A joint project of

Exploring Dam Removal

A Decision-Making Guide

American Rivers is a national non-profit conservation organization dedicated to protecting and restoring healthy natural rivers and the variety of life they sustain for people, fish, and wildlife.

American Rivers delivers innovative solutions to improve river health, raise awareness among decision-makers, and serve and mobilize the river conservation movement.

By changing how dams operate and removing dams that are old, unsafe, and harm the environment, we bring back native fish and wildlife. By promoting natural alternatives to levees, dikes, and dredging, we restore natural functions of rivers and wetlands. We help keep enough unpolluted water in our rivers for the freshwater species and communities that depend on this water and its natural flow. We help communities protect their rivers from upstream water withdrawals, pollution, and the insidious effects of sprawl. We put special emphasis on protecting wild rivers and the rivers of Lewis and Clark, as the bicentennial of their expedition approaches.

Trout Unlimited's mission is to conserve, protect and restore North America's trout and salmon fisheries and their watersheds.

We work to accomplish this mission at local, state, and national levels with an extensive and dedicated volunteer network. Trout Unlimited's national office, based just outside of Washington, D.C., and its regional offices employ professionals who testify before Congress, publish a quarterly magazine, intervene in federal legal proceedings, and work with the organization's 125,000 volunteers in 500 chapters nationwide to keep them active and involved in conservation issues.

American Rivers
1025 Vermont Avenue, NW, Ste 720
Washington, DC 20005
202/347-7550
RiversUnplugged@amrivers.org

Trout Unlimited
211 South Patterson St., Ste 180
Madison, WI 53703
608/250-2757
RestoreRivers@tu.org

Cover photo credits: left – Naugatuck River in Connecticut after the Anaconda Dam Removal. Photo: Laura Wildman, Milone and Macbroom; right, top – Matilija Dam on the Ventura River in California. Photo: Mark Capelli; right, middle – Sheboygan River in Wisconsin after the Franklin Dam Removal. Photo: River Alliance of Wisconsin; right, bottom – Canoers portaging Octoraro Creek Rubble Dam on Octoraro Creek in Maryland.

Acknowledgements

Written by Margaret Bowman, Steve Higgs, Elizabeth Maclin, Serena McClain, Matt Sicchio, and Amy Souers of American Rivers and Sara Johnson and Brian Graber of Trout Unlimited.

Special thanks to Elizabeth Brink, International Rivers Network; Scott Carney, Pennsylvania Fish and Boat Commission; Wayne Edwards, United States Society on Dams; Joan Harn, National Park Service; Laura Hewitt, Trout Unlimited; Stephanie Lindloff, New Hampshire Department of Environmental Services; Karen Pelto, Massachusetts Riverways' River Restore Program; Helen Sarakinos, River Alliance of Wisconsin; and Marcin Whitman, California Department of Fish and Game, for reviewing and commenting on the report.

Through their generous support of American Rivers' and Trout Unlimited's dam removal and river restoration work, we would like to thank the following for making this report possible:

Anonymous
American Canoe Association, Dixie Division
Beneficia Foundation
Gilbert and Ildiko Butler Foundation
The Coldwater Conservation Fund
National Oceanic and Atmospheric Administration
Community-Based Restoration Program
The Compton Foundation, Inc.
Jessie B. Cox Charitable Trust
The Dolphin Trust
The Educational Foundation of America
The French Foundation
Gabilan Foundation
Richard and Rhoda Goldman Fund
The George Gund Foundation
Paul Hohenlohe and Jennifer Stauer
Robert and Dee Leggett
NLT Foundation
National Fish and Wildlife Foundation
The New-Land Foundation, Inc.
New York Times Company Foundation, Inc.
Nu Lambda Trust
The Pew Charitable Trusts
Steven and Barbara Rockefeller
Elmina B. Sewall Foundation
The Spring Creek Foundation
Town Creek Foundation
The Turner Foundation
U.S. Fish and Wildlife Service
Virginia Environmental Endowment
The William Penn Foundation
Robert Youngman

This report does not necessarily reflect the views of the above organizations and individuals.

Table of Contents

Part I. Introduction

A. The Option of Dam Removal

There are approximately 75,000 dams greater than six feet high in the waterways of the United States. Many thousands of smaller dams also block our nation's rivers[1]. Dams provide important benefits to society. They generate hydropower, provide water for crops and human consumption, help manage floods, create navigable waterways, and provide recreational opportunities. But dams, both large and small, come with significant costs. Dams have fundamentally changed the ecology of hundreds of thousands of river miles in our country, damaged habitat, disrupted native populations of fish and wildlife, and adversely affected some local economies and communities.

Most dams were designed to provide one or more economic and social functions.

Functions of dams:
- Generate hydropower
- Divert water for irrigation
- Store water for human consumption
- Facilitate navigation
- Create recreation opportunities

In recent years, several things have happened to cause many to take a second look at the value of some dams. First, we have learned a great deal about the adverse impacts of dams on river ecosystems and neighboring communities. Second, an increasing variety of non-structural alternatives to dams for flood management, irrigation, water storage, and power generation have been developed. And third, all dams across the country are continuing to age and an increasing number are in need of substantial repair.[2] At the same time, there is an increased understanding and appreciation for the many societal values of healthy rivers and fisheries. As a result, many communities, dam owners, and agencies across the United States are finding that in some circumstances dam removal can serve as an effective river restoration tool and also provide economic and social benefits.

[1] The National Research Council has estimated the number of small dams in the United States may number as high as 2.5 million. National Research Council. 1992. Restoration of Aquatic Ecosystems: Science, Technology and Public Policy. Washington (DC): National Academy Press.

[2] The American Society of Civil Engineers (ASCE) gave dams a grade of D in their *2001 Report Card for America's Infrastructure*—citing age, downstream development, dam abandonment, and lack of funding for dam safety programs (www.asce.org/reportcard/). A full one-quarter of all United States dams are now more than 50 years old, and ASCE estimates that by the year 2020 that figure will reach 85 percent. *Dam Repair and Rehabilitation, ASCE Policy Statement 470.* American Society of Civil Engineers, March 13, 2000. (www.asce.org/pressroom/news/policy_details.cfm?hdlid=152).

Anaconda Dam on the Naugatuck River in Connecticut. Photo: Laura Wildman, Milone and Macbroom.

A 1999 report, *Dam Removal Success Stories* compiled by American Rivers, Friends of the Earth, and Trout Unlimited, identified over 465[3] dams that have been removed in the United States. Professor Molly Pohl of San Diego State University has catalogued over 400 dams greater than six feet high or longer than 100 feet that have been removed since the 1920s.[4] Many of these were removed because they were old, obsolete, or posed safety hazards. Many other dams were removed to restore river ecology and bring back fish and wildlife. Dams have also been removed to provide recreational benefits, enhance aesthetics, and improve water quality.

Most dams result in one or more negative effects.

Negative effects of dams:
- Disrupt natural functions and connectivity of ecosystem
- Inundate wildlife habitat
- Block movement of fish and other aquatic species
- Block/slow river flow
- Alter timing of river flow
- Alter water temperature and quality
- Hold back silt, woody debris, and nutrients
- Hinder recreational opportunities on river
- Change aesthetics and traditional values of natural setting.

When appropriate, dam removal can benefit rivers, wildlife, and neighboring communities that reap the rewards of a healthy river. It can achieve ***environmental improvements*** by restoring natural flows to a river, removing blockages to fish migration, re-establishing healthy river habitat for fish and wildlife, returning river rapids and riverside lands, and improving water quality. Dam removal can lead to ***community revitalization*** through the generation of additional revenues

[3] Since the publication of the 1999 report, we are now aware of over 500 U.S. dams that have been removed.
[4] Pohl, M. 2001. *Constructing Knowledge on American Dam Removals* in US Society on Dams, The Future of Dams and Their Reservoirs, Denver (CO):USSD at 501-509.

from improved fishing and boating opportunities in the restored river, and by creating riverfront revitalization opportunities, such as riverside parks, historical interpretive exhibits, and green spaces. And dam removal can result in the ***elimination of safety hazards*** posed by deteriorating, unsafe, or abandoned dams. Dam removal can also be the most ***fiscally prudent*** choice to meet river management and dam safety goals.

While hundreds of dams have been removed, that does not mean that all dams should be torn down. In fact, very few of all documented dams in the United States are even being considered for removal. The removal of 400 dams represents just over one-half of one percent of the more than 75,000 dams over six feet tall existing across the country. Many dams continue to serve important public or private functions such as flood control, irrigation, and hydropower generation. In some cases, changing the way a dam operates will provide enough ecological improvements to the river to justify the continued benefits of the dam. In other cases, removing a dam could have adverse ecological effects – such as the release of contaminated sediments – that are too costly to mitigate. And in some cases, dams are retained because they represent a significant aspect of the community's history.

The concept of dam removal can arouse strong emotions, both from advocates of dam removal and from opponents. However, a decision whether or not to remove a dam should not be based on emotions or entrenched positions, but on a balanced analysis of the pros and cons of both dam removal and dam retention.

How can you tell if a dam is a good candidate for removal? How do you weigh a dam's costs and benefits to the river, the dam owner, and to society? Because every river and dam is unique, there is no generic formula or quick checklist for determining if a dam should be removed. Not all benefits and costs can be quantified, nor do they apply to all dams and rivers. Judgment is required to balance and compare options. *Exploring Dam Removal* presents questions that will help sort out the many issues surrounding dam removal in order to increase the likelihood that an informed decision can be made.

Why remove a dam?

The following are potential benefits of dam removal:

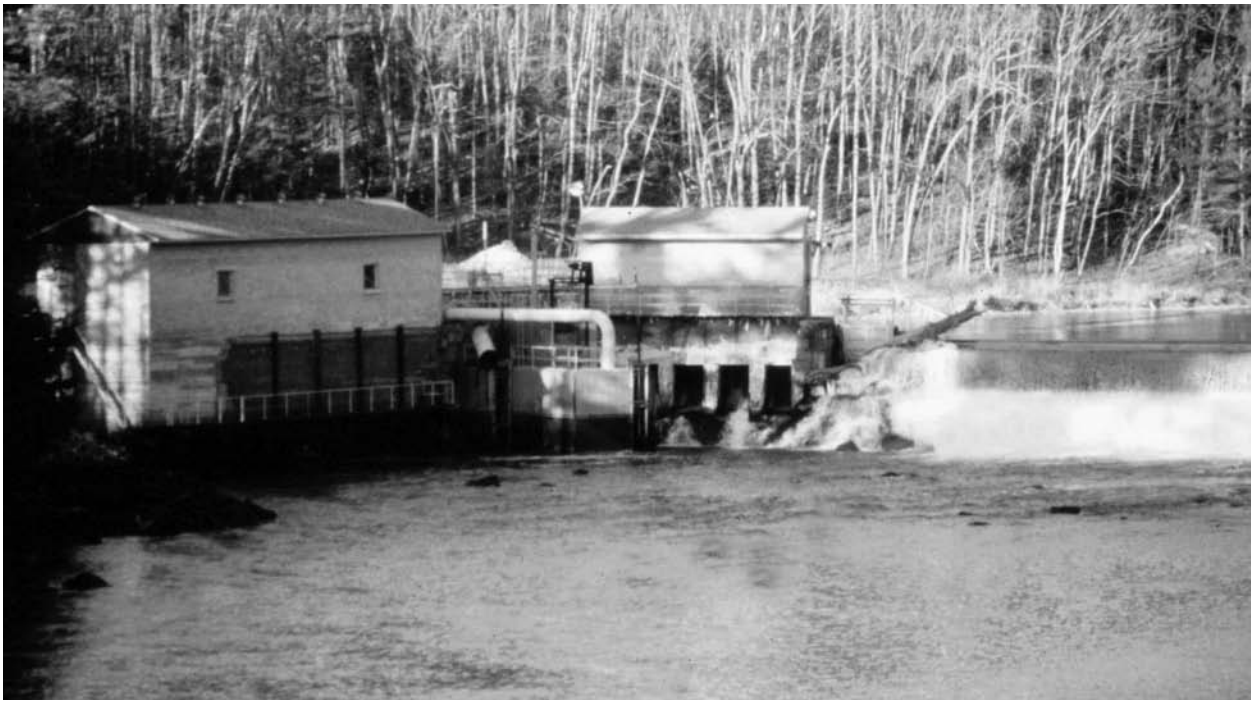
- Restore river habitat
- Improve water quality
- Re-establish fish movement
- Rehabilitate threatened and endangered species
- Eliminate dam safety concerns
- Save taxpayer dollars
- Improve river aesthetics
- Improve fishing opportunities
- Improve recreational boating opportunities
- Improve public river access
- Community revitalization

B. How to Use This Guide

1. Structure of Exploring Dam Removal:

Exploring Dam Removal: A Decision-Making Guide is divided into four areas of consideration: (a) ecological, (b) economic, (c) societal, and (d) technical/engineering. Each section provides a brief overview of topics shown through experience to be useful in determining if a dam should be removed. Not all of these issues will have direct relevance or major significance in each dam removal, but each issue should be reviewed to determine whether it is relevant or important to the dam removal decision. If an issue is important to the decision, a more thorough set of questions is available in the Appendix to enable you to explore the issue in more depth.

There are few "easy" dam removal decisions. Most dams have both positive and negative impacts. The challenge in making a sound decision about whether or not to remove a dam is to identify all of the costs and benefits of keeping that particular structure, as well as the costs and benefits of removing it, and balance the findings to deter-



Smelt Hill Dam on the Presumpscot River in Maine. Photo: Laura Wildman, American Rivers.

mine the best option. *Exploring Dam Removal* helps to ensure that a full range of costs and benefits are identified. Obtaining the answers to the questions identified here and in the *Appendixes* will enable a more complete analysis of the options of keeping or removing a dam and can have an impact on the cost and ultimate feasibility of either decision. Working through the many issues involved in deciding to keep or remove a dam can offer surprising conclusions that can lead to a reasoned approach – reducing subjectivity and increasing objectivity.

2. Challenges in Answering the Questions:

One challenge in developing answers to all of the questions identified in *Exploring Dam Removal* is determining the ***level of review necessary*** to reach a dam removal decision (a determination that can be complicated by multiple stakeholders and agencies with differing interests). *Exploring Dam Removal* identifies many questions that should be asked when making a decision. This does not mean, however, that every question should be thoroughly analyzed and answered for each dam removal decision. Many of the questions will not apply to all cases and others can be answered simply without extensive analysis. In other cases, more in-depth analysis or field studies may be needed to answer some of the questions presented both here and in the Appendix.

Another challenge in deciding whether or not to remove a dam is determining how to cope with ***uncertainty of outcomes***. Because relatively few dam removals have been studied or even described in available reports, many uncertainties exist about how to remove a dam and how the river, fish, wildlife, and neighboring community will respond once the dam is removed. Uncertainty is a factor in most ecological and business decisions. But uncertainty in such a relatively new arena can make some dam removal decisions more complex. Uncertainty in itself should not negate the dam removal option. Some level of caution should be exercised when proceeding without scientific certainty, but the door should be left open for action in the case of continued harm and degradation of a river and its neighboring community. Uncertainties surrounding the dam removal option should be identified, under-

stood by all decision-makers, and factored into the decision. As experience with dam removal increases, so will the ability of scientists, resource managers, and engineers to predict the feasibility and cost of a decision to keep or remove a dam, and the impact this decision will have on a river system and its neighboring communities.

An additional challenge is often presented by the need to make decisions on a dam-by-dam basis, while impacts on rivers occur on a ***watershed basis*** and numerous dams can result in significant cumulative impacts. To the extent possible, a dam removal decision should be based not only on an understanding of the specific impacts of the dam in question, but also on a general understanding of how those impacts relate to the watershed as a whole and combine with impacts or benefits from dams or other sources. This does not mean that a dam removal decision must be put on hold until a full watershed analysis is conducted. In most situations this is not a practical option. However, you should determine whether some watershed analysis or planning has already been conducted. If none has, a level of watershed consideration or analysis appropriate for the scale of the project and the scope of its impacts should be determined.

