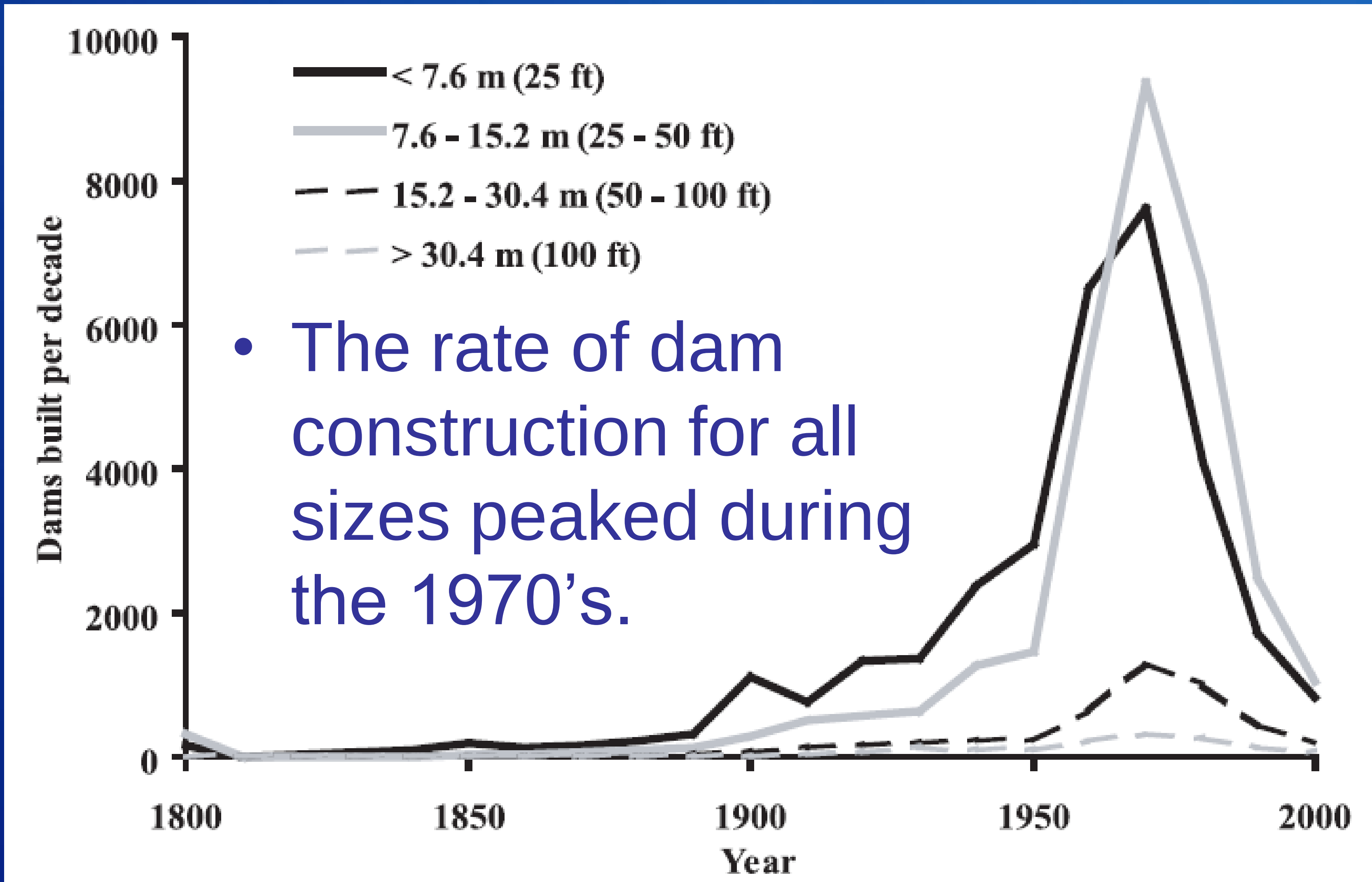
History of U.S. Dam Construction



- The rate of dam construction for all sizes peaked during the 1970’s.

Heinz Center, 2002

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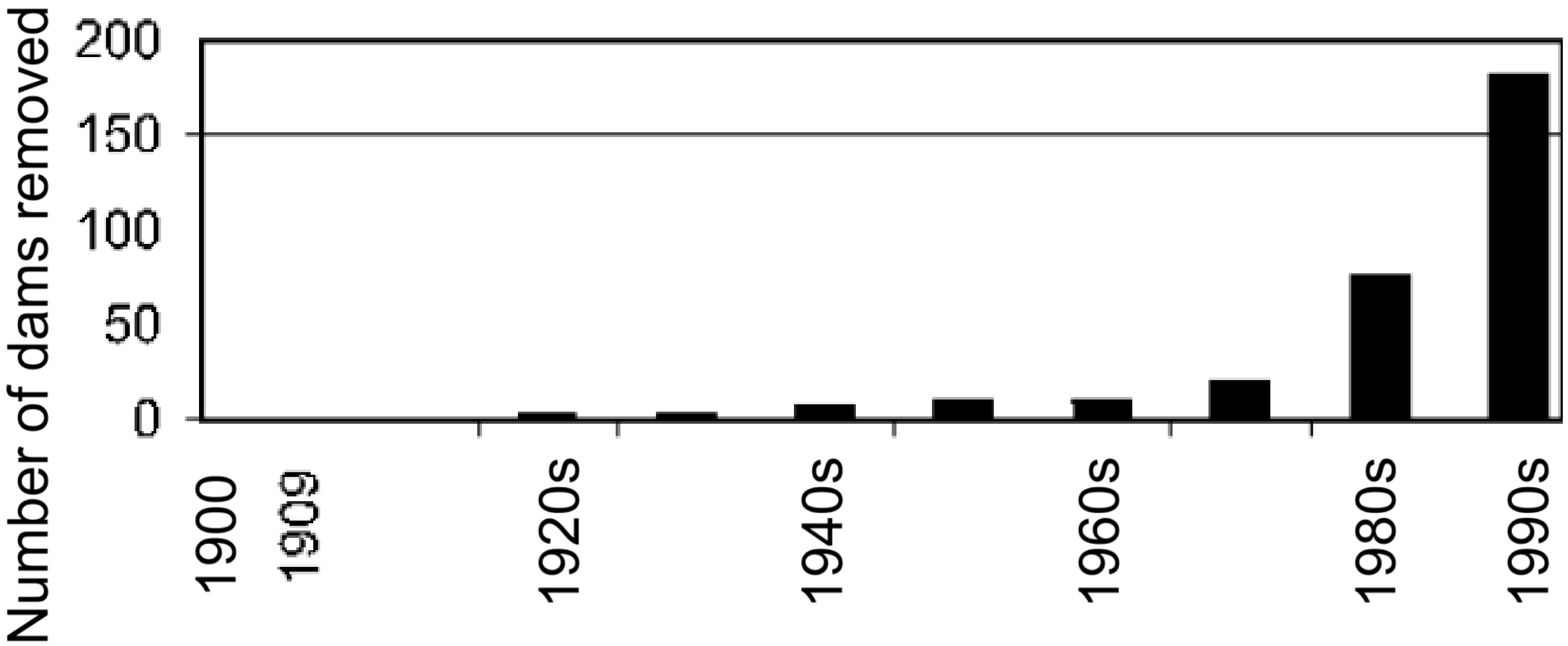
History of U.S. Dam Removal

