Hungry Horse Mitigation Plan

Fisheries Mitigation Plan for Losses Attributable to the Construction and Operation of Hungry Horse Dam

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HUNGRY HORSE MITIGATION PLAN

FISHERIES MITIGATION PLAN FOR LOSSES ATTRIBUTABLE TO THE CONSTRUCTION AND OPERATION OF HUNGRY HORSE DAM

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The Consultation Group for Hungry Horse fisheries mitigation planning helped shape the recommendations we present in this plan. Many individuals in the group participated in a series of consultation meetings and many informal discussions spanning 14 months. A subgroup of consultation members reviewed a first version of this document. We incorporated into a final draft, their comments, input from policy-makers, and the Northwest Power Planning Council staff. The full consultation group, six scientists and three economists reviewed the final draft. We have incorporated these reviews into this final document. Also, we have had extensive discussions with individual consultation members as we've revised the document.

We thank the following consultation group members for their help during the consultation process, and for reviewing the final draft:

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U.S. Bureau of Reclamation	Rich Clark, Richard Prange, Dennis Christenson
U.S. Fish & Wildlife Service Creston National Hatchery	Larry Lockard
U.S. Forest Service Flathead National Forest	Mary Peterson
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Major authors of this document included John Fraley and Brian Marotz (Montana Department of Fish, Wildlife and Parks), and Joe DosSantos (Confederated Salish and Kootenai Tribes). Sharon Sarver typed the manuscript.

Brian Marotz

PREFACE

We prepared this document for the following purposes:

(1) Provide the Northwest Power Planning Council (NPPC) with documentation on fisheries losses caused by the construction and operation of Hungry Horse Dam;

(2) Present to the NPPC a flexible plan to mitigate for these documented losses;

(3) Incorporate views of a broad range of citizen, agency, tribal, and other interests into one document, thereby facilitating the NPPC process of public involvement.

This document is not an implementation plan. Details of the exact timing of each mitigation measure, firm decisions on the number and species of fish involved in each measure, and firm dollar amounts are difficult to predict in such a dynamic process. Rather, we wish to take the approach of preparing an implementation plan with the help of the consultation (advisory) group after the NPPC approves this planning document and provides more specific direction. Because of this approach, some of the scientists' comments requesting major new analysis or extensive new details will be used during preparation of the more specific, implementation plan.

We recommend that detailed funding aspects (eg. trust fund) be negotiated between the agency implementation group (Montana Department of Fish, Wildlife and Parks, Confederated Salish and Kootenai Tribes, U.S. Fish and Wildlife Service) and the Bonneville Power Administration after the NPPC reaches a decision on this plan.

We urge readers not interested in the technical details of losses, flow modeling, and cost analyses to read only the Executive Summary and the Recommended Mitigation Measures sections.

EXECUTIVE SUMMARY

In this document we present fisheries losses, mitigation alternatives, and recommendations to protect, mitigate, and enhance resident fish and aquatic habitat affected by the construction and operation of Hungry Horse Dam. This plan addresses six separate program measures in the 1987 Columbia Basin Fish and Wildlife Program. We designed the plan to be closely coordinated in terms of dam operations, funding, and activities with the Kerr Mitigation Plan presently before the Federal Energy Regulatory Commission. This document represents a mitigation plan for consideration by the Northwest Power Planning Council process; it is not an implementation plan.

Flathead Lake is one of the cleanest lakes of its size in the world. The exceptional water quality and unique native fisheries make the Flathead Lake/River system extremely valuable to the economy and quality of life in the basin. The recreational fishery in Flathead Lake has an estimated value of nearly eight million dollars annually. This mitigation process represents our best opportunity to reduce the impacts of hydropower in this valuable aquatic system and increase angling opportunity.

We based loss estimates and mitigation alternatives on an extensive data base, agency reports, nationally and internationally peer-reviewed scientific articles, and an innovative biological model for Hungry Horse Reservoir and the Flathead River. We conducted an extensive, 14-month scoping and consultation process with agency representatives, representatives of citizen groups, and the general public. This consultation process helped identify issues, areas of agreement, areas of conflict, and advantages and disadvantages of mitigation alternatives. The results of the scoping and consultation process helped shape our mitigation plan. Our recommended plan is based firmly on principles of adaptive management and recognition of biological uncertainty. After we receive direction from the NPPC, we will add more detailed hypotheses and other features necessary for a long-term implementation plan.

The construction and operation of Hungry Horse Dam caused extensive losses and impacts to fish populations, aquatic invertebrates, and aquatic habitat. Construction of the dam blocked access to 363 miles of tributary reaches with gradients suitable for salmonid spawning and rearing. Also, the dam blocked access to 85 miles of the South Fork Flathead River. This blockage eliminated at least 40 percent of the bull trout and westslope cutthroat trout spawning runs from Flathead Lake. The reservoir behind the dam supports a fishery. However, about 78 miles (1,000 acres) of spawning and rearing stream habitat were eliminated by inundation. The dam provides benefits such as flood control, less ice buildup in the Flathead River because of warmer water temperatures, and increased minimum flows during drought.

Operation of Hungry Horse Dam causes large fluctuations in reservoir levels and rapid daily fluctuations in volume of water discharged to the South Fork Flathead River and the main stem Flathead River. Seasonal flow patterns have changed dramatically. Operations caused significant losses of kokanee spawning beds. Reduction of the kokanee population in Flathead Lake reduced forage for trophy-sized lake trout. Frigid water released from the deep layers of the reservoir have reduced trout growth from May through October in the South Fork and main stem Flathead rivers to a fraction of pre-dam levels and disrupted life cycles of aquatic insects. Releases of warmer water temperatures during the winter and maintenance of minimum flows in the Flathead River during low flow periods could be considered partial benefits of dam operation for fish. Social benefits of the dam include water storage, flood control and power production.

Based on our work and comments from a 24-member consultation group, we recommend a two-phase mitigation program. First, we ask for rapid implementation of non-operational mitigation and selective withdrawal. We will work with Bonneville Power Administration (BPA) and the Bureau of Reclamation (USBOR) to refine cost estimates. Second, we plan to work with BPA and other agencies to assess our operational recommendations over the next two years in the Columbia River System Operation Review. This work will balance dam operations to protect resident fish at Hungry Horse Dam and other facilities.

To mitigate for net losses of fisheries, aquatic insects, and aquatic habitat attributable to Hungry Horse Dam, we recommend a combination of non-operational mitigation, operational mitigation and evaluation/monitoring (Table 1).

A mix of mitigation techniques offers the best chance to offset losses caused by dam construction and achieve mitigation objectives. Non-operational actions (requiring no changes in dam operations) include: (1) aquatic habitat improvement; (2) fish passage improvements; (3) hatchery upgrades, fish production, and fish planting; and (4) off-site mitigation using these same techniques. We estimate that \$500,000 per year (1990 dollars) will be required for these actions over a negotiated mitigation period. Estimates of one-time capital costs for hatchery upgrades include \$2,075,000 for Creston National Fish Hatchery and the State Rose Creek Site, and \$2,675,000 for the Somers State Hatchery (see appendix report). Hatcheries will be designed to accommodate production of any salmonid species. Costs given in this report represent working estimates; we plan to work with BPA to refine the figures.

We propose to work with BPA to upgrade the hatcheries in the most cost-effective way possible. BPA has indicated they would consider providing engineering and design services. This could greatly reduce costs of the hatchery upgrades. Logistically, it will require several years for BPA to add capital costs to their budget for this effort. Full scale construction of the hatchery improvements will also require several years.

Initially, hatchery managers will focus on increasing the kokanee population in Flathead Lake. This approach involves considerable uncertainty because of potential predation by an increasing population of small lake trout, competition with *Mysis*, and other factors. However, this approach carries little risk of genetic or disease problems for native fish species. An accompanying program of predator reduction through innovative angling regulations will be necessary for the best chances of success. Because of the time required to approve funds and to construct the hatchery improvements, we will not meet the stated production goals for several years. Thus, we will be able to examine more closely the fluctuating food web in Flathead Lake

Table 1. Recommended fisheries and aquatic habitat mitigation actions for losses attributable to Hungry Hor Dam. The costs indicated are estimates only. The Department and Tribes propose to work with BPA to refine the estimates and accomplish mitigation as cost-effectively as possible.

Mitigation Action	Species Benefitted	Quantifiable Habitat or Fisheries Benefit Goal	Cost Estimates from power revenue	Cost Estimates from lost power production
NON-OPERATIONAL:				0
Aquatic habitat Improvement	bull trout, westslope cutthroat	31 acres/year, stream and reservoir	$220,000	0
Fish Passage Improvements	bull trout, westslope cutthroat	equivalent of 5-10 blocked areas, 5-10 miles of stream reopened each year	$50,000	0
Hatchery Fish Production and Fish Planting	bull trout, westslope cutthroat, kokanee	10,000,000 kokanee/year, in Flathead Lake 100,000 cutthroat/year, 100,000 bull trout/year primarily planted in restored tributaries to establish spawning runs	$180,000/year operations and maintenance; $2,675,000 in capital costs for upgrade of Somers State Hatchery; $2,075,000 for upgrade of Creston National Hatchery and Rose Creek site	0
Off-Site Mitigation	other target species and species presently in the region	combination of the above fishery techniques at the level of funding requested	$50,000/year	0
OPERATIONAL:				
Reservoir Elevation Control (eg. drawdown limits, refill timing)	westslope cutthroat, bull trout, mountain whitefish in the reservoir and to smaller extent downstream	full extent of the reservoir and downstream river reaches	0	BPA preliminary estimate is 25 to 76 megawatts of firm power loss
Temperature control in dam discharges--selective withdrawal (water volume changes not required)	all species	5 miles of the South Fork Flathead River, 47 miles of the Flathead River, and Flathead Lake	$12,360,000 provided by congressional appropriation for construction, annual cost for operations = $8,410	0.2 megawatts
Volume control of dam discharges--minimum flow of 3,500 cfs, ramping to restrict fluctuations, evaluation of re-regulatory dam	all species	1.5-5 miles of the South Fork Flathead River and 47 miles of the Flathead River	unquantified costs borne by various agencies to conduct reregulating dam feasability study and Environmental Impact Statement	Being calculated by BPA
Evaluation and Monitoring	all species	evaluate and improve mitigation techniques in the basin	$150,000/year	0
Total Costs of Non-operational Mitigation annually			$500,000	
Cost of Monitoring/Evaluation annually			$150,000	
Capital Costs for Hatchery Upgrades			$4,750,000	

and allow more time for stabilization. This has been a major concern of many consultation group members.

Managers will begin a step-wise, adaptive management approach to evaluate the best methods of increasing cutthroat and bull trout in the system. Little scientific or social support exists at this time for direct plants of these species into Flathead Lake or Hungry Horse Reservoir. Many scientists have urged us to exercise extreme caution in supplementing native species. We will concentrate on trying to establish new spawning runs by imprinting genetically pure stocks in restored tributaries.

Planting kokanee for five years after we reach production goals may fail to restore the fishery. If this is the case, we will focus more on native species enhancement in tributaries and in off-site areas. During the kokanee trials, we will be developing better methods for enhancing native species. Rehabilitation and planting of lakes outside the interconnected lake-river system would replace a portion of lost angling opportunities without compromising the native stocks. Many enhancement opportunities exist off-site in high mountain lakes and closed basin lakes in the area.

Operational mitigation actions include: (1) installation of a selective withdrawal system to correct downstream water temperatures; (2) reservoir level control to protect the reservoir fishery, based on a variable biological rule curve and sliding scale; (3) maintenance of a 3,500 cfs minimum flow in the Flathead River at Columbia Falls for riverine fish species and invertebrates; (4) consideration of a 700 cfs minimum flow in the South Fork Flathead River <u>after</u> selective withdrawal is installed; (5) full feasibility assessment of a re-regulatory dam to control high discharges from Hungry Horse Dam; and (6) ramping rates to moderate discharges until a re-regulatory dam is built, if feasible. A re-regulating dam with usable storage of 3,264 acre feet could smooth flow fluctuations from two to four hours of peak generation. Longer periods of peaking operations would cause changes in flow in downstream waters. Operational mitigation actions carry costs to the power system; final costs will be calculated by Bonneville Power Administration during the System Operation Review. Positive changes in habitat conditions through these operational changes are very likely to benefit fish populations, particularly in the long term.

We strongly recommend immediate retrofitting all four penstocks at Hungry Horse Dam with selective depth of water withdrawal mechanisms. The Bureau of Reclamation (USBOR) has made a preliminary cost estimate for construction and for annual operation of a selective withdrawal system. We recommend that the USBOR seek a congressional appropriation for these funds. A portion of these funds could be reimbursable by BPA. We ask that selective withdrawal go forward now because little power impacts are anticipated from this action. BPA and the USBOR have estimated a 0.2 megawatt loss resulting from a seasonal 1.5 foot loss of head if the system was installed.

Monitoring and evaluation are critical parts of any adaptive management plan. We recommend a monitoring/evaluation program of $150,000 per year (1990 dollars) for the mitigation period. This figure represents 23 percent of the annual costs for implementing mitigation. Many scientists have recommended a similar level of monitoring in a program emphasizing adaptive management. The evaluation and feedback process will increase the chances of success of mitigation efforts, especially considering the present fluctuations in fish populations and trophic structure in the system.

Funding options for non-operational mitigation and monitoring include annual contracts with BPA through the Interactive Planning Process, annual payments adjusted to 1990 dollars by the consumer price index, or a trust fund. We recommend pursuing a trust fund option because it meets the implementing agencies' goals of annual investment in the resource and principles of adaptive management, and it meets the goal of the utilities for establishing a spending cap. The trust fund should be designed to account for overhead rate and inflation to preserve the mitigation level recommended in 1990 dollars. The Department and Tribes could negotiate annual contracts with BPA until the trust fund is established.

Success of this mitigation plan may be limited by: (1) trophic level fluctuations ongoing in the Flathead system; (2) shortcomings of present mitigation technologies; (3) lack of sufficient mitigation sites to replace lost habitat (particularly for bull trout); and (4) general uncertainty associated with ecological/social plans. After the NPPC approves the plan and provides guidance, we will prepare a detailed implementation plan. In implementing the plan, managers must be flexible and continue to listen to a broad range of citizen and scientific interests. The advisory group must be closely involved as the implementing agencies put the plan into action.

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INTRODUCTION

Background

From 1933 to 1985, 23 federal dams were built on the Columbia River system. Construction and operation of these dams and others, resulted in a sharp decline in anadromous salmon and steelhead populations, and in damage to resident (freshwater) fish and to wildlife in Oregon, Washington, Idaho, and Montana (Northwest Power Planning Council, 1987). In 1980, the U.S. Congress passed the Pacific Northwest Electric Power Planning and Conservation Act (the Act), designed in part to balance hydropower development and other natural resources in the Columbia system. The Act formed the Northwest Power Planning Council (the Council) and directed the Council to "promptly develop and adopt . . . a program to protect, mitigate and enhance fish and wildlife . . . on the Columbia River and its tributaries." The Act also specified that (1) the Columbia should be treated as a system (thus including resident fish in upstream reaches); and (2) the Bonneville Power Administration (BPA), acting in behalf of ratepayers, would be required to use revenue and legal authority to protect and mitigate impacts on natural resources to the extent that they have been influenced by federal hydroelectric operations.

In Montana, three dams were built in the Flathead River system, including one federal project (Hungry Horse Dam), and two privately operated facilities (Kerr and Bigfork dams). These dams blocked fish migration corridors, removing access to historic spawning and rearing areas for migratory fish species such as westslope cutthroat trout and bull trout. Dam operations caused large fluctuations in downstream waters and seasonal drawdown of reservoirs. The changes had serious consequences for riverine and reservoir fish.

To address these fisheries losses, the Montana Department of Fish, Wildlife and Parks (MDFWP) implemented (with BPA funding) measures of the Council's Fish and Wildlife Program to: (1) quantify hydropower-related fisheries losses; (2) recommend operational constraints at the hydropower facilities; and (3) recommend measures to compensate for fisheries losses when changes in operations would not be practicable. BPA provided funding for the Confederated Salish and Kootenai Tribes (CSKT) to conduct a similar effort on tribal lands in the south end of Flathead Lake and the Flathead River below Kerr Dam.

Relationship to Specific Fish and Wildlife Program Measures

Specific fish and wildlife program measures called for studies to identify losses attributable to Hungry Horse Dam, recommendations for mitigation, and related issues:

- Program measures 903(b)(1 and 2) call for "development of operating procedures to limit drawdown of Hungry Horse and Libby Reservoir for power purposes to protect resident fish to the fullest extent practicable." These program measures call for drawdown limits to protect resident fish. Also, the measure states: "In years when the drawdown limit is exceeded for power purposes, BPA shall fund the mitigation of fish losses to the extent those losses are caused by power operations."

- Measure 903(b)(3) calls for BPA to fund projects leading to the establishment of reservoir levels to maintain or enhance reservoir fisheries.

- Measure 903(b)(4) states: "Bonneville shall fund the design, construction, operation, and maintenance of mitigation projects in the Flathead River and Flathead Lake system to supplement natural propagation of fish in the river. These projects counter the effects of habitat loss in and below the South Fork of the Flathead River caused by dam construction and by drawdown and discharges of water from Hungry Horse Reservoir. Bonneville shall fund a study to determine levels of production necessary to mitigate the effects of the hydropower system and shall submit the results of the study to the Council for review prior to approval of mitigation measures."

- Measure 903(b)(5) related to effects in Flathead Lake caused by operations of Hungry Horse and Kerr dams.

- Program measures 903(a)(1-4) address minimum flows in the Flathead River, and funding of projects to evaluate effects of Hungry Horse discharges on the fishery in the Flathead system.

- Program measure 903(a)(4) addresses Bigfork Dam on the Swan River, a tributary to Flathead Lake.

These program measures are in BPA Action Items 7.11 and 7.15 in the Fish and Wildlife Program.

In this report we summarize fisheries losses detailed in other documents and present a plan to protect, mitigate, and enhance fisheries and aquatic habitat resources affected by the construction and operation of Hungry Horse Dam. Development of this mitigation plan was consistent with Section 900 of the Columbia River Basin Fish and Wildlife Program (Northwest Power Planning Council, 1987), and the Upper Flathead System Fisheries Management Plan (Montana Department of Fish, Wildlife and Parks, Confederated Salish and Kootenai Tribes, 1989). In conjunction with this process, mitigation for Kerr Dam is being pursued with the Montana Power Company through the Federal Energy Regulatory Commission. The MDFWP is working with the Pacific Power and Light Company to reconstruct a fish ladder over Bigfork Dam.

