6

Economics and Dam Removal

Dam removal is not unambiguously good, but attaching a more precise valuation is difficult because formal benefit–cost analysis procedures do not necessarily apply to dam removals. Existing procedures are intended for the evaluation of federal water resource development projects, especially the construction of large dams. Even if a particular dam removal qualifies as a federal action, economic analysis is secondary to certain overriding environmental considerations, such as the preservation of endangered species, or to safety concerns.

On the other hand, few dam removals are without controversy, and most involve numerous and diverse stakeholders, many of whom may be concerned about the justification for the ultimate decision. Benefit–cost analysis provides a disciplined process for identifying and measuring all potential effects of removal, both positive and negative. It arrays the impacts on various stakeholders in a way that allows comparisons to be made, and trade-offs negotiated.

The application of the federal benefit–cost analysis paradigm to proposed dam removals produces an interesting and somewhat complex inversion of the issues familiar to dam builders. On first impression, it may appear that the beneficial and adverse effects of dam construction would simply change sides. That is, the beneficial effects of dam removal might be thought of as the avoided costs of dam operation and avoided external costs, and the adverse effects of dam removal might be the lost beneficial effects of dam operation.

Although some of these relationships may be relevant, a number of new issues intrude on dam removal economics. These include the problem of defining a reference case. Conventional benefit–cost analysis

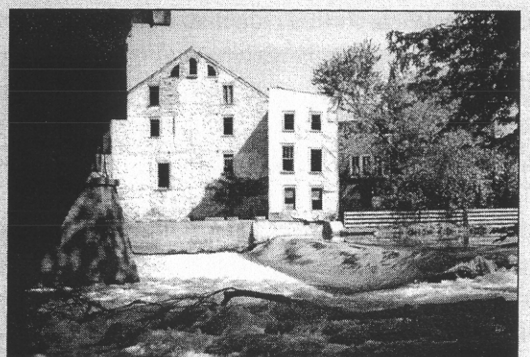
typically defines a no-action alternative, in comparison to which all beneficial and adverse effects are measured. With an existing dam, possibly in deteriorated condition and perhaps unsafe, no action may not be an alternative. A different type of reference case needs to be specified. For example, in cases in which it can be assumed that the monetary benefits of removal (avoided rehabilitation and operating costs) exceed the monetary costs (dam removal costs and the value of lost services), the non-quantitative environmental benefits might not be considered. This does not mean they are unimportant. In fact, states may be supportive precisely because dam removal assists them in achieving policy goals of improved water quality and habitat, and availability of fish and game species.

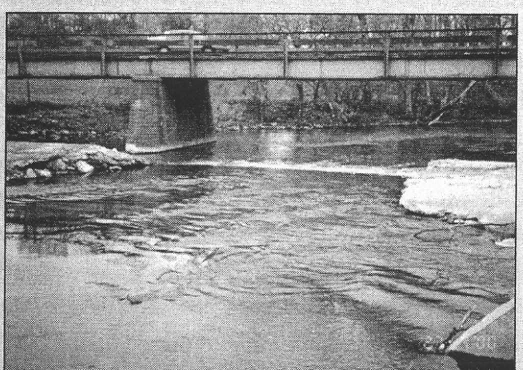
Dam removal may serve multiple economic objectives. The removal of Hinkletown Dam in Pennsylvania, for instance, restored fish habitat and cleared the way for new bridge construction (Box 6.1). When a dam is removed in the hope of restoring fisheries and/or various riparian environments, resources that were lost when the dam was built are not necessarily the ones that will be recovered. Future fish runs may differ from past ones for various reasons, riparian vegetation may regrow in different ways from its historical condition, and stream morphology may change as well. Introduced or exotic species in the area or reservoir also may compromise restoration goals. To prepare a credible economic analysis, the analyst not only needs to predict what will happen, but also needs to say when. In some cases there may be a significant lag after dam removal before ecosystem restoration or other removal objective is realized or attains management objectives. Because of discounting in the economic assessment, such lags can greatly reduce the weight given to a particular beneficial effect.