~860 dams removed as of 2010



Heinz Center, 2003

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Reasons for Dam Removal

- Eliminate safety hazards and liability
- Provide for fish and boat passage
- Restore rivers and their ecosystems

Common Factor

- In nearly all dam removal cases, the original purpose of the dam was no longer being served or the present function of the dam could be met through other means.

Dam Removal Challenges

- Policy
  - Loss or replacement of project benefits
  - Cultural or historical significance
- Funding
- Technical
  - Structural integrity during removal
  - Diversion and care of stream and habitat
  - Reservoir sedimentation and downstream impacts to water quality and river channel
  - Uncertainty

U.S. Dam Removal Science Initiatives

- Heinz Center for Science, Economics and the Environment
  - Dam Removal: Science and Decision Making (2002)
  - Dam Removal Research Status and Prospects (2003)

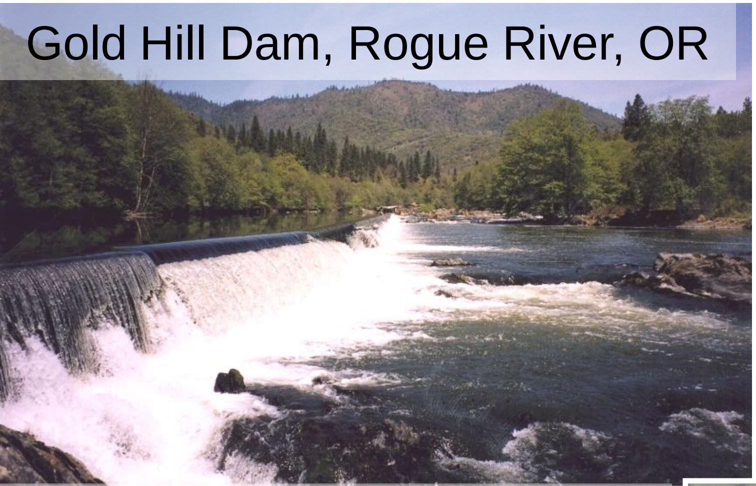
U.S. Dam Removal Guidelines

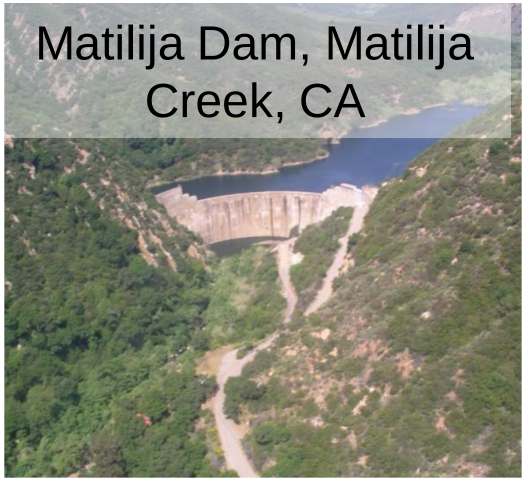
- American Society of Civil Engineers
  - Guidelines for Dam Decommissioning (1997)
  - Monograph on Sediment Dynamics upon Dam Removal (2011)
- Aspen Institute (Policy Guideline)
  - Dam Removal - A New Option For a New Century (2002)
- U.S. Society on Dams
  - Guidelines for Dam Decommissioning Projects (2012)

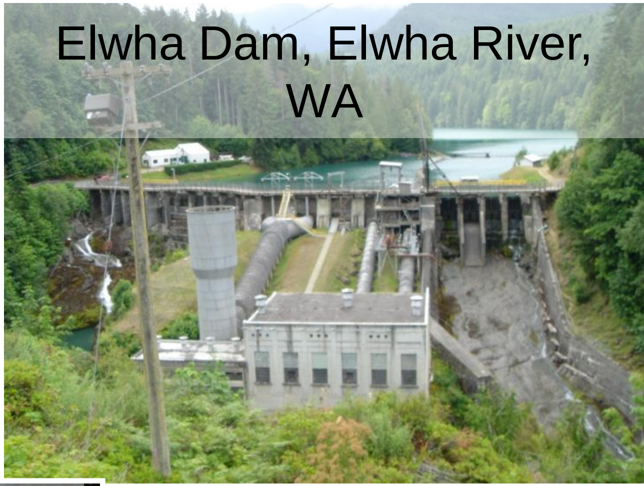
U.S. Dam Removal Initiatives

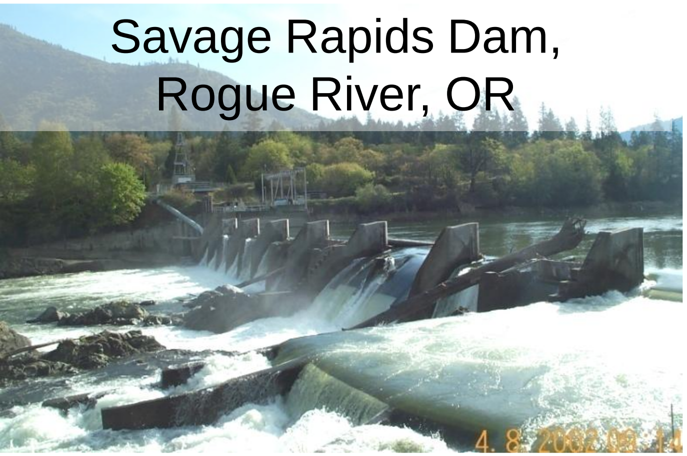
- Various state-level requirements
- American Rivers (non-profit organization)
  - Technical advice and support for dam removals
- University of California at Berkeley
  - Clearing House for Dam Removal (website)