The 1987 Fish and Wildlife Program calls for the Montana Department of Fish, Wildlife and Parks (Department) and the Confederated Salish and Kootenai Tribes (Tribes) to present recommendations for further action regarding resident fish mitigation for Hungry Horse Dam by October 1989. We requested a one-year extension of this date to complete work with the Montana Power Company on the Kerr Dam relicensing process, and for the Department to complete the quantitative biological model for Hungry Horse Reservoir and the Flathead River. The date for our presentation of this mitigation plan to the full Northwest Power Planning Council is now scheduled for spring 1991, because of the time required to incorporate the results of the consultation/scoping process and the time required to link our biological models with BPA's power system models to illuminate tradeoffs. We presented our basic recommendations to the "Fish Four" subgroup of the NPPC in January 1991.

The NPPC is particularly concerned with three specific aspects of resident fish mitigation planning: documentation of losses, evidence of biological gains, and conflict with anadromous fish restoration (Northwest Power Planning Council, 1987). First, we maintain that fisheries losses attributable to Hungry Horse Dam are well documented in this report and in our cited publications. Second, we feel that our discussions under the cost:benefit section of this report document the potential biological gains. However, we fully recognize the uncertainty associated with any large scale mitigation effort. Indeed, this uncertainty is an integral concept of adaptive management. Third, non-operational mitigation measures will not conflict with efforts to restore anadromous fish.

We don't anticipate significant impacts to anadromous fish if operational guidelines are adopted. The water budget period coincides with refill at Hungry Horse Reservoir. Refill is necessary for the operation of the power system, recreation, and resident fish. Hungry Horse Reservoir operations are not involved in providing water budget flows. The water budget period coincides with runoff in the unregulated North and Middle forks of the Flathead River, which provides about 60 percent of the inflow to Flathead Lake. These unregulated forks provide significant flows during the water budget period. It is important to note that channel restrictions and local reservoir water requirements for power limit further use of water from upstream reservoirs like Hungry Horse for additional anadromous fish flows. In summary, we do not feel that our recommendation package will significantly affect efforts to restore anadromous fisheries.

Scoping Process

We formed a consultation group in January 1990 which met periodically to help guide preparation of this mitigation plan. The group helped us to prepare a scoping document, which we mailed or made available to more than 500 people in Montana concerned with biological or power resources. We received 35 scoping document returns. Although the return rate was low (7 percent), many of the respondents provided extensive and detailed comments. Several consistent positions were evident. Fitting Hungry Horse Dam with a selective withdrawal to moderate river temperatures received wide support. Aquatic habitat improvement and fish passage improvements also received wide support. Reservoir water level and river flow changes, and hatchery fish production received strong support, but some respondents expressed caution or opposition.

The consultation group for Hungry Horse fisheries mitigation consists of representatives from fish and wildlife resource agencies, utility groups, local government, fisheries and wildlife conservation groups, ecological conservation groups, and others. Approximately 30 people, representing 24 entities, participated. The group has helped MDFWP and CSKT organize the issues, identify areas of agreement and disagreement, review fisheries losses and mitigation options, and review aspects of this mitigation plan. Records of the consultation meetings (see Appendix Report) form a summary of the major issues and controversies surrounding fisheries mitigation for Hungry Horse Dam.

A series of three open houses were held on Hungry Horse fisheries mitigation. Results from these open houses (see Appendix Report) further clarified issues, and provided direction on public sentiment.

Two drafts of this document were reviewed by consultation group members; six scientists and three economists reviewed the final draft. We incorporated into this document their comments and input from policy-makers and the Northwest Power Planning Council staff.

We have incorporated the results of these public involvement processes into this plan to the fullest extent practicable. Also, we have continued to consult with individual group members up to the date of finalizing this report. In our discussion of mitigation alternatives, we address comments received against and in favor of each recommend mitigation step under advantages and disadvantages. The companion Appendix Report contains the results of these scoping and consultation processes. Many of the more detailed scientific comments will be addressed as we prepare the implementation plan.

DESCRIPTION OF THE PROJECT AREA

The Flathead River system in northwest Montana is the northeastern-most drainage of the Columbia River Basin (Figure 1). Flathead Lake is the largest natural lake in the western United States, with a maximum length of 27 miles and a surface area of 125,000 acres. Its mean depth is 170 feet; maximum depth is 372 feet (Potter, 1978; J. Stanford, pers. comm.). Flathead Lake is one of the cleanest lakes of its size in the world (Dr. J. Stanford, UM Biological Station, pers. comm.). The lake and its tributaries have unique ecological, recreational, and economic values to the people of Montana. The largest tributary to the lake is the Flathead River with an average annual flow of 9,763 cfs. The North, Middle, and the South forks of the Flathead River drain large tracts of public lands including the Flathead National Forest and Glacier National Park.

Twenty-five fish species reside in the Flathead Lake and River system; ten are native. Principal native game fish species include westslope cutthroat trout (*Salmo clarki lewisi*), bull trout (*Salvelinus confluentus*), and mountain whitefish (*Prosopium williamsoni*). Non-native species include lake trout (*Salvelinus namaycush*), lake whitefish (*Coregonus clupeaformis*), rainbow (*Onchorhynchus mykiss*) and kokanee (*O. nerka*). Many of the species are migratory, using the river and its tributaries for spawning and rearing (Fraley and Shepard, 1989; Likness and Graham, 1988). After maturing in the lake, bull trout spawn in the fall, and cutthroat

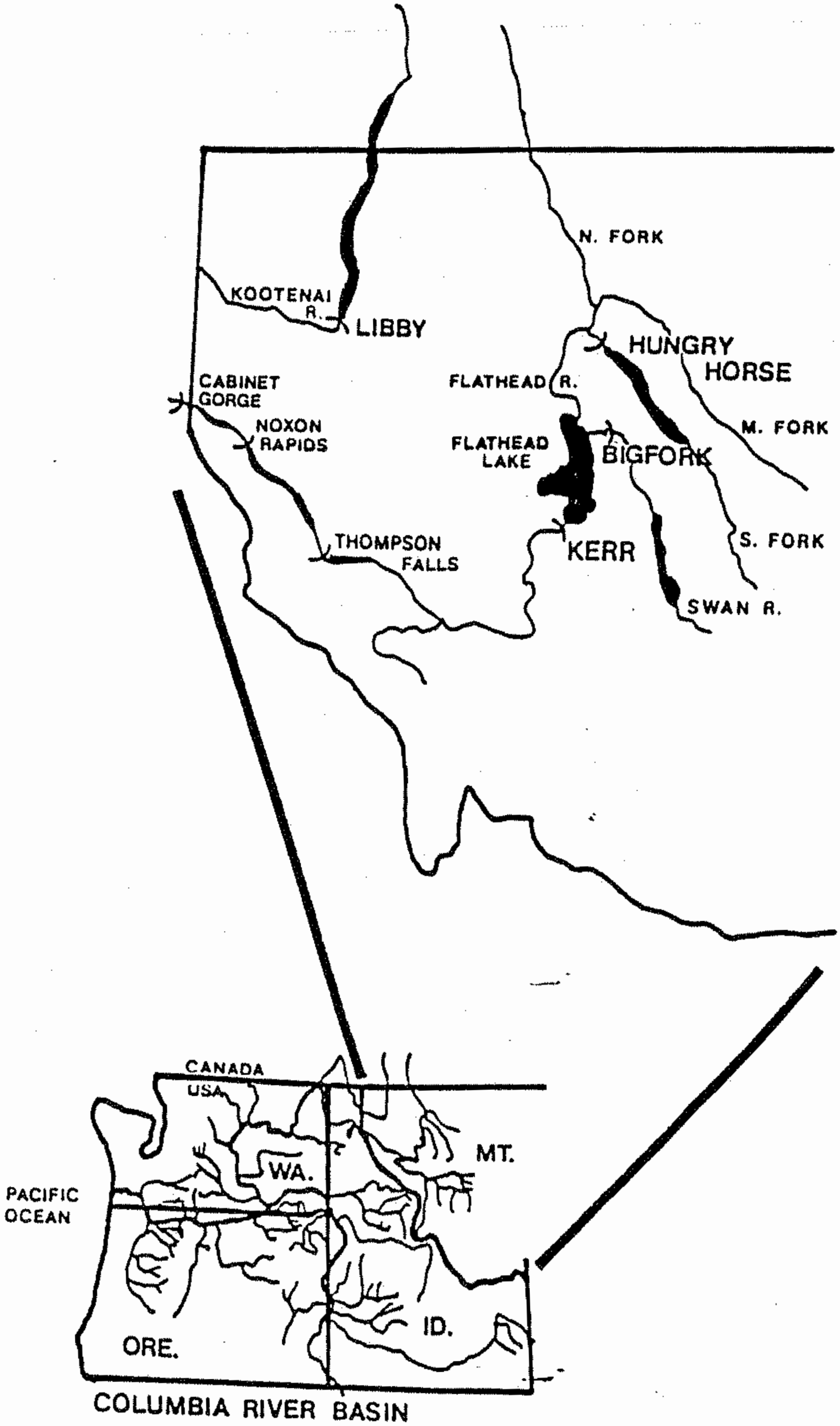

Figure 1. The Upper Columbia River System in Western Montana.

spawn in the spring, in headwater tributaries. Juveniles of these species grow in tributaries for one to three years before emigrating to Flathead Lake. Some cutthroat reside only in the river or in tributaries.

Kokanee spawn in the river system and along the lakeshore in the fall. Emergent fry enter the lake the following spring (Fraley and Clancy, 1988). Recently, kokanee populations in Flathead Lake have declined dramatically. The decline has been related to hydropower impacts, an increase in *Mysis* shrimp densities, predation and other factors (Fraley and Decker-Hess, 1987; Beattie et al., 1990; Beattie and Clancy, In Press; Spencer et al., In Press).

The Flathead River and two tributaries, the South Fork of the Flathead River and Swan River, and Flathead Lake are presently affected by dams. Kerr Dam was completed in 1938 and has a generating capacity of 168 megawatts. The dam, operated by the Montana Power Company, is located 5 miles downstream of the natural lake outlet (Figure 1). The Flathead River flows for 72 miles below Kerr Dam to join the Clark Fork of the Columbia River. Prior to impoundment, the water level of Flathead Lake remained relatively constant near 2,883 feet (mean sea level) msl from September to mid April. Spring runoff typically increased the lake elevation to the annual maximum (2,893 feet) in May and June. Since impoundment, the lake has been held near full pool from June 15 into September. Drawdown usually begins in mid September and minimum pool is reached in March. Flood control and recreational constraints on the project affect the lake levels from April to October.

Hungry Horse Dam was completed in 1952, and the reservoir reached full pool elevation of 3,560 feet msl in July 1954. The dam impounded the South Fork of the Flathead River 5 miles upstream from its confluence with the Flathead River. Hungry Horse is a 35-mile long storage reservoir with a surface area of 23,813 acres at full pool, and is operated by the Bureau of Reclamation. The primary benefits of the project are flood control and power production at downstream projects. Water passes through 19 downstream projects, generating approximately 4.6 billion kilowatt hours of energy annually as compared to 1.0 billion at the Hungry Horse project. Hungry Horse and Kerr dams are regulated in concert with the complex network of electrical energy producing systems, water consumption needs, and flood control requirements throughout the Pacific Northwest. Neither Kerr or Hungry Horse dams is equipped with fish passage facilities.

Useable storage in Hungry Horse Reservoir ranges from 3,336 ft. msl to full pool elevation 3,560 and includes 2,986,109 acre-feet which is 86.2 percent of the total reservoir volume. Dead storage at 3,336 ft. is 13.8 percent of maximum volume. For the period of water years 1954-1990, maximum reservoir drawdown averaged 79.4 feet (or 77.8 feet if 1988 is excluded). The maximum drawdown on record of 178.7 feet in 1988 reduced the volume to 22.7 percent of full pool. In 1989, the reservoir failed to refill from the deep drawdown, reaching a maximum elevation of 69.6 feet below full pool.

The typical operation schedule begins in July, when the reservoir refills to full pool. Drawdown generally begins in August, declining gradually toward minimum pool in April. The major evacuation of water occurs from December through March for power production and flood control After reaching minimum pool, the reservoir stores water during spring runoff and rises again toward full pool. The reservoir has failed to refill ten times since filling for the first time in July 1954.

Reservoir operation has varied considerably since Hungry Horse was first filled. Historic operation can be classified into three periods based on maximum drawdown which usually occurs during April: (1) 1955-1964 when drawdown averaged 64 ft.; (2) 1965-1975 when drawdown averaged 92 ft; and (3) 1976-1987 when it averaged 66 ft. (Figure 2). Water fluctuations in the impoundment affect the reservoir biota by dewatering substrate needed for benthic insect production, reducing the volume of the warm, sunlit zone required for primary production, zooplankton, and fish growth, and by reducing the surface area resulting in fewer terrestrial insects available to feeding fish. Smaller reservoir volumes cause fish to become concentrated, increasing the likelihood of mortality by predation. Rapid refilling from a deep drawdown reduces the depth of the sunlit zone and weakens thermal stability. The combined effects slow trout growth and reduce angler opportunity.

Discharges cause fluctuations in the South Fork River downstream and in the main stem Flathead River below the South Fork confluence. The fixed water withdrawal outlets in the dam release cold water (39-41° F) yearlong, influencing the thermal regime in the Flathead River and the aquatic environment.

The Swan River flows for approximately 54 miles before entering Swan Lake, then meanders for 12 miles until its entry to Flathead Lake. Bigfork Dam is located 1 mile above the mouth of the Swan River which enters Flathead Lake; it was built in 1902 and has a generating capacity of 4.1 megawatts. A fish ladder was constructed in the 1930s and modified in the late 1960s to enable Flathead Lake migratory salmonid populations to pass around the 12-foot high dam. However, because of the design flaws in the ladder, fish migration upstream into the Swan drainage is very limited (Zubik and Fraley, 1987).

Since 1985, the Department and Pacific Power and Light Company have studied the feasibility of an improved fish ladder over Bigfork Dam. This action would open historical spawning and rearing area lost to fish from Flathead Lake. However, there is danger that lake trout and lake whitefish could invade the Swan system. Establishment of lake trout in Swan Lake could cause severe reductions in the kokanee population (Beattie et al., 1990). Lake trout and lake whitefish could also compete with native species. If built, the fish ladder must be carefully monitored.

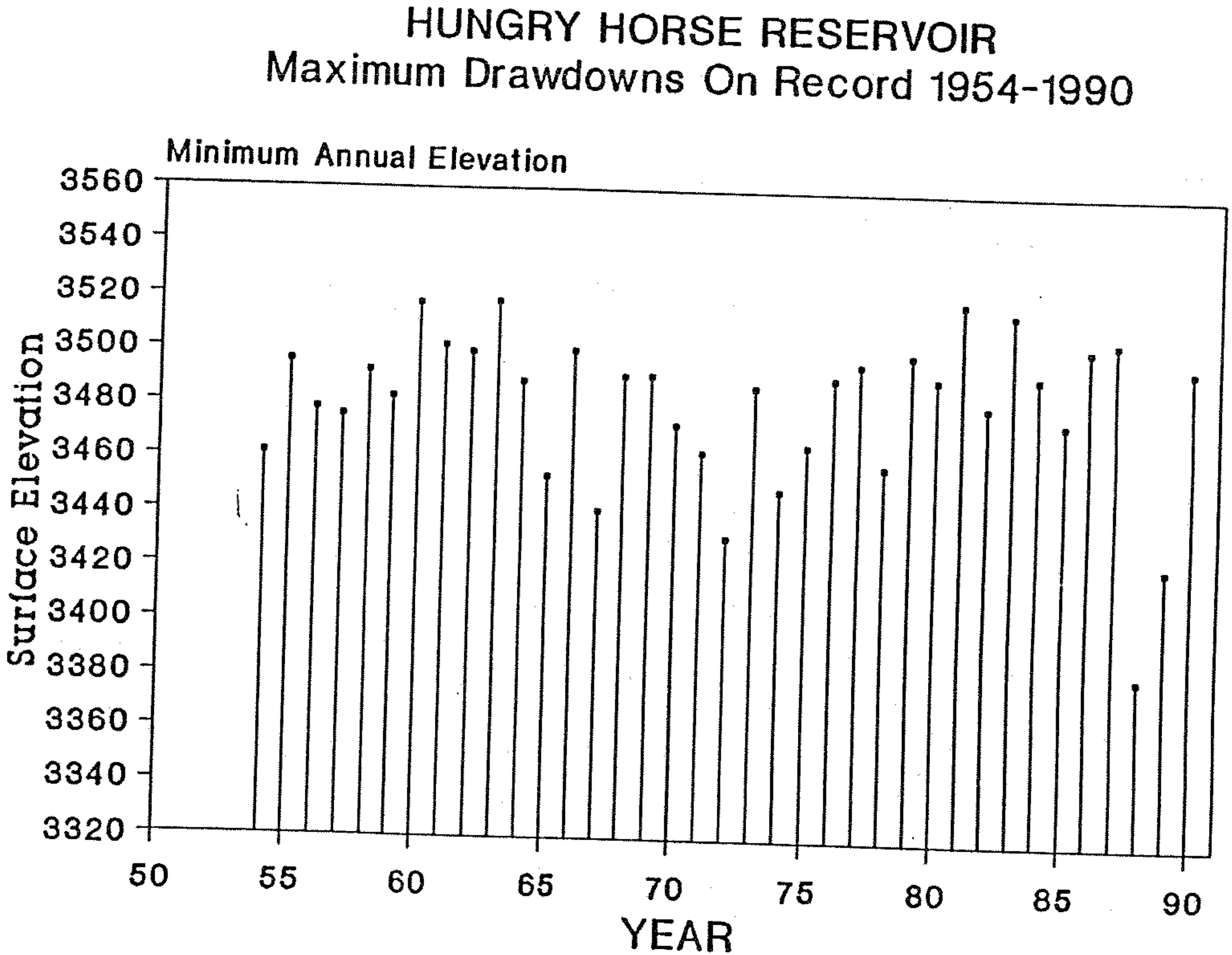

Figure 2. Minimum pool elevations during water years 1954 through 1990 at Hungry Horse Reservoir.