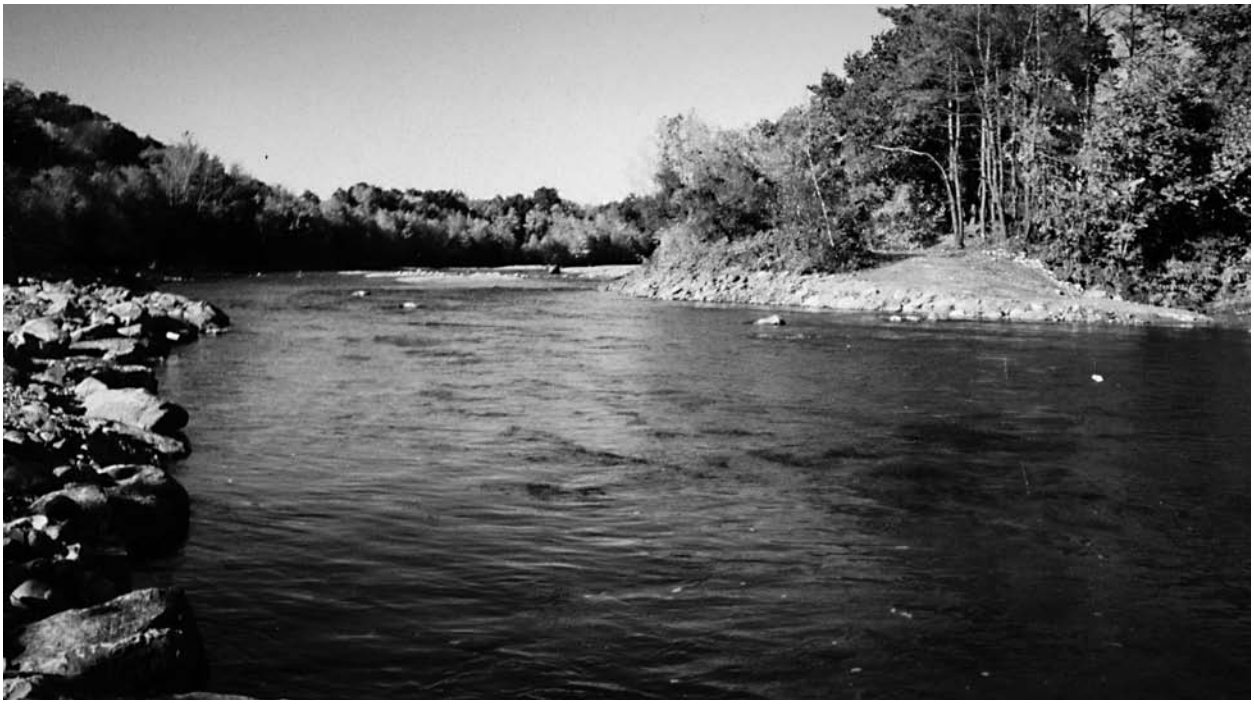
3. Reaching a Final Decision:
Although *Exploring Dam Removal* provides guidance on identifying all of the costs and benefits of both dam removal and dam retention, it does not attempt to direct how these costs and benefits should be balanced. This balancing decision depends on many unique factors that will vary from case to case. Thus, no simple (or even complex) formula can be developed to determine the appropriate decision in every case.

Making a final decision, once all of the information is collected, will be affected by many factors, including:

- The ecological circumstances surrounding the case;
- The economic circumstances surrounding the case;
- The complexity of the issues;
- The legal and political context in which a decision must be made;
- The impetus for considering dam removal (e.g., fisheries restoration goal, dam safety concern);
- The identity of the decision makers (e.g., dam owner, state agencies);
- The amount of controversy surrounding the decision; and
- The number, identities, and strength of various stakeholders.

In making a final decision, we recommend that you examine all of these factors to understand the influences on the decision. Perhaps the most significant of these factors is the initial impetus for dam removal consideration. We recommend that you look closely at what you have found (by exploring questions herein) in the context of the initial impetus that led you to consider dam removal. For example, if your goal is to restore native fisheries in the most cost-effective manner, your answer as to whether you believe the dam should be removed may be different than if your goal is to find the least-cost alternative for dealing with a public safety hazard. On the other hand, dam removal may be the most prudent option for achieving both goals.

It is unlikely that the "correct" answer will magically appear after answering the questions in *Exploring Dam Removal*. However, if those involved know and understand the answers to these questions, the decision-making process will be substantially improved. Even if the final decision is not the one you would have preferred, at least it will have been a well-informed process, and the information and understanding gained can help shape future decisions.



Naugatuck River in Connecticut after the Union Dam Removal. Photo: Laura WIldman, Milone and Macbroom.

4. Terminology:

Some comments on terminology:

- First, ***dam removal*** or ***dam decommissioning*** is commonly used to describe a range of options, from full removal of the dam and restoration of the river to a breach or notching of the structure or removal of spillway gates. All of these options should be considered when making a dam removal decision. However, for the purposes of *Exploring Dam Removal*, dam removal is generally considered to be a full removal of the structure and associated site restoration.
- Second, the term ***community*** is often used in *Exploring Dam Removal*. The scope of this term depends on the particular circumstances of the dam. For example, for a small dam that does not affect many people or much fish and wildlife habitat, the local neighborhood directly affected by the dam may be the appropriate community. But for a large dam with many broad ecological, economic, and social impacts, the community may be a broader region or even the whole nation.
- Third, *Exploring Dam Removal* often refers to ***species of concern***. This describes species of fish and wildlife identified by state or federal natural resource agencies as threatened, endangered, or rare, as well as species that are of economic or cultural importance. For example, although American shad are not listed as a threatened or endangered species, they are a species of concern to communities along the Chesapeake Bay who stand to gain economically from a restored shad fishery.
- Finally, the terms ***small dam*** and ***large dam*** are used generically in this document, without a firm dividing point between them. There are generally five factors that determine whether a dam is small – height, width, acre-feet of impounded water, location in country (e.g., a small dam in the west could be 30 feet tall, where the same dam in the east would be large), and size of the river (e.g., a 25-foot dam on a large river might be small, whereas a 25-foot dam on a small river could be large).

C. For More Information

Many resources already exist to help determine whether or not to remove a dam. A toolkit of resources, as well as links to additional resources are available on the American Rivers and Trout Unlimited web pages (www.americanrivers.org and www.tu.org); by phone (AR: 202-347-7550, TU: 703-522-0200); or via email (AR: RiversUnplugged@amrivers.org, TU: RestoreRivers@tu.org). A few of the available resources are listed below.

- **Dam Removal: A Citizen's Guide to Restoring Rivers** (River Alliance of Wisconsin and TU) - A guide offering citizens a blueprint for how to advocate for selective dam removal as a river restoration tool and to aid in the decision-making process.
- **Dam Removal Success Stories: Restoring Rivers Through Selective Removal of Dams That Don't Make Sense** (AR, Friends of the Earth, TU) - A report documenting more than 465 dams that have been removed across the country, and including 25 detailed case studies of dam removal success stories. It also provides a comprehensive review of the history and benefits of removing dams that don't make sense.
- **Paying for Dam Removal: A Guide to Selected Funding Sources** (AR) - A report presenting information on federal, state, local, and private funding mechanisms that can be used to finance dam removal and associated river restoration projects. It is a tool for anyone seeking funds to finance the removal of a dam that no longer makes sense - e.g., dam owners, government officials, non-governmental groups, individuals.
- **Permitting Issues Related to Dam Removal** (AR) - A short summary of the types of federal, state, and local permits that may be required for removal, followed by some general observations about how best to approach the permitting process for dam removal projects.
- **Small Dam Removal: A Review of Potential Economic Benefits** (TU) - A publication capitalizing on current research and Trout Unlimited's experience in small dam removal to provide decision makers insight into the potential economic benefits that can be realized by utilizing the removal of small dams as a river restoration tool. Some of the economic benefits discussed include improved sport fisheries, community revitalization, increased paddlesport opportunities, and significant cost savings of dam maintenance.
- **Ecology of Dam Removal: A Summary of Benefits and Impacts** (AR) - This report summarizes the findings of *Undamming Rivers: A Review of the Ecological Impacts of Dam Removal*, a paper by University of Pennsylvania Ph.D. candidate Angela Bednarek that outlines the short- and long-term ecological benefits and impacts associated with dam removal and its effectiveness as a tool in river restoration.
- **Taking a Second Look: Communities and Dam Removal** (TU, AR, and others) - A 22-minute video informing dam owners, local businesses, public officials, resource agencies, and other concerned community members about the community benefits of dam removal. Featuring case studies of communities that have removed dams in Wisconsin, Maine, and California, this video addresses many of the issues and concerns that are involved in the dam removal process.
- **Data Collection: Researching Dams and Rivers Prior to a Removal Decision** (AR) - This fact sheet contains a variety of sources to get interested parties started on researching their dam and river, including links to finding maps, historical documents, biological data, etc.

Upcoming publications include:

- **Engineering and Other Technical Issues Related to Small Dam Removals** (TU, AR and others)
- **Alternatives to Dams** (AR, International Rivers Network)
- **Historical Issues and Dam Removal** (AR)

Matilija Dam on the Ventura River in California. Photo credit: Mark Capelli.

Several state and federal agencies have personnel qualified to help answer questions about dam removal and stream restoration. These agencies include:

- State natural resources agencies, such as a Department of Natural Resources, Department of Environmental Conservation, or Department of Fish and Game
- United States Fish and Wildlife Service (www.fws.gov)
- Natural Resources Conservation Service (www.nrcs.usda.gov)
- National Park Service – Rivers, Trails, and Conservation Assistance Program (www.nps.gov)
- United States Geological Survey – Water Division (www.water.usgs.gov)
- United States Bureau of Reclamation (www.usbr.gov)
- United States Army Corps of Engineers (www.usace.army.mil)

Additional information can be found by contacting local universities or professional trade associations, including:

- American Fisheries Society (www.fisheries.org)
- Association of State Dam Safety Officials (www.damsafety.org)
- Friends of the Earth's River Restoration Program (www.foe.org/foenw/rivers/main.html)
- Friends of the River's River Reborn Program (www.friendsoftheriver.org/riversreborn/main3.html)
- International Rivers Network's River Revival Program (www.irn.org/revival/decom)
- Massachusetts Department of Fisheries, Wildlife, and Environmental Law Enforcement, River Restore Program (www.state.ma.us/dfwele/RIVER/rivRestore.htm)
- National Performance of Dams Program – Stanford University (npdp.stanford.edu)
- New Hampshire Department of Environmental Services (www.des.state.nh.us/dam.htm)

- River Alliance of Wisconsin's Small Dams Program (www.wisconsinrivers.org/SmallDams/prog_dams.html)
- River Recovery – Restoring Rivers through Dam Decommissioning (www.recovery.bcit.ca/index.html)
- The Academy of Natural Sciences (www.acnatsci.org/research/pcer/manatawny.html)
- The Aspen Institute (www.aspeninst.org/eee/dams.html)
- The Heinz Center (www.heinzctr.org/programs/dam_removal.htm)
- United States Society on Dams (www.ussdams.org)
- Wisconsin Department of Natural Resources (www.dnr.state.wi.us/org/water/wm/dsfm/dams/removal.html)

Part II. General Questions

Before specific pros and cons of removing a dam can be reviewed, certain basic information should be gathered. This information will provide context for the dam and the river on which it is located, as well as for the decision-making process.

- What service(s) was the dam structure designed (or later altered) to provide, such as mechanical power, hydropower, flood control, water supply, recreation, irrigation, or navigation?
- What service(s) or benefits does the dam structure provide today?
- What year was the dam built? What year(s) did it undergo significant repairs and/or reconstruction?
- What is the size and design (e.g., concrete gravity, earthen, timbercrib) of the dam? Size of the impoundment?
- Are construction and/or modification plans and specifications available?
- Of what materials is the dam constructed?
- Who owns the dam? Is the dam owner actively involved in dam management and maintenance?
- What public agency, if any, has regulatory authority?
- Is there a potential that contaminated sediments have collected behind the dam?
- Are there any published resource management plans for the river? Are there any published development plans for the community?
- What underlying objective prompted the analysis of whether or not to remove the dam (e.g., address safety problem, restore fish movement, FERC relicensing)?
- What is the legal context for the decision about whether or not to remove the dam (e.g., voluntary decision, environmental regulatory decision, licensing decision, dam safety decision)?
- Who are the decision makers? What is the decision-making process? Who has the ultimate decision-making authority?
- Who has a stake in the decision about the future of the dam? Have all of the stakeholders' interests been identified?

For More Information:
For additional guidance on finding information about a particular dam, please see the Know the Dam Worksheet in the report *Dam Removal: A Citizen's Guide to Restoring Rivers* (www.wisconsinrivers.org/SmallDams/toolkit-order-info.html), produced by the River Alliance of Wisconsin and Trout Unlimited (2000), and American Rivers' *Data Collection: Researching Dams and Rivers Prior to a Removal Decision* (www.americanrivers.org/damremoval toolkit/datacollection).

Part III. Ecological Issues

Dams and their associated structures can fundamentally change a river ecosystem. Dams disrupt a river's natural course and flow, altering water temperatures, redirecting river channels, transforming floodplains, fragmenting habitat, displacing fish and wildlife, and disrupting a river's continuity and connectivity. Additionally, some of the characteristics of an ideal dam site, such as fast-moving water and a rocky river bottom, are also characteristics of prime spawning habitat, so dams can be especially damaging to fisheries when they inundate this habitat. These riffles are generally the most productive habitats with the greatest natural diversity in a river system.

Removing a dam can restore a river's ecological functions and critical habitat by improving the transport of sediments, improving the water quality of the river, allowing the movement of fish and other riverine species, and restoring the natural flow of a river. But dam removal may not be necessary to accomplish this goal. And in some situations, dam removal may set river restoration back, causing harm – rather than good – to the river system. The following questions highlight issues that should be addressed to more fully understand the ecological pros and cons of dam removal.

CASE STUDY

One thousand miles of river habitat were reopened when the seven-foot high, 260-foot long Quaker Neck Dam was removed from the Neuse River in 1998. Eight migratory fish species and one endangered mussel species benefited from the restored habitat.

Learn more about this case study by visiting the following link:
www.americanrivers.org/tableofcontents/ssneuse.htm or by contacting
Mike Wicker, US Fish and Wildlife Service, mike_wicker@fws.gov, (919) 856-4520.

A. Upstream Flow and Habitat

A dam often floods upstream habitat, creating a flat-water impoundment or reservoir where a swift or meandering river once flowed. The size of the dam and the site topography determine the size of the impoundment[5] and the amount of upstream habitat that is flooded or altered. An impoundment's habitat, which is more lake-like in appearance, is significantly different from free-flowing river habitat.

[5] Impoundment - A manmade facility, often behind a dam or other obstruction, for the storage, regulation, and/or control of water. Also used to refer to a reservoir.

Example of suitable fish habitat. Photo: Bonneville Power Administration.

CASE STUDY

Historic fish runs and the return of native riparian species have already been witnessed at several post-dam removal sites, including Edwards Dam on the Kennebec River in Maine, Woolen Mills Dam on the Milwaukee River in Wisconsin, and Waterworks Dam on the Baraboo River in Wisconsin.

For complete case studies on these removals, visit www.amrivers.org/damremoval/successstoriesreport.htm.

Riverine fish that evolved to live in the free-flowing river may not be able to survive in an impoundment and may be replaced with non-riverine species that thrive in the impoundment's lake-like water. The more dams there are on a river, the more significant this loss of riverine habitat becomes. Removing a dam can help restore the natural upstream riverine and riparian habitat. Species that require flowing water will find new areas to live, spawn, and feed in the habitat no longer altered by the dam.

However, dam removal eliminates impounded habitat and may reduce or change the type of riparian wetland habitat. Species that prefer the languid flow and organic profile of the impoundment will now find themselves in unsuitable habitat. Depending on the species of concern[6] and the presence of other lakes, reservoirs, or impoundments in the region, this may or may not be a positive outcome.