Sediment guidelines are needed for a wide range of dam removals

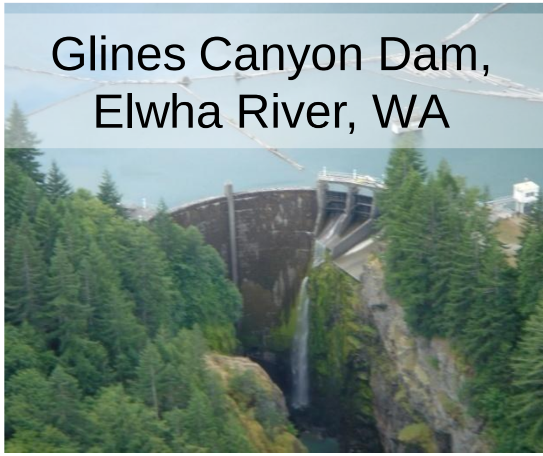

Gold Hill Dam, Rogue River, OR


Matilija Dam, Matilija Creek, CA

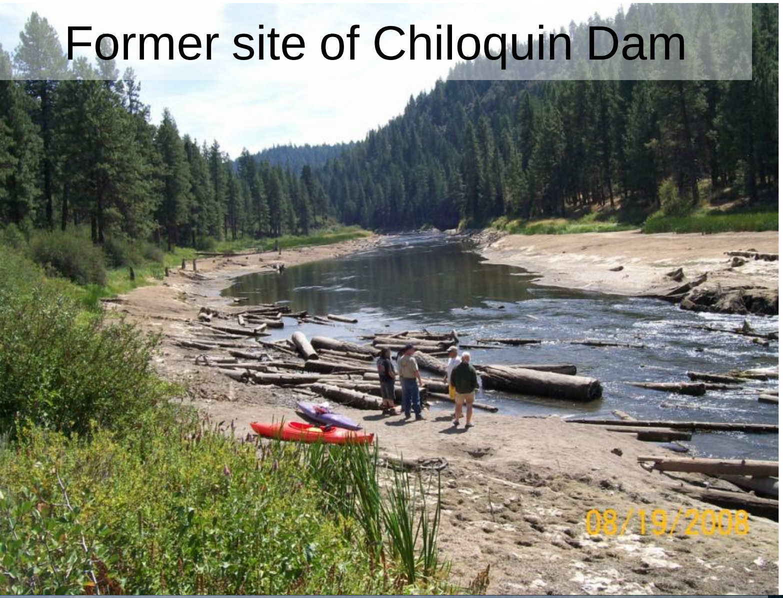

Elwha Dam, Elwha River, WA


Savage Rapids Dam, Rogue River, OR


Chiloquin Dam, Sprague River, OR


Glines Canyon Dam, Elwha River, WA

And a wide range of sediment issues



Former site of Chiloquin Dam


Reservoir sediment behind Matilija Dam


Reservoir sediment in Lake Mills behind Glines Canyon Dam

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Potential Sediment Issues

- Reservoir restoration
- Temporary increase in suspended sediment concentration and turbidity
- Riverbed sediment deposition
  - increased flood stage
  - temporary impairment of habitat
- Sediment burial of water intakes
- Release of contaminants
- Wood and other debris
- Downstream coastal deltas
- Downstream reservoirs

Intake sedimentation

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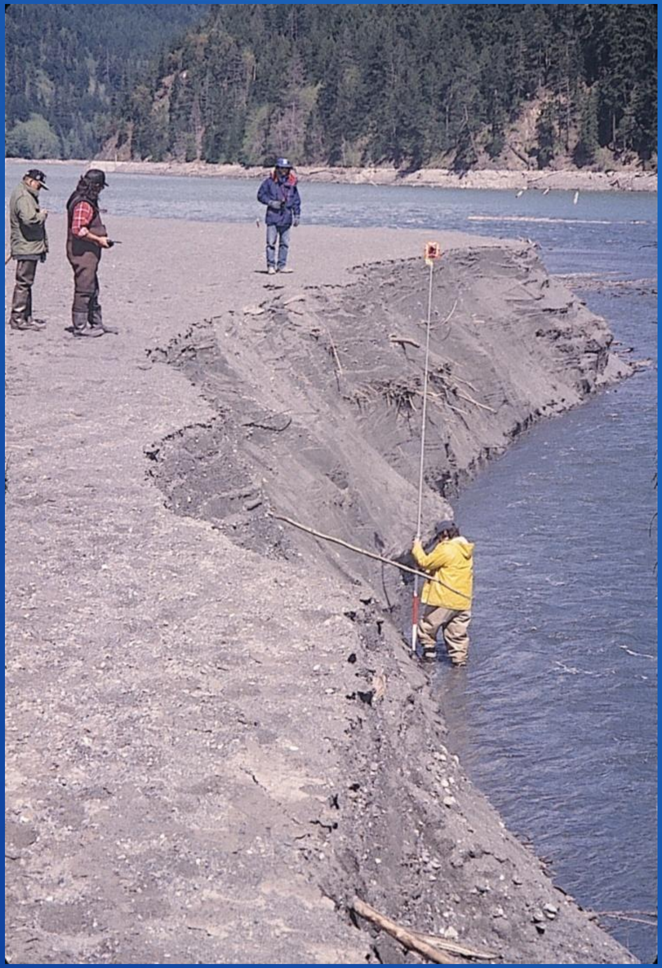
Variables Affecting Sediment Impacts