METHODS

Determination of Fisheries Losses in the Flathead System

We calculated losses of migratory westslope cutthroat in the Flathead system caused by the construction of Hungry Horse Dam and blocking of fish migration using a habitat-based approach (Fraley et al., 1989; Zubik and Fraley, 1987). Stream order and gradient were found to be significantly related to juvenile westslope cutthroat densities in tributary reaches in the upper Flathead Basin (Fraley and Graham, 1982). Using this relationship, we calculated the rearing potential in tributaries of the South Fork Flathead River which were inundated or isolated from the Flathead system by Hungry Horse Dam. We assumed that streams with gradients of six percent or less were populated by migratory cutthroat juveniles, while resident cutthroat occupied tributary sections with gradients greater than six percent. To calculate potential losses of rearing westslope cutthroat in the portion of the South Fork Flathead River which was inundated, we estimated cutthroat densities in representative reaches of the South Fork above the reservoir (Zubik and Fraley, 1988) and applied these densities to the portion of the river inundated by the reservoir. In these analyses, we assumed that inundated stream reaches were at the same level of carrying capacity as reaches not under the reservoir. Our estimates on cutthroat losses are conservative because we only considered streams of gradients less than six percent.

We estimated losses of migratory bull trout caused by the construction of Hungry Horse Dam (and blocking of the South Fork Flathead River) based on the proportion of drainage area that the South Fork comprised in relation to the North and Middle forks. Assuming that bull trout escapement was proportional to drainage area, we estimated the historic spawning run in the South Fork based on the average known spawning runs of bull trout in the North and Middle forks from 1980-1986.

Impacts of the operation of Kerr and Hungry Horse dams on kokanee reproduction in the Flathead River and Flathead lakeshore were documented by various methods of determining egg and pre-emergent fry mortality (Decker-Hess and McMullin, 1983; Fraley and McMullin, 1983). We documented emergent fry survival using emergence traps placed over spawning areas in regulated and unregulated portions of the system (Fraley et al., 1986a). We also analyzed the historic relationship between operations of Kerr and Hungry Horse dams and kokanee year-class strength (Fraley and Decker-Hess, 1987; Fraley et al., 1986). The loss of adult kokanee in the Flathead system caused by hydroelectric operations was estimated by comparing historic and recent spawning escapements (Fraley et al., 1989; Beattie et al., 1988). Historic escapement along the Flathead Lake shoreline was conservatively estimated to equal the number of mature kokanee caught in the fall fishery of 1962 and 1963. Recent escapements were estimated by counting either spawning fish or redds (Fraley and Decker-Hess, 1987).

Quantitative Biological Models and Biological Rule Curves (BRC's) for Hungry Horse Reservoir

We constructed a hydrologic/biological model for Hungry Horse Reservoir (Anderson, 1990; Gustafson, 1989) and used it to produce dam operation guidelines (rule curves) for optimizing biological production (Fraley et al., 1989). Physical and biological characteristics of Hungry Horse Reservoir were assessed from 1983 through 1990 (Table 2). We examined three localities in the basin to detect longitudinal variation in physical and biological characteristics (May et al., 1988). Field data from 1983 through 1988 were used to construct the models; the remaining years were used for preliminary model testing and refinement. Model components were validated after construction. The basic modeling strategy is to make maximal use of extensive data gathered by MDFWP and existing data to develop empirical relationships which capture as much of the observed biological variation as possible. The use of theoretical relationships and literature coefficients was held to a minimum and used only to limit the scaling of coefficients, whose exact values have little or no effect on interpretation of the output. The model is thus reservoir specific. The overall approach and refined sampling design are, however, portable given access to the needed data. The model is intended to be predictive over the range of physical conditions encountered during the collection of the data, and to the extent that surface area and volume dominate, for some range of conditions beyond that.

The biological model has major components: physical environment, thermodynamic, and biological. The biological model contains primary production, secondary production, and fish community (Figure 3). Calculations in the higher trophic level model components receive input from the preceding trophic submodels, much as energy is transferred through a biological system. Submodels were calibrated to field measurements individually to avoid unrealistic predictions of dam operation effects on reservoir biology.

The physical environment model was a digitized three-dimensional representation of the reservoir topography and volume, by which the daily hydrologic balance in inflow, reservoir surface elevation, and dam discharge were calculated. The range of dam discharges is restricted by physical limitations of the dam structure and downstream concerns. The physical maximum discharge is limited by immediate downstream flood constraints and the maximum turbine capacity at hydraulic head relationship. The minimum discharge corresponds with recommended flows for downstream fisheries. Discharge limits are further controlled by the combined flows of the three forks of the Flathead River as measured at Columbia Falls. The dam regulates flows in the South Fork. A default minimum combined flow of 3,500 cfs at Columbia Falls has been set for the entire year for riverine fish production. Maximum combined flow is 44,800 cfs; when flows in the North and Middle forks approach this flood stage, dam discharge is reduced accordingly toward the absolute physical minimum of 145 cfs. Minimum and maximum discharges may be set by the user within the limitations defined by flood control and the physical limitations of the dam.

The superimposed thermal structure was modelled on 11 years of daily climatological records (U.S. Weather Service, Kalispell, Montana) empirically calibrated to measured thermal

Table 2. Physical and biological samples collected at Hungry Horse Reservoir, 1983-1990.

Sample Type	Total Number of Samples Hungry Horse
Water Column Profiles (water temperature, dissolved oxygen, pH, conductivity, solar input)	302
Primary Production profiles	95
Zooplankton (30 m vertical tows, Schindler trap)	881
Zooplankton Loss through outlet	119
Surface insects (1 x 0.33 m surface tow)	1,342
Benthos (Peterson dredge)	857
Emergence (1 m^2 surface traps)	726
Fisheries	
Horizontal experimental gill nets	1,490
Vertical experimental gill nets	9
Dual-beam Hydroacoustic surveys (whole reservoir)	2
Stomach content analyses	1,992

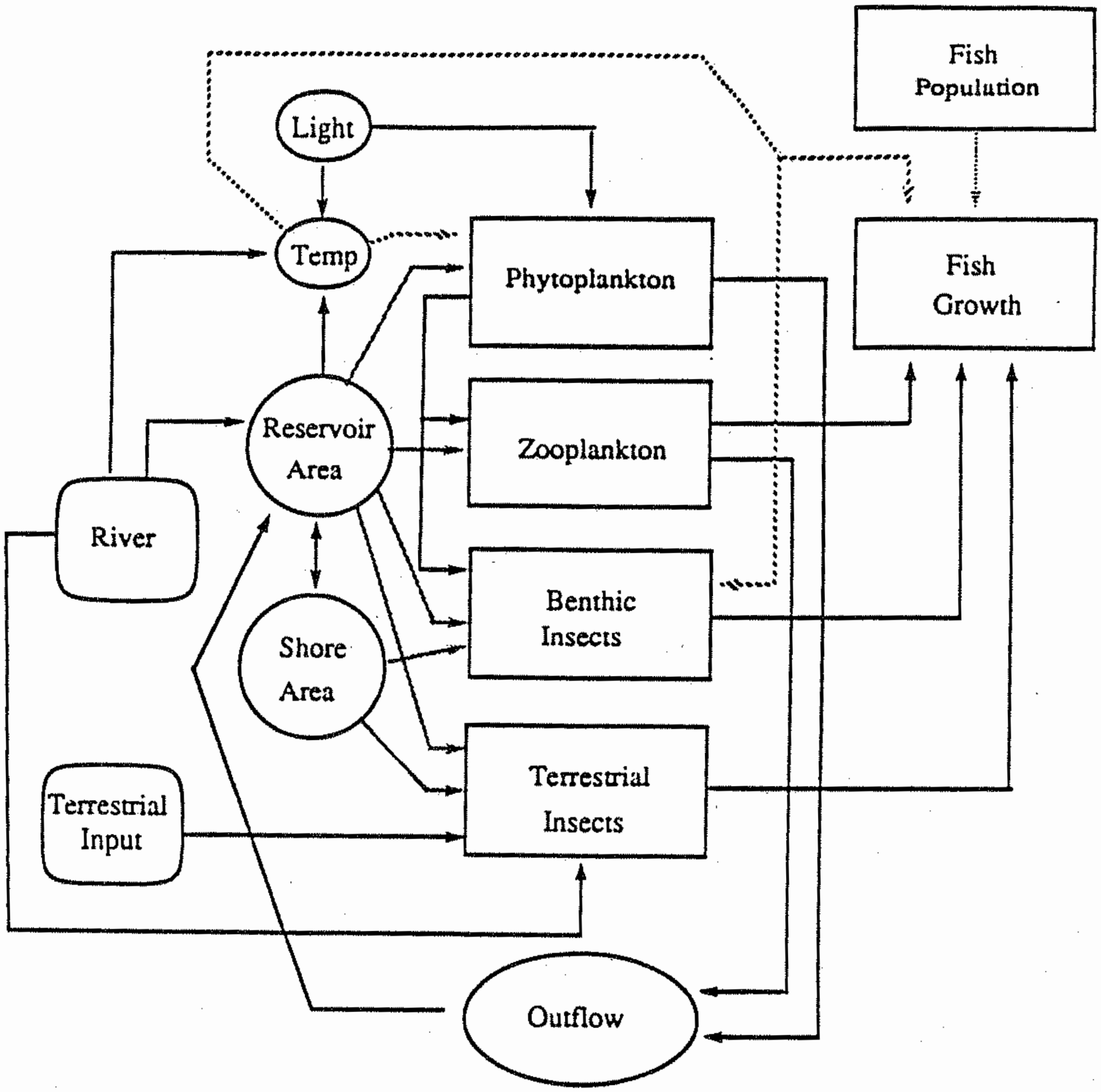

Figure 3. Compartmental diagram of model interconnections.

conditions at the study reservoir, long-term inflowing tributary temperatures, the physical properties of water, and basin topography.

During 1990, a downstream hydrologic and thermal component was added to the reservoir model. Long-term flow and temperature data from the North, Middle, and South forks of the Flathead River were used to calculate the combined flows and temperature in the main stem below the South Fork confluence. Long-term flow data from other tributaries entering the river and Flathead Lake, plus the hydrologic conditions of the basin and the physical characteristics of the lake outflow were used to extend the hydrologic component through Kerr Dam discharges. This improvement provides instant evaluation of the effects of Hungry Horse discharges on Flathead Lake elevations and flows in the Flathead River downstream from Kerr Dam.

The component was also modified to simulate a selective depth of water withdrawal mechanism on Hungry Horse Dam. A selective withdrawal structure would allow dam operators to release water from various depths in the reservoir and correct water temperatures in the tailwater toward natural conditions. The model links discharges with the proper level in the reservoir thermal structure, then mixes the combined flows of the three river forks to calculate the resulting river temperature. Consecutive trials using fixed and selective withdrawal were used to evaluate the effectiveness of the proposed structure and assess biological effects in the reservoir.

We analyzed the effectiveness of a re-regulating dam, which was considered for installation in the South Fork by the Bureau of Reclamation (BOR, 1986). River flows below the rereg were assessed under various peaking and operational strategies. The intent is to minimize fluctuations in the main stem Flathead River yet allow maximum flexibility in Hungry Horse operation.

The vertical distribution of primary production was quantified by light and dark bottle ^{14}C liquid scintillation techniques at each sampling depth (0, 1, 3, 5, 10, 15, 20, and 25 m). Associated light attenuation was measured with a photometer. Chlorophyll was measured at the study depths and below the dam to assess loss of algal biomass through the dam. A least-squares linear regression used to empirically model primary production within the tolerance limits of light and temperature removed about 70 percent of the raw variance. The model outputs an annual schedule of total production, minus phytoplankton production lost through the dam outlet.

We predicted secondary production by correlating zooplankton density and distribution, benthic biomass, emergence of aquatic insects and terrestrial insect deposition with environmental parameters. Zooplankton data were linked to primary production by measured carbon transfer efficiencies and theoretical community models (Ulanowicz and Platt, 1985). Estimated total zooplankton production was subdivided into the major genera by relative biomass estimates derived from field samples. Sampling in the tailwater showed that direct loss of zooplankton biomass through the dam was significantly greater when the reservoir was isothermal and when surface elevation approached the outflow depth. Loss densities were greatest when zooplankton were concentrated within reduced reservoir volumes. Model output includes monthly and annual estimates of biomass lost through the dam and annual estimates of production of *Daphnia*, *Bosmina Diaptomus*, *Cyclops*, *Epischura*, and *Leptodora*.

Benthic biomass was sampled with a Peterson dredge. Regression analysis indicated a significant decrease in biomass with increased frequency of dewatering. Insect emergence traps on the water surface, however, revealed that production of emergers varied inversely with depth. Since aquatic dipterans become available as food for fish upon emergence, the greater emergence in the shallow zones after inundation and recolonization attest to the importance of shallow areas for fish food production. Substrate at elevations near full pool are more frequently dewatered, limiting production. The model calculates the area of wetted reservoir bottom. Benthic production was calculated from a linear regression of standing stock of aquatic Diptera larvae by reservoir bottom elevation (permanently wetted, occasionally dewatered and frequently dewatered), and dipteran emergence per unit biomass based on emergent insect capture.

Terrestrial insect deposition was treated separately for nearshore ($\leq$ 100 m) and offshore areas. Seasonal deposition of each taxonomic order was assumed to be proportional to measured standing stocks in surface tows. The model describes the influx of the four orders of terrestrial insects in percent of maximum deposition.

Estimates of food production from the secondary production component were included in fish food availability calculations. Westslope cutthroat trout growth is modeled on water temperature, food availability, monthly growth increments from otolith analyses and annual increments from scales. The model output is a table representing the end of month growth in length (mm) and biomass (g) of fish (ages III to V). Only westslope cutthroat that emigrated from their natal tributary at age III are represented.

The effects of dam operation on primary production, secondary production, and fish growth were examined by model simulations of one year. Benthic insect production estimates assumed that the simulation continued for two identical years and fish growth simulations continued for three years to assess growth at three, four, and five years of age.

We assessed the effect of reservoir elevation on biological production. We subdivided this analysis into two parts:

1. We created elevation schedules using the maximum, mean, and minimum daily elevations for the period 1954-1989. The curves were input to the model with the long-term average inflow volume to compare biological production (Figure 4).

2. We ran a series of model simulations setting the reservoir at varying elevations (full pool to 3,340 ft. in increments) assuming an average annual inflow volume. Inflow rate was held constant to allow a constant reservoir elevation.

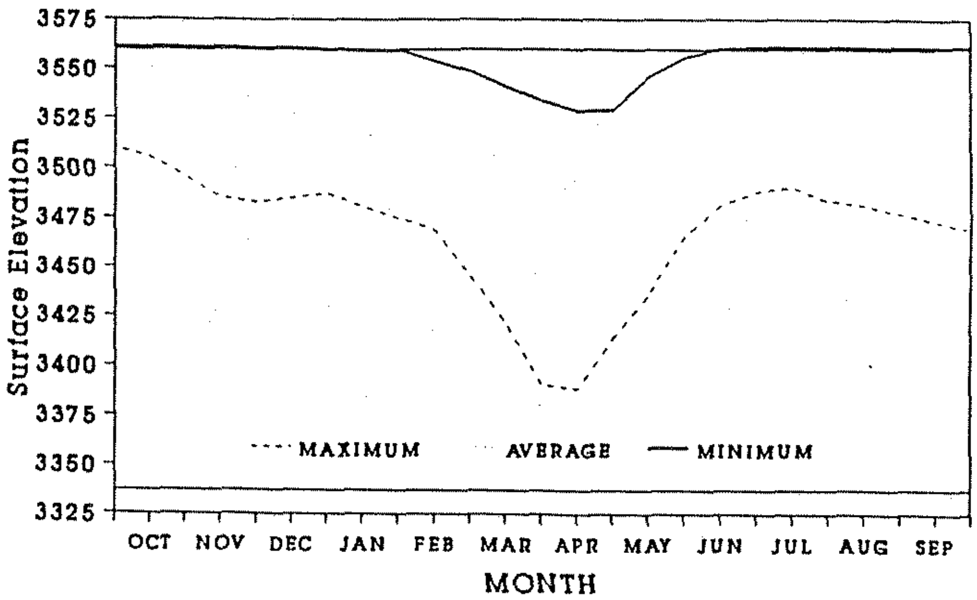

Figure 4. Mean, minimum, and maximum daily reservoir drawdown at Hungry Horse Reservoir for the period 1954 through 1990.

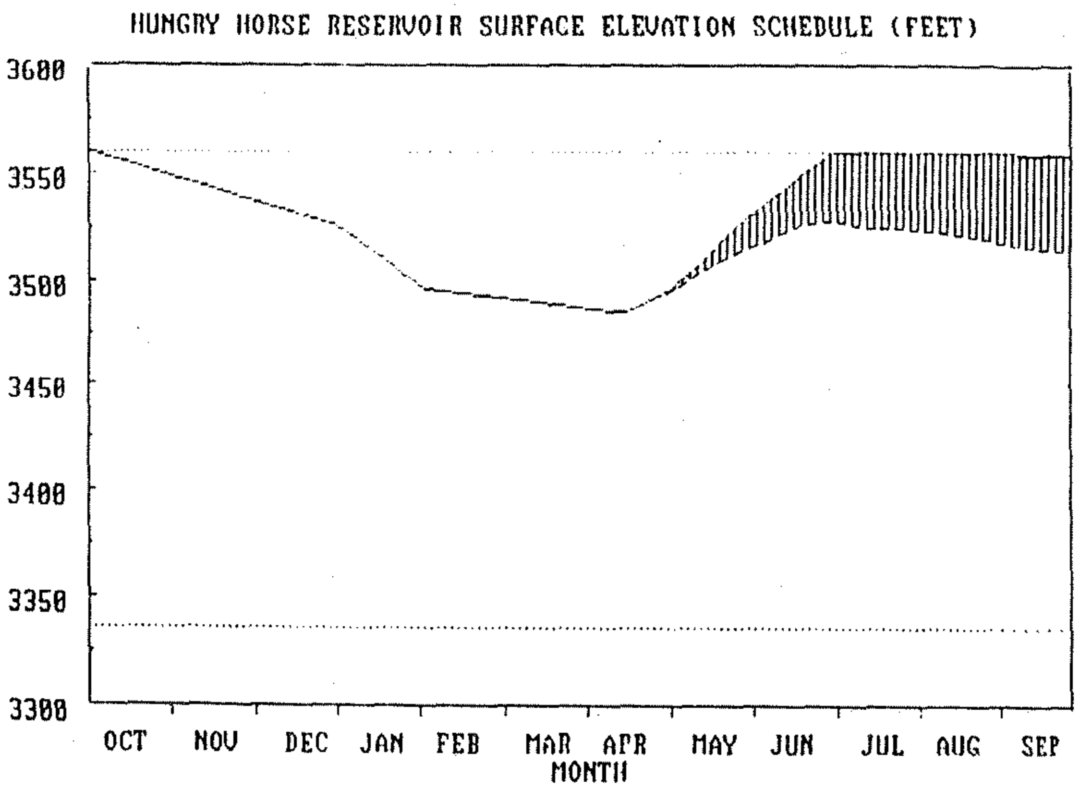

Figure 5. Comparison of proposed Biological Rule Curve-1 from four-year critical period analysis (top) and realized elevation schedule (bottom) resulting from an extremely dry year observed in water year 1942. Shaded area highlights the difference between the two elevation schedules.