The adverse effects of removal include a number of straightforward cost items, such as the cost of removing the structure and disposing of the debris. However, this category also includes costs for which little data or expertise exists. For example, it is necessary to predict how the sediment will move after the dam is breached, and to identify adverse environmental impacts associated with the sediment load. The movement of clean sediment can be beneficial to downstream beaches (e.g., the case of Rindge Dam). Furthermore, the duration of these impacts also needs to be estimated. As with certain items on the benefits side of the ledger, there is only modest experience with this phenomenon, and estimates of magnitude and duration of dam removal effects necessarily involve substantial uncertainty.

Box 6.1 The Removal of Hinkletown Dam in Pennsylvania

Dams may be removed for a variety of reasons, including those unrelated to safety, species management, or river restoration. Hinkletown Mill Dam was a rock-filled timber crib dam capped with concrete located 38.7 miles above the mouth of the Conestoga River in Pennsylvania. The dam was approximately 7 feet high with a crest length of 92 feet. It originally was built in the 1700s to provide waterpower for a flourmill, which ceased operations sometime between 1940 and 1965. In 2000, the state highway department removed this obsolete, run-of-river dam. The realignment of approach roadways and modifications to a state highway bridge required the construction of new bridge piers at the same location as the dam.





Hinkletown Mill Dam before removal (upper photograph), and the river during the removal.

Photos courtesy of the Pennsylvania Department of Environmental Protection

NO-ACTION ALTERNATIVE

The analyst needs to define a point of reference for use in identifying and measuring the beneficial and adverse effects resulting from any action. Conventionally, this has been a no-action alternative: a scenario of events characterized by the absence of the action under study. The consequences of the proposed action are identified by comparing present and future conditions with the action to present and future conditions without the action. For example, if it is argued that a dam to be built will provide downstream flood protection, it needs to be shown that the expected flood damages with the dam (proposed action) will be lower than those expected without the dam (no action). The same "with–without" logic applies to all beneficial and adverse effects of a project.

However, the term "no action" is something of a misnomer. In almost every case, it involves action of some type. Conventional benefit–cost analysis requires that the no-action alternative be both feasible and the most likely set of events in the absence of the action under study. For example, if a water supply dam is planned to replace a community's contaminated groundwater, no-action alternatives do not include the continued supply of contaminated water or the absence of water supply. Instead, the analyst needs to determine the community's most likely response to the water supply problem if the dam is not built (e.g., importing water from another community or drilling new wells into a different aquifer). The no-action alternative incorporates whichever strategy proves feasible and is found to be the most likely choice. Benefit–cost analysis of the proposed dam considers only the differences between outcomes if the dam is built versus if it is not (and the no-action plan is implemented).

This same logic can be applied to dam removal. Many dams proposed for removal have structural or other safety deficiencies and some may no longer serve the purpose for which they were built. Furthermore, these conditions can be interdependent. Deteriorating turbines and generators may lead to the abandonment of a privately owned hydroelectric dam, especially if the combined cost of powerhouse renovation and needed (safety-related) structural improvements to the dam makes further investment infeasible. Conversely, if a dam no longer serves any economic purpose for some external reason, there may be a reduced willingness to carry out safety-related improvements.

In defining a no-action alternative to a proposed dam removal, it is clear that "no action" needs to include whatever actions are necessary to protect human life and comply with applicable regulations. These actions may include rehabilitation of the structure, spillway enhancements, and appropriate maintenance of the dam over the planning period. In this way, the avoided life-cycle cost of the safety upgrade becomes a beneficial effect of removal. But it is also possible that a previously abandoned dam (one that no longer serves any economic purpose) will become a viable asset once again after the safety-related deficiencies are corrected.