- Reservoir sediment mass, size gradation, quality (contaminants), and spatial distribution
- Extent and rate of reservoir sediment erosion
- Tolerance and adaptability of sensitive species
- Sensitivity of critical infrastructure to
  - Sediment blockage at water intakes
  - Water quality for specific users
  - Flood protection



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Subcommittee on Sedimentation Guideline Objective

- Provide a decision framework to determine the level of assessment needed to evaluate dam removal sediment impacts.
  - data collection
  - predictive analysis
  - modeling
  - monitoring

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Workshops were used to help develop the guidelines

- National experts were invited to two workshops
  - Government
  - Universities
  - Consultants

Workshop in Portland, Oregon
October 14 - 16, 2008

Field Trip to Marmot Dam

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Workshop in State College, Pennsylvania, October 27 - 29, 2009



Field Trip to McCoy Dam

Key Concepts

- Ability to use guidelines iteratively
  - Start with easily available data and assume full & instantaneous removal (worse case impact scenario)
  - Where warranted, collect more data and perform more complex analysis
  - Revisit predictions and revise analysis and monitoring plan as needed
- Compare impacts to background sediment conditions (dynamics) within current setting

Key Concepts

- Not all sediment is bad!
  - Include benefits from sediment releases as well as impacts

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Guideline Steps

Understand Dam Removal Project Goals and Objectives

- Meet with stakeholders to determine project goals and objectives.
  - Fish and boat passage
  - Dam site and historic preservation
  - Reservoir topography and vegetation
  - Downstream sediment load and water quality

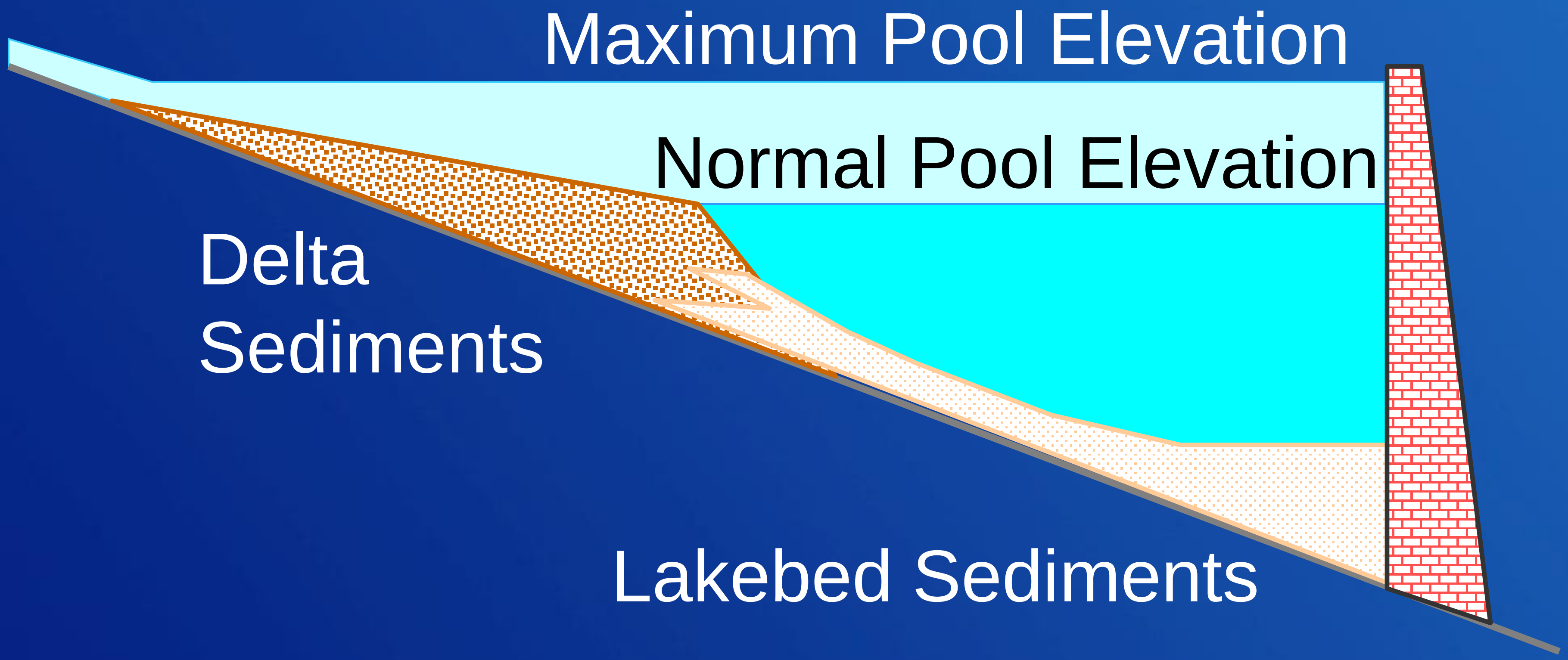
Reconnaissance and Data Gathering

- Dam history (construction and operation)
- Watershed and streamflow
- Reservoir-pool and stream-channel size
- Reservoir sedimentation history
- Sediment impact concerns
  - Short and long-term concerns
  - Site-specific and reach-scale concerns

Characterize Reservoir Sediment

- Reservoir sediment volume
- Sediment 3D spatial distribution
- Grain size (gravel, sand, silt, clay)
- Sedimentation history, including sluicing or dredging
- Structures or debris buried in the sediments