We also assessed the biological effects of failure to refill the reservoir. Analysis of reservoir refill failure requires two model simulations and subsequent comparison of results. Factors influencing results include: (1) distance of maximum refill elevation from full pool; (2) reservoir operation prior to spring runoff (ie. reservoir refill during the prior year and maximum drawdown during April); and (3) volume of reservoir inflow. To provide an example of this analysis, we used the two elevation schedules in Figure 5 and assumed the long-term average inflow schedule.

We assessed the effectiveness of selective withdrawal vs. modified reservoir operation to control downstream water temperatures and maintain biological production in the reservoir. For this analysis, it was important to use an actual year of record. Water year 1982 was chosen because inflow was near average (107.6 percent of normal). Maximum drawdown was 79 feet below full pool, close to 75 feet as in the proposed biological rule curve for good water conditions (BRC1). The reservoir was at full pool for nearly the entire period July 1 through September 30 (> 3,559.17 until refill July 18, then full through September 30). Model simulations were run using: (1) the actual 1982 elevation schedule, with and without selective withdrawal; and (2) a modified 1982 schedule allowing reservoir drafting after July 15 through September 30 (Figure 6), with and without selective withdrawal. Present discharge limitations were imposed during the model simulations: 3,500 cfs minimum and 44,810 cfs maximum flows in the Flathead River at Columbia Falls (Figure 7). Biological analyses evaluated trout growth units on a monthly basis in the main stem Flathead River, loss of biological production through the dam from Hungry Horse Reservoir, and biological effects within the reservoir. The human factor in selective withdrawal management has been adequately addressed by the model; withdrawal depths are set in a step-wise manner to simulate discrete manual adjustments by dam operators. Trout growth units are equivalent to temperature degree days between 6 and 17° C, the range at which trout growth can occur under wild conditions (Fraley and Graham, 1982). One day at 7° C equals 1 trout growth unit. Other biological effects were evaluated as previously described.

With help from BPA, we assessed tradeoffs between biological production and power generation. We used results of successive trials using different dam operation scenarios to optimize biological production during waters years ranging from drought to flood, and to develop variable dam operation rule curves or "Biological Rule Curves" (BRC's). The BRC's were designed for analysis with BPA's System Analysis Model (SAM) to assess tradeoffs between biology and power production. The SAM analysis could not be performed without first running a four-year critical period analysis using BPA's HYDRO6 model. After consulting with BPA modelers and planning personnel, it was determined that BRC's should be developed for a four-year critical period (extended drought, BRC1-4).

Although our Biological Rule Curves were designed to be variable depending on reservoir inflow forecasts, the critical period analysis required only one first year rule curve. Therefore, we developed a proposed BRC for average inflow conditions. The worst water year in history, 1942 (1.1884 million acre feet, 43.8 percent of normal), was used as input to the model. Inflow was insufficient to refill the reservoir (Figure 5, bottom line). The resulting curve, using 1942

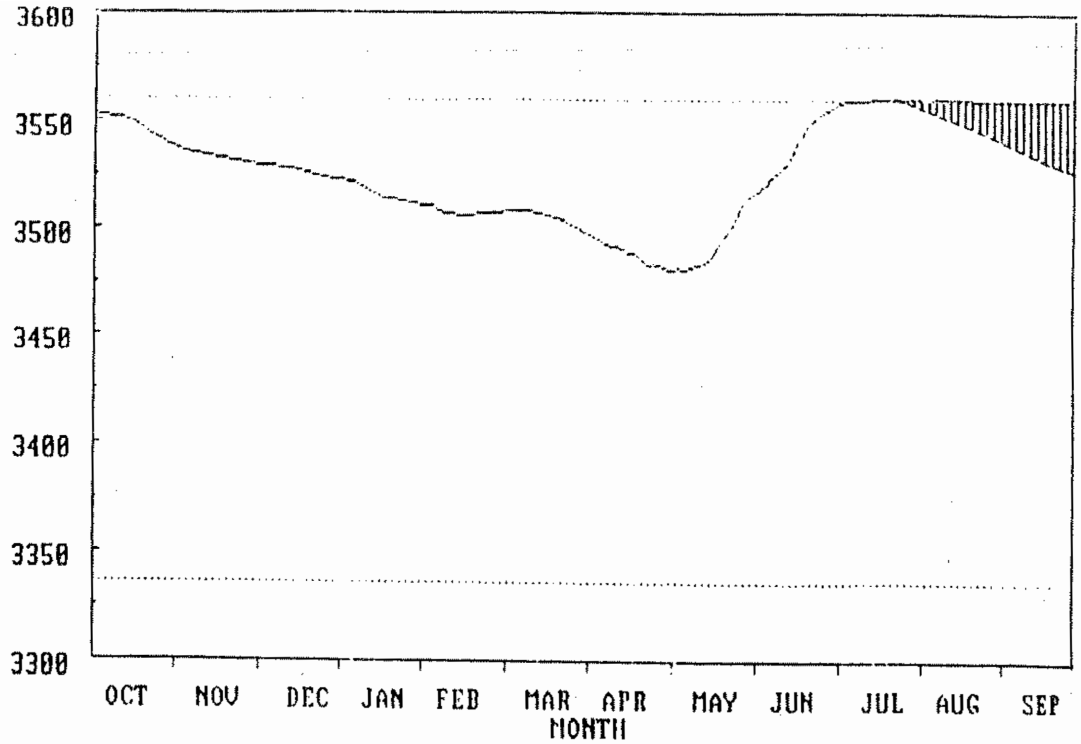

Figure 6. Actual surface elevation schedule from water year 1982 (top), and modified schedule allowing reservoir drafting from July 15 through September 30. Shaded area highlights the difference between the two operation scenarios.

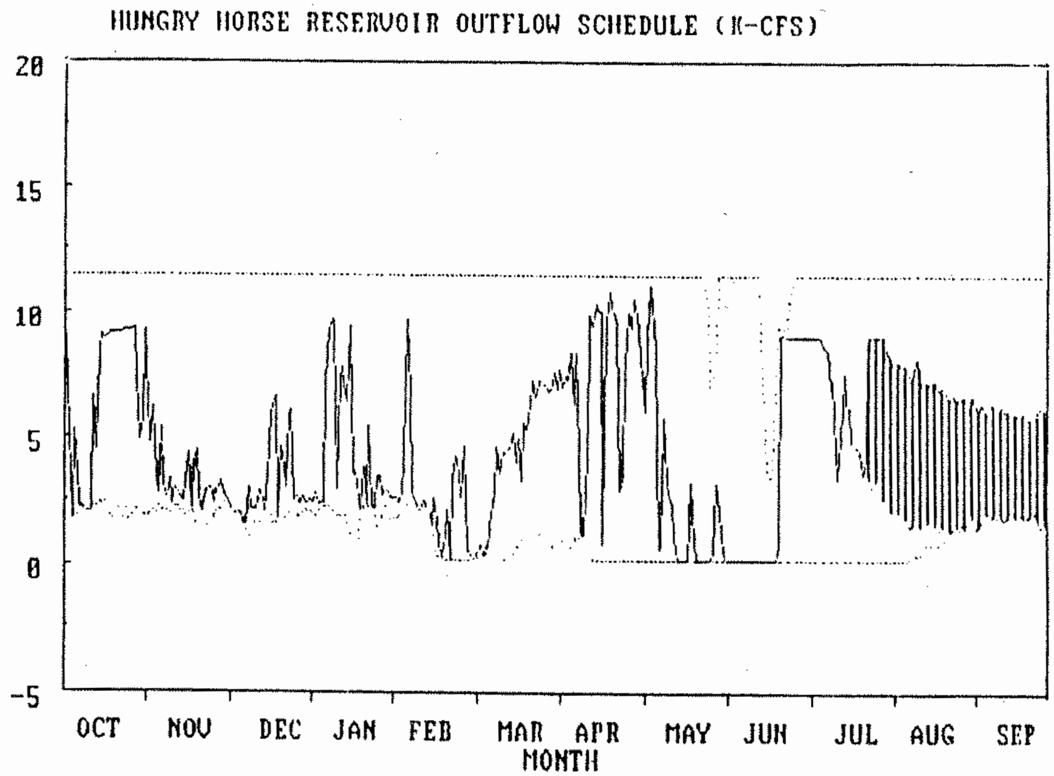

Figure 7. Dam discharge from water year 1982 (solid bottom line), and modified outflow schedule (solid top line) allowing for reservoir drafting from July 15 through September 30. Shaded area highlights difference between the two discharge schedules. Dashed lines denote minimum and maximum discharge limits dictated by downstream concerns.

inflow, became BRC1 in the critical period analysis. BRC's 2-4 were developed by continuing the model run for three additional years, using water year 1942 as input. Because the probability of such an extreme drought extending for four years is low, we considered BRC1-4 to be a worst case scenario. Bonneville Power Administration modelers adjusted BRC1-4 (based on a critical period at Hungry Horse) to the critical period for the entire Columbia River system. The new BRC's were input to HYDRO6 to assess impacts on the ability of the system to produce firm energy.

Mitigation Objectives

The loss estimates described in our previous reports and summarized in this report form the basis of our mitigation objectives. No fisheries mitigation has taken place for construction and current operations of Hungry Horse Dam; therefore, we converted the estimated net losses directly into mitigation goals. In estimating losses, we attempted to factor out all non-hydropower related losses. For example, in determining kokanee losses in the Flathead River, we considered only those areas directly exposed to fluctuating flows during a period when *Mysis* was not a factor. Also, our loss estimates are very conservative and only those with a sound quantitative basis are claimed. Therefore, we feel that the specific hydropower related losses represent net losses. We feel that unquantified losses offset benefits of the project for fisheries. Unquantified losses which offset benefits of the project include:

1. Lost biological production and angling opportunity from 1954 to present: We are not adding up lost fish populations and angling opportunity since dam construction. We are simply recommending a program to replace annual production beginning with approval of the plan.

2. Declines in lake trout growth in Flathead Lake because of loss of forage fish: Kokanee once made up most of the lake trout diet.

3. Reductions in fish growth in the South Fork and main stem Flathead River because of temperature effects: We have not quantified the loss in angling opportunity and fish survival caused by frigid water releases from Hungry Horse Dam. We are asking that the thermal problem be corrected.

4. Reductions in aquatic invertebrate populations and disruption of invertebrate life cycles: Colder releases during summer and warmer water during winter have changed the natural food web of the river. We can't quantify or place a dollar figure on this loss.

5. Recreation value and innate value of the loss of the free flowing South Fork Flathead River: The recreational value and angling value on 35 miles of free flowing river would exceed that of the fluctuating reservoir.

The unquantified losses listed above offset habitat benefits from Hungry Horse Dam which include:

1. Increased minimum flows in the Flathead River during specific months and low water periods. Even though this provides more water, these augmented flows impact temperatures more severely: Selective withdrawal would change this into an unqualified benefit.

2. Warmer releases during winter, reducing ice build-up: This is both a habitat and a social benefit.

3. Fish habitat created by Hungry Horse Reservoir: The reservoir supports a fishery.

4. Blocking of the South Fork drainage could be considered a benefit in terms of preventing exotic species from entering the drainage from downstream.

We recognize the social benefits provided by flood control and power production. However, these benefits come at the expense of the aquatic habitat.

Assessing Mitigation Alternatives

We developed mitigation alternatives based on Montana's fisheries mitigation guidelines. In addition to our own management plans and those of other cooperators, the Fish and Wildlife Program has been guided by the standards in Section 4(h) of the Act. As a result of these influences, Montana's fisheries mitigation guidelines are to:

- Protect, mitigate, and enhance biological production in the affected waters;
- Emphasize natural fish production and habitat whenever possible;
- Mitigate with artificial propagation to enhance fish populations and provide recreation when full mitigation of natural production is not possible;
- Emphasize mitigation for designated species of special concern such as westslope cutthroat or bull trout where appropriate;
- In the Flathead system, mitigate in conjunction with the Confederated Salish and Kootenai Tribes, as specified in the Fisheries Co-management Plan; and
- Emphasize cooperation with power/water management interests in determining reservoir operations and mitigation.

Development of mitigation alternatives was consistent with the Northwest Power Planning and Conservation Act, the Council's Fish and Wildlife Program, consultations with agency cooperators, and the hydrologic constraints of the Columbia River system. We incorporated, to the greatest extent practicable, input from a scoping process and direction from the consultation group for Hungry Horse fisheries mitigation.

We developed mitigation measures and the preferred mitigation direction based on the current state of fisheries mitigation technology and accepted fisheries enhancement techniques. Improvements in technology and evaluation/feedback on success of mitigation measures will likely result in continual adjustments in the mitigation plan. This adaptive management feature is essential to successful mitigation over the long term (Lee and Lawrence, 1986; Walters, 1986; Hollings, 1980).

We calculated benefit:cost ratios for mitigation alternatives, in part, based on the following assumptions:

1. Net economic value of an angler day is $90 in the Flathead Lake and River system and $51 on Hungry Horse Reservoir (Duffield et al., 1987).

2. Half of the fish produced under each mitigation alternative are harvested by anglers.

3. Anglers catch an average of four fish/day (Graham and Fredenberg, 1983; Fredenberg and Graham, 1983).

We outline other specific assumptions under each measure.

RESULTS AND DISCUSSION

Fisheries Losses and Impacts

Losses Caused by Dam Construction

Fisheries losses caused by the construction of Hungry Horse Dam were determined by Zubik and Fraley (1987) and Fraley et al. (1989). Construction of the dam blocked 40 percent of the area available for the annual spawning migration of bull trout and cutthroat trout. Hungry Horse Reservoir inundated 36 miles of tributary habitat with gradients of less than 6 percent. In addition, 327 miles of tributary habitat in the upper South Fork drainage, with gradients less than 6 percent, were blocked to migratory cutthroat in the Flathead system by Hungry Horse Dam. Based on stream order and gradient relationships, the total loss of 363 miles of tributary habitat represents an annual loss to the Flathead Lake and River system of approximately 175,500 migratory juveniles (standing stock) age I-III (Table 3). Also, we calculated that habitat supporting 11,600 migratory cutthroat juveniles was lost to the Flathead Lake and River system when Hungry Horse Reservoir inundated 57 km of the South Fork Flathead River. In summary,

Table 5. Estimated number of adfluvial cutthroat juveniles lost (standing stock) by stream order and gradient categories (for gradients less than six percent) in tributary reaches of Hungry Horse Reservoir.

Stream order	Gradients (%)	Number of reaches	Length (m)	Number of cutthroat per 100 m (mean)	Total calculated loss (number of fish)
Reaches inundated by Hungry Horse Reservoir <u>(lost to all spawning adults and rearing juveniles</u>					
2	0.4 - 1.8	4	4,770	22.7	1,083
2	2.2 - 2.6	2	4,004	56.9	2,278
2	2.8 - 3.6	5	5,370	77.6	4,167
2	4.0 - 5.8	8	5,108	31.6	1,614
3	0.6 - 0.6	1	8,692	22.3	1,938
3	2.6 - 3.8	9	9,384	25.4	2,384
3	4.3 - 5.9	5	4,096	43.4	1,778
4	0.9 - 0.9	1	3,956	5.2	206
4	2.0 - 3.5	4	12,874	13.5	1,738
	Total	39	58,254		17,186
Reaches above full pool (includes upper South Fork drainage; <u>lost to spawning and rearing fish from Flathead Lake</u> but available to spawners from Hungry Horse Reservoir					
2	1.5 - 1.5	1	877	22.7	199
2	2.2 - 2.3	4	9,739	56.9	5,541
2	2.8 - 3.8	7	13,905	77.6	10,790
2	3.9 - 5.9	32	79,047	31.6	24,979
3	0.7 - 1.0	2	10,916	22.3	2,434
3	1.1 - 1.4	2	9,898	38.9	3,850
3	1.7 - 2.2	8	51,918	62.9	32,656
3	2.6 - 4.0	20	86,468	25.4	21,963
3	4.1 - 5.9	20	62,865	43.4	27,283
4	0.3 - 0.6	8	38,963	5.2	2,026
4	1.1 - 1.3	5	40,337	24.0	9,681
4	1.7 - 4.8	13	68,778	13.5	9,285
5	0.6 - 0.8	3	53,220	14.3	7,610
	Total	125	526,931		158,297
				Grand Total	175,483

we calculated that at least 65,500 migratory cutthroat were lost annually from Flathead Lake populations, based on the average age class distribution and migration rates of each age class of cutthroat.

The loss of spawning and rearing habitat in the inundated river and tributaries totaled approximately 77 miles, or 1,000 acres. The reservoir habitat, which replaced this lost stream habitat, does not support spawning and rearing for bull trout and westslope cutthroat.