Bottom Line – Upstream Flow and Habitat: *Will the restored river and riparian habitat upstream outweigh the loss of impounded habitat?*

[6] See Part I, Section B4 above for an explanation of "species of concern".

B. Downstream Flow and Habitat

A river in its natural state is dynamic. Natural river flows fluctuate according to season and region. For example, in some regions, large spring flows correspond to snowmelt, and low summer flows correspond to warm dry weather. River species often require seasonal flows to trigger growth and reproduction cycles. A dam can eliminate these natural flow variations. Some dams also divert water out of the river channel, creating low flows, which can eliminate habitat and change natural water temperatures. In some situations, certain stretches of river are completely dewatered. However, some dams in arid regions ensure flows year round where without the dam the river may naturally dry up in low rain years. Other dams change natural flows by storing water and releasing it at times to suit human needs, such as hydropower generation or flood control. When these trickle-or-torrent releases are rapidly changed, they can damage habitat, impact timing of reproductive cues, and flood or strand fish and wildlife.

CASE STUDY

In order to restore runs of coho salmon, chum salmon, steelhead, and cutthroat trout, Goldsborough Dam in Washington State was removed in May 2001. This obsolete dam was blocking passage for these anadromous species along Goldsborough Creek. As the project progresses, it is expected to improve stream habitat and open up 14 miles of spawning and rearing habitat.

Learn more about this case study by visiting the following link: www.amrivers.org/damremovaltoolkit/goldsboroughdam or by contacting Shawn Cantrell, Friends of the Earth, (206) 297-9460, foenw@igc.org.

Removing a dam can restore a river's natural flow fluctuations and can often return water to formerly dewatered stretches of river.[7] However, returning natural flows below a dam can sometimes be accomplished though changes in how the dam is operated, without having to remove the dam. Further, returning natural flows below a dam can displace species that have adapted to the altered flows. Depending on the species of concern, this may or may not be desirable.

Bottom Line – Downstream Flow and Habitat: *Is dam removal necessary to restore natural flows to the river? Do the benefits of restored flows outweigh the impacts on species that prefer unnatural flows?*

C. Fish and Wildlife

Scientists have found that when river habitat and natural flow fluctuations are restored to a river, natural diversity and populations of river and riparian species increase. Higher species diversity is typically an indicator of better river health; and riverine species typically require less in management costs than non-native species.[8]

However, removing a dam eliminates impoundment habitat and sometimes can change or reduce the quantity of wetland habitat. This may cause a reduction in species preferring that habitat. Depending on the quality of

[7] Dam removal does not always guarantee restored natural flows because it does not guarantee there are not water withdrawals.
[8] Not all restored rivers, however, exhibit great species diversity. Pristine trout streams, for example, naturally tend to have low fish diversity. When removing a dam and restoring a river, groups often look to restore species native to the stream and restore natural diversity.

Denil fish ladder at dam on Pleasant Lake in Stetson, Maine. Photo: Steve Brooke.

the habitat in the impoundment and the presence of other lakes, reservoirs, or wetlands nearby, this loss may or may not be significant. Further, the process of removing a dam may temporarily disrupt habitat for species sensitive to changes in water quality and water level. However, taking certain precautions in the timing and design of the removal may minimize this impact.[9]

One cannot simply tabulate a balance sheet of species gains and losses when determining whether or not net impact to fish and wildlife populations is positive or negative. Much of this decision depends on the relative "importance" given to different species and the individual or party designating priority species.

Bottom Line – Fish and Wildlife: *Is the net impact of dam removal on fish and wildlife populations positive or negative?*

D. Passage and Movement of Fish and Other Species

A dam can block both upstream and downstream movement of fish and other wildlife. This is the case for sea-run (anadromous and catadromous) species that migrate between oceans and rivers, as well as resident fish[10] and wildlife that move up and down a river to find suitable spawning, rearing, and foraging habitat. Dams have also proved to be a significant problem for potadromous[11] species. The slow water flow and large surface area of lake-

[9] For further discussion on timing and process of removal, see the Technical/Engineering section below (Part VI).
[10] Resident Fish – Species that reside in freshwater throughout their lives.
[11] Potadromous – Species that migrate between large lakes and rivers, such as the Great Lakes.

like impoundments created by many dams can lead to the increase of predatory species. Large impoundments also affect the temperature and oxygen levels of the water, leading to virtual thermal blocks to fish migration.

Fish passage devices, such as denil fish ladders (see photo), can be installed on a dam to allow some species of fish to move upstream and downstream of the structure, though delays and mortality occur. Passage techniques are far more developed for some species (e.g., salmon) than for others (e.g., sturgeon) and effectiveness varies. Many times, even if adult fish are able to move upstream through fish passage devices to spawn, youth moving downstream have trouble swimming through a slow-moving impoundment and through fish passages meant for adult fish.

Dam removal almost always eliminates the need for fish passage structures. With the dam gone, the delays and mortality associated with fish passage systems disappear. In addition, because effective fish passage systems can be costly to build and maintain, dam removal may be a more cost-effective method of providing fish passage without ongoing maintenance and operations costs.

In some cases, dams and other blockages in a stream can provide benefits to fish populations. For example, a dam may serve as a barrier to undesirable non-native species, preventing them from moving upstream or downstream and reaching vulnerable native species and habitats. A dam may also prevent downstream fish contaminated with parasites or toxins from infiltrating the river's upper reaches. In these situations, dam removal may not be advisable, or a smaller barrier may need to be constructed after removal to prevent undesired migrations. In addition, conducting dam removal activities when fish are migrating can cause harm. Scheduling the removal at a time when fish are not migrating up or downstream can avoid this harm.

CASE STUDY

California's Ventura River once replenished coastal beaches with its flow of sand and sediment. But since the construction of Matilija Dam in 1947, an estimated five to seven million cubic yards of sediment have backed up in the reservoir. Because of the sediment build-up, the dam can no longer provide flood control and its water storage capabilities are greatly diminished. In addition, because sand can no longer travel downstream, beaches are suffering from erosion. One of the more cost-effective options being considered in the sediment management plan associated with the dam's removal is to let the sediment disperse naturally over time. If it is determined that the sediment must be removed and disposed of, it will be the greatest cost associated with the dam removal and river restoration. But once the dam is removed, natural sediment supplies can be restored to the beaches of Ventura and southern steelhead trout will be able to migrate freely to their historic spawning ground in the headwaters of the Ventura River.

Learn more about this case study by visiting the following link: www.americanrivers.org/damremoval-toolkit/currenteffortsventura.htm or by contacting Paul Jenkin, Matilija Coalition, paul@matilija-coalition.org, (805) 648-4005.

Bottom Line – Passage and Movement of Fish and Other Species: *Will dam removal improve safe passage of migrating fish and movement of resident fish and wildlife? Is dam removal necessary to accomplish this? Can dam removal be done without enabling the spread of undesirable species?*

Example of a poor river bank stabilization. Photo: U.S. Army Corps of Engineers.

E. Sediment Movement

Sediment is an essential component of the river ecosystem, containing a variety of important nutrients that riverine species require to survive and thrive. It is naturally found on the streambank, the riverbed, and in the water column. Sediments carried in a river's water column often drop to the riverbed when a flowing river enters a slow moving impoundment behind a dam. For larger dams in sediment-rich rivers, the sediment accumulation behind the dam can be significant.

Sediment accumulation in the impoundment can negatively impact fish and wildlife by reducing its depth, inundating valuable habitat, increasing water temperatures and depleting the water of dissolved oxygen. It can also deprive the river and coastal habitats below the dam of needed sediment. However, impoundment sediment can also trap certain toxins and other undesired chemicals (such as PCBs), limiting their dispersal downstream.

Dam removal can help restore the natural sediment balance to the river. In some cases, allowing sediment to redistribute naturally downstream may be the least environmentally damaging option and often has the same impact as a large storm event. However, in other cases, such as when contaminated or large amounts of sediment are stored behind the dam, it may be necessary to remove, partially remove or stabilize the sediment in place. Regardless, sediment trapped in the impoundment should be carefully managed during removal so that large amounts of sediment are not re-suspended, harming habitat and species downstream. Larger sediments that

cannot be re-suspended may move along the stream bottom, as part of the bed load, resulting in scouring and/or inundation of critical aquatic habitat.

Bottom Line – Sediment Movement: *What is the current net impact of the accumulated sediment on the impoundment and downstream habitats? How will sediments released during dam removal impact the riparian and riverine habitats in the short and long term?*

F. Water Quality

Because a dam fundamentally changes a river's flow, it also can change many aspects of water quality, including temperature, nutrient transport, oxygen content, and turbidity. Some dams release water from the top of the impoundment where it has been unnaturally warmed, while other dams release water from the bottom of the impoundment where it has been unnaturally cooled. When water is released from the bottom of the impoundment, it can also be oxygen deprived and kill fish and wildlife downstream. These temperature and oxygen variations can eliminate native fish and wildlife. However, they can also enable popular coldwater sportfish to thrive in traditionally warmwater rivers.

Removing a dam can restore natural water temperatures, enhance nutrient transport, increase the river's oxygen content (through restoration of riffle habitat), and reduce turbidity. However, the process of removing a dam may have short-term negative water quality impacts. For example, the release of sediments from the impoundment can cause short-term turbidity in the river that could be temporarily harmful to fish and wildlife. In addition, if water is released from large impoundments too rapidly, it can become supersaturated with dissolved gas, which can cause gas bubble disease in fish downstream. A slower impoundment drawdown can avoid this impact.

CASE STUDY

When the Little Goose Dam on the Snake River was drawn down in 1992, supersaturation of dissolved gas occurred in the water, turbidity levels increased, and many reservoir fish and insects perished. Fortunately, the supersaturation and turbidity were short-term with minimal impacts on overall fish and wildlife populations.

Learn more about this case study by contacting Rob Masonis, American Rivers, rmasonis@amrivers.org, (206) 213-0330.

Bottom Line – Water Quality: *Will dam removal have a net benefit on water quality, taking into account both short-term and long-term impacts and benefits?*

G. Riparian Areas

Riparian[12] areas are among the most diverse ecosystems. Riverside lands are flooded and historic riparian zones are lost when an impoundment is created behind a dam. If the dam is removed, the natural riparian corridors and

[12] Riparian – Habitat found on stream banks and riverbanks, where semiaquatic and terrestrial organisms mingle.

Union Dam on the Naugatuck River in Connecticut prior to removal. Photo: Laura Wildman, Milone and Macbroom.

riverside lands can be restored, with potential benefits for native fish, birds, plants, insects, and other wildlife. Following the removal of smaller dams, there may only be a modest amount of newly exposed lands. For dams with larger impoundments, the exposed upland could be extensive. When large impoundments are removed, the actual footage of the riparian zone may be reduced due to transformation of a wide impoundment into a narrower river, but the quality of riparian habitat will be increased due to its association with riverine instead of lacustrine-like waters.

Restoring a river's natural flow through dam removal may increase the frequency of flooding in some riparian areas. Flooding promotes riparian plant growth, revitalizes inland wetlands, and creates small ephemeral[13] ponds that serve as nurseries for aquatic species. Significant flooding, however, can also harm wildlife and human property. In other cases, dam removal may reduce flooding upstream from the dam due to a reduction in water levels and provide more riparian corridor for terrestrial wildlife.

Dam removal, however, can also pose some negative ecological impacts on riparian areas. Some dams stabilize flows, reducing flood scour of downstream riparian habitat, enabling larger, more mature riparian habitat. Depending on the species of concern, this may or may not be desirable. Additionally, when a dam's impoundment is drawn down, previously stable riparian soils may become unstable and subject to erosion. Particularly unstable areas around the former impoundment may require human intervention (e.g., streambank stabilization with plantings, shaping) to limit erosion. Removal of small dams often exposes the old toe[14] of a riverbank, for example,

[13] Ephemeral – Lasting a very short time.
[14] Toe – The lowest portion of an embankment.

which is naturally the point of greatest shear stress. While historically that toe was held by vegetation, upon re-emergence that vegetation does not exist, and therefore planted vegetation or artificial elements may be needed for stabilization until natural vegetation can be re-established.

Bottom Line – Riparian Areas: *Will there be a net gain in the amount and quality of riparian habitat as a result of dam removal?*

H. Wetland Areas

Different types of wetlands serve different functions and provide different habitats. The construction of a dam and impoundment may destroy naturally occurring wetlands. However, as the impoundment fills and expands, new wetlands may be created above the dam.

When a dam is removed, wetlands created by the dam's impoundment may be transformed as the impoundment is drawn down. In many cases this loss of wetlands is countered by the re-creation of wetlands associated with a restored riparian corridor. The type, amount and value of wetlands lost or gained due to dam removal varies from case to case, and must be considered in weighing the costs and benefits of removal.

Bottom Line – Wetland Areas: *How will the wetlands gained by dam removal compare in amount, type, and habitat value to the wetlands lost by dam removal?*

I. Location of the Dam within the Watershed

The position of a dam within a river basin is important in determining the potential ecological benefits of removal. For example, removing a dam may restore critical spawning habitat for migratory fish, but this will only be valuable if fish passage is provided at dams downstream. Further, if a second dam is located just upstream of the dam under consideration for removal, removal may only restore a small amount of habitat.

Multiple dams on a river can have a cumulative impact on water quality, fish, and wildlife. The amount of impounded versus free-flowing river in the basin, and the relative size of the impoundment lost and potential free-flowing river gained, can provide perspective on the importance of the dam and dam removal. Future

CASE STUDY

An unprecedented plan to restore the Naugatuck River basin is being implemented in Connecticut thanks to a series of public-private partnerships. The project includes dam removal or construction of fish passage at eight run-of-river dams and the upgrading of six municipal wastewater treatment plants. The full project is expected to improve water quality significantly and restore more than 32 miles of river, allowing passage for sea-run brown trout, American shad, alewives, blue-back herring, and other aquatic species.

Learn more about this case study by visiting the following link: www.amrivers.org/table-ofcontents/ssnaugatuck or by contacting Laura Wildman, American Rivers, lwildman@amrivers.org, (860) 652-9911.

Little Goose Dam on the Snake River. Photo: American Rivers Photo Library.

potential for fish passage or removal at other dams is also important in understanding the impact of the dam and dam removal on fish movement in the basin.

That said, dam removal should not be automatically ruled out simply because there are other blockages upstream and/or downstream or because it opens up few river miles. Restoring even a small amount of riverine habitat can often provide significant benefits to resident fish and other species that depend on the river for life. Coldwater fisheries, for example, can benefit by removal of a headwater dam if the impoundment caused increased water temperatures.

Bottom Line: *Will dam removal significantly enhance the river's ecological values, given the location of the dam relative to other dams in the watershed?*

J. For More Information

In recent years, scientists have conducted numerous studies on the ecological effects of dams on river ecosystems. However, few address the ecological impacts of dam removal on a river system. While some studies are currently underway to address this deficiency, a great deal of additional research needs to be carried out to understand better and predict the ecological impacts and benefits of dam removal.

- Digging Deeper: More in-depth questions that expound on the criteria presented in this section can be found in the Appendix to this report.
- For a good summary of the existing science on dam removal, see Bednarek, A.T. 2001. *Undamming Rivers: A Review of the Ecological Impacts of Dam Removal.* Environmental Management. Vol. 27(6): 803-814.
- For an abridged summary of the existing science, see American Rivers. Feb. 2002. *The Ecology of Dam Removal: A Summary of Benefits and Impacts* (www.amrivers.org/damremovaltoolkit/ecologyofdamremoval.htm).
- For a bibliography of dam removal studies, see American Rivers. *Dam Removal Bibliography* (www.amrivers.org/damremovaltoolkit/dambibliography.htm). June 2001.
- For additional information on ecological research being done on pre- and post-dam removal, visit the Academy of Natural Sciences at www.acnatsci.org/research/pcer/manatawny.html or contact Karen Bushaw-Newton at bushaw@acnatsci.org.
- The Heinz Center. 2002. *Dam Removal: Science and Decision Making*. Washington (DC): The Heinz Center.
- For information specific to your dam and/or your watershed, contact your state natural resource or environmental management agency.