The no-action option also needs to take into consideration the anticipated costs, direct and indirect, that will be incurred if actions to protect human life fail. Because many small dams are privately owned, the loss of life due to dam failure has extenuating social aspects that, although difficult to measure, may have a significant impact on the dam owner and surrounding community.

VALUING THE OUTCOMES OF DAM REMOVAL

Market versus Nonmarket Goods

Some dam services, such as hydroelectric energy, are market goods. These services are sold or can be sold in existing markets at prevailing prices. The market determines values, and market transactions provide the data necessary for calculation. Certain outcomes of dam removal, such as the cost of breaching or the cost of removing portions of the structure, are also market goods. In this case, market transactions provide information on the value of labor, materials, machines, and so on used in the effort.

However, many outcomes of dam removal are not market goods and cannot be valued directly using market data. These outcomes include lost dam services, such as recreation, irrigation, water supply, and flood protection. These are nonmarket goods because users are not asked to pay any price (e.g., for recreation, flood protection), or the price is set administratively and does not reflect any market phenomena (e.g., for irrigation water). The environmental changes produced by dam removal (including the restoration of fish habitats) are also nonmarket goods because they are not priced and have no near substitutes that can be valued as market goods.

Methods are available for placing monetary values on nonmarket goods in some, but not all, circumstances. The commonly used methods can be organized into two general approaches. The revealed preference

approach includes methods requiring that the nonmarket good be a weak complement for some market good. In this case, the characteristics of the market good can be used to impute the value of the nonmarket good. Certain other nonmarket goods, not necessarily related to market goods, can be valued directly using one of a number of stated preference methods. Freeman (1993) is a standard reference for nonmarket valuation methods.

Revealed Preference Valuation Approaches

In the water resource field, two revealed preference methods have been widely applied: the travel cost method and hedonic price analysis.

- **Travel Cost Method.** Some services provided by dams, such as water-based recreation, must be used *in situ.* No one can use these services unless they travel to the location of the dam and reservoir. Even though the recreation service may not be priced, users reveal something of their valuation for that service through their willingness to incur travel costs (the weakly complementary market good). The application of this method usually involves the recording of automobile license numbers at recreation sites as well as detailed interviews with a sample of visitors. Certain aspects of the method are controversial, such as the usual assumption that the only purpose of a respondent's trip was to visit the site in question. If other stops were made, or if the trip itself was considered pleasurable, the travel cost method may overestimate the value of the service. On the other hand, other factors may cause the method to underestimate the value.
- **Hedonic Price Analysis.** If the visual amenity of a lake benefits property owners near the shore of the lake, then the amenity can be said to be consumed as part of a bundle of market and nonmarket goods (housing services, location convenience, etc.). Because the value of the amenity is assumed to decline on a smooth gradient as properties are located farther from the shore, it is possible to design a statistical analysis of many property values that will separate the component of property price attributable to the amenity. This method is quite limited in application because it can deal only with nonmarket goods that are bundled with market goods, and it further requires rather large datasets and carefully executed

statistical analysis. Biases are also possible, especially when the analysis does not satisfactorily control for housing attributes that may be correlated with distance from a shoreline.

There are additional market-based methods, including methods based on avoidance costs, or alternative costs. These are not included here because they are not widely applied to water resource projects.

Stated Preference Valuation Approaches

Stated preference methods are also described as direct valuation methods because they do not rely on related goods or actual markets in any way. Rather, these methods solicit valuations directly from users. The most common stated preference methods rely on survey research, most often in the form of personal or telephone interviews, or mailed questionnaires. The survey instruments describe a hypothetical market for the nonmarket good and ask respondents to state their valuations in one of a number of ways.

