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ENVIRONMENTAL MITIGATION AT HYDROELECTRIC PROJECTS

Volume 1. Current Practices for Instream Flow Needs, Dissolved Oxygen, and Fish Passage

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EXECUTIVE SUMMARY

The purpose of environmental mitigation requirements at hydroelectric projects is to avoid or minimize the adverse effects of development and operation. Hydropower mitigation usually involves costs, such as reduced profits to developers and reduced energy production. Much of the existing hydropower capacity in the United States will be subject to new mitigation requirements in the near future because many nonfederal projects are due for relicensing and federal projects are being reevaluated and upgraded. The relicensing process allows the revision of mitigation requirements, and new requirements could reduce existing energy capacity. To address concerns about the effects of environmental mitigation on these important energy resources, the U.S. Department of Energy (DOE) Hydropower Program has initiated a study of environmental mitigation practices at hydroelectric projects.

This first report of the Environmental Mitigation Study examines current mitigation practices for water quality [specifically, dissolved oxygen (DO)], instream flows, and upstream and downstream fish passage. This review describes information on the types and frequency of mitigation methods in use, their environmental benefits and effectiveness, and their costs. The project is conducted jointly by Oak Ridge National Laboratory (ORNL) and Idaho National Engineering Laboratory (INEL).

Information on mitigation practices was obtained directly from three sources: (a) existing records from the Federal Energy Regulatory Commission (FERC), (b) new information provided by nonfederal hydropower developers, and (c) new information obtained from the state and federal natural resource agencies involved in hydropower regulation. The hydropower projects targeted for study in this report were those projects that could be identified as having requirements for water quality, fisheries, or instream flows from a FERC compliance monitoring data base. The information provided by these projects includes the specific mitigation requirements imposed on the project, the specific objectives or purposes of mitigation, the mitigation measures chosen to meet the requirement, the kind of post-project monitoring conducted, and the costs of mitigation.

Information on specific mitigation practices was obtained from 280 projects, more than 40% of all the projects licensed during the 1980s that were identified a priori as having the mitigation requirements of interest. Of all projects receiving FERC licenses or license exemptions since 1980, instream flow requirements are the most common mitigation requirement, followed by requirements for downstream fish passage, DO protection, and upstream fish passage facilities. The proportion of projects with environmental mitigation requirements has increased significantly during the past decade.

Instream Flows

Instream flows are water that is released to the natural river channel below the project to maintain various nonpower water benefits. This study considered only instream flows designed for protection of fish resources. Hydropower operators provided information on the methods used to determine the instream flow requirements at their projects. More than one method for estimating instream flow needs was reported to have been used at many projects. Of the established and documented methods used to determine requirements for instream flows, the most frequently applied was the Instream Flow Incremental Methodology (IFIM). This method is complex and expensive to apply. Half of the project operators reported that professional judgment of resource agency staff was at least one of the methods used to set instream flows. Professional judgment was often cited in conjunction with the IFIM.

It appears that monitoring sufficient to evaluate the positive benefits of instream flow requirements to fish resources is very uncommon, a conclusion that has been corroborated recently by an independent study by the U.S. Fish and Wildlife Service. Information obtained for this DOE study indicates that flow monitoring (continuous, daily, or less frequently) is conducted at about 50% of the operating projects licensed with instream flow requirements. Operators of 20% of constructed projects licensed with instream flow requirements reported collection of some fish data, either by the project or by resource agencies.

Dissolved Oxygen

Water released from hydropower reservoirs can have low DO concentrations, especially during the summer and at large projects with deep reservoirs, low flushing rates, or warm climates. In response to the need to maintain adequate DO, which is necessary for respiration of aquatic organisms, methods have been developed to improve the quality of hydropower releases. These methods have been reviewed extensively in other studies, and they include tailrace aeration techniques (weirs, surface aerators, and diffusers), powerhouse aeration techniques (turbine venting and draft tube aeration), and operational techniques (adjustments to spill flows and turbine operating schedule).

Fifty-six projects provided information concerning DO for this study. About half were small (generating capacity <10 MW) projects. Most responses were from the northeastern United States. Of the DO mitigation technologies, increasing nonpower discharges (spill flows) is the most commonly used. More than 60% of all responding projects use spill flows, 9% use control of intake level to select oxygenated water for release, and nearly 30% use some form of artificial aeration of water passing through the turbine. Several projects use more than one mitigation method.

Of the projects that reported on DO mitigation, ~75% indicated that water quality (most commonly water temperature and DO concentration) is monitored, but biological monitoring is rarely conducted. Consequently, the actual biological benefits of DO mitigation are usually unknown.

Upstream Fish Passage

Blockage of upstream fish movements by dams may have serious effects on fish species whose life histories include spawning migrations or other seasonal changes in habitat requirements. Anadromous fish (e.g., salmon, American shad, blueback herring, and striped bass), eels, and some resident fish (e.g., trout, white bass, and sauger) have spawning migrations that may be constrained by hydroelectric dams. Maintaining or enhancing populations of such fish may require facilities for upstream fish passage.