Part IV. Economic Issues

Dams provide important economic benefits to society, including hydropower, irrigation, navigation, flood control, domestic and industrial water supply, and recreation. But these benefits often come at a price, including environmental and recreational impacts and dam maintenance and repair costs. In many cases, removing dams can have distinct economic benefits, such as cost savings over repairing and maintaining the dam, potential for community riverfront revitalization, increased income to local fishing and boating industries, and decreased costs related to water quality improvements and fisheries management. However these dam removal benefits may come at a price as well, due to the loss of economic benefits from the dam.

To determine the economic costs and benefits of a dam removal, it is critical to compare the long and short-term costs and benefits associated with maintaining a dam to those associated with the proposed dam removal and subsequent restored river.

It is also important to be aware of the distinction between the private and public costs and benefits of keeping or removing a dam. For example, the cost of operating and maintaining a dam is often the owner's responsibility (e.g., an individual, municipality, utility), while environmental costs associated with a dam (e.g., need for water quality improvements) may accrue to everyone in the community.

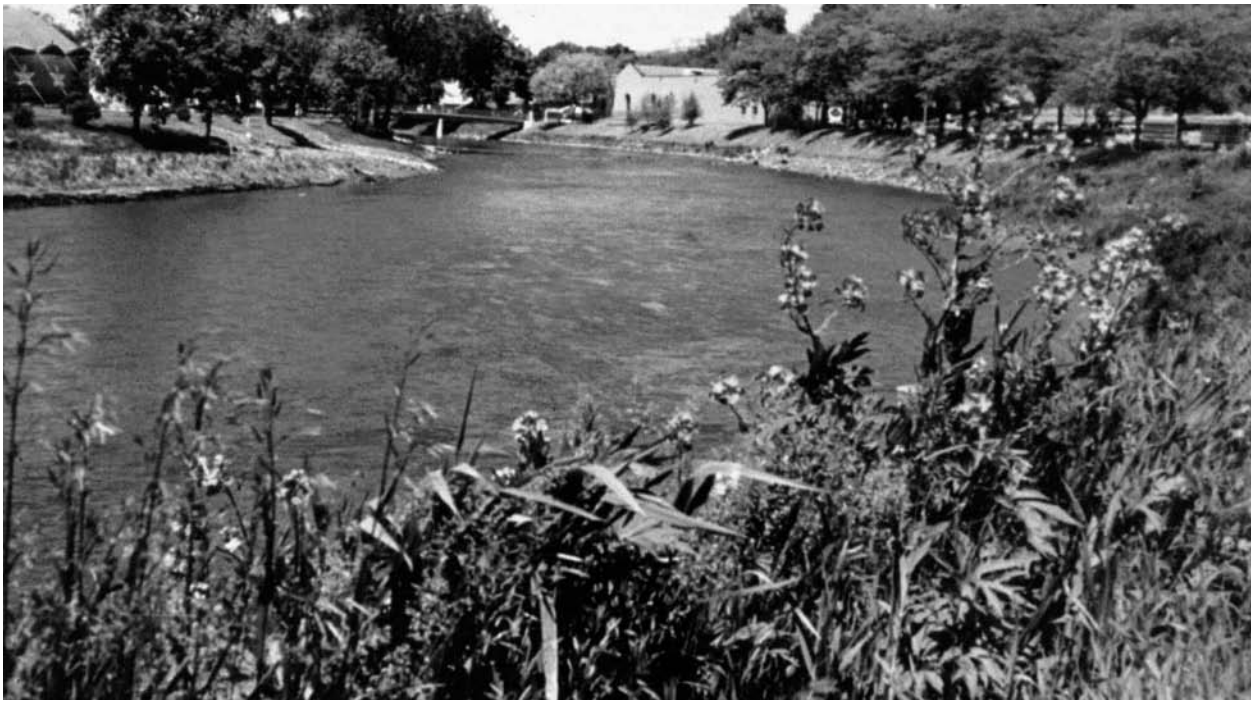
CASE STUDY

Like many dams, the aging Waterworks Dam on the Baraboo River in Wisconsin was removed due primarily to public safety and economic concerns. The estimated cost to repair the dam ranged between $694,600 and $1,091,500. The removal itself cost only $213,770, a savings of at least $480,830. Furthermore, by removing the dam, the city avoided any future maintenance, environmental, and liability costs associated with the dam.

Learn more about this case study by visiting the following link: www.amrivers.org/tableofcontents/barabooriverwisconsin.htm or by contacting Helen Sarakinos, River Alliance of Wisconsin, hsarakinos@wisconsinrivers.org, (608) 257-2424.

A. Dam Owner's Costs and Benefits

A dam owner often gains economic benefits from the operation of the dam. But reaping these benefits comes at a price. Funds must be spent to maintain and repair the dam, to operate the structure, and to protect the dam



Baraboo River in Wisconsin after the Waterworks Dam removal. Photo: River Alliance of Wisconsin.

owner against liabilities associated with dam ownership. However, dam removal also comes with costs, including funds spent on removing the dam and, if necessary, replacing its uses.

Bottom Line – Dam Owner's Costs and Benefits: *Are the long-term costs of operating and maintaining the dam less or more than the costs of removing the dam? Do any benefits of the dam need to be replaced, and if so, by whom?*

B. Societal Costs and Benefits

In most cases, a dam does not benefit (or harm) only the dam owner. Many dams provide benefits that accrue to other business interests and to society as a whole, such as flood control, water supply, irrigation, and power generation. These same dams can also have enormous societal costs. Impacts resulting from failure of an unsafe dam or from exacerbated flooding effect more than the dam owner. They also can have a devastating effect on the neighboring community. The societal costs and benefits to others of maintaining and removing the dam must also be assessed.

Bottom Line – Societal Costs and Benefits: Are others in the community responsible for any additional costs and benefits of maintaining or removing the dam?

C. Recreational Costs and Benefits

A dam and its impoundment can provide significant recreational benefits to local communities. For example, a dam's impoundment may provide opportunities for flatwater boating and swimming. However, dams eliminate free-flowing rivers and thus can have an impact on community revenues as well. For example, removing a dam could enhance economic benefits from river-based sport fishing, canoeing, rafting, and kayaking. A restored and healthy river could also attract local businesses to the area.

Bottom Line – Recreational Costs and Benefits: *Will dam removal positively or negatively influence community revenues from recreation?*

CASE STUDY

The removal of Grist Mill Dam on Soudabscook Stream in 1998 not only saw the return of such migratory fish as Atlantic Salmon and sea-run brook trout, it gave an economic boost to the Town of Hampden. The newly restored river generated additional revenue from commercial and recreational fishing; enhanced canoeing and kayaking opportunities; and decreased expenditures for repairs to a local highway affected by the impoundment.

Learn more about this case study by visiting the following link: www.amrivers.org/tableofcontents/souadabscook.htm or by contacting Elizabeth Maclin, American Rivers, emaclin@amrivers.org, (202) 347-7550.

D. Environmental Costs and Benefits

To gain an accurate assessment of the economic costs and benefits of dam removal and dam retention options, it is necessary to include environmental costs and benefits. Some environmental costs and benefits are hard to quantify (such as the value of species decline or water quality improvements), but these should not be ignored. Methods exist to put dollar values on these costs and benefits, but the methods can be time consuming and expensive. For small dam removals, these studies could cost more than the removal. If it is not feasible to quantify these costs and benefits, they should still be explicitly included in the dam removal balance sheet. The questions in Part V of the Appendix may help provide a sense of the range of these values, even if it is not feasible to obtain firm numbers.

CASE STUDY

In 1997, FERC ordered the removal of Edwards Dam on the Kennebec River in Maine because the cost of installing fish passage was 1.7 times more than removing the dam, and would only provide passage for three of the seven fish species of concern.

Learn more about this case study by visiting the following link: www.amrivers.org/tableofcontents/sskennebec.htm or by contacting Laura Rose Day, Natural Resources Council of Maine, lrose_day@nrcm.org, (207) 622-3101.

Bottom Line – Environmental Costs and Benefits: *Do the net environmental costs (or benefits) of keeping the dam outweigh the net environmental costs (or benefits) of removing the dam?*

Shopiere Dam on Turtle Creek in Wisconsin. Photo: River Alliance of Wisconsin.

E. Property Values

One of the most uncertain issues in dam removal decisions is determining the effect removal might have on neighboring property values. Many dams create impoundments where people enjoy living and recreating. One concern is that when these impoundments are drawn down, adjacent property values will drop. To date, there have been few studies that address this topic, but anecdotal evidence indicates that property values do not always decline after a dam is removed.[15] In fact, property values may actually increase following a dam removal that improves water quality, restores the river ecosystem, and provides recreational benefits. Although a firm answer is unlikely to be available, the questions in Part V of the Appendix can help to identify the potential for change in property values.

Bottom Line – Property Values: *Will dam removal positively or negatively affect property values adjacent to the stream? Will these effects, if any, be short or long term?*

F. Distribution of Costs and Benefits

In order to conduct a thorough analysis of the costs and benefits of different options, the recipient(s) of the benefits and the bearer(s) of the costs must be identified. For example, some dams provide significant benefits to the dam owner (e.g., private water supply), but no benefits to the local community. At other dams, the benefits may

[15]See Trout Unlimited. 2001 *Small Dam Removal: A Review of Potential Economic Benefits* (www.tv.org/small_dams/whats/_tv/doing/2b_edu_materials.html).

primarily accrue to the local community (e.g., recreation) while the private dam owner or even another community may bear the burden of most of the dam's costs (e.g., safety, maintenance).

Bottom Line – Distribution of Costs and Benefits: *Who benefits the most from retaining/removing the dam? Who bears the costs for retaining/removing the dam?*

G. Availability of Funding for Dam Repair or Removal

When making a dam repair or removal decision, one factor to consider may be the availability of funding for the two options. In addition to funding from the dam owner, federal, state, local, and private pools of funds may exist to repair unsafe dams. Similarly, funding for removal of dams is increasingly available from federal, state, local, and private sources. In addition to funds for repair and removal of dams, funding is also available for river restoration and post-removal community planning.

Bottom Line – Availability of Funding for Dam Repair or Removal: *What funds are available to pay for dam maintenance/repair or removal?*

H. For More Information

For more information on the economic analysis of dam removal and river restoration, the following studies are a good place to begin extended research. As always, it is a good idea to contact your state natural resources and/or environmental management agency for information about a specific dam in your area.

- Digging Deeper: More in-depth questions that expound on the criteria presented in this section can be found in the Appendix to this report.
- Trout Unlimited. 2001 *Small Dam Removal: A Review of Potential Economic Benefits* (www.tu.org/small_dams/whats_tu_doing/ 2b_edu_materials.html).
- For additional information on the economic valuation of the environment, one may also want to review studies by Dr. Robert Costanza, co-founder of the International Society for Ecological Economics and author of Costanza, R. 1991. *Ecological Economics: The Science and Management of Sustainability.* New York (NY): Columbia University Press.

CASE STUDY

Mill Brook, a tributary of the Presumpscot River in Maine, overtopped and breached Highland Lake Dam during a fall flood. The Federal Emergency Management Agency (FEMA) declared the site a disaster area. The Army Corps of Engineers inspected the dam and recommended replacement. Even though removing the dam was much cheaper ($250,000), FEMA funds would only cover the costs of repair/replacement. In the final agreement, 90 percent of the replacement cost ($1,700,000) was covered by FEMA and the state, while the city and neighboring towns covered the remaining 10 percent ($170,000). The dam replacement project was completed in March 2000.

Learn more about this case study by visiting the following link: www.americanrivers.org/damremovaltoolkit/millbrook.htm or by contacting Bill Hover, GZA Environmental, whover@gza.com, (617) 969-0050.

• Whitelaw, E. and Macmullan, J. *A Framework for Estimating the Costs and benefits of Dam Removal, with Specific References to Dams on the Lower Snake River.* BioScience (Forthcoming, Aug. 2002).

Part V. Societal Issues

Removing a dam means changing the characteristics of a river and, possibly, the human community through which the river flows. While the biological impacts of dam removal can be felt far upstream and downstream, the human impacts can range even farther. The most directly affected people are often those in the community where the dam is located, and in communities above or below the dam. But a much broader community may have a stake in the resources and recreational opportunities associated with the river. This community may be regional, national, or even international. In addition, in states where the water belongs to all of the state's citizens, the Public Trust Doctrine[16] entitles every citizen to a voice in the discussion.

The issue of dam removal often spurs a community to examine its heritage, values, and vision for the future. In many cases, the societal needs that prompted the building of a dam have changed dramatically over time, so that the dam is no longer serving its original purpose or any other economic function. The community may now place higher value on the aesthetics and recreational opportunities of a free-flowing river. Nonetheless, for many the dam may be an integral part of the community. Community sentiment toward the structure, the impoundment, and the river can have a major impact on decisions to keep or remove a dam.

Dam removal means change, and by nature, human beings are often resistant to change. For many, especially those with little understanding of the issues or control of the situation, the changes potentially associated with removing a dam elicit fear, a sense of loss, or both – which can result in an emotionally charged and divisive decision-making process. In many cases, when stakeholders are able to get past positions (e.g., keep the dam or remove the dam) and explore interests (e.g., honoring history of community, healthy river, fishing opportunities), they may find many things in common. Often creative thinking may then lead to a "win-win-win" situation for the dam owner, the river, and the community.

[16] Public Trust Doctrine – The principle that each state owns the land and navigable waters. Title to these resources is held by the state in trust for the benefit of its citizens.

Welch Dam on the Cannon River in Minnesota. Photo: Craig Regalia, Minnesota Department of Natural Resources.

A. Community Understanding of the Dam, the River, and Dam Removal

University research[17] has shown that dam repair/removal decisions are often based on inaccurate and incomplete information. Community members often have no previous experience with dams or with rivers, and may not fully understand the functions and benefits of either. For example, some believe all dams provide flood control, but only certain dam structures provide this service, and others may actually exacerbate downstream flooding or upstream high water damage. In other situations, some may believe that the dam has no function when it still serves an important purpose. If the purpose and current function of a dam are not clear, it will be difficult to understand the impacts of dam removal. Likewise, without a basic understanding of the functions and values of a healthy river system, it will be difficult to understand what is gained or lost with the decision. Further, all these efforts to enable an informed decision process require more lead time than exists for a lot of communities making a decision, particularly when a dam is under orders for repairs. If public safety is a factor, this decision-making timeline must often be condensed.

Bottom Line – Community Understanding of the Dam, the River, and Dam Removal: *Do the decision-makers and other concerned parties have sufficient information to make an informed decision about dam removal? Or dam retention?*

[17] Born, S.M., et al. 1998. *Socioeconomic and institutional dimensions of dam removal: The Wisconsin Experience.* Environmental Management. Vol. 22(3): 359-370.

B. Service(s) Provided by the Dam

Most dams were originally designed to carry out a certain function or functions, such as providing water for irrigation or human consumption, producing mechanical or hydropower, or managing floodwaters. Many provide other societal benefits as well, such as recreational opportunities. These functions and services change over time as societal needs and desires change. The dam's services should be assessed to determine if they still are needed and, if so, to see if they could be replaced through other, more river-friendly means[18]. Although many dams still provide an important service, due to technological advances and changing societal needs, some dams (especially smaller structures) no longer serve the purpose for which they were built, and no longer provide any other service or economic value that justifies their continued existence and the costs associated with their retention.

CASE STUDY

Canoeing opportunities were greatly enhanced when the Welch Dam was taken out of Minnesota's Cannon River. Prior to removal, canoeists were faced with the reservoir's slack water, then had to portage around the dam. The dam removal significantly enhanced one of Minnesota's most popular canoeing routes.

Learn more about this case study by visiting the following link: www.americanrivers.org/tableofcontents/sscannon.htm or by contacting Tim Schlagenhaft, Minnesota Dept. of Natural Resources, (507) 280-5058.