- **Contingent Valuation Method.** This is the most familiar stated preference approach. At the simplest level, the nonmarket good is described, a hypothetical market transaction is proposed, and the respondent is asked what he or she would pay for the good (or what payment would be accepted to forgo the good). The actual question may be open-ended ("What would you pay?"), multipart, or based on a payment card or some other device. The survey also includes questions on personal attributes (age, gender, education, income, etc.) that are used later to extrapolate sample responses to a larger population.
- **Contingent Referendum Method.** This is similar to the contingent valuation approach in all respects except that the elicitation question has the form "Would you pay $__, yes or no?" This is generally an easier question for respondents to answer, and it avoids some types of bias, but the method requires a much larger sample to produce useful results.
- **Contingent Ranking Method.** With this method, the respondent is not asked for a monetary value but instead is asked to rank a number of situations that involve different levels of the nonmarket good in question. This establishes a type of value relative to the (possibly known) values of other goods involved in the ranked alternatives. With careful design, this method can produce a monetary valuation.
- **Contingent Activity Method.** The respondent is asked how he or she would vary certain activities in response to a gain or loss in the nonmarket good. For example, if a dam is to be removed, nearby residents might be asked how often they would travel to the site, as opposed to their travel habits before the removal. An examination of the activities may provide a basis for valuing certain nonmarket goods.

All stated preference methods depend on the skill with which the survey instrument is designed and applied, as well as the sample size and the way in which results are analyzed. In addition to a possibly large error arising from the hypothetical nature of the valuation, there are numerous sources of potential bias. These include sample bias, nonresponse bias, strategic bias, starting point bias, anchoring, and implied value cues. Properly designed instruments administered by well-trained, professional interviewers generally avoid these biases or reduce them to low levels. The inherent error (sometimes called hypothetical bias) depends, in part, on the type of good being valued. If respondents have experience with purchases of a similar good or otherwise can imagine that good being traded in a market, the hypothetical may be minimal. If respondents cannot conceive of an actual market transaction involving the same or a similar good, then the questions may be difficult to answer and the hypothetical bias large.

Following the widely noted use of contingent valuation (CV) to estimate damages resulting from the *Exxon Valdez* oil spill, concerns were raised in the literature regarding the economic consistency of CV results, especially in the presence of significant non-use values. In response, the National Oceanic and Atmospheric Administration (NOAA) convened a panel of prominent social scientists, co-chaired by Nobel laureates Kenneth Arrow and Robert Solow. The NOAA panel developed a comprehensive set of guidelines designed to ensure reliable CV studies (*Federal Register*, Volume 58, pp. 4601–4614 [1993]). The panel's principal addition to the previous literature on this subject was the subset of guidelines described as the "burden of proof" requirements. These include criteria such as an acceptably low nonresponse rate, responsiveness of valuation to scope of damage, and respondents' understanding of the task. A later review by Carson et al. (1996) demonstrated that CV studies using the best practice of the time, including the *Exxon Valdez* study, complied fully with the NOAA panel guidelines. With respect to professionally designed and executed studies, the review concluded, "the Panel's concerns about temporal reliability, question format, and social desirability biases appear unwarranted" (Carson et al., 1996).

Generally, stated preference methods are broadly applicable to a variety of nonmarket goods. They also have the unique capability to measure intrinsic values (existence value, option value, bequest value) as well as use value. Properly done, the valuations produced by these methods can be credible and reasonably accurate. However, the techniques involved are very demanding. The necessary work is costly and time consuming and requires a high level of skill and experience. Anything less runs the risk of producing severely biased results.

BENEFICIAL OUTCOMES OF REMOVAL

Restored Environmental Services

The removal of a dam of almost any size usually has a profound effect on the stream and its riparian environment. Specifically, the stream flows freely again; there is no longer a distinction between upstream and downstream areas in the reach containing the dam site. Land previously inundated is exposed and revegetated. Slack water habitats and flat-water recreation areas may be lost, and stream habitats may be expanded and reconnected. Some fish habitats are lost, and others re-created. Although many dam removal decisions may be prompted by issues of human safety or other potential hazards, increasingly the restoration of fish habitats and fluvial processes also motivate dam removals, especially where dams have functioned as migration barriers to spawning by anadromous fish populations.