Reservoir Sedimentation



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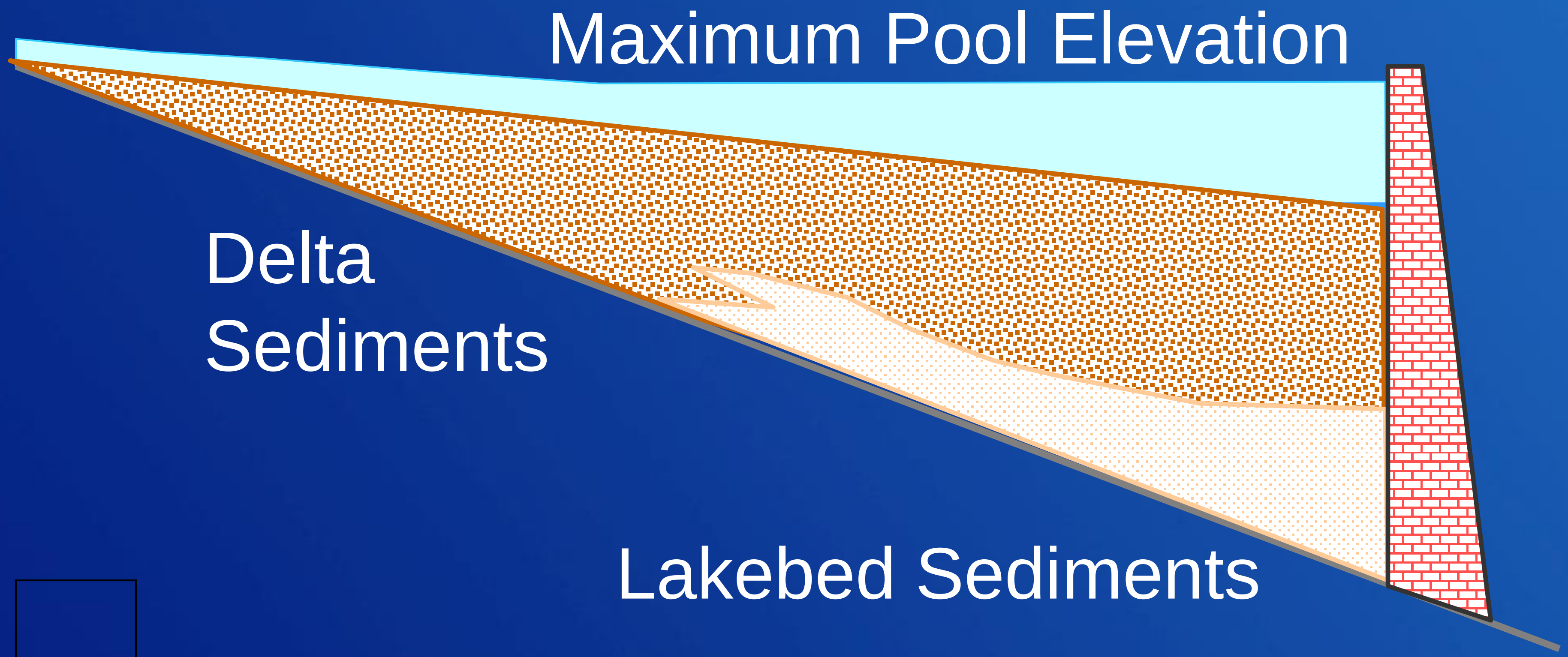
Reservoir Sedimentation



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Assess For Contaminants

- Historical land use activities
  - Likely contaminants?
  - Prior sediment sluicing or flushing?
  - Present upstream contaminant sources?
- Contaminant testing requirements
  - Screening level sampling
  - Definitive survey

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Scale the reservoir sediment volume to the stream's annual sediment load.

- Scale the coarse and fine sediment volumes separately
- Estimate the amount of sediment that can be eroded
- Re-check the sediment scale

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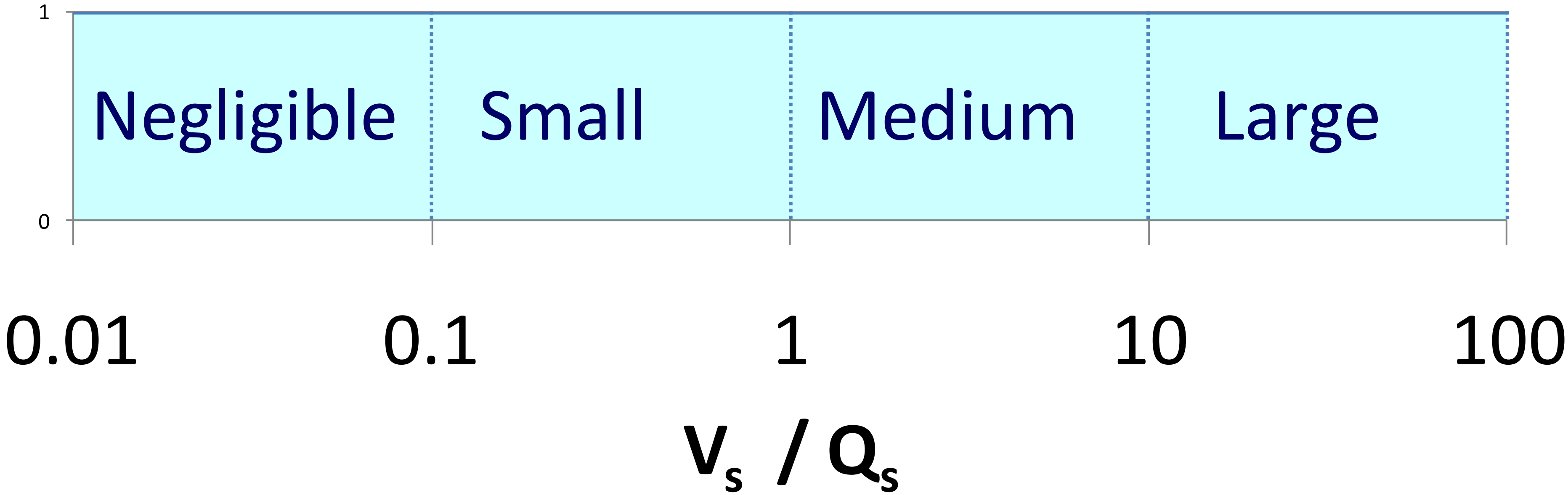
Reservoir Sediment Volume (V_s) Relative to the Average Annual Sediment Load (Q_s)