Bottom Line – Service(s) Provided by the Dam: *Does the dam provide any services? Are these services as valuable as the services provided by a free-flowing river? If yes, can these services be provided through alternative means?*

C. Who Benefits from and Who Bears the Costs of the Dam

Understanding who has gained or lost from the presence of the dam, who stands to gain or lose from the dam's removal, and what their various interests are, is critical to a good decision-making process. This will be especially helpful in determining some of the economic issues to consider in deciding whether or not to remove a dam.

A dam can have direct and indirect benefits for many people, as can a free-flowing and healthy river system. Some dams serve the public (e.g., recreation, flood control), while others serve private entities (e.g., private water supply). In many cases the party shouldering the costs of keeping a dam is not the party reaping the benefits. While many people may benefit from a dam, many may also benefit from a restored river. But, as with dam retention, the parties gaining the benefits of dam removal may not be the same parties bearing the costs.

Bottom Line – Who Benefits From and Who Bears the Costs of the Dam: *Who benefits from and who bears the costs of the dam? Who will benefit from and who will bear the cost of a restored river?*

[18] For more information, see American Rivers. *Alternatives to Dams* (forthcoming, 2002).

Conodoguinet Creek in Pennsylvania after the Good Hope Dam removal. Photo: Sara Nicholas, American Rivers.

D. Community Sentiment Toward the Dam and the River

Community sentiments about the dam and the river are important factors to consider when deciding whether or not to remove a dam. For example, in some communities the dam is an important part of the community's identity and pride; in other communities few people are even aware that it is there. After community members have had the opportunity to become well informed about the benefits and costs of the dam and the benefits and costs of a free-flowing river, community sentiments should be assessed by talking with opinion leaders (e.g., the mayor, business owners, conservation organizations), and multiple views taken into consideration.

The level of social or political activity around the dam and the dam removal decision is one way of judging how the community feels about the dam and the river. However, the social or political activity may be the result of a vocal minority, rather than the general consensus

CASE STUDY

Removal of Woolen Mills Dam on the Milwaukee River in Wisconsin has rejuvenated the local community. The restored river and park now provide economic and recreational opportunities for individuals, businesses, and the entire community. Not only are local businesses benefiting from downtown economic development spurred by the new Riverwalk, recreational opportunities have improved with the addition of an athletic field, canoe launch, and riverbank fishing areas. The removal of Woolen Mills Dam has served to restore ecological integrity to the Milwaukee River and improve quality of life for the local community.

Learn more about this case study by visiting the following link: www.americanrivers.org/tableofcontents/ssmilwaukee.htm or by contacting Helen Sarakinos, River Alliance of Wisconsin, hsarakinos@wisconsinrivers.org, (608) 257-2424.

of the community. The views of a minority faction should be considered in the dam removal decision, but care should be taken not to attribute them to the whole community.

Bottom line – Community Sentiments Toward the Dam and River: *How do community members feel about the dam? About the river? About dam removal?*

E. Historical Role of the Dam

Many communities, especially along the northern tier of the United States, owe their existence to a dam and its associated industries. Because of this, some dams have important historical value. The State Historic Preservation Office should be contacted early in the decision-making process to help ascertain whether a structure has historical significance. State and local historical societies are also excellent sources of information about the site's potential historical significance. If it is considered significant, steps may need to be taken to adequately document and preserve the history of the dam. Sometimes, the dam's historic value may rule out dam removal as an option. However, in most cases dam retention is not necessary to preserve the historic significance of the structure. Commemorative plaques, educational kiosks near the river, or even a display with parts of the dam preserved near the river or in a local museum could help honor and preserve the memory of the dam in the event of removal.

When a State Historic Preservation Office determines that a dam has true historic significance, the need to record and commemorate its history may be legally required. In other cases, it may be important to the community – but not legally mandated – to document and honor the dam's historical role in the communities' development.

CASE STUDY

When considering dam removal, it is important to bring State Historical Societies and State Historic Preservation Offices (SHPO) into the process early on. Failure to inform the SHPO in a timely manner delayed the removal of McGoldrick Dam on the Ashuelot River in New Hampshire an entire year. Once the SHPO was notified of the pending dam removal, the historic nature of the site had to be documented through photographs and an historic inventory. Even though involvement of the SHPO significantly delayed the project, the state was able to use the opportunity to develop historic interpretive signs to commemorate the structure and educate the public.

Learn more about this case study by visiting the following link: www.amrivers.org/damremovaltoolkit/mcgolderickdam.htm or by contacting Stephanie Lindloff, New Hampshire Department of Environmental Services, slindloff@des.state.nh.us, (603) 271-8870.

Bottom Line – Historical Role of the Dam: *Does the dam have true historical value, and are there ways to commemorate the historical value without keeping the dam?*

Neuse River in North Carolina after the Quaker Neck Dam removal. Photo: Mike Wicker, U.S. Fish and Wildlife Service.

F. For More Information

More information about the societal issues discussed above can be found through the following sources:

- Digging Deeper: More in-depth questions that expound on the criteria presented in this section can also be found in the Appendix to this report.
- Born, S.M., et al. 1998. *Socioeconomic and institutional dimensions of dam removal: The Wisconsin Experience.* Environmental Management. Vol. 22(3): 359-370.
- Johnson, S. and Graber, B. *Enlisting the Social Sciences in Decisions about Dam Removal*. Bioscience (Forthcoming, Aug. 2002).
- Federal Advisory Council on Historic Preservation (www.achp.gov)

The following sources may provide additional information about the historic value of a particular dam:

- State, tribal, and federal historic preservation offices (www.achp.gov/programs.html)
- Old news clips and photos
- Historical photos and stories about the pre-dammed river
- Aerial photographic records from Natural Resource Conservation Service, Department of Defense, United States Geological Survey, and others
- State historical societies and state libraries

Part VI. Technical/Engineering Issues

While engineers have the capability to repair or rebuild virtually any dam structure or to manage the issues involved in removing any structure, the costs and complexity can vary considerably. Thus, what is technically feasible may not be practical. Listed below are engineering issues that may arise in considering whether to remove or repair a dam and mitigate for the associated environmental impacts. Many options exist for handling the various engineering issues and all options should be considered. When a project seems at first to be financially infeasible, creative thinking by engineers and project planners can often lead to financially viable alternatives.

A. Feasibility of Repairing and Maintaining the Dam

Maintaining a dam involves: (1) safety repairs or upgrades; (2) repairs or upgrades to continue efficiently providing the dam's intended uses; and (3) mitigation of the dam's environmental impacts. The questions here focus on the engineering issues and related costs associated with these maintenance needs.

A1. Safety Repairs or Upgrades

The typical life expectancy of a dam is about 50 years.[19] The structural integrity of dams naturally diminish over time, requiring periodic maintenance and repairs. Repairing and upgrading a dam can be straightforward, or it can be challenging, depending on the age, size, and condition of the structure. Often the full extent of necessary repairs will not be known until construction begins. Regular maintenance and repairs can extend the life of a dam. However, repairing or

CASE STUDY

Faced with the risk of failure of Rat Lake Dam on Whitestone Creek, the residents of Brewster, Washington had to decide whether to remove or repair the dam. After an extensive cost-benefit analysis of the various options, dam removal was selected as the most cost-effective option. The cost of removal ($52,000) was a fraction of the cost of rehabilitating the existing dam ($261,000) or building a new 120-foot high dam downstream.

Learn more about this case study by visiting the following link: www.amrivers.org/tableofcontents/sswhitestone or by contacting Doug Johnson, Washington Department of Ecology, (360) 407-6623.

[19] *Dam Safety: A National Concern.* Association of State Dam Safety Officials, January 12, 2001. (www.damsafety.org/print.cfm?pageid=infocentral&content=damsafety101), Jan. 12, 2001.

Detters Mill Dam on Conewago Creek in Pennsylvania. Photo: Scott Carney, Pennsylvania Fish and Boat Commission.

rebuilding an old structure to bring it up to today's safety standards can be expensive, sometimes prohibitively so, particularly if the owner is an individual or small community. In some cases, the most efficient and cost-effective way to eliminate the safety hazard is to remove the dam.

Bottom line – Safety Repairs or Upgrades: *If the dam is unsafe, will dam removal cost less than repairs and ongoing maintenance? Are repairs to the dam prohibitively expensive?*

A2. Repairs or Upgrades to Continue Efficiently Providing the Dam's Intended Uses

Often a dam will need periodic repairs or upgrades to continue providing its services. For example, impoundments fill with sediment over time as material is trapped and deposited behind the dam. In order to maintain the uses of the impoundment, this buildup often must be managed. If the dam produces hydropower, the hydropower equipment must be maintained and periodically upgraded in order to continue cost-effective production.

Bottom line – Repairs or Upgrades to Continue Efficiently Providing the Dam's Intended Uses: *If expensive upgrades are needed to maintain the dam's services, is it more cost effective to remove the dam and find alternatives to replace those services?*

A3. Mitigation of the Dam's Environmental Impacts

Some dams can be operated to decrease their impact on the aquatic environment. The need for environmental mitigation depends on a variety of factors, including the degree of environmental degradation in the river, the fish and wildlife species that currently or historically inhabited the area, the designated use of the waterbody, and the legal requirements that apply to the dam.[20]

Bottom line – Mitigation of the Dam's Environmental Impacts: *If environmental mitigation measures are needed, is it more cost effective to keep the dam and mitigate for its environmental impacts or remove the dam?*

B. Feasibility and Design of Dam Removal

For many dams, especially small ones, dam removal is a relatively straightforward demolition project, though care must be taken to protect the surrounding structures and natural environments. For other dams, engineering the removal can be complex. Many of the questions related to the feasibility and design of a dam removal will be most relevant once a decision has been made to remove a dam. However, these questions should be reviewed in advance because they may have an impact on both the feasibility and cost of removal. For example, sometimes removal can impact other infrastructure in, near, or over the river (e.g., bridges and water lines). Although in most situations protecting this infrastructure from damage is a simple process, in some cases it may be so complex, expensive, or both that dam removal may not be practically feasible. The sections below address some of the key engineering issues that arise in a removal.

B1. Obtaining Dam Removal Permits

Before a dam is removed or even repaired, permits are required to proceed with the work. These can include federal, state, and municipal permits. The permitting process is designed to minimize or negate potential impacts on the environment, navigation, and other

CASE STUDY

Once an abundant source of food for the settlers at Plymouth, the alewife in Town Brook now have to be trucked upstream around Billington Street Dam. In an effort to restore this historic stream, the Town of Plymouth, Massachusetts along with a number of state and federal partners, is seeking to remove the dam. Because project design costs exceeded earlier estimates, aspects of the engineering plan had to be changed in order to manage the top layers of impounded sediment behind the dam, which were contaminated with asbestos. Project managers also had to work with Massachusetts' extensive permitting laws. To meet state permitting requirements, the engineers decided to break the removal into two phases: dredging and disposal of the contaminated sediment, and the physical removal of the dam.

Learn more about this case study by visiting the following link: www.state.ma.us/dfwele/river/rivRestore or by contacting Karen Pelto, Massachusetts River Restore, karen.pelto@state.ma.us, (617) 626-1542.

[20] For a broader discussion of questions that should be asked about environmental impacts of the dam and dam removal, see Ecological Issues (Part III).

Franklin Dam on the Sheboygan River in Wisconsin. Photo: Edward Mueller.

concerns. In some cases the regulatory process can play a significant role in determining restoration or repair options and costs.

Some states have streamlined permitting processes for environmental restoration projects such as dam removals. In other states, no specific permitting procedures for restoration projects are available, and basic regulations and permitting procedures can be quite stringent. For example, some states do not allow any violations of water quality standards, even if the violations are short-term and are part of a restoration project (such as turbidity related to dam removal). In these cases, necessary measures must be taken in the removal process, or dam removal may not be possible.

Bottom line – Obtaining Dam Removal Permits: *Will permitting requirements affect the design, cost or feasibility of the removal? Are there permitting requirements for dam repair, reconstruction, or related to any of the services provided by the dam that will affect the feasibility or cost of keeping the dam?*

B2. Protecting Against Environmental Impacts

Removing a dam can cause short-term disruptions to the areas immediately upstream and downstream of the structure – including altered flows, increased turbidity, disturbance from the presence of heavy machinery, and in some cases disturbance from controlled detonations. These disruptions, although short-term, must be timed appropriately to ensure that critical life stages of aquatic species are not harmed. Steps that can be taken to reduce impacts include: limiting the erosion caused by construction equipment; managing sediment to limit the amount released when the dam is breached; timing the removal to not coincide with fish spawning runs, mussel burrowing periods,

or other seasonal habitat requirements; constructing a temporary structure (e.g., cofferdam) to decrease turbidity and/or divert fish and wildlife away from the site; and timing the removal during appropriate flow conditions.[21]

Bottom line – Protecting Against Environmental Impacts: *What steps must be taken to eliminate or minimize the environmental impacts of the dam removal?*

B3. Managing Sediment

The amount, type, and potential movement of sediment trapped behind a dam are critical pieces of information in determining the most effective engineering option for removal. A sediment management plan needs to be developed for all dam removals, and can significantly impact the design, cost, and even feasibility of a dam removal.

Sediment dispersal downstream may or may not be a welcome result of dam removal. In some cases, downstream river stretches and deltas are sediment-starved due to the presence of the dam, and release of sediments is considered a positive outcome, replenishing beaches and redistributing gravel and sand for riverine habitat. In other cases, dispersal of sediment may threaten downstream aquatic habitat, water quality, and property.

There are a number of options for managing sediment. In some cases, simply allowing sediment to naturally redistribute downstream can be the best option, both technically and ecologically. In some cases, sediment can be stabilized in the impoundment. And in other cases, dredging and removing some or all of the sediments may be the best approach.

CASE STUDY

In the 1980s, the Fox River Paper Company considered removal of the Rising Dam on the Housatonic River in Massachusetts because it was in need of expensive safety repairs. In evaluating the sediment behind the dam, the Massachusetts Department of Environmental Protection found significant amounts of PCBs. The dam's owner decided that it would be cheaper to repair the dam and maintain the sediment behind the dam than remove the dam and contaminated sediment.

Learn more about this case study by visiting the following link: www.americanrivers.org/damremovaltoolkit/housatonic.htm or by contacting Myron Petrovsky, mbpcnslt@javanet.com.

If contaminated sediments are present behind the dam in higher quantities than are present downstream, the design of the removal may be changed significantly. It may be necessary to dredge the sediments before removal in a manner that will not resuspend toxic particles. Depending on the nature of the contaminants, it may also be necessary to treat and/or properly dispose of the sediments after they have been removed.

Bottom line – Managing Sediment: *Is there a feasible method of managing the sediment behind the dam?*

[21] For more information about identifying potential environmental impacts of the removal, see Ecological Issues (Part III).

Elwha Dam on the Elwha River in Washington State. Photo: John Rosapere.

B4. Removing Structures

The physical removal of a dam is often a straightforward deconstruction process. Dams are commonly removed with heavy equipment including a backhoe with a hydraulic hammer or bucket attachment. In some cases, detonation devices are used to break up particularly dense materials. The permitting process often significantly guides the procedures that can be implemented during removal. For example, regulations may specify whether or not heavy equipment can be operated in the channel, commonly known as working "in the wet."

The current condition of the structure can also influence removal procedures. An aging, structurally unsound dam may break apart very easily with construction equipment, but could also make conditions more difficult to control. If there are portions of the dam that are likely to fail under the pressure of heavy machinery and demolition equipment, a contractor may need to consider alternative methods for removal, particularly if the dam is too long to be reached entirely from the banks of the river. Determining the age of a dam or viewing original construction drawings or photos can provide some insight into its structural integrity. The longer a dam has been subject to the erosive and corrosive power of water, and impacts from freeze/thaw conditions, seismic activity, and vegetation growth, the more likely a dam has been structurally compromised. This knowledge can help determine the resistance the materials are likely to provide to demolition efforts.

The ability to access the dam site can also impact the design and cost of removal. Where a site is relatively inaccessible or where regulations do not permit heavy equipment in the water, access to the site may need to be developed, adding to project expenses. This may involve constructing temporary roads or platforms, or working from floating barges. Sometimes water needs to be diverted away from an area using a cofferdam or by breaching the dam at a location that allows the river to flow away from the current construction area.