However, it is important to note, as emphasized in the previous chapter, that the restored habitats and biological communities will not necessarily be identical to those that were lost when the dam was constructed. Fish runs may or may not approximate those of historical record and may develop only after some time. Exposed land may revegetate with exotic trees or plants. An assessment of restored environmental functions, therefore, requires a determination of what is likely to be created and how long it will take.

The economic consequences of restored environmental functions related to dam removal are of two types: use values and intrinsic values.

Use values are economic measures of valuable environmental services that result from environmental functions. For example, the recovery and expansion of fish habitat (function) may lead to an increased population of harvestable fish (service). This increase can be quantified by a comparison to populations associated with the no-action alternative. Then the increased population can be converted to increased catch by commercial fishers and/or increased recreational fishing days, as appropriate. These predicted outcomes are economic goods, which can be valued by any one of a number of methods, providing a monetary measure of the use value of restored environmental services.

Intrinsic values are not directly related to the economic use of a dam or reservoir. Some restorations of environmental functions are regarded by society as valuable in their own right, simply because of their existence or the knowledge that resources will be preserved for future generations. These intrinsic values are also known as option values, existence values, and bequest values. They are likely to appear in cases in which the affected resource functions are unique in some way (no similar functions are generally available in other places) and the action that creates or destroys them is essentially irreversible. Irreversibility often is defined to include cases in which a reversal of the action is possible but very unlikely on economic grounds. The only available methods for placing monetary values on intrinsic values are the family of stated preference methods: contingent valuation, contingent referendum, or factorial analysis (Freeman, 1993; Randall, 1991). The use of these valuation methods requires substantial skill on the part of the analyst and may be costly or infeasible in particular situations.

Avoided Costs

When the costs associated with dam removal are compared to the costs implied by a properly designed no-action alternative, it becomes apparent that most direct costs of the no-action alternative are avoided by dam removal. These include the costs of rehabilitating the existing structure, making any required enhancements (spillway reconstruction), and maintaining the existing structure throughout the planning period, including liability insurance costs. These avoided costs are among the beneficial outcomes of dam removal. Sometimes the avoided costs of rehabilitating the structure drive the removal decision, as in the case of the Sandy River dams in Oregon (Box 6.2).

Box 6.2 Removal versus Renovation Costs: The Case of the Sandy River Dams in Oregon

Two dams on the Sandy River in Oregon (Little Sandy Diversion Dam and the Marmot Dam) will be removed soon because the costs of the renovations necessary for renewal of their Federal Energy Regulatory Commission (FERC) license would be much greater than the costs of removal. Marmot Dam, built in 1912, is a concrete gravity dam that is 47 feet high and 195 feet long. Its reservoir area is filled completely with sediment and unusable for water storage. Little Sandy Diversion Dam, built in 1906, is smaller, with a height of 16 feet and a length of 114 feet. Portland General Electric (PGE) currently owns and operates the two dams under a FERC license. Marmot Dam and Little Sandy Dam divert water to the Bull Run Hydroelectric Project, which generates 22 megawatts of electric power. The FERC license for the hydroelectric project will expire on November 16, 2004.

On May 26, 1999, PGE announced its decision to surrender its operating license and decommission the project because the two dams would need costly renovations before the license could be renewed. The estimated cost for removing the two dams is $22 million and will be covered by PGE, the city of Portland, and the state of Oregon (Environmental News Network, 1999). Portland, the first major urban area to have a fish listed under the federal Endangered Species Act (ESA), is 30 miles west of the two dams and is interested in this project because it helps the city comply with ESA requirements (Environmental News Network, 1999). The removal of Little Sandy Dam would open up a 12-mile stretch (now virtually dry) of the Little Sandy River Basin to salmon and steelhead trout. The removal of Marmot Dam would open up 10 miles of the Sandy River. The National Marine Fisheries Service and other federal and state agencies also will provide assistance with this project.