Based on the proportion of drainage area and average spawning runs in the North and Middle forks, we calculated that approximately 2,000 adult bull trout spawners were lost from the Flathead Lake population when Hungry Horse Dam was constructed. The actual loss would be approximately two or three times that number of adults in Flathead Lake because only one-half to one-third of the adult population spawn each year. The annual loss of 2,000 adult bull trout spawners translates into a loss of approximately 250,000 young bull trout migrants returning to Flathead Lake. We derived this estimate of loss of juvenile bull trout using the following information from a study of bull trout life history in the Flathead system (Fraley and Shepard, 1989):

1. Female/male ratio of 1:3.7;

2. 5,482 eggs/female;

3. 35 percent egg to fry survival;

4. 40 percent survival to each subsequent age class; and

5. Most fish migrate at age II and III.

Downstream Losses Caused by Dam Operations

Downstream impacts from the operation of Hungry Horse Dam were determined by Graham et al. (1980), McMullin and Graham (1981), Appert and Graham (1981, 1982), Fraley and Graham (1982), Fraley and McMullin (1983), Fraley (1984), Clancy and Fraley (1986), Fraley et al. (1986), Beattie and Clancy (1987), Fraley and Decker-Hess (1987), Beattie et al. (1988, 1990), and Fraley et al. (1989). Extensive work at the University of Montana Biological Station has documented the effects of Hungry Horse Dam operations on the downstream aquatic environment. See Stanford (1990) for a review of this work.

Aquatic insect community structure and timing of life cycle events were severely disrupted in the South Fork, and moderately disrupted in the main stem Flathead River below the South Fork by temperature and volume changes caused by Hungry Horse Dam (Appert and Graham, 1981, 1982; Stanford, 1990). Migration and rearing habitat of westslope cutthroat trout, bull trout, and mountain whitefish are also affected by changes in water volume and temperature. Stranding of insects and fish is common due to the large fluctuations in flow (Stanford, 1990). Fraley and Graham (1982) concluded that water temperature units for trout growth were less than half of natural levels in the main stem Flathead River below the South Fork. Trout growth was virtually non-existent in the South Fork below Hungry Horse Dam. These effects are prevalent on five miles of the South Fork Flathead River and 47 miles of the main stem Flathead River. The total stream habitat area affected amounted to 2,200 acres.

Researchers found a statistical relationship between Hungry Horse operations and the size of adult kokanee in the Flathead system. Because the growth rate of kokanee is density dependent, the length of mature fish is an index of their abundance. The relationship implies that in years when operations were unfavorable, fewer juvenile kokanee were produced. As these juveniles matured, their growth rate was greater because they had fewer competitors for food. The analysis showed that the length of mature kokanee varied with the flows in the Flathead River as influenced by Hungry Horse Dam. This relationship was derived from 19 years of data, 1966 through 1984 (Fraley and Decker-Hess, 1987), and demonstrates a direct link between hydropower operations and the decline of spawning kokanee.

The statistical relationships assume that kokanee growth in Flathead Lake is inversely dependent on density, ie. growth rate is low when kokanee are relatively abundant and high when the kokanee population is depressed. A number of studies of sockeye and kokanee in other lake systems support the assumption of density dependence in Flathead Lake. Fish density was the best single predictor of sockeye smolt size in several lakes in British Columbia (Hyatt and Stockner, 1985). Juvenile sockeye growth was inversely correlated to fish density in three lakes in the Fraser River system (Goodland et al., 1974). Juvenile kokanee size was inversely related to kokanee abundance in Libby Reservoir (Chisholm et al., 1989). The increasing length of mature kokanee in Flathead Lake between 1975 and 1983 coincided with observed decline in the population (Decker-Hess and McMullin, 1983; Fraley and Decker-Hess, 1987). Rieman and Bowler (1980) suggested that density dependence has a more dramatic affect on growth rate when kokanee populations are at very low and very high density.

We conservatively estimated the annual loss of main stem river-spawning kokanee to be 96,300 adult fish (Beattie et al., 1988; Fraley et al., 1989). This figure does not include escapement to the North, South, and Middle forks of the Flathead River. A creel survey in 1975 estimated that main stem escapement exceeded 330,000 kokanee. Subsequent spawning surveys (Fraley and McMullin, 1983) indicate that 65 percent of these fish derived from unusually successful spawning in the upper main stem in 1971 to 1972, when hydro operations at Hungry Horse Dam were favorable. The remaining 35 percent (115,500), derived from reproduction in spring, influenced spawning areas. We believe that this lower figure (115,500) approximates historic main stem spawning escapement. Between 1980 and 1984, after a previous period of unfavorable operation at Hungry Horse Dam had impacted spawning success in the main stem (but before *Mysis* had reached sufficient levels to affect kokanee in Flathead Lake), spawning escapement averaged 19,200 fish. The loss attributable to hydro operation is the difference between 115,500 and 19,200, or 96,300 fish. If mitigation responsibility included the enhanced level of the main stem run, the loss would be the difference between 330,000 and

19,200, or 310,800 fish. In summary, we consider 100,000 fish, or about one-third of the river spawning run, a conservative figure for kokanee losses during the 1973-1980 period. Losses occurred during other years, but were more difficult to quantify and attribute to dam operations.

Agricultural and domestic development along the river banks, angler harvest, and increased abundance of predatory fish during the period could also have influenced kokanee spawning success and recruitment since Hungry Horse Dam was built. But, we believe that the cumulative impacts of hydro operations were far more significant in reducing kokanee production. There appears to be no relationship between numbers of hatchery fry planted sporadically in Flathead Lake in the 1960s and 1970s and subsequent numbers of adult fish. *Mysis* were first discovered in Flathead Lake in 1981 and should not have affected kokanee populations during this period. As a consequence of kokanee losses, growth of lake trout in Flathead Lake has declined significantly. The area guides report a 30 percent decline in the average size of lake trout caught since the early 1980s.

We also studied the effects of Kerr Dam operations on kokanee in Flathead Lake (Decker-Hess and Graham, 1982; Decker-Hess and McMullin, 1983; Beattie et al., 1985; Fraley and Decker-Hess, 1987; others). We incorporated these results into the Kerr Dam mitigation planning process through the Federal Energy Regulatory Commission (FERC). We present a summary of the results below; however, these losses were accounted for in the FERC process.

Flathead Lake water level fluctuations associated with the operation of Kerr Dam have negatively impacted the reproductive success of lakeshore spawning kokanee. Since the mid 1970s, the increasing demand for electrical energy in the fall and winter has prompted Montana Power Company to draft the lake more rapidly in the fall and hold the lake near minimum pool for a longer period in the winter. As the lake level recedes in the fall, kokanee redds above the minimum pool elevation are exposed. Unless the incubating eggs are wetted by groundwater seeps, high mortality is incurred within a few days after exposure (Decker-Hess and McMullin, 1983).

Even where favorable groundwater discharge maintains viable eggs, successful emergence is prevented because emergent alevins are isolated from the lake. High egg mortality has reduced the lakeshore-spawning "stock" to 2-4 percent of the total escapement in the Flathead system. Surveys in the early 1950s documented 30 spawning areas on the east and west shores of the lake. By the early 1980s, only 12 areas, including only one site on the west shore, attracted spawning runs. A creel survey of the popular lakeshore fishery for spawning kokanee in the fall of 1962 estimated that 134,000 fish were harvested. Because the total lakeshore run averaged about 3,000 fish from 1980-1985 (Fraley and Decker-Hess, 1987), at least 131,000 adults have been lost annually because of dam operations. A different interpretation of the relative magnitude of sport harvest and escapement of shoreline spawners (ie. anglers harvested only half the total run) suggest that the annual loss is 262,000 fish.

The more recent collapse of the kokanee population has been explained by a number of scientists as a case of *Mysis*-related effects on a population already stressed by hydropower operations and other factors (Beattie et al., 1990; Beattie and Clancy, In Press; Spencer et al., 1991). Beattie et al., 1990, concluded that predation by increasing numbers of lake trout and lake whitefish (species which eat *Mysis*) may have been more important in the kokanee decline than direct competition of kokanee and *Mysis* for zooplankton.

Biological and Habitat Impacts in Hungry Horse Reservoir Caused by Dam Operations

We calculated biological impacts in Hungry Horse Reservoir using our data-based trophic level model. Primary production (carbon fixation) peaked between June and August. Model output of annual totals (metric tons of carbon fixed) was more sensitive to reservoir elevations during July and August than to the depth of maximum withdrawal during late winter and early spring. Failure to refill the reservoirs resulted in decreased surface area and water volume of optimal conditions for biological productivity. Direct loss of production through the dam was greatest when surface elevation approached the depth of withdrawal and discharge volume was maximized. Production decreased at an accelerated rate as surface elevation deviated from full pool (Figures 8 and 9).

Zooplankton production responded to simulated dam operation in the same manner as phytoplankton (Figure 10) and the annual production schedule was nearly the same shape. Zooplankton production under mean, minimum and maximum drawdown scenarios was reduced with increased withdrawals (Figure 11). Washout of zooplankton through dam penstocks slightly increased as drawdown approached the fixed withdrawal elevation. Loss of zooplankton biomass measured in the tailwater was significant when the reservoir was isothermal (May and Fraley, 1986) and when surface elevation approached the outflow depth. Predicted loss of *Daphnia* biomass was more sensitive to the latter (Figure 12).

Benthic biomass, an important spring food supply for trout, was least ($P \leq 0.05$) in the frequently dewatered layer of the reservoir and varied inversely with the frequency of dewatering (May et al., 1988). Captures of emergent insects indicated decreased production per unit biomass with increased depth, however, attesting to the importance of frequently dewatered shallow areas for fish food production. These shallow areas are severely affected by hydropower. Because of the basin morphometry, shoreline length increases at approximately 40 feet from full pool (May and McMullin, 1983). Similarly, the surface area of the 10, 30, and 50 foot depth zones remain relatively stable as the reservoir elevation declines to 3,495 ft. msl. This results in relatively stable benthic insect production until reservoir drawdown exceeds 65 feet (Figure 13). As the reservoir surface declines below 65 feet from full pool, benthic production declines rapidly.

A reduced range of reservoir fluctuation can greatly enhance benthic production (Benson and Hudson, 1975). Reservoir drawdown causes benthic insect mortality when dewatered substrate dries or freezes (Grimas, 1961; Kaster and Jacobi, 1978). Larval densities are reduced in unprotected areas where wave action resorts the substrate (Cowell and Hudson, 1968). During June through September, when the reservoir is thermally stratified, benthic production

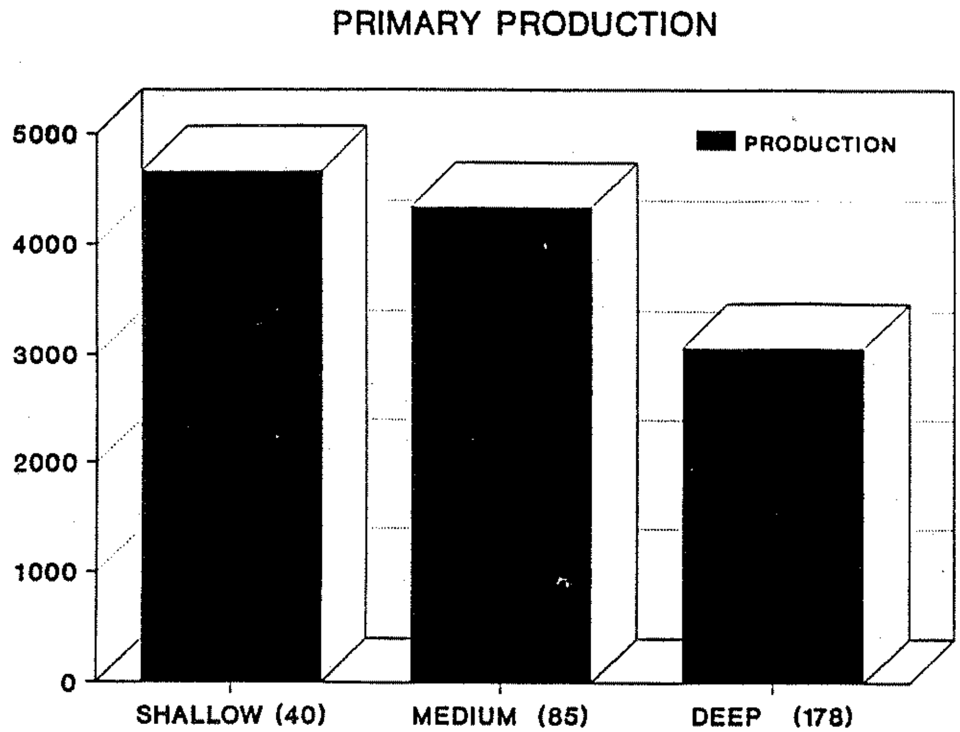

Figure 8. Annual primary production (metric tons) as compared to maximum (shallow), mean (middle), and minimum (deep) daily reservoir elevations during the period 1954 through 1990.

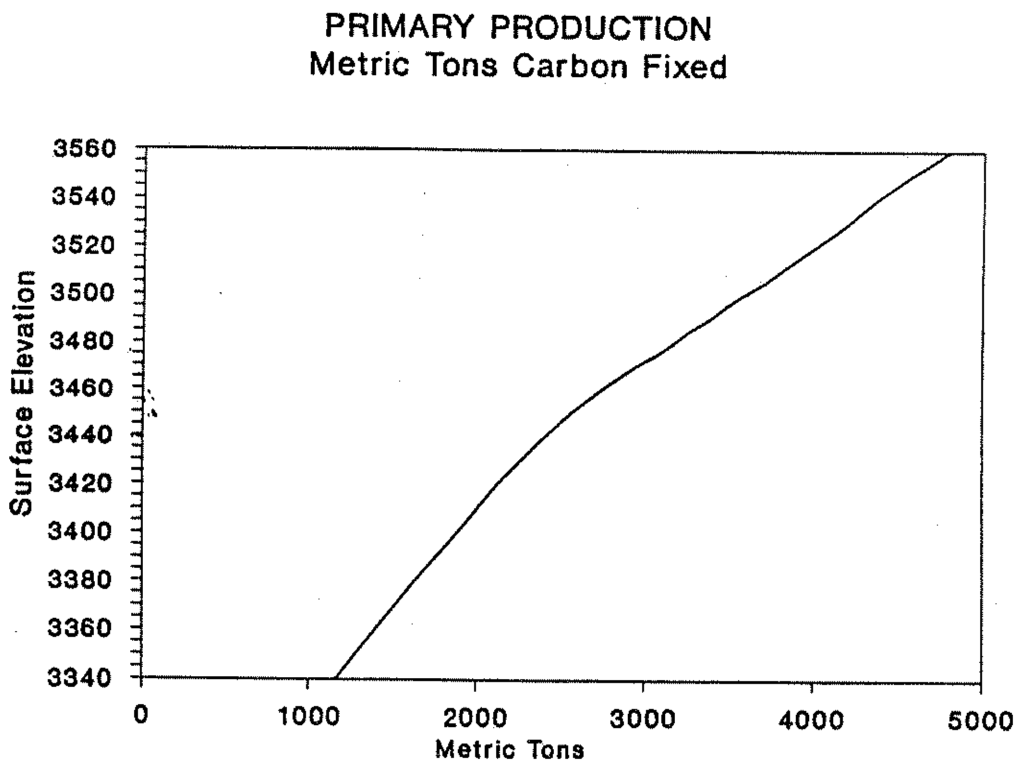

Figure 9. Primary production as related to reservoir surface elevation.

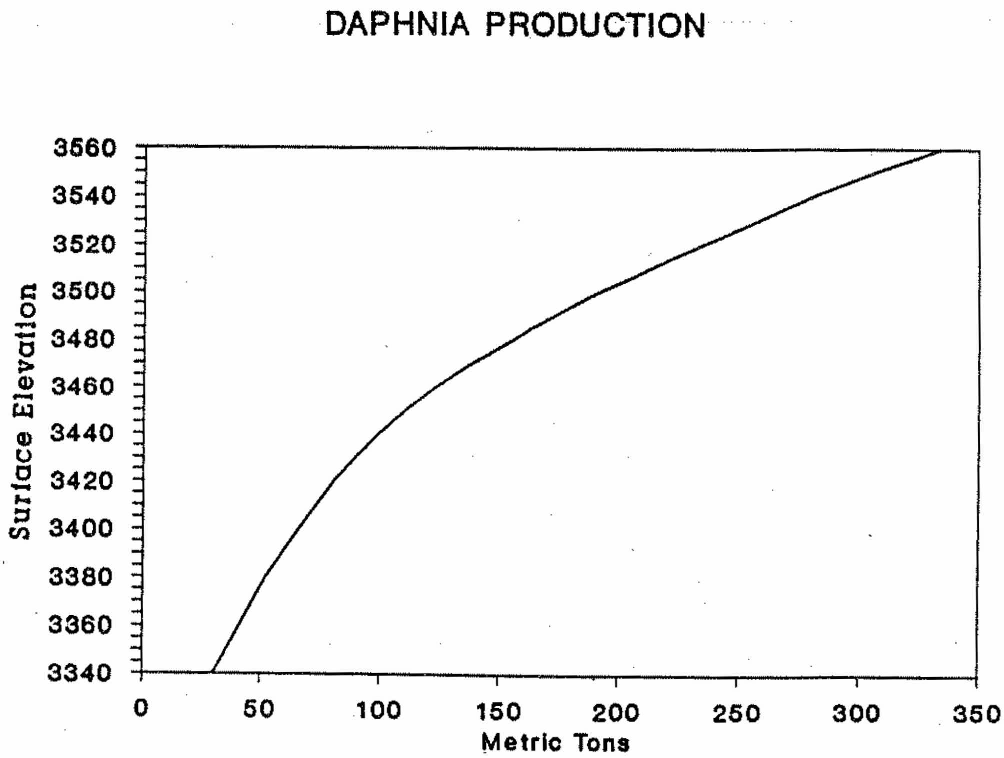

Figure 10. Daphnia production as affected by surface elevation.