The presence of nearby disposal sites for removed material, and sediments if dredged, can also influence removal costs. Disposing of material on-site or re-using material can significantly reduce project costs. For example, disposed material may be used to fill and reclaim power canals and other facilities associated with the former dam, to help stabilize the re-exposed channel, or for habitat structures within the channel.

In general, care should be taken not to over-engineer the removal, as this can lead both to unnecessary costs and to unnecessary impacts on the environment. Case studies of successful removals of dams of similar size should be gathered, if available.

Bottom line – Removing Structures: *What is the most cost effective and environmentally sound dam removal method?*

B5. Protecting Infrastructure

Removal of a dam can affect nearby infrastructure, such as bridges and wells. Actions may need to be taken to mitigate for these impacts. It is important to include these mitigation projects in cost estimates and engineering designs. In some situations, these mitigation projects can have a significant impact on the overall cost of the dam removal option.

If structures such as bridges, water or sewer lines, and wells were built in or near the impoundment with the dam in place, they may need to be stabilized or relocated when the dam is removed. Buildings associated with the dam (e.g., a mill building or powerhouse) that have foundations dependent upon the dam structure may also need to be stabilized. Water intake structures, boat docks and ramps, and sewage outfalls may become ineffective at lower water levels and therefore may need to be extended or relocated. Also, draining a large impoundment may cause the local water table to drop, which can result in what is known as bank slumping, where the drained soils can no longer support weight and fall into the river. Slumping can damage structures built along the banks of the river, including homes, roads, and bridges. A very slow drawdown of the impoundment may be required to minimize the risk of slumping.

CASE STUDY

In February 2000, the U.S. government purchased Elwha Dam on the Elwha River from its private owners with the sole purpose of removing it and restoring anadromous fish runs within the basin. Due to the massive amounts of sediment and water that will be released, downstream infrastructure must be modified prior to removal of the dam. Water withdrawal systems must be replaced, and local roads and well heads must be raised. The National Park Service and the Bureau of Reclamation are looking into building an open channel pre-treatment facility, infiltration gallery for industrial users, a second well for municipal use, and modifying existing wells. Once these projects are complete and funding has been appropriated, Elwha Dam can be removed.

Learn more about this case study by visiting the following link: www.amrivers.org/damremovaltoolkit/elwa.htm or by contacting Jim Mumford, Bureau of Reclamation, (208) 378-5240.

Prairie River in Wisconsin after the Ward Paper Mill Dam removal. Photo: River Alliance of Wisconsin.

The results of dam removal may also have an impact on other dams downstream due to changes in flows and dispersal of sediment. Depending on the proximity of downstream dams and their capacity to handle such changes, the design of the dam removal may have to be altered to lessen the impacts.

During the removal process, the relative uncertainty of weather conditions and the structural integrity of the dam may create liability concerns from potential damage to downstream property and infrastructure. To manage this, the removal strategy may require a more conservative approach, affecting both time and cost estimates.

Bottom line – Protecting Infrastructure: *Are there structures that will have to be stabilized, retrofitted, or relocated if the dam is removed?*

B6. Restoring the Channel

The necessary extent of channel restoration depends on the size of the impoundment and the need for additional habitat improvement. In many cases, the stream's natural healing ability precludes the need for extensive restoration engineering, especially with small dams in rural areas. Run-of-river[22] dams with narrow impoundments may also need very little channel restoration work. At other dams, particularly those with large amounts of sediment, active channel restoration may be necessary because as the restored river carves a channel through the sediment,

[22] Run-of-River – The amount of water entering the reservoir is equal to the amount of water exiting the reservoir.

it may leave behind steep banks that are subject to erosion and provide little habitat value. Active channel restoration may also be necessary in cases where the channel needs to be guided away from existing infrastructure, such as roads and bridges.

Where necessary, channel restoration work should be included in cost estimates for dam removal. However, much of the restoration work may have to take place well after the removal of a structure to allow time for the channel to find a course before more active work is conducted.

Bottom line – Restoring the Channel: *Does the new river channel need to be actively designed or can the river naturally find its own channel?*

B7. Restoring Recovered Land

Dam impoundments are often nutrient-rich and can be full of seeds that were deposited on the impoundment bottom. Commonly, plant life will grow quickly when the land is exposed and planting vegetation will not be necessary. However, in some cases actively revegetating exposed areas before passive vegetation takes root can prevent erosion, prevent invasive plant species from taking over, and allow for the restoration of native flora.

Bottom line – Restoring Recovered Land: *Will the recovered land need to be actively revegetated?*

C. For More Information

For additional information on the technical and engineering aspects of dam removal, look for:

- Digging Deeper: More in-depth questions that expound on the criteria presented in this section can also be found in the Appendix to this report.
- Trout Unlimited and American Rivers. *Engineering and Other Technical Aspects of Small Dam Removals* (forthcoming, 2002).
- Graber, B., et al. 2001. *Technical Issues in Small Dam Removal Engineering,* in The Future of Dams and Their Reservoirs. Denver (CO): USSD. United States Society on Dams Annual Lecture, July 2001.
- Bowman, M. *Legal Perspectives on Dam Removal.* BioScience (Forthcoming, Aug. 2002).
- American Rivers. 2000. *Obtaining Permits to Remove a Dam*. (http://www.amrivers.org/damremovaltoolkit/dampermits.htm).
- An Aspen Institute Report on dam removal decisions, scheduled to be released in Fall 2002, contains a chapter on lessons learned in the implementation of dam removal. (www.aspeninst.org/eee/dams.html).

VII. Conclusion

The questions involved in determining the most appropriate future for a dam, the river in which it is located, and the surrounding community are many and can be complex. Few of these questions can be readily and neatly identified as a "single" issue, such as strictly an ecological, economic, social, or engineering issue. The engineering issues are perhaps the most accurately labeled, but even most of these issues have economic impacts. The reality is that most of the questions presented here do not have "yes" or "no" answers; rather, they can and will be answered many ways depending on site specifics, who is asking the question, who is answering it, and other variables.

While there is often no definitive answer to a question about whether a particular dam should be removed, there is a right and wrong way to go about making a dam removal decision. We hope that *Exploring Dam Removal* has helped to identify the information needed to make a good dam removal/retention decision in your community – one that is based on an assessment of all the facts, after consultation with the affected parties, and using objective criteria.

In your community, there may be sound reasons not to remove a dam. Even if the dam remains, however, you can still take steps to improve river health such as operating the dam differently, restoring riparian habitats, or reducing pollution from agricultural and domestic runoff sources. If you do choose to remove a dam, you may want to consider contacting a nearby environmental or conservation group, and you may want to consult the dam removal resource materials described at the end of the Introduction. Whether you are a concerned dam owner, citizen, agency employee, engineer, community leader, conservationist, or environmentalist, the staff at American Rivers and Trout Unlimited hope we can help you make the right decision about whether or not to remove your dam.

For additional information on dam removal or any of the information presented in this document, contact:

American Rivers
1025 Vermont Avenue, NW, Ste 720
Washington, DC 20005
202/347-7550
RiversUnplugged@amrivers.org

Trout Unlimited
211 South Patterson St., Ste 180
Madison, WI 53703
608/250-2757
RestoreRivers@tu.org

Appendix: Digging Deeper

Below is an in-depth selection of questions that will allow stakeholders and decision-makers a more thorough understanding of all of the issues that should be considered when deciding whether or not to remove a dam. As discussed in Part I, not all of these issues will have direct relevance or major significance in each dam removal. The list of questions provide information to enable you to explore in more depth those issues that are relevant or important to your dam removal decision and will enable you to explore an issue in more depth. The level of analysis appropriate for each of these questions depends on the size of the dam and the scope of its impacts. In most circumstances, the majority of these questions can be answered (or roughly estimated) relatively easily. In some circumstances, answering these questions will require research and field studies.

As with the body of *Exploring Dam Removal*, this Appendix is divided into four areas of consideration: (a) ecological, (b) economic, (c) societal, and (d) technical/engineering. Within each section, questions are provided that will explore the effect of keeping the dam, and the effect of removing the dam. Many issues that need to be considered when making a decision about whether or not to remove a dam do not fit neatly into one of these four categories, as such there is significant overlap between the four areas of consideration. Thus, some questions are repeated in several categories.

I. Ecological Issues

A. Upstream Flow and Habitat

Bottom Line: *Will the restored river and riparian habitat upstream outweigh the loss of impounded habitat?*

EFFECT OF KEEPING THE DAM

1. Is this a run-of-the-river dam or peaking dam?
2. How much lake-like habitat does the dam create? And what type?
3. How many species and which species of fish and other wildlife benefit from the impoundment?
4. Are these fish capable of naturally reproducing or must they be regularly stocked?
5. How abundant is reservoir and lake habitat in the region?
6. Does the reservoir and lake habitat in the region provide enough suitable habitat for lake-like species?
7. How many acres of wetlands does the dam create? And what type?
8. What species benefit from these wetlands?
9. How much riparian and riverine habitat was flooded, warmed, or otherwise altered by the dam and its impoundment?
10. How many species of riverine fish and other wildlife are negatively impacted by the dam's fragmentation and the inability to access riverine habitat?
11. If other dams exist on the river, how much impounded and riverine habitat is available on the river?

EFFECT OF REMOVING THE DAM

1. How much riverine habitat is likely to be restored? And what type?
2. How much riparian and upland habitat is likely to be restored? And what type?
3. How many species and which species will benefit from the restored habitat?
4. Will dam removal open up and/or restore critical riverine and riparian habitat for species of concern?
5. Will restoration of previously submerged lands provide beneficial habitat for species of concern?
6. How abundant is riverine habitat in the watershed?
7. Does currently available riverine habitat provide suitable flows for sustaining habitat for riverine species?
8. Will there be specific zoning restrictions in the riparian habitat to restrict further development/encroachment?
9. What type, quality, and how much wetland habitat is likely to be lost?
10. What type, quality, and how much wetland habitat is likely to be restored?
11. How much and what quality of impoundment habitat is likely to be lost?
12. What species will suffer from loss of either wetland or impoundment habitats?
13. Will loss of the impoundment or wetlands eliminate beneficial habitat for species of concern?
14. Is there other suitable habitat in the watershed for lake-like species affected by the dam removal?
15. Will removal of the dam affect groundwater supply for legal wells?
16. Does the dam affect the groundwater table, and if so, will riparian wetlands be affected by drawdown of the impoundment?

B. Downstream Flow and Habitat

Bottom Line: *Is dam removal necessary to restore natural flows to the river? Do the benefits of restored flows outweigh the impacts on species that prefer unnatural flows?*

EFFECT OF KEEPING THE DAM

1. Is the dam run-of-the-river or does it alter the natural flow regime?
2. How has the dam altered flows downstream?
3. How has the dam altered downstream riparian and riverine habitat?
4. How will flow alterations with the dam in place impact fish and wildlife species?
5. What species benefit from the change in flows created by the dam?
6. What species are adversely affected by the change in flows created by the dam?
7. Could keeping the dam, but changing how it is operated, restore more natural flows? Will sediment buildup eventually eliminate this flexibility?

EFFECT OF REMOVING THE DAM

1. Will dam removal restore the river's natural flows?
2. If natural flows were restored to the river, which riverine and riparian habitats will benefit?
3. If natural flows were restored to the river, which riverine and riparian habitats will be adversely affected or eliminated?
4. How many species, and which species, will benefit from the restored flows and new habitat?
5. How many species, and which species, will be adversely affected by the restored flows and new habitat?
6. How will current and future watershed conditions and stormwater runoff affect flows?

C. Fish and Wildlife

Bottom Line: *Is the net impact of dam removal on fish and wildlife populations positive or negative?*

EFFECT OF KEEPING THE DAM

1. What fish and wildlife species benefit from the dam? Are these species of concern?
2. What fish and wildlife species does the dam negatively affect? Are these species of concern?
3. Can riverine species reproduce at a sustainable rate in the impoundment? Are they threatened by non-native species?
4. Are contaminated sediments built up behind the dam currently harming fish and wildlife or likely to in the future?
5. Is the current condition of fish and wildlife consistent with published river or fisheries management plans applicable to the area?

EFFECT OF REMOVING THE DAM

1. What fish and wildlife species will benefit from dam removal? Are these species of concern?
2. What fish and wildlife species will suffer from dam removal? Are these species of concern?
3. Will the process of removing the dam negatively impact fish and wildlife populations in the short-term? Long-term?
4. If any contaminated sediments are built up behind the dam, will their release be harmful to fish and wildlife?
5. Will dam removal be consistent with published river or fisheries management plans applicable to the area?
6. Could any negative impacts to fish and wildlife that are attributed to the removal process be reduced or eliminated by altering the project's timing or design?

D. Passage and Movement of Fish and Other Species

Bottom Line: *Will dam removal improve safe passage of migrating fish and movement of resident fish and wildlife? Is dam removal necessary to accomplish this? Can dam removal be done without enabling the spread of undesirable species?*

EFFECT OF KEEPING THE DAM

1. Does the dam prevent undesirable, non-native, diseased, or contaminated species from spreading throughout the river system?
2. Does the dam block movement or migration of fish or other wildlife (such as shrimp or mussels)? Are any of these species of concern?
3. Does the dam have effective fish passage devices, or could they be installed, to aid passage of fish and wildlife species? Will the devices be effective at passing all species and "life stages" of concern? What species mortality rates are associated with these devices? What is the cost of installing and maintaining the fish passage devices?
4. What kind of impact does the impoundment have on fish migration (e.g., affecting upstream and/or downstream migration as the species navigates a lake-like as opposed to a river environment)? Can this impact be reduced or eliminated?
5. What is the cumulative impact of all of the river's dams on fish migration? Can these impacts be reduced or eliminated?

EFFECT OF REMOVING THE DAM

1. Will dam removal result in an increased survival rate for species of concern by allowing these species to reach appropriate spawning, rearing, and foraging habitat?
2. Will dam removal restore access to any species' historic range?
3. Will removing the dam encourage the spread of undesirable species? Could measures be taken (e.g., building another smaller barrier) to prevent the spread of undesirable species?
4. Will removing the dam allow contaminated or diseased fish to move into sections of the river not currently contaminated?
5. Will the physical deconstruction of the dam have a negative impact on the movement of fish and other aquatic species (e.g., mussels)? Can the removal process be timed to avoid negative impacts or will temporary fish passage be necessary?

E. Sediment Movement

Bottom Line: *What is the current net impact of the accumulated sediment on the impoundment and downstream habitats? How will sediments released during dam removal impact the riparian and riverine habitats in the short and long term?*

EFFECT OF KEEPING THE DAM

1. How sediment-rich is the river upstream from the dam? Downstream of the dam?
2. How much sediment has built up behind the dam?
3. How does sediment buildup affect water quality and fish and wildlife in the impoundment?
4. How does the associated release of sediment-starved water from the dam benefit or harm the river, fish and wildlife, and coastal habitat downstream?
5. Are/were there land use practices upstream (e.g., industry, mining, agriculture) that may have resulted in release of contaminants into the river that could have accumulated in the impoundment sediments?
6. Do the sediments behind the dam contain harmful contaminant levels?
7. Are the contaminant levels in the impoundment sediments greater than levels in sediments below the dam?

EFFECT OF REMOVING THE DAM

1. Will dam removal release sediment from the impoundment and deliver sediment to areas downstream? Do these downstream areas need the sediment?
2. Could a change in grade cause a headcut that will destabilize the upstream reach? If deemed harmful, could this headcut be prevented by grade controls downstream and/or upstream of the current dam site?
3. What will be the short- and long-term impacts of the dispersal of sediment following dam removal on downstream water quality and habitat? If negative, could these impacts be reduced or eliminated?
4. If the sediments contain harmful contaminants, what impact will their release have on water quality, fish and wildlife species, and public health? Can the contaminated sediments be removed from the impoundment or stabilized in place?
5. Are the contaminant levels in the impoundment sediments greater than levels in sediments below the dam?
6. How has the channel changed downstream of the dam? Does it have the capacity to convey sediment flows if the dam is removed?