ADVERSE OUTCOMES OF REMOVAL

Direct Costs of Removal

As in the case of avoided costs, a comparison of dam removal costs to those implied by the no-action alternative identifies a number of direct costs incurred only in the case of removal. These include the cost of studies and investigations needed to plan the removal effort, monitoring costs, the cost of breaching and removing the physical structure, and the cost of managing sediment flows. Table 6.1 shows a sampling, grouped by state, of the total costs of various dam removals in the United States.

Table 6.1 Examples of Dam Removal Costs in the United States[a]

State	Watercourse	Project Name	Height (feet)	Length (feet)	Removal Costs ($ million)
CA	Cold Creek	Lake Christopher Dam	10	400	0.100
CA	Lost Man Creek	Upper Dam	7	57	0.029
CO	Ouzel Creek	Bluebird Dam	56	200	1.500
FL	Chipola River	Dead Lakes Dam	18	787	0.032
ID	Colburn Creek	Colburn Mill Pond Dam	12	35	0.030
ID	Clearwater River	Lewiston Dam	45	1,060	0.633
ME	Kennebec River	Edwards Dam	24	917	2.1
ME	Pleasant River	Brownville Dam	12	300	0.078
ME	Pleasant River	Columbia Falls Dam	9	350	0.030
ME	Souadabscook Stream	Grist Mill Dam	14	75	0.056
ME	Stetson Stream	Archer's Mill Dam	12	50	0.013
MI	Muskegon River	Newaygo Dam			1.300
MN	Cannon River	Welch Dam	9	120	0.046
MN	Kettle River	Sandstone Dam	20	150	0.208
NC	Little River	Cherry Hospital Dam	7	135	0.069
NC	Neuse River	Quaker Neck Dam	7	260	0.206
NM	Santa Fe River	Two-Mile Dam	85	720	3.200
OH	Little Miami River	Jacoby Road Dam	8	100	0.010
OR	Bear Creek	Jackson Street Dam	11	120	1.200
OR	Evans Creek	Alphonso Dam	10	56	0.055
PA	Conestoga River	American Paper Products Dam	4	130	0.060
PA	Conestoga River	Rock Hill Dam	13	300	0.110
PA	Little Conestoga River	East Petersburg Authority Dam	4	20	0.005
PA	Little Conestoga River	Maple Grove Dam	6	60	0.017
PA	Muddy Creek	Amish Dam	3	40	0.002
PA	Muddy Creek	Castle Fin Dam	5	383	0.210
VT	Clyde River	Newport No. 11 Dam	19	90	0.550
WA	Whitestone Creek	Rat Dam Lake	32	240	0.052
WI	Baraboo River	Waterworks Dam	14	220	0.213
WI	Bark River	Slabtown Dam	10	60	0.030
WI	Eighteen Mile Creek	Colfax Dam	20	350	0.241
WI	Manitowoc River	Manitowoc Rapids Dam	16	400	0.045
WI	Milwaukee River	Milwaukee Dam	19	432	0.345
WI	Pine River	Parfrey Glen Dam	19	450	0.154
WI	Willow River	Mounds Dam	58	430	0.170
WI	Willow River	Willow Falls Dam	60	160	0.450

Source: Data from American Rivers et al. (1999).
[a] These costs are for dam removal only and do not include site, reservoir, or downstream restoration.

Lost Dam Services

Dams typically provide a number of services, even when they are intended as single-purpose assets. The impoundment behind a flood control dam also may support recreational uses, enhance the market value of surrounding property, and provide valued fish habitat for introduced game species. A water supply reservoir may offer flood protection benefits for downstream property. When dam services are considered, it is important that the analysis extend to all services that would be supported by the no-action alternative, whether part of the original dam purpose or not. Generally speaking, a dam removal terminates all dam services. In this case, the monetary value of the services associated with the no-action alternative becomes one of the adverse outcomes of removal. Sometimes, blocking fish migration (as a dam might) is seen as beneficial, such as for the protection of upstream habitat for exclusive use by resident species such as bull and rainbow trout, or as a barrier to invasions of exotic species.