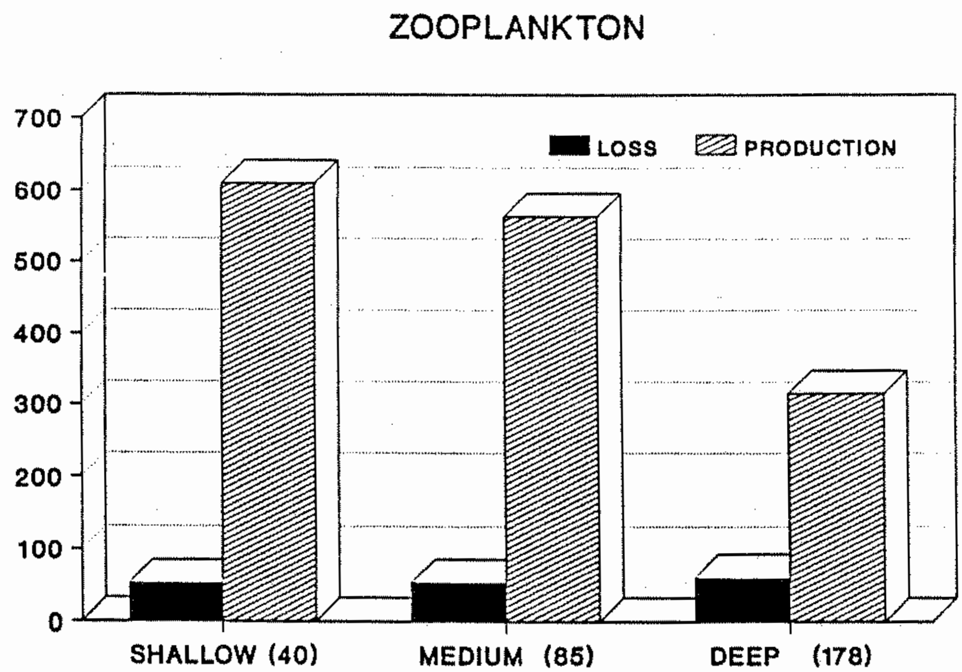

Figure 11. Zooplankton production and downstream loss (metric tons) as compared to maximum (shallow), mean (middle), and minimum (deep) daily reservoir elevations during the period 1954 through 1990.

DAPHNIA WASHOUT

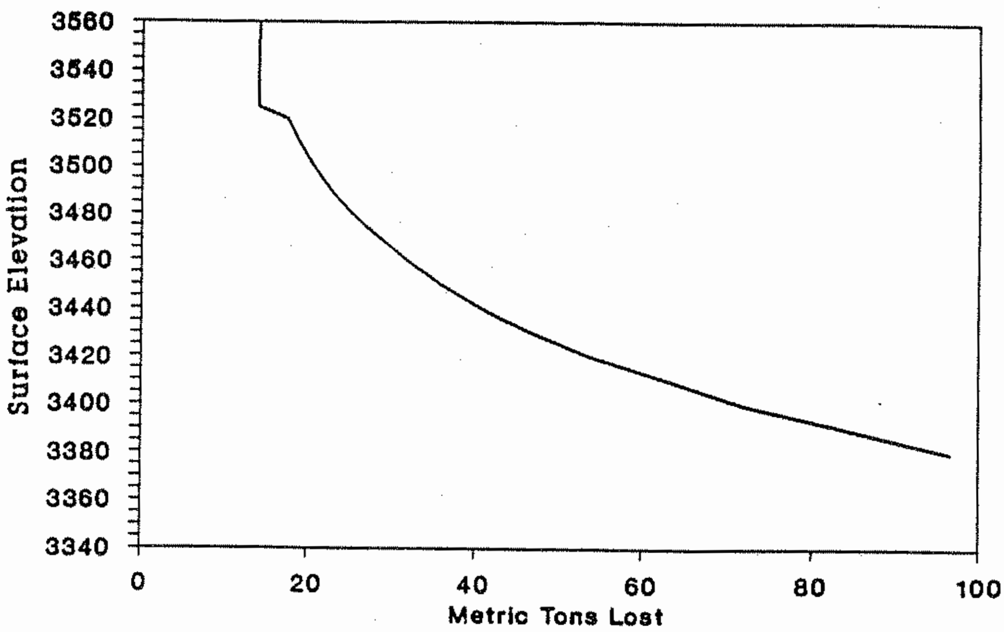

Figure 12. Loss of Daphnia through Hungry Horse Dam as related to reservoir surface elevation.

BENTHIC PRODUCTION

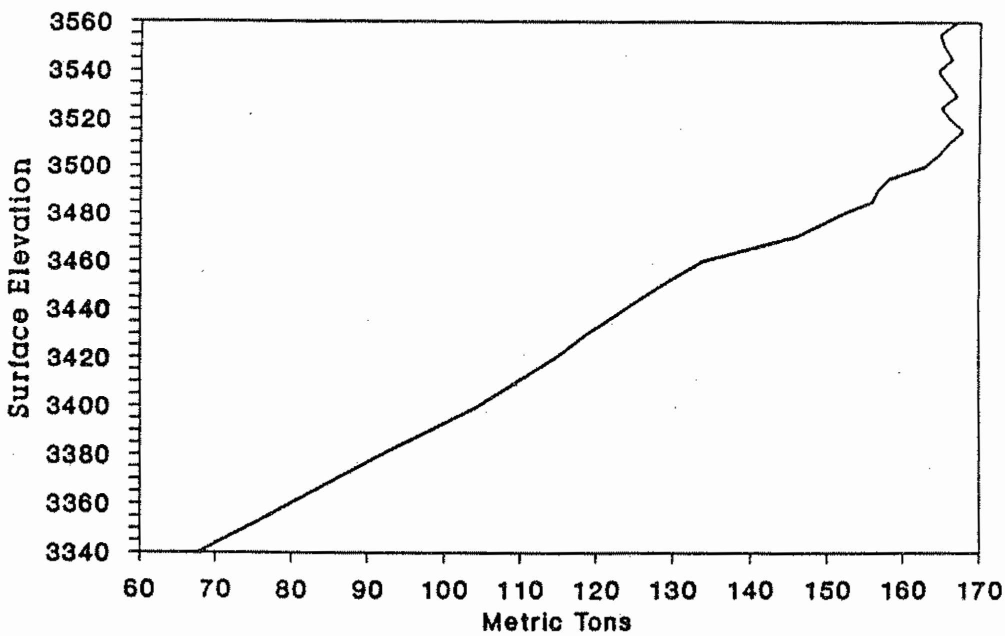

Figure 13. Benthic production as related to reservoir surface elevation.

may be temporarily increased when surface elevation declines, bringing warm sunlit water in contact with substrate containing high densities of larvae. Model simulations using the minimum, mean, and maximum daily elevations reveal a significant reduction in benthic insect production with increasing reservoir drawdown (Figure 14).

Surface insects make up the bulk of trout food items during fall. Deposition of land insects onto the reservoir surface peaks in August and September (May et al., 1988). Average densities in nearshore (< 100 m) samples were greater than densities sampled offshore, but the difference was not statistically significant ($P > 0.05$). Terrestrial density was proportional to the reservoir surface area. The activity period of the four major insect orders are significantly different and were modeled separately. Simulated drawdown schedules that remain at full pool during the months of insect activity show no loss of potential insect deposition. Conversely, operation schedules that deviate from full pool result in lost potential; the loss increases with reduced surface area (Figure 15).

Trout growth is dependent on water temperature and food availability. Stomach content analyses revealed that terrestrial insects comprised most of the food eaten, followed by benthic insects and zooplankton (May et al., 1988). Hymenoptera (flying ants, bees) were the most important terrestrial insect consumed and aquatic dipterans comprised about all of the aquatics ingested. Cutthroat selected *Daphnia pulex* almost exclusively when feeding on zooplankton, apparently due to its larger size. Cutthroat fed on *Daphnia* over 1.8 mm in length.

The diet of cutthroat trout varied seasonally in response to food availability (May and Weaver, 1987). In May, aquatic insects were the most important food item eaten, followed by terrestrial insects. From June through October, terrestrial insects dominated the diet. During this period, aquatic diptera were also an important component of the diet. When terrestrial insects were no longer available in November and December, the cutthroat switched to feeding primarily on *Daphnia pulex*.

A model simulation using the minimum, mean, and maximum daily reservoir elevations on record (Figure 16) revealed that reduced reservoir elevations negatively affected trout growth by reducing food availability and volume of water offering optimal conditions. Figure 16 compares the growth of three-year-old cutthroat trout, during their first year in the reservoir, under the three drawdown schedules.

Based on scale and otolith analyses, growth rates were highest in July and gradually decrease by late November. Biomass increase was greatest from August through September and weight continued to increase through November. Growth in the later summer and fall is very important for the juvenile cutthroat their first year in the reservoir. From August through November, juveniles obtained a mean of 55 percent (70 mm) of their growth in length and 68 percent (118 g) of their growth in weight. Growth from September through November is also important when 48 percent of the annual growth in weight is accrued. Reservoir at or near full pool during this time encourages trout growth. It is, therefore, important that the reservoir remain at full pool through September 15 and decline only gradually through November.

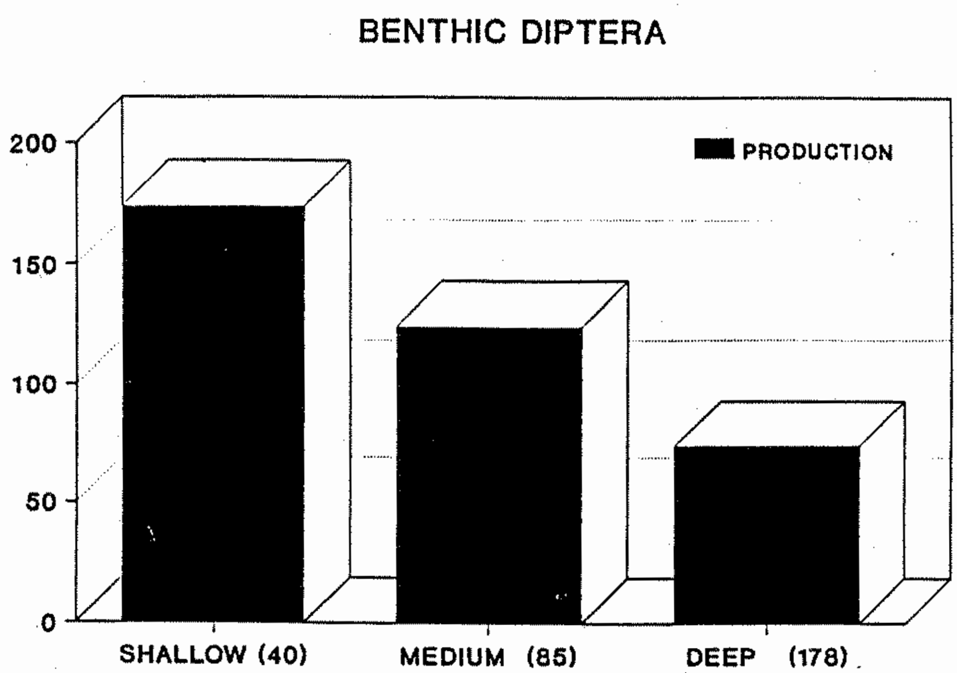

Figure 14. Benthic production (metric tons) as compared to maximum (shallow), mean (middle), and minimum (deep) daily reservoir elevations during the period 1954 through 1990.

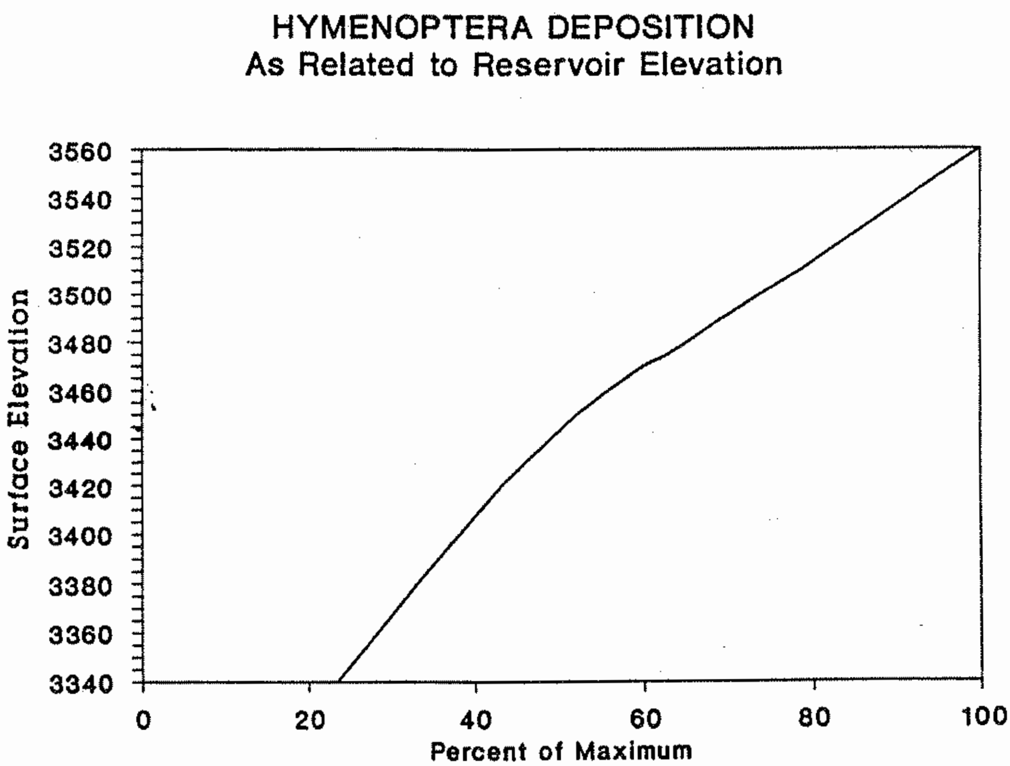

Figure 15. Deposition of hymenoptera as related to reservoir surface elevation.

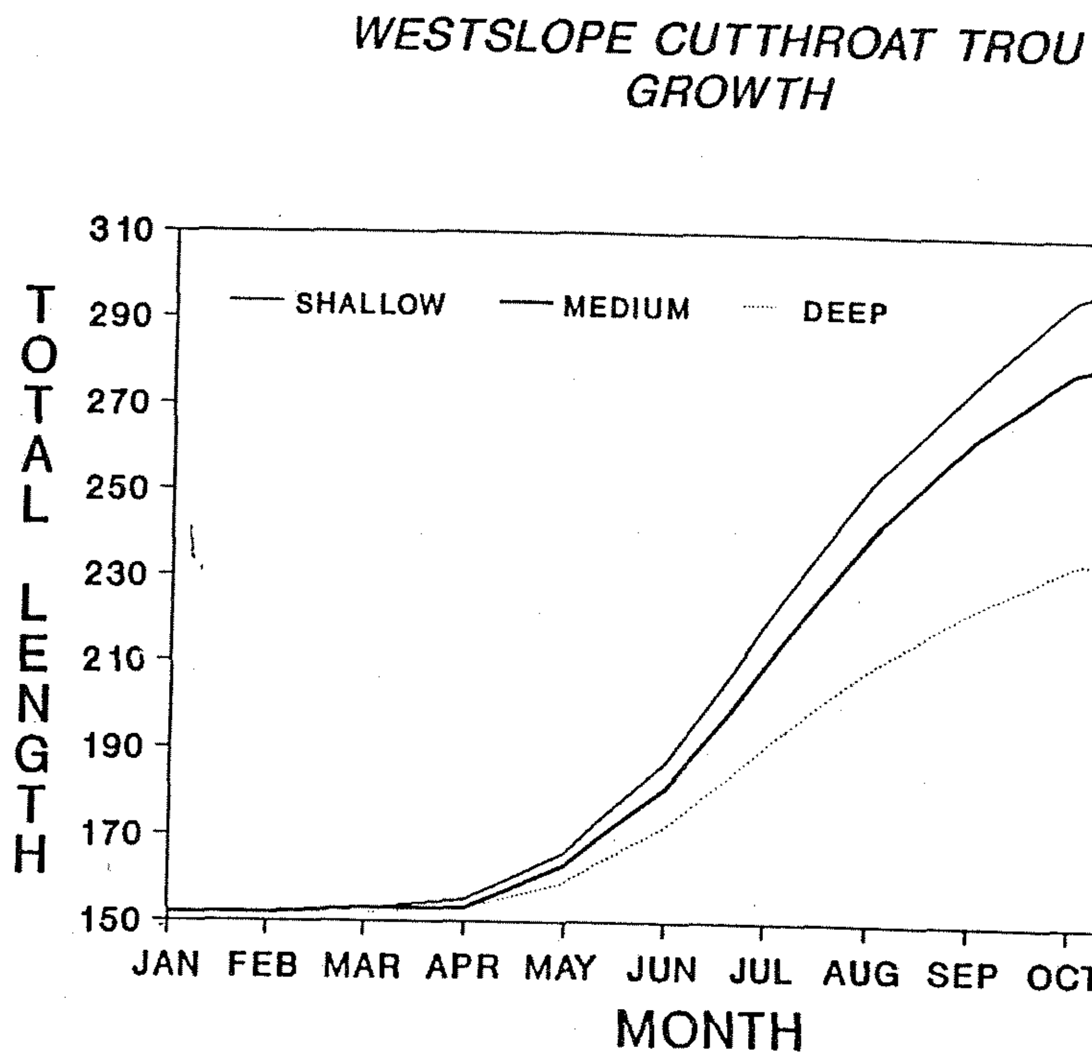

Figure 16. Comparison of cutthroat trout growth (mm) during their first year in the
under three operation scenarios.

Mitigation Objectives

We converted net losses and ongoing impacts attributable to Hungry Horse Dam directly into mitigation objectives:

Non-operational

Not requiring changes in operations:

1. Replace lost annual production (minimum of 65,000 westslope cutthroat annually) from the inundated 43 miles of tributaries and 35 miles of South Fork Flathead River using a mix of hatchery production, habitat improvement, and improvements in fish passage.

2. Replace lost annual production of 250,000 young bull trout in the lost stream sections using a mix of the above fisheries techniques.

3. Replace lost annual production of 100,000 kokanee adults initially through hatchery production and pen rearing in Flathead Lake; partially replace lost forage for lake trout in Flathead Lake.

We will attempt to meet these objectives by replacing production with a mix of species determined through adaptive management.