F. Water Quality

Bottom Line: *Will dam removal have a net benefit on water quality, taking into account both short-term and long-term impacts and benefits?*

EFFECT OF KEEPING THE DAM

1. What was the water quality in the river prior to dam construction both up and downstream?
2. How does water quality at or near the dam compare with free-flowing segments of the same river?
3. What positive impacts, if any, does the dam have on water quality, including impacts on temperature, turbidity, alkalinity, dissolved oxygen, pH, and nutrient loads?
4. What negative impacts does the dam have on water quality, including impacts on temperature, turbidity, alkalinity, dissolved oxygen, pH, and nutrient loads?
5. Are the segments of the river around the dam violating Clean Water Act Total Maximum Daily Load (TMDL) standards?
6. If the dam negatively impacts water quality, does this have an effect on any species of concern?
7. Can poor water quality be mitigated with the dam in place?

EFFECT OF REMOVING THE DAM

1. What positive impacts will dam removal have on water quality, including impacts on temperature, turbidity, alkalinity, dissolved oxygen, pH, and nutrient loads?
2. What negative short-term and long-term impacts will dam removal have on water quality (e.g., turbidity, supersaturation)?
3. What measures could be taken to lessen the short-term or long-term negative impacts of dam removal on water quality?
4. What impacts will improved water quality have on any species of concern?

G. Riparian Areas

Bottom Line: *Will there be a net gain in the amount and quality of riparian habitat as a result of dam removal?*

EFFECT OF KEEPING THE DAM

1. How has the dam affected riparian areas upstream?
2. How has the dam affected riparian areas downstream?
3. What riparian species benefit from the presence of the dam? Are any of these species of concern?
4. What riparian species suffer from the presence of the dam? Are any of these species of concern?
5. Is there similar habitat nearby that provides enough suitable habitat for species that suffer from the presence of the dam?

EFFECT OF REMOVING THE DAM

1. How much riparian habitat both upstream and downstream will be restored through dam removal? Is this suitable habitat for species of concern?
2. How much riparian habitat both upstream and downstream will be lost through dam removal? Is this currently habitat for species of concern? Are there actions that can be taken to avoid loss of this habitat?
3. Is there similar habitat nearby that provides enough suitable habitat for species that will suffer from removal of the dam?
4. Will the process of dam removal have a short-term impact on any upstream or downstream riparian habitat? What can be done to reduce these impacts? To what extent and over what timeframe will this riparian area be able to be restored following dam removal?

H. Wetland Areas

Bottom Line: *How will the wetlands gained by dam removal compare in amount, type, and habitat value to the wetlands lost by dam removal?*

EFFECT OF KEEPING THE DAM

1. What wetland areas are associated with the river and impoundment with the dam in place? Is this suitable habitat for wildlife species, especially species of concern?
2. What wetland areas were associated with the river prior to dam construction? What was the impact on fish and wildlife species, especially species of concern, from the loss of wetlands due to construction of the dam?
3. Do the wetlands created by the impoundment (if any), or other nearby wetlands, provide suitable habitat for the species that suffered from loss of wetlands due to construction of the dam?

EFFECT OF REMOVING THE DAM

1. How much and what type of wetlands will be restored if the dam is removed?
2. How many and what type of species will benefit from these restored wetlands? Are any of these species of concern?
3. How much and what type of wetlands will be lost if the dam is removed?
4. What species will suffer from these lost wetlands? Are any of these species of concern?
5. Do the wetlands created by dam removal (if any), or other nearby wetlands, provide suitable habitat for the species that will suffer from the loss of wetlands due to dam removal?

I. Location of the Dam within the Watershed

Bottom Line: *Will dam removal significantly enhance the river's ecological values, given the location of the dam relative to other dams in the watershed?*

EFFECT OF KEEPING THE DAM

1. Where is the dam located within the river basin?
2. Where is the dam located in relation to the nearest upstream and downstream dams?
3. What are the cumulative ecological impacts of the dams on the river?
4. Are any other upstream or downstream dams potential candidates for removal or installation of fish passage devices in the short and long term?
5. Are there potential decision points at other dams on the river that will prompt a discussion about dam removal or fish passage (e.g., Do they meet safety standards? Are they due for relicensing by FERC?)

EFFECT OF REMOVING THE DAM

1. Will any benefits gained by dam removal be diminished because of the presence of other dams in the basin?
2. How significant will the quality and quantity of restored habitat be in the broader picture of the basin or ecosystem?
3. Are any other upstream or downstream dams potential candidates for removal or installation of fish passage devices in the short and long term?

II. Economics Issues

A. Dam Owner's Costs and Benefits

Bottom Line: *Are the long-term costs of operating and maintaining the dam less or more than the costs of removing the dam? Do any benefits of the dam need to be replaced, and if so, by whom?*

EFFECT OF KEEPING THE DAM

1. What are the economic benefits to the dam owner of owning and operating the dam?
2. What are the ongoing direct costs to the dam owner of keeping the dam, including insurance, operation, and maintenance costs?
3. What are the possible liability risks of keeping the dam (e.g., public safety hazards, environmental impacts)? Who is liable for these risks?
4. What will be the cost of repairing the dam (today and in the future), including project design and construction? Who will bear these costs?
5. What are/will be the costs of maintaining the impoundment, including (if necessary) current and future costs of dredging? Who will bear these costs?
6. What are the regulatory costs of keeping the dam, including annual registration fee(s), environmental compliance, permitting, and liability expenses? Who will bear these costs?

EFFECT OF REMOVING THE DAM

1. What are the regulatory costs to the dam owner of dam removal, including environmental compliance, permitting, and liability expenses?
2. What is the cost to the dam owner of removing the dam structure, including project design and disposal of waste materials?
3. Is reuse of waste materials and/or stored sediments a possibility (assuming they are not contaminated)?
4. What is the cost of site restoration following removal? Who will bear these costs?
5. What is the cost of stabilizing, retrofitting, or relocating nearby infrastructure (e.g., bridges, sewer or water lines, intakes, wells) affected by the dam removal? Who will bear these costs?
6. What will be the cost of managing sediment during and following dam removal? Who will bear these costs?

B. Societal Costs and Benefits

Bottom Line: *Are others in the community responsible for any additional costs and benefits of maintaining or removing the dam?*

EFFECT OF KEEPING THE DAM

1. What is the economic value to the public of retaining the dam (e.g., water supply, navigation, recreation, power generation, flood control)?
2. Does the dam provide economic value to other individuals and businesses (e.g., irrigation water for farmers, process water for factories)?
3. Does the dam's operation provide tax revenues to the local community?
4. Does the dam's presence and/or operation cause periodic damage to infrastructure (e.g., upstream or downstream flooding, ice jams affecting bridges or sewer or water mains)?
5. Does the presence of the dam require floodplain insurance for downstream property owners?

EFFECT OF REMOVING THE DAM

1. Is it possible to replace the dam's benefits through alternative means?
2. Will there be any adverse ecological or economic impacts as a result of implementing these alternatives?
3. What will be the public costs of replacing the dam's benefits through alternative means?
4. What will be the cost to other individuals and businesses of replacing the dam's benefits through alternative means?
5. Will removal of the dam alleviate negative impacts it once had on infrastructure (e.g., upstream or downstream flooding, ice jams)?
6. Is the removal of the dam likely to cause periodic damage to infrastructure (e.g., flooding, ice jams)?

C. Recreational Costs and Benefits

Bottom Line: *Will dam removal positively or negatively influence community revenues from recreation?*

EFFECT OF KEEPING THE DAM

1. What are the current economic benefits from the recreational use (e.g., sport fishing, boating) of the impoundment?
2. What are the costs (e.g., maintaining boat ramp, stocking fish in an impoundment, periodic dredging, aquatic weed harvesting) associated with obtaining the economic benefits from the recreational use of the impoundment?
3. What industry, if any, is dependent upon the impoundment?
4. What is the financial impact of the dam on river recreation opportunities? Are there nearby locations that provide alternative river recreation opportunities?
5. Do impoundment recreation opportunities attract other income into the community?
6. Does the public have access to the impoundment?

EFFECT OF REMOVING THE DAM

1. What are the expected economic benefits from the recreational use (e.g., sport fishing, boating) of the restored river?
2. What are the expected economic benefits from the recreational use of the previously submerged land (e.g., hiking, park activities)?
3. What are the expected negative impacts to community revenue, if any, from loss of recreation in the former impounded area?
4. What are the costs (e.g., maintaining boat ramp, stocking fish in river, park maintenance) associated with obtaining the economic benefits of the restored river?
5. What is the potential for community economic development through parks, riverwalks, and other community revitalization initiatives in areas adjacent to the restored stream?
6. What is the expected financial impact of dam removal on impoundment recreation opportunities? Are there nearby locations that provide alternative impoundment or lake recreation opportunities?
7. Will the restored river's recreation opportunities attract other businesses and income into the community?
8. Will the public have access to the restored river?

D. Environmental Costs and Benefits

Bottom Line: *Do the net environmental costs (or benefits) of keeping the dam outweigh the net environmental costs (or benefits) of removing the dam?*

EFFECT OF KEEPING THE DAM

1. Does the dam support any artificial commercial or recreational fisheries (e.g., artificial coldwater trout fishery)? If so, what economic value do they provide?
2. What are the costs of providing fish passage, fish hatcheries, and/or improving fish habitat that may have been harmed by the dam?
3. What are the costs of maintaining environmental health, such as clean water, that may be affected by the continued presence of the dam?
4. What are the costs, both up and downstream, associated with the dam retaining sediment in its impoundment?
5. Does the build up of sediment behind the dam impact the service(s) that the dam provides?
6. What are the mitigation costs for other environmental damage that may be associated with the dam?
7. What funds, if any, are invested in stocking fish in the reservoir?

EFFECT OF REMOVING THE DAM

1. Will there be mitigation costs for environmental impacts associated with the removal?
2. Will there be decreased costs related to water quality improvements? To fisheries management following dam removal?
3. How much funding (if any) will need to be invested in fish stocking following removal to "jump start" restoration?
4. How much funding (if any) will need to be invested in restoration, vegetation, and bank stabilization in the former impoundment?
5. What will be the costs of complying with environmental regulations during and after dam removal?
6. How much funding (if any) will need to be invested in managing sediment during the dam removal?

E. Property Values

Bottom Line: *Will dam removal positively or negatively affect property values adjacent to the stream? Will these effects, if any, be short or long term?*

EFFECT OF KEEPING THE DAM

1. How does the dam and/or the dam's impoundment affect the value of adjacent property?
2. Do neighboring properties gain significant benefit from the dam or impoundment (e.g., through recreation, scenic views)?
3. Do neighboring properties suffer costs associated with the dam (e.g., high water damage, poor water quality)?
4. Do neighboring properties pay for the operation and maintenance of the dam (e.g., through lake association membership)?
5. Do many neighboring properties have piers or docks located on the impoundment?
6. Is there a current setback requirement that prevents adjacent property owners from developing the land adjacent to the impoundment or river?
7. Do landowners have access to the impoundment? Does the public?
8. Have property values adjacent to the impoundment increased, decreased, or stayed the same over the past decade relative to other properties in the community?

EFFECT OF REMOVING THE DAM

1. What will be the short- and long-term impacts, both positive and negative, on the value of properties affected by the dam removal?
2. Who will own the reclaimed land following dam removal (e.g., adjacent landowner, dam owner, state)?
3. Will neighboring properties pay for any of the costs associated with dam removal (e.g., through lake association membership)?
4. If the reclaimed land changes hands, will the new landowner pay local property taxes?
5. Will landowners gain a scenic view of the stream or river and associated riparian areas (e.g., wetlands and waterfowl)?
6. Will landowners have access to the restored river and reclaimed land for recreation? Will the public?
7. Have property values adjacent to the river increased, decreased, or stayed the same over the past decade relative to other properties in the community?
8. Will downstream landowners need to add levees or relocate for flood control? What is the impact on their property values and insurance premiums?

F. Distribution of Costs and Benefits

Bottom Line: *Who benefits the most from retaining/removing the dam? Who bears the costs for retaining/removing the dam?*

EFFECT OF KEEPING THE DAM

1. Who pays the operational costs of the dam (e.g., the dam owner, dam users, tax payers)?
2. Who benefits from dam operations?
3. Who pays for the environmental costs of the dam?
4. Who profits from the environmental benefits of the dam?
5. Who pays for the safety costs/risks associated with the dam?
6. Who has profited from any enhanced recreational benefits associated with the dam?
7. Who has profited from any increased tax base benefits associated with the dam?

EFFECT OF REMOVING THE DAM

1. Who will pay for dam removal (e.g., the dam owner, dam users, tax payers)?
2. Who will benefit from dam removal?
3. Who will pay for the environmental costs of dam removal?
4. Who will profit from the environmental benefits of dam removal?
5. Who will pay for the safety costs/risks associated with dam removal?
6. Who will profit from any enhanced recreational and/or increased tax base benefits associated with dam removal?
7. Who will benefit and who will be hurt by changes in property values associated with dam removal?
8. Who will pay to replace lost benefits associated with the dam (e.g., water supply, power, navigation, flood control)?

G. Availability of Funding for Dam Repair or Removal

Bottom Line: *What funds are available to pay for dam maintenance/repair or removal?*

EFFECT OF KEEPING THE DAM

1. Are funds available for routine dam operation and maintenance? Who provides these funds (e.g., dam owner, lake association, federal government, state government)?
2. Are funds available for dam repair or replacement? Who provides these funds now and in the future?
3. Are funds available for recreational improvements to the impoundment (e.g., dredging, weed harvest, fish stocking)? Who provides these funds?
4. Are funds available to design, construct, and maintain environmental mitigation (e.g., fish passage structures) at the dam? Who provides these funds?
5. What new funding opportunities (e.g., grants for community revitalization) may become available as a result of dam repair, replacement, and/or improvements to the impoundment?

EFFECT OF REMOVING THE DAM

1. Are funds available to support the planning, engineering, and construction phases of a dam removal project? Who will provide these funds (e.g., dam owner, lake association, federal government, state government)?
2. Are funds available to provide mitigation for any negative impacts to infrastructure (e.g., wells, bridges, water treatment facilities, utility lines)? Who will provide these funds?
3. Are funds available to support the post-removal river restoration phase of a dam removal project? Who will provide these funds?
4. What new funding opportunities (e.g., grants for river restoration or community revitalization) may become available as a result of a dam removal?

III. Societal Issues

A. Community Understanding of the Dam, the River, and Dam Removal

Bottom Line: *Do the decision-makers and other concerned parties have sufficient information to make an informed decision about dam removal or dam retention?*

1. Are people aware that there is a dam in their community/region?
2. Do decision-makers understand the current purpose(s) and benefits of the dam? Does the community?
3. Do decision-makers understand the negative impacts of the dam on the river ecosystem? Does the community?
4. Do decision-makers understand the functions and benefits of a healthy river system? Does the community?
5. Do decision-makers understand the consequences of dam removal? Does the community?
6. Has the media disseminated information associated with the dam removal decision? Has this information been balanced and accurate?
7. How can decision-makers and the community be better informed about the issues associated with the dam removal decision (e.g., public meetings, library, other public displays)?
8. Are there knowledgeable and reliable information sources about the dam? About the river? About dam removal?
9. Are decision-makers working under a tight timeframe? Is it possible to extend that timeframe?