External Costs of Removal

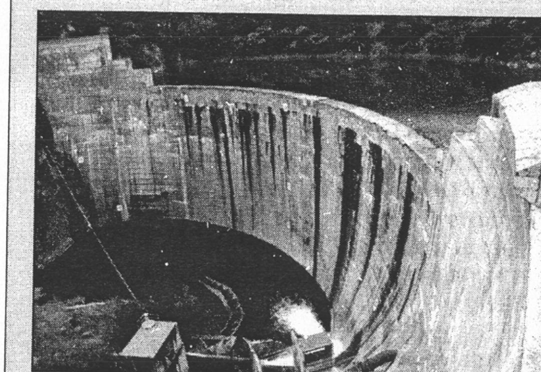
Just as dam construction imposes costs on third parties and on society as a whole (environmental costs, typically), dam removal creates external costs as well. These include certain environmental costs associated with the removal itself, such as the temporary loss or degradation of downstream habitat due to sediment flows. External costs also may include the loss of visual amenities, if either the impoundment or the dam structure itself is regarded as a point of interest in the local landscape. For this reason, some dam removal proposals contemplate the preservation of a large portion of the dam structure, to retain some of the visual interest. It is important to conduct a wide search for external outcomes of both dam removal and the no-action alternative, so that a comparison between the two sets of outcomes can reveal the external consequences of removal (Box 6.3).

CHALLENGES FOR ECONOMIC ANALYSIS OF DAM REMOVALS

The application of conventional methods of benefit–cost analysis to dam removals can assist with decision making related to dam removal projects. To some extent, an economic analysis of these projects involves the same

Box 6.3 Matilija Dam: Factors To Consider in Benefit–Cost Analysis

The case of Matilija Dam illustrates the complexities of a benefit–cost analysis of a potential dam removal. Matilija Dam was constructed in 1947 on Matilija Creek, a tributary of the Ventura River in Southern California, to control flood surges and provide a constant supply of water to the Ojai Valley (U.S. Bureau of Reclamation, 2000). The structure is a variable-radius concrete arch dam that stands 190 feet tall and 620 feet wide. Notches were cut in the 1960s to prevent the structure from collapsing and in 2000 for a dam demolition demonstration project. Matilija Dam no longer provides any significant flood control or water storage capacity. Moreover, the structure has blocked endangered steelhead trout from approximately 85 percent of their habitat on the creek and trapped much of the sediment needed to replenish downstream Ventura County beaches (U.S. Bureau of Reclamation, 2000).



Matilija Dam in 2001.

Photo courtesy of Sarah Baish

Today, there is a broad consensus that Matilija Dam's negative impacts greatly outweigh its benefits, and it soon may become the largest dam ever removed in the United States. In the summer of 2001, the U.S. Army Corps of Engineers took the lead in a feasibility study to determine the preferred method for removing the dam and assess the costs and benefits of removal (Ventura County Flood Control District, 2001). The Matilija Dam Ecosystem Restoration Feasibility Study is a collaborative effort that includes many federal, state, and local government agencies and several nonprofit organizations. The study is expected to be completed in 2004 and to cost $4.2 million. The feasibility study needs to consider the following factors in the analysis.

Costs of Removing Matilija Dam

Direct Costs

A 2000 Bureau of Reclamation study estimated that removing the dam would cost $21–$180 million. The wide range in cost is due to

Box 6.3 continued

different methods of dismantling the dam. The least expensive method, but also the one that poses the highest risk of downstream flooding, would be to remove the dam gradually and allow the natural river flood flows to transport the sediment downstream. The most expensive method would be to remove the sediment using a slurry pipeline, depositing it directly on Ventura County beaches (U.S. Bureau of Reclamation, 2000).