- Average annual sediment load based on
  - downstream transport capacity for coarse sediment
  - upstream supply for fine sediment

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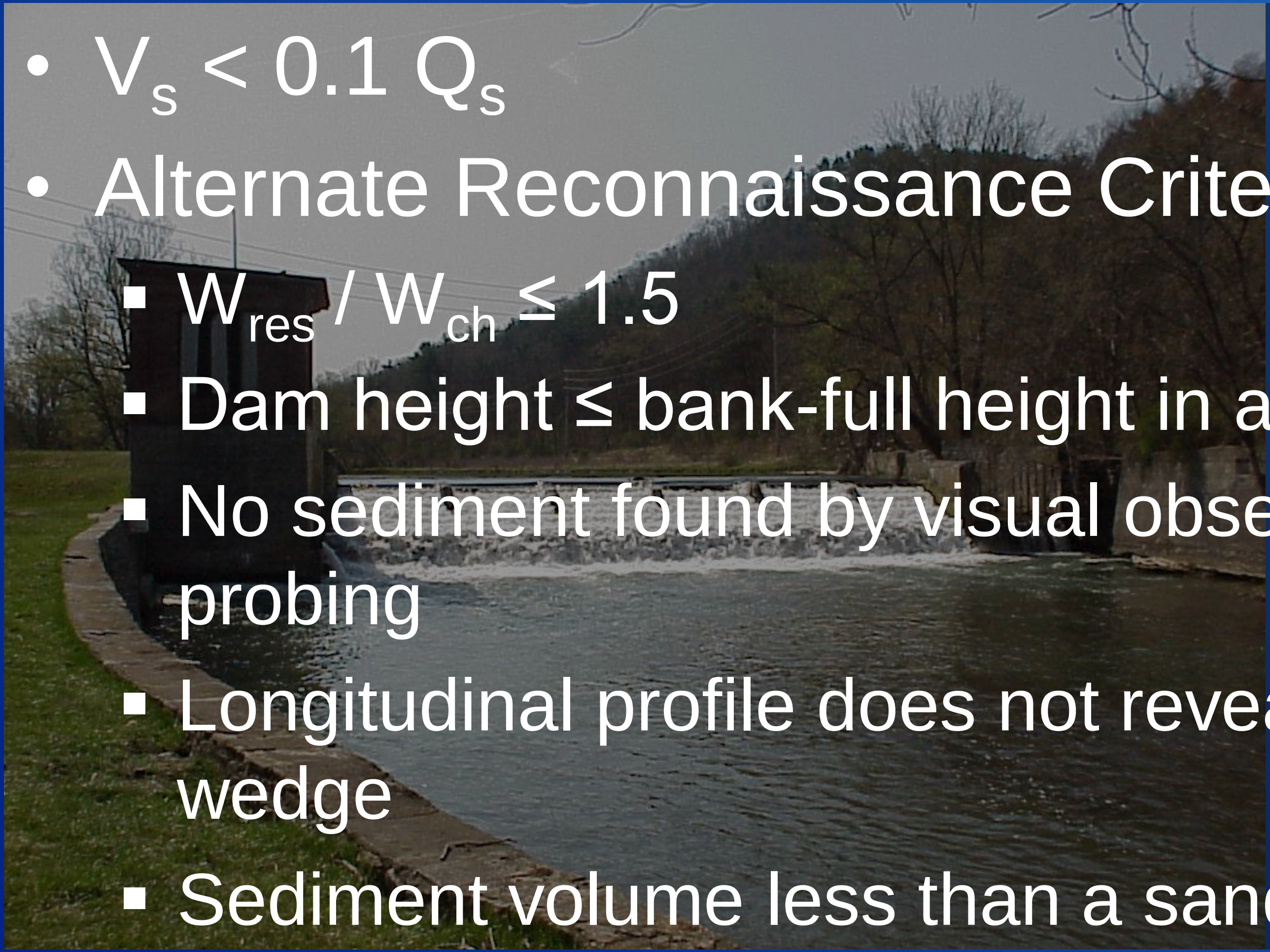
Criteria for Negligible Reservoir Sediment Volume (V_s)



- $V_s < 0.1\ Q_s$
- Alternate Reconnaissance Criteria
  - $W_{res} / W_{ch} \leq 1.5$
  - Dam height ≤ bank-full height in alluvial reach
  - No sediment found by visual observations or probing
  - Longitudinal profile does not reveal a sediment wedge
  - Sediment volume less than a sand or gravel bar

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Develop Dam Removal and Sediment Management Alternatives

- Partial or complete dam removal
- Rapid or staged dam removal
- Removal during certain seasons or flows
- Check for downstream channel degradation
- Check for non-erodible materials in reservoir
- Check for species sensitive to sediment
- Contaminant removal

Reservoir Sediment Management Alternatives

- River Erosion
- Mechanical Removal
- Reservoir Stabilization

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River Erosion

- River is allowed to erode a channel through the reservoir sediments
- The rate of erosion depends on the rate of reservoir drawdown
- Most commonly adopted alternative
- Least cost, but maximum turbidity and downstream deposition