Operational

Changes in operation required:

1. Maintain a minimum flow in the Flathead River below the South Fork (3,500 cfs) similar to the average minimum flow before dam construction; maintain a reasonable minimum flow ($\approx$700 cfs) in the South Fork Flathead River;

2. Return the water temperature regime to near natural levels in the South Fork of the Flathead River below Hungry Horse Dam and in the main stem Flathead River below the junction of the South Fork;

3. Moderate high discharges of water into the South Fork and main stem Flathead River to the fullest extent practicable;

4. Manage Hungry Horse Reservoir levels to protect reservoir ecology and resident fish populations.

Non-operational Alternatives

Non-operational remedies are designed to mitigate for losses due to construction of Hungry Horse Dam and for the effects of operation on kokanee. A mix of techniques are required to reach the stated mitigation objectives.

Fisheries Habitat Enhancement and Stabilization

Stream, reservoir, or lake habitat could be improved by adding fish cover, removing silt, fencing stream banks, adding spawning gravel, and other means. Benefits can be measured in terms of acres of habitat improved. We estimate that costs for lake, reservoir, and stream habitat work would average $7,000/acre. Pilot mitigation work on Mill Creek cost $5,315/acre for materials and contracted construction, and $1,650 in FWP labor costs. We assume that habitat improvement cost on the reservoir would be similar.

MDFWP is testing habitat structures, called tree bundles, in Hungry Horse Reservoir. These structures provide substrate for benthic insect production and cover for juvenile and adult fish. Living dikes (see Appendix Report) would impound water in the drawdown zone for benthic production and recolonization. These structures should be tested for biological and cost-effectiveness.

Many potential stream sites exist for habitat improvement work: the North Fork, Middle Fork Flathead drainages, the Swan River system, the Stillwater/Whitefish River system, and various spring creeks around the valley. Improvements in these areas would directly benefit the fishery in Flathead Lake and Flathead River. Improvements in tributaries to Hungry Horse Reservoir would benefit that fishery. Habitat in shoreline areas of Hungry Horse Reservoir represent a large potential area for habitat improvement. Most habitat improvement opportunities are best suited for westslope cutthroat trout.

River channel habitat in the Flathead River below the South Fork junction has been altered by flow fluctuations from Hungry Horse Dam. Some of these channel areas could be stabilized using state-of-the-art engineering techniques (Appendix Report).

Advantages

Fisheries habitat improvement carries important advantages as a mitigation alternative. Fish are produced through natural reproduction once a spawning run is established into the area. Therefore, the young fish produced from spawning adults approximate the original fish lost. The project life is relatively long and maintenance costs are relatively low.

Disadvantages

A relatively large cost is associated with improving each acre of habitat. Results are slow in coming; spawning runs require time to become established. Supplementation with hatchery fish is usually required to establish spawning runs. A long time period of production is required to achieve a favorable benefit/cost ratio.

Benefit/Cost Analysis

The Mill Creek project provides an example of the cost of stream habitat improvement projects. Some of the work on this project was completed with volunteer labor, so actual contracted costs could be higher. Yet, the project represents a good example of cost if such economizing measures are used.

The three-mile section of stream improved for $100,995 (includes FWP labor costs) represented 14.5 acres of aquatic habitat ($7,000/acre). Assuming 100 migrant fish to the Flathead system could be produced annually from each acre (this is based on other basin tributaries), and a 30-year low maintenance ($500/year) effective life, the project would produce $319,772 of benefit over the period for the $115,995 invested. This translates to a 2.76:1 benefit/cost ratio. The benefits were discounted to 1990 dollars using a real discount rate of three percent.

Fish Passage Improvements

Fish passage could be restored in many tributaries to Hungry Horse Reservoir and in tributaries around the basin where culverts have blocked fish migrations. Fish passage can be restored by replacing unpassable culverts with new culverts, open-bottom arch culverts or bridges. Also, structures have been designed which would allow fish passage through culverts (Clancy and Reichmuth, 1990). However, these structures will operate only in culverts of moderate or low gradient.

Some streams have natural barriers to fish migration. These barriers could be removed, or modified to allow fish passage and make available additional spawning and rearing area.

Advantages

Many areas are not presently producing significant numbers of fishes of concern (bull trout and cutthroat trout) simply because spawning fish cannot access the habitat. This mitigation alternative would offset some of the spawning and rearing habitat lost when Hungry Horse Dam was constructed. In most areas, habitat improvement would not be necessary.

Disadvantages

Most opportunities exist in tributaries around Hungry Horse Reservoir. Thus, fish will not be replaced in Flathead Lake. Replacement of culverts may, in some cases, be extremely expensive. For example, the U.S. Forest Service (USFS) estimates that replacing the Felix/McInernie Creek culverts on the east side of Hungry Horse Reservoir would cost over $750,000 (this includes the cost of re-routing a portion of the existing road). Supplementation with hatchery fish may be required to re-establish spawning runs. Passage improvement structures, rather than full replacement, may be much more cost effective. If full replacement of the Felix-McInernie culvert is chosen, we will cooperate with the USFS in planning, but will ask that agency to fund the replacement.

Benefit/Cost Analysis

Because of flood frequency, corrosion, and rust, we assumed a 25-year effective culvert life with no maintenance (Glenn Weeks, U.S. Forest Service engineer, pers. comm.). Replacing the Felix and McInernie creek culverts would reopen 363 square meters of high quality spawning habitat and many thousands of square meters of rearing habitat. We estimate that the streams could produce 16,800 two-year old migrant westslope cutthroat annually if fully seeded (420,000 fish over a 25-year period), based on the following assumptions:

1. 1,000 eggs/female;

2. 5.4:1 female/male ratio (May and Fraley, 1986); and

3. Survival rates of .35, .40, .40 for egg to fry, one- and two-year fish, respectively.

Based on assumptions described in the methods section and discounting the annual payments using a three percent discount rate, yields a total economic value of 3,291,084 in 1990 dollars. This translates into a 4.4:1 benefit/cost ratio. Benefit cost ratios would be even greater if passage structures could be used at certain projects, or if projects were conducted in the Flathead River system where angler day values are higher.

We estimate that fish passage could be restored in a small stream (for example North Logan Creek) for $20,000, including all planning, materials, and labor costs. Based on the assumptions mentioned above, North Logan Creek could produce about 16,000 two-year-old migrant cutthroat over a 25-year period. Using the assumptions and real discount rate from the previous paragraph yields a present value (1990 dollars) of $71,045. The benefit/cost ratio is 3.5:1 for this project.

Hatchery Fish Production and Fish Planting

We believe that a significant level of hatchery fish planting in the Flathead system is required to replace production from the large acreages of spawning and rearing habitat lost when Hungry Horse Dam blocked the South Fork Flathead River. Bull trout, in particular, are very selective in their choice of spawning habitat (Fraley and Shepard, 1989). Only a small percentage of the habitat available in the North and Middle forks is suitable for bull trout (ie. only a small percentage fits their selective requirements). They require upwelling areas in clean unembedded streambed gravels. Tributaries of the South Fork Flathead River contained some of the highest quality spawning and rearing habitat available to bull trout in Flathead Lake. Some anecdotal reports indicate that the bull trout spawning run in the South Fork once exceeded the run in the North and Middle forks combined. Habitat in the South Fork cannot be replaced because of limited opportunities in the area presently available.

Existing hatcheries could be upgraded and modernized, or new hatcheries could be built, to produce the necessary fish for the mitigation effort. Improved hatchery space could be used to produce higher quality fish to meet recovery plan objectives. Additional raceways could be used to develop a Flathead Lake brood stock or other individual genetic strains from throughout the Flathead basin. These fish could be used for imprint planting in streams to start new runs of bull trout, cutthroat, or other species. Also, fish could be held longer in the hatchery or in net pens in Flathead Lake or Hungry Horse Reservoir and released directly into the lake environments.

Under present conditions, hatchery fish planting in Flathead Lake will be required to replace losses of kokanee due to operations of Hungry Horse Dam. These fish would be raised to a 2-inch size; a proportion would be reared in net pens in Flathead Lake. Fish of this size released later in the spring have been found to survive better in Lake Pend Oreille, Idaho (Hoelscher et al., 1990).

The mix of fish species and relative numbers of each species produced would be adjusted through evaluation/monitoring and feedback. Flexibility will be required for this effort to be successful.

Advantages

Planting of hatchery fish can provide more immediate benefits than other mitigation alternatives. Size of fish introduced can be controlled and adjusted for maximum survival. Hatchery production allows replacement of lost fish when not enough opportunity is available to replace them by natural means as we feel is the case in the Flathead system. Development of genetically distinct brood stocks could be used to aid native species recovery programs and maintain genetic diversity. Some hatchery fish may reproduce and contribute to natural spawning runs.

Disadvantages

Hatchery fish are considered less viable and do not survive as well as wild fish. Also, planting of large numbers of hatchery fish can be detrimental to wild populations of the same species for several reasons. First, hatchery fish compete for living space. Second, hatchery fish can interbreed with wild fish and weaken genetic stocks. Third, presence of an intense fishery for hatchery fish can cause overharvest of the smaller number of wild fish. Hatchery fish are produced each year and may not provide continued annual return for each initial investment. We assume that spawning and rearing habitat limit populations of bull trout and westslope cutthroat in Flathead Lake. If this assumption is wrong, hatchery supplementation would not be required assuming major operational changes were implemented.

Benefit/Cost Analysis

We estimate minimum costs for raising fish at existing, upgraded hatcheries at \$2.00/pound. We assumed a discounted operation and maintenance budget of \$3,454,000 over 30 years and capital costs for hatchery refurbishing of \$4,750,000. Under stated assumptions, hatchery fish production would yield a net economic benefit of \$1,012,500 per year. This transfers into a 2.4:1 benefit/cost ratio.

Off-site Mitigation

Off-site mitigation includes the three mitigation techniques described above, conducted in areas outside the interconnected Flathead Lake and River system. Off-site mitigation may not mitigate for target species, and ranks lowest in priority. Off-site mitigation offers an advantage if sites exist locally where a small investment would yield good returns. A successful off-site fishery may concentrate anglers, thus relieving fishing pressure in areas where we are attempting to restore naturally sustainable fisheries. The disadvantage is that fish losses are not replaced in the affected area. Also, angler day values are lower off-site than in Flathead Lake or River. Cost/benefit analyses would be the same as described under the three non-operational mitigation alternatives.

Operational Alternatives

Operational remedies are designed to correct ongoing habitat problems associated with dam operations in the Flathead River and Lake system and in Hungry Horse Reservoir. Our reservoir model represents an important tool in analyzing these measures. The model should prove valuable for continually improving recommendations.

Downstream Temperature Improvement Using Selective Withdrawal

A multi-level outlet system was proposed for further study in 1976 by the Pacific Northwest River Basin Commission to improve the temperature regime in the South Fork and main stem Flathead River for trout production. Presently, Hungry Horse Dam is fitted with a single outlet located 75 m below the dam crest. Water discharged from this depth remains about 4° C (40° F) during all months of the year. Installation of a selective withdrawal structure on Hungry Horse Dam would allow managers to withdraw warmer water from different depths of the reservoir during the May through October period. Thus, the temperature regime could be returned to natural in the South Fork Flathead River and main stem Flathead River below the junction of the South Fork.

Fraley and Graham (1982) estimated that addition of a selective withdrawal system could increase trout growth in the South Fork Flathead River by a factor of ten. Growth in the main stem Flathead River could be almost doubled.

The following analysis was designed to address whether Flathead River temperatures could be moderated without the addition of a selective withdrawal mechanism if the reservoir was maintained at full pool from July 1 through September 30. A comparison of the actual 1982 operation schedule to a modified schedule allowing an early fall draft (Figure 6) revealed that trout growth units could be increased from 359.4 to 585.5, an increase of 37 percent (Figure 17). The analysis was repeated with and without simulated selective withdrawal. Trout growth units improved dramatically with selective withdrawal even when the reservoir remained full July 1 through September 30, from 585.5 to 1,359.6, or 2.3 times more trout growth potential (Figure 18). Allowing for early fall draft, selective withdrawal, would improve trout growth from 369.4 units to 1,353.62, units an increase of 3.7 times.

Biological conditions in Hungry Horse Reservoir would be impacted somewhat by selective withdrawal. Loss of phytoplankton and zooplankton would increase substantially as warm water containing the organisms is released downstream (Table 4). Temperature degree days within the reservoir would also be reduced, limiting food production and volume of optimal water temperatures. Based on model simulations, cutthroat trout growth during 1982 would have been reduced by 4 mm had selective withdrawal been implemented.

Advantages

Selective withdrawal would return the South Fork and main stem Flathead River to natural temperatures from May through October. Improved temperatures would greatly enhance fish growth. Near-natural temperatures in the Flathead River would aid natural timing of fish spawning migrations from Flathead Lake. Also, these temperatures would be more conducive to the natural timing of insect life cycle events and natural insect community structure.

Angling would improve through higher catch rates and larger fish. Free nutrient levels might actually decline in the river because of the shallower withdrawal depth; suspended organic

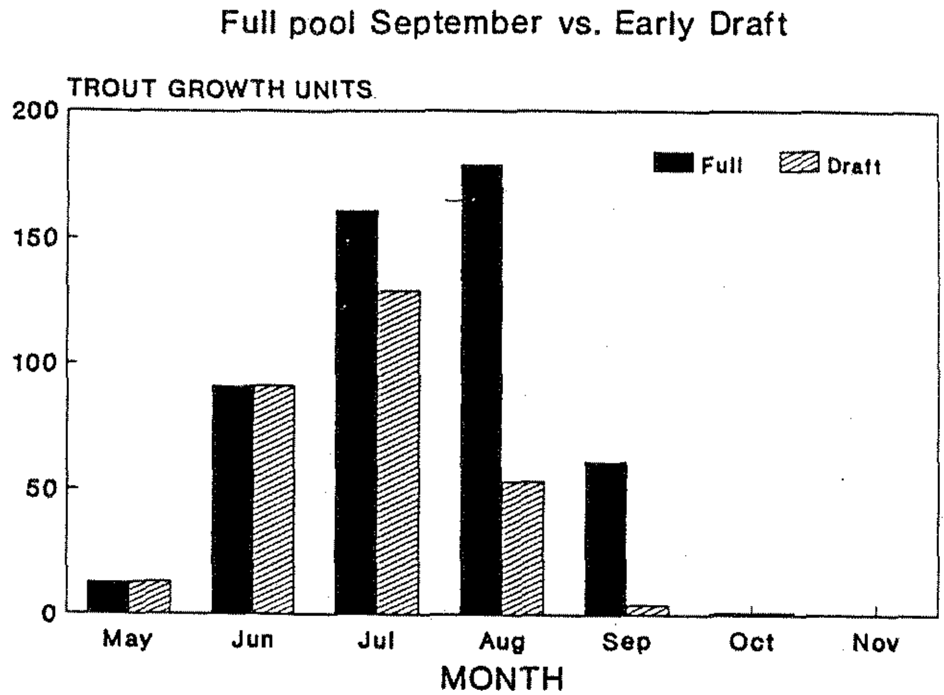

Figure 17. Trout growth units in the Flathead River at full pool July 1 through September 30, as compared to early fall drafting.

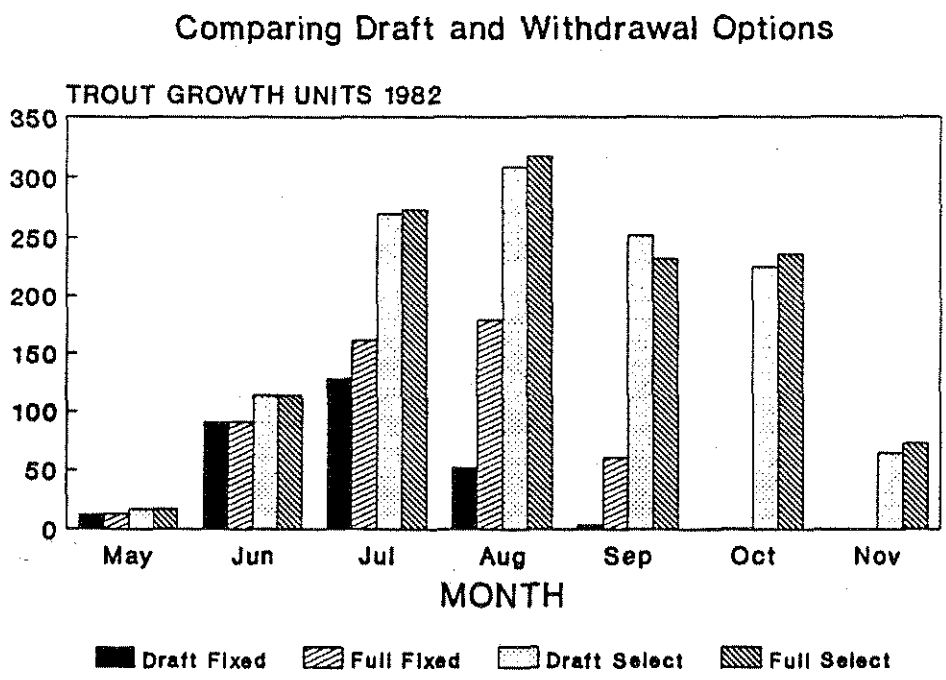

Figure 18. A comparison of trout growth units in the Flathead River, with and without selective withdrawal, at full pool July 1 through September 30, or allowing early drafting July 15 through September 30.

Table 4. Biological effects in Hungry Horse Reservoir as related to selective withdrawal and early fall drafting[a].

	Operational Alternative			
	Full-Select	Full-Fixed	Draft-Select[b]	Draft-Fixed
Primary Production (metric tons)	4,379	4,423	4,256	4,319
Phytoplankton Loss (metric tons)	46	0	63	0
Daphnia Production (metric tons)	292	294.9	274.8	278.7
Daphnia Loss (metric tons)	118.9	13.9	178.7	16.31
Hymenoptera Input Percent of Maximum (metric tons)	100	100	91.9	91.9
Benthic Production (metric tons)	157.3	170.3	157.7	183.7
Fish Growth				
Cutthroat trout length at end of first season (mm)	299	303	294	302

[a] 1982 water year

[b] 1982 water year modified to allow early draft

carbon would probably increase (Dr. L. Bahls, Montana Water Quality Bureau; Dr. J. Stanford, UM Biological Station, pers. comm.). Selective withdrawal may not require any changes in operations that would affect power production. Stanford (1990) hypothesized that cold discharges of water into Flathead Lake during the summer disrupts natural production of plankton in the upper water layers of the lake. Thus, more natural temperatures in the Flathead River could also benefit Flathead Lake.