Lost Dam Services

▪ *Potable water supply* The Casitas Municipal Water District would lose approximately 400 acre-feet of water per year, which currently serves 1,000 nearby residents. If the dam is not removed, the reservoir is expected to be filled completely with sediment by 2010 (U.S. Bureau of Reclamation, 2000).

▪ *Fire- fighting water supply* The reservoir is used occasionally as a water source by fire-fighting helicopters. Alternatives could include nearby Casitas reservoir or the Pacific Ocean.

External Costs of Removal

▪ *Loss of reservoir wetlands* Approximately 20 acres of wetlands exist at the reservoir, supporting numerous plant and animal species (U.S. Bureau of Reclamation, 2000). Although new wetlands would be created once the dam is removed and the reservoir drained, removal would result in an overall loss in wetlands.

▪ *Increased sedimentation to downstream dam* Robles Diversion Dam is located downstream of Matilija Dam and currently needs to be cleared of sediment every 5 years. This cycle will increase with the removal of Matilija. A facility that will allow sediment to be flushed through the Robles dam during high flows is being planned (U.S. Bureau of Reclamation, 2000).

Benefits of Removing Matilija Dam

Restored Environmental Services

▪ *Fisheries* Removing Matilija Dam would open up 30 miles of stream for anadromous species of fish, including 85 percent of the remaining habitat of endangered steelhead trout. The population of steelhead trout has been reduced to fewer than 200 from a historical run of at least 4,000 adult fish per year (Capelli, 1999). One study has shown that a single steelhead may be worth $75 to $300 because of increased sport fishing business revenues (e.g., from fishing and outdoor equipment, lodging, guide services, and restaurant meals). Increasing the sport catch in the Ventura River by 2,000 adult fish (about half of the historical run) could generate as much as $600,000 per year to those industries (Marx, 1996–1997).

▪ *Beach sediment* Matilija Dam traps much of the natural supply of sediment for replenishing Ventura County beaches 16 miles

Box 6.3 continued

downstream. Estimates show that up to 70 percent of the 50 years of sediment trapped behind the dam is suitable for placement on beaches, an amount sufficient to widen all south county beaches by 30 feet (Marx, 1996–97). Removal of the dam may increase coastal tourism on the beaches, which in 1992 brought in an estimated $45 million to Ventura County (State of California, 1997), and will increase the protection of shorefront property from erosion and storms.

▪ *Recreation* The dam's removal would increase recreational opportunities within the former dam site and Matilija Canyon. Public access to nearby Los Padres National Forest also would be enhanced.

Avoided Costs

▪ *Maintenance* The removal would eliminate the cost of constant dam maintenance for the owner, the Ventura County Flood Control District.

▪ *Dam safety liabilities* The removal would eliminate future dam safety liabilities for the Ventura County Flood Control District.

▪ *Beach replenishment and other protective measures* To deal with high erosion rates attributable to the dam, costly measures such as beach nourishment, groins, revetments, and a seawall have been used in Ventura County. These structures are falling into disrepair, and multimillion-dollar projects are necessary to maintain them.

types of engineering cost estimates that are familiar to dam builders. The evaluation of one category of dam removal outcomes—lost dam services—may be facilitated if there are usable data on some or all of these services in past years.

Dam removals also have a number of impacts that are not familiar to dam builders. In some cases, the environmental outcomes may be difficult to predict because of a lack of experience with similar events. Predictions of many dam removal outcomes are likely to be quite uncertain, as are the predictions of the times at which such outcomes will appear. Because the anticipated benefits of a removal may consist largely of uncertain environmental changes expected to arrive at uncertain times, this lack of solid information influences dam removal decisions. Furthermore, all outcomes are identified and measured by comparison to a reference case—the no-action alternative. As noted above, the specification of such an alternative raises a number of questions as to what is, and what is not, to be included.

An additional unfamiliar issue concerns the valuation or quantification of various beneficial and adverse outcomes, especially the environ-