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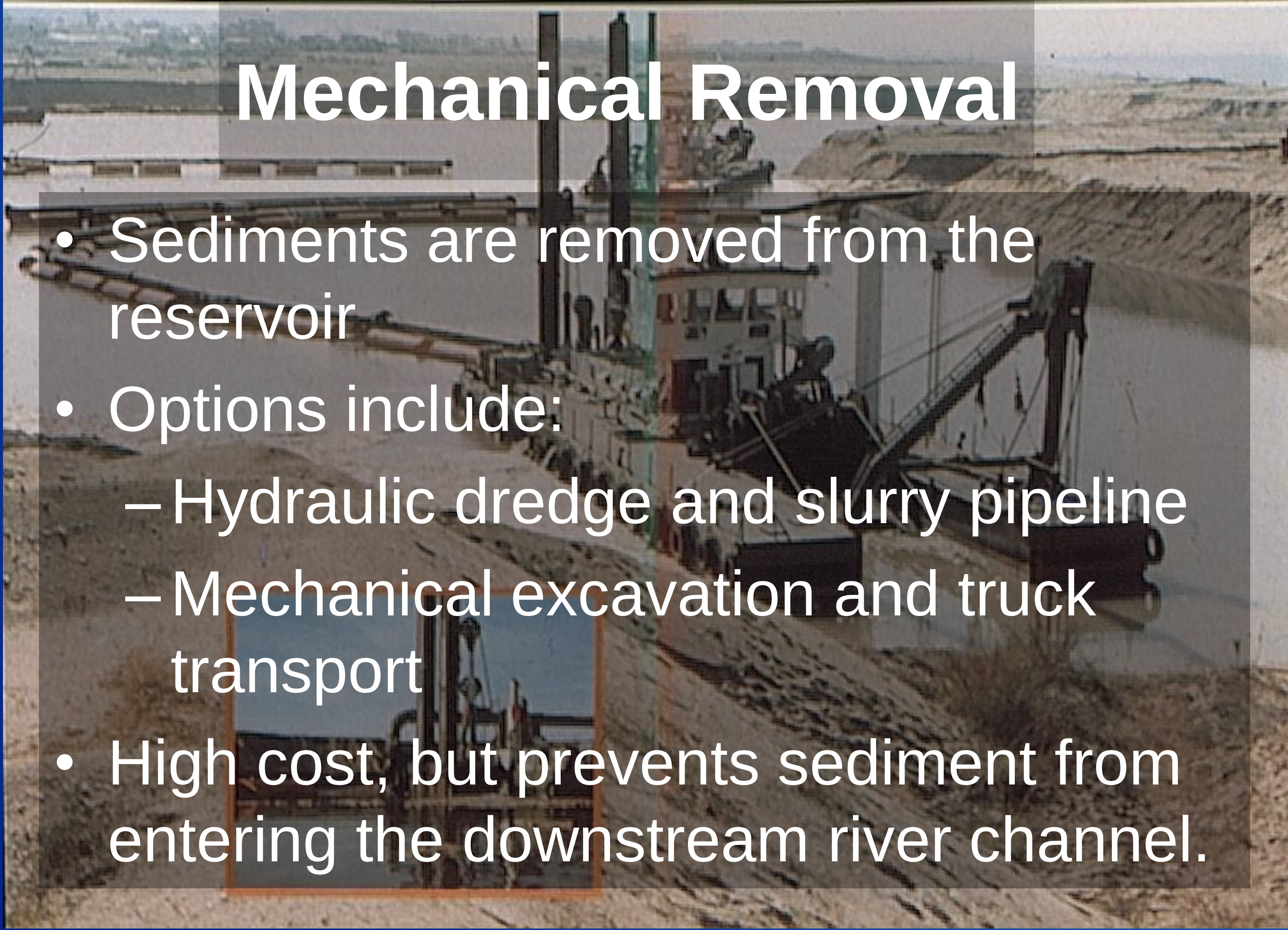
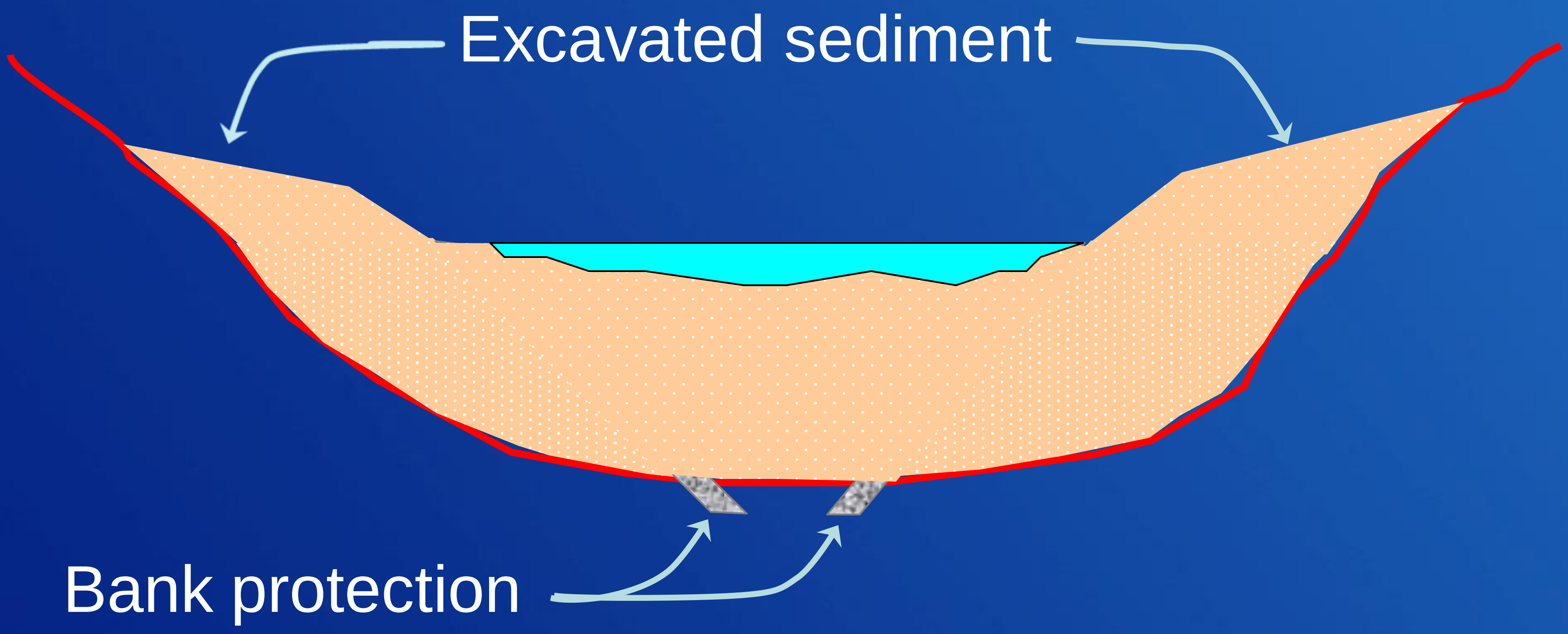
Mechanical Removal



- Sediments are removed from the reservoir
- Options include:
  - Hydraulic dredge and slurry pipeline
  - Mechanical excavation and truck transport
- High cost, but prevents sediment from entering the downstream river channel.