B. Service(s) Provided by the Dam

Bottom Line: *Does the dam provide any services? Are these services as valuable as the services provided by a free-flowing river? If yes, can these services be provided through alternative means?*

EFFECT OF KEEPING THE DAM

1. What service(s) was the dam designed (or later altered) to provide, such as mechanical power, hydropower, flood management, water supply, recreation, irrigation, or navigation?
2. What service(s) or benefits does the dam and/or its impoundment provide today?
3. Are any of these benefits "lifeline" services (e.g., water supply, fire protection, flood management)?
4. Does the dam provide services that do not have readily identifiable market value (e.g., aesthetic preferences)?
5. Is the need for the dam's services expected to remain the same, increase or decrease over the remaining life of the dam?
6. Is the dam the best source for these services, and if so, is it predicted to continue to be the best source?
7. Is the dam able to provide these services in an economically viable manner today? In the future?
8. Are repairs or upgrades currently needed to maintain the purposes of the dam (e.g., dredging the impoundment, repairing/upgrading the power turbines)? Will such repairs be needed in the future?
9. Is regular operation required to maintain the purposes of the dam (e.g., security measures, raising and lowering gates, clearing fish ladders and/or trash racks)?
10. Is it predicted that the dam will be needed in the future for other services?
11. What effect, if any, will deregulation of the electric industry and other industry changes have on services provided by this dam?
12. Will future public works in the area (e.g., bridge replacement, road repairs) be positively or negatively affected by keeping the dam?
13. How many resources (e.g., time, money, energy) have recently been invested in maintaining/operating, rebuilding, or repairing the dam?
14. Does the dam and the impoundment affect groundwater levels in the area? Are legal wells currently accessing groundwater in these affected areas?

EFFECT OF REMOVING THE DAM

1. Can any services provided by the dam that have readily identifiable market value (e.g., hydropower, flood control, water supply) be provided through an economical and environmentally superior alternative?
2. Could any "lifeline" services that are identified above (e.g., water supply, fire protection, flood control) be replaced or mitigated if the dam is removed?
3. What economic and ecological impacts, if any, will these alternatives have?
4. Can any services that do not have readily identifiable market value (e.g., aesthetic preferences) be satisfied by alternate means (e.g., nearby dam or lake) or by new or different services or benefits provided by a restored river ecosystem (e.g., restored waterfalls, riffles and associated wildlife)?
5. How many resources (e.g., local/state/federal funds and studies) have already been invested in improving water quality, fish and sediment transport, and other functions of the river?
6. How much more improvement will be gained by removing the dam?
7. Does the dam and impoundment affect groundwater levels in the area? Will legal wells that currently access groundwater in these affected areas be impacted by the dam's removal? What will be required to mitigate these impacts (e.g., cost, equipment)?

C. Who Benefits From and Who Bears the Costs of the Dam

Bottom Line: *Who benefits from and who bears the costs of the dam? Who will benefit from and who will bear the cost of a restored river?*

EFFECT OF KEEPING THE DAM

1. What people or groups benefit from the dam (e.g., individuals, communities, businesses, and interest organizations)? How many people benefit? How do they benefit (e.g., economically, quality of life)?
2. Are the primary beneficiaries public or private entities?
3. What people or groups have suffered from the presence of the dam (e.g., individuals, communities, businesses, and interest organizations)?
4. Are those hurt by the presence of the dam public or private entities?
5. Are there other free-flowing river resources nearby to make up for the loss of the free-flowing river?
6. How many people are employed by or at the dam and associated industries?
7. Who owns/maintains the dam? Is the dam abandoned?
8. Does the owner have the financial wherewithal to maintain the dam safely now and in the future?
9. Is the entity responsible for the cost of maintaining the dam also the entity that reaps the economic benefits associated with it?
10. How dependent is the community on the impoundment? How many houses are on the waterfront?
11. Is there public access to the impoundment?
12. Is the impoundment a popular recreation destination? How many people use the impoundment for recreation? How many people benefit from the impoundment, both directly (e.g., recreation) and indirectly (e.g., tourism industry)?
13. Does the impoundment have positive aesthetic qualities? Negative aesthetic qualities?
14. What downstream recreational opportunities does the dam provide, if any?
15. Is the water quality good year-round? Or is the impoundment algae-laden, malodorous[23], or both during any season?
16. Does the dam affect any tribal treaty obligations (e.g., tribal fishing rights)?

EFFECT OF REMOVING THE DAM

1. What people or groups will benefit from the dam removal (e.g., individuals, communities, businesses, and interest organizations)? How many people will benefit? How will they benefit (e.g., economically, quality of life)?
2. Will the primary beneficiaries be public or private entities?
3. What new recreational opportunities will the restored river offer? How many people will be likely to benefit, both directly (e.g., recreation) and indirectly (e.g., tourism industry)?
4. Will there be public access to the restored river? Will the primary beneficiaries be public or private entities?
5. Are there other benefits to the community of a restored river (e.g., improved water quality)?
6. How many people will visit and use the restored river for purposes other than recreation (e.g., researchers)?
7. How many people will be affected by the loss of the impoundment, both directly (e.g., loss of impoundment marina) and indirectly (e.g., loss of flat-water boating opportunity)?
8. Are there other lakes or impoundments nearby that could make up for this loss?
9. Do the economic benefits of a restored river outweigh the cost of removing the dam?
10. What aesthetic qualities will be revealed by dam removal (e.g., riffles, waterfalls, rock formations)?
11. How will dam removal impact waterfront property? Will adjacent landowners gain "new" land? Will property values increase or decrease (short-term and long-term)?
12. How has the public consideration of dam removal affected property values around the impoundment, if at all?
13. Could dam removal be part of a larger effort to revitalize the riverfront? To provide economic development opportunities?
14. Will removal of the dam affect water rights?
15. Will dam removal affect tribal treaty obligations (e.g., tribal fishing rights)?

D. Community Sentiments Toward the Dam and the River

Bottom Line: *How do community members feel about the dam? About the river? About dam removal?*

EFFECT OF KEEPING THE DAM

1. How does the community feel about the dam (e.g., pride, indifference)? Is there a general consensus about this sentiment or are there multiple opinions?
2. Has community sentiment about the dam changed over time?
3. How does the dam fit into the heritage of the community?
4. Are there people in the community who wish to preserve the dam because of its real or perceived historic value? Is there a general consensus about this sentiment or are there multiple opinions?
5. What is the current level of support for keeping the dam? Is there a general consensus about this sentiment or are there multiple opinions?
6. Do any local/regional/national elected or appointed officials support dam retention?
7. Does anybody else support dam retention (e.g., government agencies, prominent businesspeople, civic or conservation groups, or celebrities)?
8. How powerful (politically, economically, socially) are the supporters of dam retention?

EFFECT OF REMOVING THE DAM

1. How does the community feel about a free-flowing river (e.g., pride, indifference)? Is there a general consensus about this sentiment or are there multiple opinions?
2. What impact will dam removal have on the community's sense of heritage? Is there a general consensus about this sentiment or are there multiple opinions?
3. Do free-flowing segments of the river have historic value? Does this extend to the currently impounded section? If so, does the community feel strongly about this historic value? Is there a general consensus about this sentiment or are there multiple opinions?
4. What is the current level of support for dam removal? Is there a general consensus about this sentiment or are there multiple opinions?
5. Do any local/regional/national politicians/officials support dam removal?
6. Does anybody else support dam removal (e.g., government agencies, prominent businesspeople, celebrities, or civic or conservation groups)?
7. How powerful are the supporters (politically, economically, socially) of dam removal?

E. Historical Role of the Dam

Bottom Line: *Does the dam have true historical value, and are there ways to commemorate the historical value without keeping the dam?*

EFFECT OF KEEPING THE DAM

1. Does the dam have true historical value? In the community? Regionally? Nationally?
2. Is the dam on the National Register of Historic Places? Is the dam on a similar state list?
3. Are there dams nearby that have similar historical significance (e.g., architecturally, culturally) that are not under consideration for removal?
4. Are there funds available (now and in the future) for maintenance, repair, and other ongoing costs associated with keeping a historically significant dam?

EFFECT OF REMOVING THE DAM

1. Are there ways to preserve the historic value of the dam in the event of dam removal (e.g., monuments, museum displays, information kiosks, partial removal)?
2. Will the State Historic Preservation Office require that a historical inventory be completed for the site prior to the dam's removal?
3. Are there resources available to complete the historical inventory, if required (e.g., agency personnel, grants, in-kind services, volunteer assistance)?
4. Does the State Historic Preservation Office consider the dam removal to affect the site's historical value? If so, what do they and the affected stakeholders (e.g., local historical society, riparian landowners) recommend to mitigate these impacts?
5. Are there resources available to honor the historical significance of the dam, in the event of dam removal (e.g., grants, in-kind services, volunteer assistance)?

IV. Technical/Engineering Issues

A. Feasibility of Repairing and Maintaining the Dam

A1. Safety Repairs or Upgrades

Bottom line: *If the dam is unsafe, will dam removal cost less than repairs and ongoing maintenance? Are repairs to the dam prohibitively expensive?*

EFFECT OF KEEPING THE DAM

1. Has the dam been regularly maintained and/or repaired? How much does annual maintenance cost?
2. When was it last inspected by a regulatory agency? What were the results of the inspection?
3. Does the dam need to be upgraded to meet modern safety regulations (e.g., is the spillway space adequate to limit the flood risk and protect the dam from failure)?
4. Is the dam currently in need of repair? If not now, how soon will the dam require repair?
5. Can the dam be repaired, or does it need to be rebuilt? How much longer can repairs extend the dam's life?
6. How much will the repair or rebuild cost?
7. If the dam is repaired, what are the estimated costs for future maintenance and repair?
8. Are there seismic requirements that were not considered when the dam was first built that require the dam to be retrofitted?
9. What will be the impacts of dam failure?
10. Are there public safety concerns about the dam (e.g., unsafe swimming conditions, falling off the dam, injury from dam structures, injury from boating over the dam)? What are the liability risks? Can public safety concerns be alleviated through fencing and signage, or are additional security measures required (e.g., video surveillance)? How much will this cost?
11. Do the services provided by the dam, if any, generate revenue that could be applied to the cost of dam repair?

EFFECT OF REMOVING THE DAM

1. How much will it cost to remove the dam and restore the river?
2. Is removal a less expensive way to alleviate safety concerns at the dam?
3. What safety concerns occur will during the removal process (e.g., heavy machinery, traffic congestion)?
4. What safety concerns might be present with a restored river (e.g., waterfall, steep streambank drop-off, rapids)? Can public safety concerns be eliminated, and if so, how much will it cost?

A2. Repairs or Upgrades to Continue Efficiently Providing the Dam's Intended Uses

Bottom line: *If expensive upgrades are needed to maintain the dam's services, is it more cost effective to remove the dam and find alternatives to replace those services?*

EFFECT OF KEEPING THE DAM

1. At what rate is the impoundment filling with sediment or aquatic vegetation?
2. Is the dam intended to carry, or can it now carry, a full water load? A full sediment load? Is there a hazard posed by failure of this dam in a sudden loading?
3. How often does the impoundment need to be dredged?
4. How much does dredging cost?
5. Will structures supporting the dam's uses, such as turbines or water supply delivery systems, need to be repaired or upgraded now or in the future?
6. How much will these repairs and upgrades cost?
7. Are there other repairs or upgrades needed at the dam or in the impoundment to maintain the current uses of the dam? Will these repairs or upgrades be needed in the future?
8. How much will these repairs and upgrades cost? Is there adequate funding available?

EFFECT OF REMOVING THE DAM

1. If repairs or upgrades are needed, are there alternatives to the dam that can replace its services (e.g., off-channel water storage, alternative energy sources, deepen existing or drill new wells)?
2. Is it more cost effective over the short- and long-term to repair, upgrade, and maintain the dam and associated infrastructure or to remove the dam and replace its uses with alternatives? Is there adequate funding available for the alternative?

A3. Mitigation of the Dam's Environmental Impacts

Bottom line: *If environmental mitigation measures are needed, is it more cost effective to keep the dam and mitigate for its environmental impacts or remove the dam?*

EFFECT OF KEEPING THE DAM

1. What measures are needed to mitigate for the dam's environmental impacts (e.g., fish passage, flow regulation, water oxygenation, temperature regulation, bottom draw)? Is this mitigation legally required to keep the dam?
2. Are there new requirements due to new regulations or condition changes (e.g., fish passage/populations restored downstream and are now at the base of the dam, modification of the hydrograph due to new water projects in the basin)?
3. Can these mitigation measures be engineered to be effective in addressing the environmental impact?
4. Will application of these mitigation measures result in a change to the services provided by the dam?
5. What will be the cost of installing these mitigation measures?
6. What will be the cost of maintaining these mitigation measures?

EFFECT OF REMOVING THE DAM

1. Can mitigation obligations be met by removing the dam?
2. Is the cost of removal less than installing and maintaining mitigation measures?
3. Are there environmental impacts of the dam removal that will lessen or negate the environmental mitigation benefits?

B. Feasibility and Design of Dam Removal

B1. Obtaining Dam Removal Permits

Bottom line: *Will permitting requirements affect the design, cost or feasibility of the removal? Are there permitting requirements for dam repair, reconstruction, or related to any of the services provided by the dam that will affect the feasibility or cost of keeping the dam?*

1. Are there any federal or state permitting regulations governing maintaining and reoperating the dam (e.g., FERC hydropower relicensing)?
2. What federal permitting regulations govern the dam removal? Will any of the requirements affect the design, cost, or feasibility of the removal?
3. What state permitting regulations govern the dam removal? Will any of the requirements affect the design, cost, or feasibility of the removal?
4. What municipal permitting regulations govern the dam removal? Will any of the requirements affect the design, cost, or feasibility of the removal?

B2. Protecting Against Environmental Impacts

Bottom line: *What steps must be taken to eliminate or minimize the environmental impacts of the dam removal?*

1. What potential short-term and long-term impacts will dam removal have on the river and fish and wildlife?
2. Can the removal be engineered or timed so that the impacts are minimized or eliminated?

B3. Managing Sediment

Bottom line: *Is there a feasible method of managing the sediment behind the dam?*

1. Are significant amounts of sediment stored behind the dam?
2. Will a sudden release of sediment from dam removal harm aquatic and riparian species downstream?
3. Is sediment needed downstream?
4. How will the release of sediment compare to what is mobilized naturally in the river during a major storm event?
5. Can the sediment release be managed by adjusting the dam removal process (e.g., by removal during low flow periods, by drawing down the impoundment slowly, by incremental breaching, by dredging the impoundment, or with a downstream sediment trap)?
6. Is there contaminated sediment behind the dam? Is the contamination isolated or spread out?
7. Does the type and level of contamination behind the dam differ from the type and level of contamination downstream of the dam?
8. Is contaminated sediment found in the section of the impoundment that will become the new river channel if the dam were removed?
9. Should contaminated sediment be stabilized, neutralized, or removed?
10. How long will the river run with a heavy sediment load after removal? What effect will this have on flood carrying capacity? On water diversions and other infrastructure? On fish and wildlife?

B4. Removing Structures

Bottom line: *What is the most cost effective and environmentally sound dam removal method?*

1. Do original blueprints of the dam exist?
2. Of what materials is the dam made?
3. What equipment is necessary to demolish the structure?
4. Can demolition be done with heavy equipment or is blasting necessary?
5. Is there adequate access to the dam for construction equipment?
6. Is it necessary to divert water for construction equipment? Will a cofferdam be necessary?
7. Can materials removed from the dam be re-used or disposed of on-site?

B5. Protecting Infrastructure

Bottom line: *Are there structures that will have to be stabilized, retrofitted, or relocated if the dam is removed?*

1. Are there structures in the floodplain upstream or downstream, such as building foundations, water intakes, bridges, culverts or utility (e.g., sewage, water supply, gas supply) pipes?
2. Do these structures need to be stabilized, retrofitted, or moved?
3. Can such stabilization or relocation be cost effectively engineered?
4. Could dam removal affect other dams downstream?
5. Are there liability concerns involving downstream structures and property during the removal process?

B6. Restoring the Channel

Bottom line: *Does the new river channel need to be actively designed or can the river naturally find its own channel?*

1. Is the impoundment large?
2. Is the dam mainly run-of-river?
3. Are there boundary restrictions for the restored channel, such as a highway or railroad?

B7. Restoring Recovered Land

Bottom line: *Will the recovered land need to be actively revegetated?*

1. Will it be necessary to re-seed or plant plugs in the exposed land?
2. Is there a threat of erosion before the land revegetates itself?
3. Is there a threat of exotic plant species taking over?
4. Can seeds and plugs be planted by hand or is machinery or aircraft necessary?