Operators of 34 projects provided information on upstream fish passage facilities either in operation or under construction. Fish ladders are by far the most commonly reported means of passing fish upstream at nonfederal hydroelectric dams. Fish elevators are a less common mitigative measure, but their use may be increasing. Trapping and hauling (by trucks) of fish to upstream spawning locations is used at some older dams, but two of the projects reported that trap-and-haul operations are being replaced by fish ladders or elevators.

Preconstruction and postconstruction studies and detailed performance criteria for upstream passage facilities are frequently lacking. Forty percent of the projects had no performance monitoring requirements. Those projects that monitor the success of upstream passage generally quantify fish passage rates (e.g., fishway counts) or, less commonly, fish populations.

Downstream Fish Passage

A variety of screening devices are employed to prevent fish that are moving downstream from being drawn into turbine intakes. The simplest downstream passage technique is the use of spill flows similar to those used to increase DO concentrations or provide instream flows. Fish are naturally transported below the hydropower project in these nonpower water releases. Techniques that incorporate more sophisticated technology are under development, but are not widely used. For example, light- or sound-based guidance measures are being studied as ways to pass migrating fish downstream with a minimal loss of flow for power generation.

Information was obtained for 85 hydroelectric projects that have downstream fish passage requirements. A number of measures, some used in combination, are employed to reduce turbine entrainment of downstream-migrating fish in turbines. The most frequently reported downstream fish passage device is the angled bar rack, in which the trash rack is set at an angle to the intake flow and the bars may be closely spaced (~2 cm). This device is commonly used in the Northeast. Other frequently used fish screens range from variations of conventional trash racks (e.g., use of closely spaced bars) to more novel designs employing cylindrical, wedge-wire intake screens. Intake screens usually have a maximum approach velocity requirement and a sluiceway or some other type of bypass as well.

As with upstream fish passage measures, performance monitoring and detailed performance criteria for downstream passage facilities are relatively rare. There are no performance monitoring requirements for 82% of the projects. Post-operation studies of passage rates or mortality rates have been conducted at a few of the projects.

Mitigation Costs

Environmental mitigation costs are estimated for each mitigation type based on information provided by hydropower developers. These costs are segmented by capital, study, operation and maintenance (O&M), and annual reporting costs. All costs are presented in 1991 dollars and in terms of average cost per project, average cost per KW of capacity for capital and study costs, and average mill/kWh for O&M and annual reporting costs. Because of the large ranges for the mitigation costs, costs are also presented by capacity categories.

Costs of providing instream flows vary widely among projects. At diversion projects (where flows for power generation are diverted around a stream reach), instream flow in the diverted reach must be subtracted from that available for generation. Storage projects that generate without a diverted reach can release instream flows through their turbines. Operators of such projects frequently reported no cost associated with instream flow releases. The instream flow capital costs averaged $99,000 per plant. Environmental studies averaged $100,000 per plant. Even the requirements on instream flows below the powerhouses can cause significant costs because of forced sales of energy at base rates compared to peak rates. The average annual revenue loss for instream flow requirements amounted to $390,000 per plant.

Total mitigation costs for DO requirements are generally the lowest of the four types studied in this report. The capital costs averaged $162,000 per plant for DO mitigation equipment. The energy generation lost because of water quality environmental requirements was ~107,000 kWh per project.

The costs of upstream fish passage mitigation are relatively easy to determine. In addition to the capital costs of constructing the fishway, there are operation and maintenance costs (e.g., for clearing debris from the fish ladder or elevator and for electrical power to operate a fish elevator), lost power generation resulting from flow releases needed to operate a fish ladder or elevator (including attraction flows), and any monitoring and reporting costs. The average costs for fish ladders at the sites where they were required was $7.6 million for capital costs and they resulted in an average loss of 194,000 kWh of annual energy production. Other costs of upstream fish passages were $51,000 for environmental studies, $26,000 for annual reporting, and $80,000 per year for additional O&M for environmental requirements.

In addition to the capital costs of constructing a downstream fish passage facility, costs typically include those for cleaning closely spaced screens or maintaining traveling screens, lost power generation resulting from flow releases needed to operate sluiceways or other bypasses, and monitoring and reporting. The average costs for angled bar racks was found to be $332,000 per plant for capital costs and $3,000 per year for O&M. Studies for angled bar racks averaged $50,000 where they were performed and $1,300 per year for annual reports.

Occasionally hydropower projects are required to make some contribution to environmental projects not associated directly with the hydro plant to compensate for some environmental damage caused by the plant. Off-site compensation was reported at a few sites that averaged $136,000 per site.

Conclusions

Requirements for environmental mitigation at hydropower projects have an important and growing effect on U.S. domestic energy resources. This study has identified both technical and economic problems associated with the most common mitigation measures: the dominant role of the IFIM, in conjunction with professional judgment by agency biologists, to set instream flow requirements; reliance on spill flows for DO enhancement; use of unproven technology such as angled bar racks for downstream fish protection. All of these measures can have high costs and, with few exceptions, there is little information available on their effectiveness. Additional study needs are identified for each type of mitigation, as well as in the areas of cost estimation, valuation of benefits, and monitoring programs.