Reservoir Stabilization



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Predict Reservoir and Downstream Effects

- Reservoir sediment removal or erosion
  - Volume left behind
  - Volume removed or eroded downstream
- Downstream channel effects
  - Turbidity
  - Aggradation and planform change
- Effects depend on the sediment management alternative

Predict Reservoir and Downstream Effects (continued)

- Compare the amount of reservoir sediment release to natural floods
- Evaluate how downstream sediment effects will vary with:
  - Stream flow
  - Time (hours, weeks, months, years)
  - Longitudinal distance from dam
  - Lateral distance from stream channel

Determine the level of additional data collection, analysis and modeling by factoring in the risk to resources.

Risk =

Probability of Sediment Impact

x Consequence of Sediment Impact

Risk Estimates

- Risk = Probability x Consequence

Risk Table	Consequence (potential resource impact)		
Probability	**Low**	**Medium**	**High**
Small	Low	Low	Medium
Medium	Low	Medium	High
Large	Medium	High	High +

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Probability of consequence tends to decrease with time and distance downstream

Probabilities			
Relative Reservoir Sedimentation Volume	**Short-term in the reservoir and below dam**	**After more time or distance**	**After more time or distance**
Small →	Small →	Negligible	
Medium →	Medium →	Small →	Negligible
Large →	Large →	Medium →	Small →

Risk Matrix

Probability Matrix			
Resource	Lake	Reach 1	Reach 2
Ecosystem	Medium	Medium	Small
Infra-structure	Small	Medium	Small
Socio-Economic	Medium	Medium	Small

x

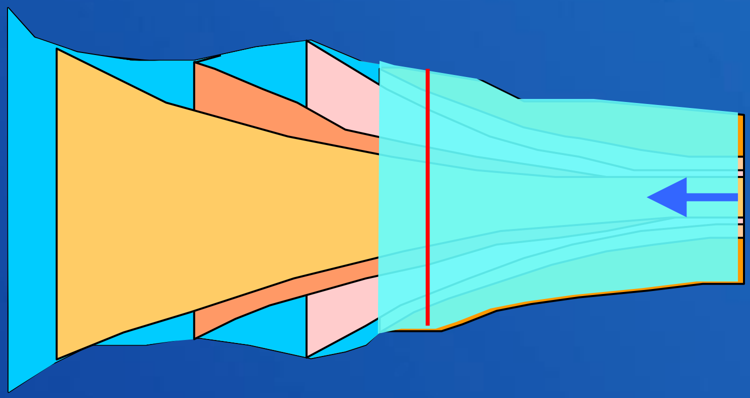
Consequence Matrix			
Resource	Lake	Reach 1	Reach 2
Ecosystem	Medium	Medium	Low
Infra-structure	Low	Medium	Low
Socio-Economic	Medium	Medium	Low

=

Risk Matrix			
Resource	Lake	Reach 1	Reach 2
Ecosystem	Medium	Medium	Low
Infra-structure	Low	Medium	Low
Socio-Economic	Medium	Medium	Low

Possible Analysis and Modeling Tools

- Conceptual model
- Numerical Models
  - Sediment wave
  - Mass balance
  - 1D & 2D hydraulic and sediment transport
  - Bank erosion and channel migration
  - Vegetation growth and mortality
  - Water quality



Possible Analysis and Modeling Tools

- Physical models
  - Reservoir sediment erosion
  - Downstream river channel
- Field tests
  - Reservoir drawdown
  - Sediment release to downstream river channel

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Level of Analysis and Modeling also depends on the Risks to Resources

Negligible	Small	Medium	Large
Simple computations	Sediment wave model	1D sediment capacity model	1D or 2D sediment model, physical model, field test

1

0

Low   Medium   High

Risk = Probability x Consequence

Assess Confidence of Input Data

- Reservoir sediment volume
- Grain sizes and spatial distribution
- Contaminant concentrations
- Reservoir sediment erosion volume
- Stream flow hydrograph

Perform Analyses

- Additional data collection
- Simple computations
- Field tests
- Numerical modeling
- Physical Modeling

Assess Prediction Confidence

- Turbidity or suspended sediment concentration
- Aggradation and flood stage
- Local versus reach-scale predictions

Determine if Sediment Impacts are Tolerable

- Assess impacts to resources of concern.
- Compare impacts to natural disturbance.
- Present to decision makers and stakeholders.
- Determine if impacts are tolerable or if they can they be avoided or mitigated.
- Modify dam removal and sediment management alternatives as necessary.

Develop Monitoring and Adaptive Management Plan

- Develop a real-time monitoring plan to determine if predictions are correct.
- Determine where, how, and why monitoring results differ from predictions
- Adapt the implementation plan to ensure that impacts are tolerable

Testing of Analysis Guidelines

- Guidelines were tested against 25 case studies at the 2009 workshop to see if level of analysis recommended by guidelines matched project approach & findings
- Case studies are from eastern and western states
- Negligible to large sediment scales

Savage Rapids Dam: April and Sept 2009

Conclusions

- The policy decision to remove a dam is based on the need for action, stakeholder input, technical information, and available funding.
- Technical information needs to consider removal of the structure, alternative ways of meeting remaining purposes of the dam, sediment management, and mitigation for impacts.

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Conclusions (continued)

- The level of sediment investigations can be scaled based on the ratio of the reservoir sediment volume to the average annual sediment load and on risk.
- Frequent communication among technical staff, managers, construction teams, and stakeholders is important throughout the project.

Next Steps for Guideline Completion

- Complete draft for review
- Obtain independent peer review
- Obtain approval from Subcommittee on Sedimentation
- Obtain approval from Federal Advisory Committee on Water Information
- Publish guidelines
- Look into website option to allow interactive tool with additional "hot linked" references

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The End

- **Eco-Prank at Glines Canyon Dam on the Elwha River**
- Photo: Mikal Jakubal in Travel & Outdoors

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