Disadvantages

Selective withdrawal would slightly decrease productivity in the reservoir because of the loss of warmer temperature layers. This would further limit *Daphnia* production, an important food supply for trout, due to increased downstream loss and lower food availability (Figure 19). Reduced phytoplankton production and temperature degree days in the reservoir would also result in a slight reduction of benthic production (Figure 20). Further refinement of the withdrawal depth schedule would offset some of the losses in reservoir productivity. We plan to optimize the withdrawal depth selection procedure in the model to improve the balance between downstream temperatures and reservoir biology.

Temperatures in Flathead Lake may increase, but probably only slightly. The South Fork comprises only about one-third of the total inflow to Flathead Lake. Also, most warming takes place in the lake itself through atmospheric and solar sources. Thus, selective withdrawal probably would not increase algae production in the lake significantly.

Benefit/Cost Analysis

We made the following assumptions to calculate a benefit/cost ratio for improving downstream water temperatures with selective withdrawal:

1. The Bureau of Reclamation could install selective withdrawal for $12,360,000; for the 30-year period, maintenance would cost $252,300, with a $150,000 refurbishment after 20 years (Dennis Christenson, USBOR, pers. comm.);

2. The net economic value of the 47-mile Flathead River fishery downstream is $850,000/year (Duffield et al., 1987);

3. Temperature improvements would increase trout growth potential from 2 to 5 times, this would at least double trout growth and angler success and increase fish survival;

4. The system would operate for 30 years without significant capital improvements; and

5. Present value (1990 dollars) of the benefits discounted at 3 percent for 30 years equals $16,660,000.

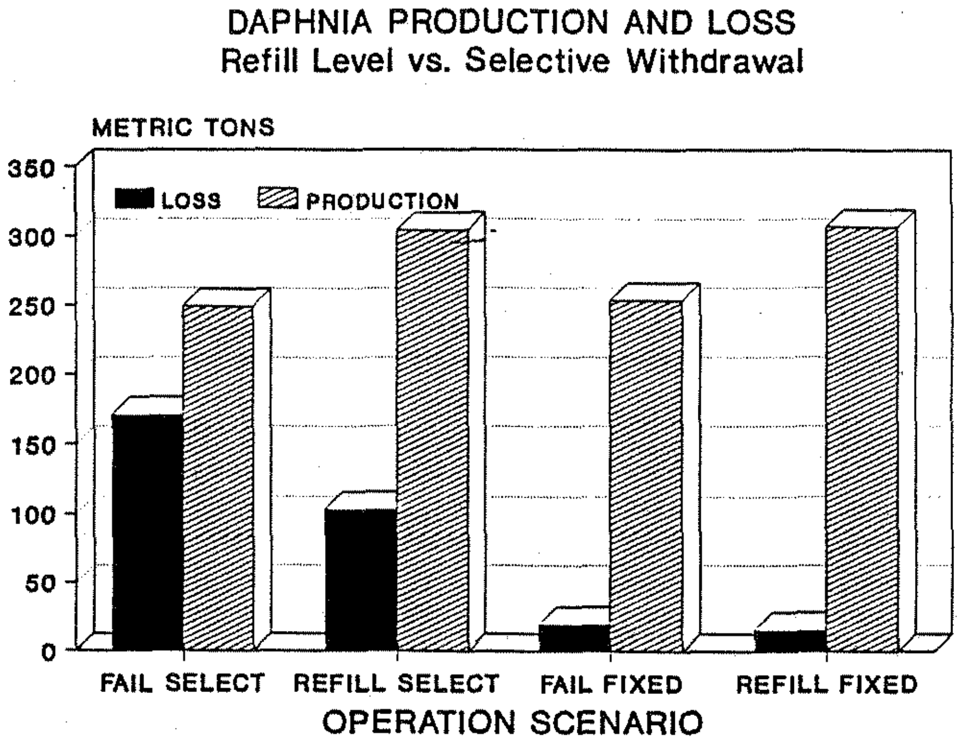

Figure 19. Comparison of Daphnia production and loss under four operational scenarios: (1) reservoir fails to refill and selective withdrawal is implemented; (2) reservoir refills with selective withdrawal; (3) refill failure with no selective withdrawal, and; (4) reservoir refills with no selective withdrawal.

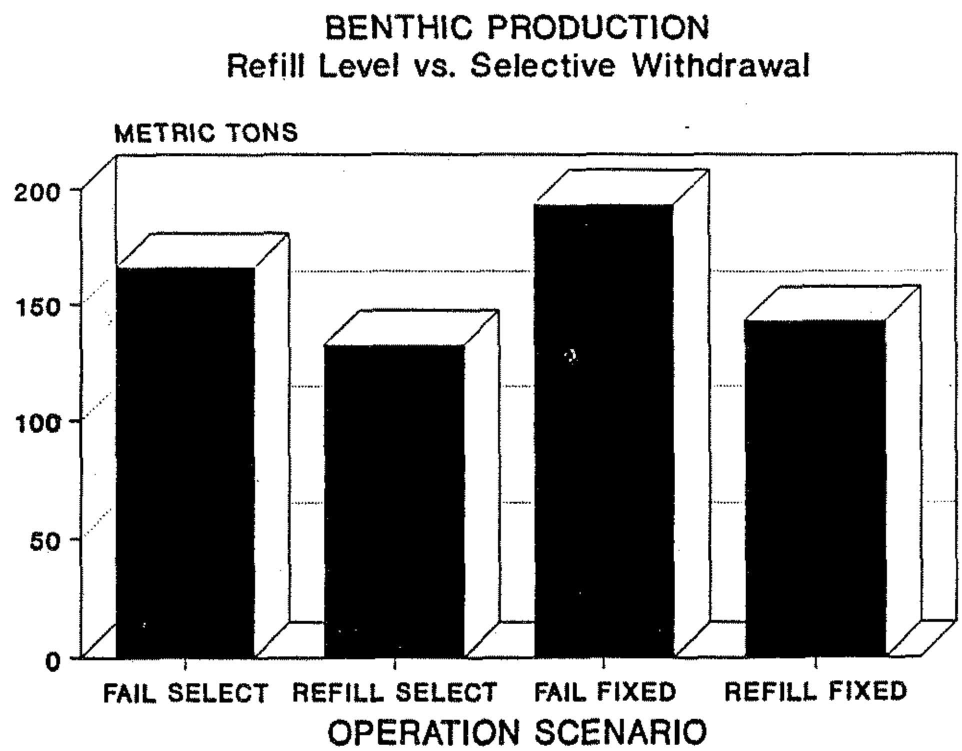

Figure 20. Comparison of benthic production under four operational scenarios: (1) reservoir fails to refill and selective withdrawal is implemented; (2) reservoir refills with selective withdrawal; (3) refill failure with no selective withdrawal, and; (4) reservoir refills with no selective withdrawal.

Under these assumptions, the benefit/cost ratio for this option is 1.3:1 (16,660,000/12,762,300). However, this does not take into account or assign a value to improvements in the aquatic insect communities or in general aquatic ecology values. Also, trout growth and angler success would probably benefit by more than a factor of two. Thus, we feel that this option carries a much higher (and admittedly difficult to quantify) benefit/cost ratio. Some power loss resulting from loss of approximately two feet of hydraulic head would occur. BPA and the USBOR have estimated a 0.2 megawatt loss resulting from a seasonal 1.5 foot loss of head if the system was installed.

Drawdown Limits and Timing of Reservoir Refill

As described under the losses and impacts section, deep drawdowns, late refill, and early drafting were found to reduce fish food production, fish growth, and increase predation of fish. Many potential scenarios exist for limiting drawdown and adjusting timing of refill and drafting. These scenarios can be calculated based on inflow forecast by the Department's reservoir biological/hydrological model. We describe the preferred scenario and biological rule curves in the section on recommended mitigation actions.

We compared biological production between the proposed BRC1 and the modified curve resulting from the worst water year on record 1942 inflows (Figure 5).

Volume and surface area were reduced during the peak growing season July through August, resulting in a net loss of 630 metric tons of carbon fixed by primary production. Because of the moderate drawdown (75 ft. msl) prior to the failure, benthic insects were unaffected in the substrate below elevation 3,485. Some recolonization occurred as surface elevation rose to the seasonal maximum, although benthic larval densities were inversely related to the frequency of dewatering and thus were limited by the previous drawdown. Thermal stratification during May through September created a warm sunlit band of water as much as 105 feet thick below current surface, enhancing benthic insect production within that range. Surface area of wetted substrate, and thus benthic production, is relatively constant from full pool down to elevation 3,495 (Figure 8). In the refill scenario, warm sunlit water influenced production in an area of reduced larval density, whereas the refill failure scenario caused warming in a nearly equivalent area of substrate of higher larval density. Therefore, benthic production was temporarily enhanced by failure to refill (Figure 20).

A deeper drawdown prior to refill failure, or a refill failure in which surface elevations remain below 3,495 would nullify the potential for a temporary gain in benthic production and result in a net loss of benthic insects.

Reduced elevations and reservoir surface area resulted in a net loss of 10 to 18 percent of trout food availability during fall (Figure 21). Hymenoptera, the most important food item in trout stomach contents, was reduced 18 percent, significantly limiting trout food availability during the period of peak trout growth potential.

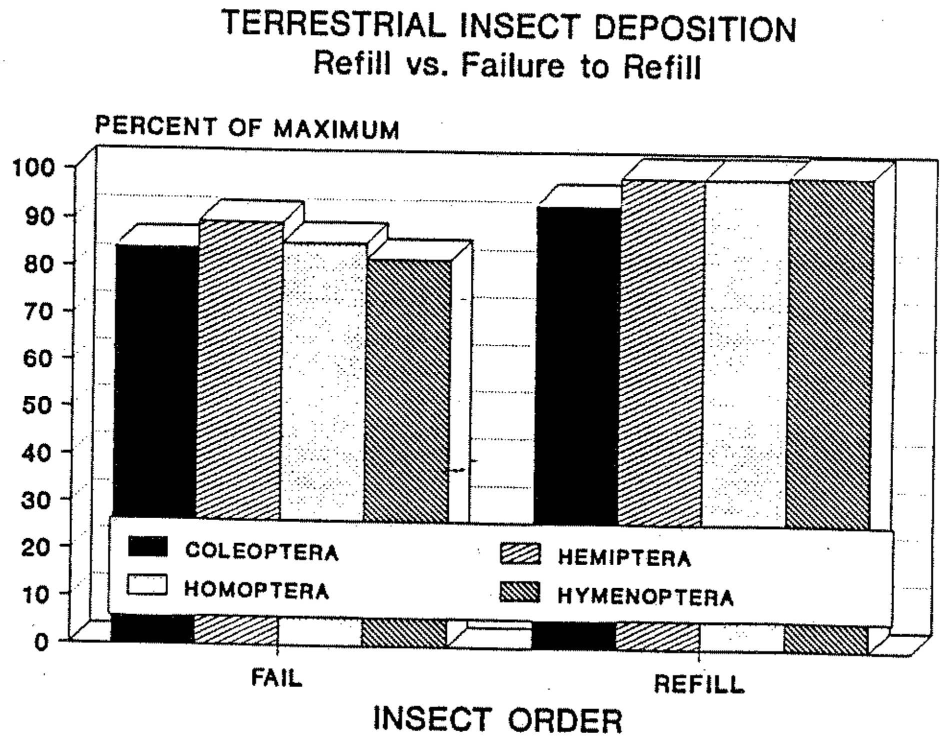

Figure 21. Deposition of the four orders of terrestrial insects as affected by reservoir refill failure at Hungry Horse Reservoir.

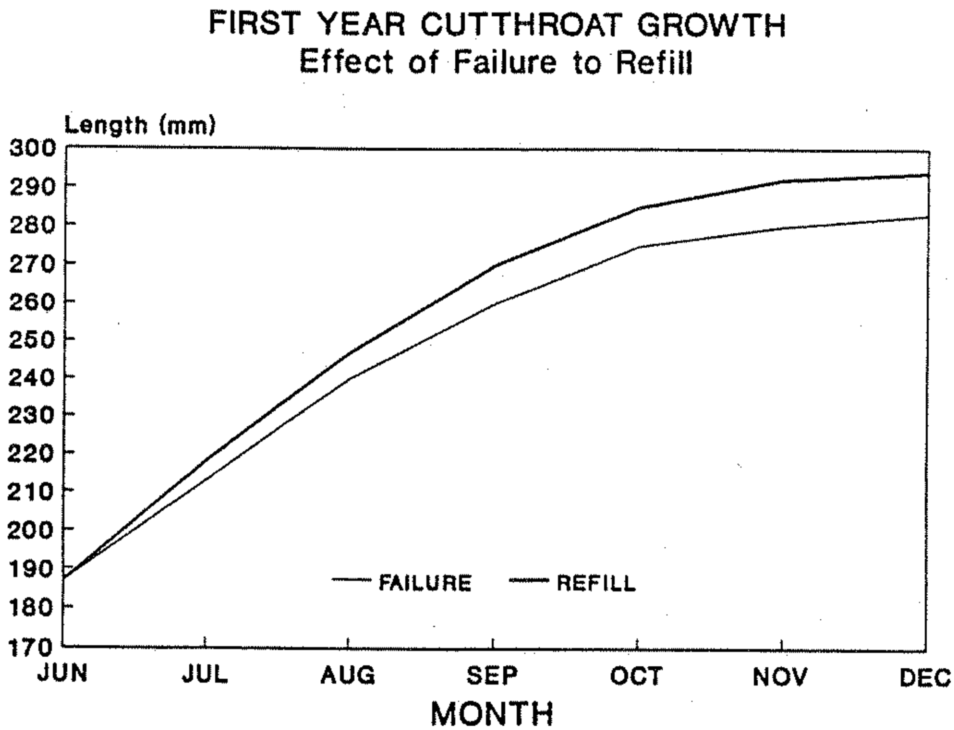

Figure 22. Effect of failure to refill the reservoir on migrant class III cutthroat trout growth during their first season in the reservoir.

Failure to refill reduced cutthroat growth by 11 mm during their first season in the reservoir (Figure 22). This reduction is significant when considered over the three-year period that the fish reside in the reservoir. The reduction in growth potential correlated with decreased volume of optimal water temperatures and a reduction in terrestrial insect availability. Increased aquatic insect production did not offset losses in terrestrial food input.

Assessing Tradeoffs Between Biological Production and Hydroelectric Generation

In the 42-month analysis of the interim drawdown limit of 85 feet, the HYDRO6 model produced an estimated average reduction of 113.4 mw in system firm power production capability. The sliding scale strategy (BRC1-BRC4), allowing for consecutively greater drawdowns during a four-year critical period, reduced the average firm power loss to 76.6 mw, should the system enter a critical period. If the reservoir is allowed to draft to dead storage in the fourth critical year, costs would be 25 megawatts. We feel these analyses represent a worst case scenario and do not reflect power costs during non-critical water periods.

During the planning horizon of this particular analysis, firm power production capability was 186.8 mw in excess of regional load; thus, the 76.7 mw loss would not have required resource acquisition to meet existing power requirement. This bias, however will continue to reduce as the region approaches load/resource balance.

The majority of firm power loss caused by our recommendation was due to unused storage remaining in the reservoir at the end of the critical period. The probability of entering the fourth critical year is exceedingly low, however.

It may, therefore, be possible to adjust our curves downward to share the risk of entering the fourth critical year with power planners. BPA modelers have agreed to conduct a probability analysis to evaluate the relative possibility of entering the fourth year and requiring a draft toward dead storage. Upon receipt of their results, we will assess probabilities and evaluate losses to biological production and amend our curves accordingly.

The analyses completed thus far did not evaluate our first year curves which were designed to be variable depending on inflow forecasts, nor have analyses been conducted using BPA's Systems Analysis Model. These analyses must be completed to fully evaluate tradeoffs.

Advantages

Biological advantages of reservoir level control are significant. Improved fisheries in the reservoir translate into improved migratory fisheries into the upper South Fork in the Bob Marshall Wilderness Complex. Restricting drafting reduces volume and temperature changes (during certain periods) in the rivers downstream.

Disadvantages

This option carries the greatest cost to the power system. Bonneville Power Administration is currently analyzing firm power impacts during a critical period using the HYDRO6 model, and revenue impacts using the System Analysis Model.

Benefit/Cost Ratio

We are unable to calculate a benefit/cost ratio until the above analyses are completed by BPA.

Minimum Flows in the South Fork Flathead River and in the Flathead River at Columbia Falls

Measure 903(a)(1) of the 1987 Fish and Wildlife Program (Northwest Power Planning Council, 1987) calls for a 3,500 cfs minimum flow in the Flathead River below Hungry Horse Dam. This recommendation was made based on instream flow studies conducted by McMullin and Graham (1981), Fraley and Graham (1982), and MDFWP (1982). These studies showed an inflection point of approximately 3,500 cfs in the Flathead River. This means that wetted aquatic habitat decreases rapidly at flows below 3,500 cfs.

This flow is important during all months of the year. Most juvenile cutthroat and bull trout enter the main stem Flathead River from upstream areas in late July to October. This is a critical period when a stable minimum flow is highly desirable. Adult cutthroat utilize the Flathead River as a holding area and migration corridor from November through April (McMullin and Graham, 1981). Minimum flows are also important for aquatic invertebrate production (Perry and Graham, 1982).

The 3,500 cfs minimum flow is met by natural (unregulated) flows in an average year from April through August and October through November. Hungry Horse Reservoir would have to provide an additional release (above natural inflows) of 500-700 cfs during September, December, and March and an additional 1,000 cfs during January and February. Flows provided by Hungry Horse would result in a four percent increase in wetted area in September, December, and March, and a nine percent increase in wetted area during January and February above natural flows in an average year.

A minimum flow in the South Fork Flathead River, if coupled with selective withdrawal, could establish a viable 5-mile long tailwater fishery. Instream flow studies in the South Fork above Hungry Horse Reservoir establish an inflection point of 700 cfs. This could be applied as a minimum flow for the South Fork below the dam.

Advantages

The biological advantages of a stable minimum flow are many. Selective withdrawal would add to the benefits by combining better temperatures with the released water. The Bureau of Reclamation has calculated that maintaining the 3,500 cfs minimum flow has very little effect on power production. This flow has been in place since 1982.

Disadvantages

The 3,500 cfs requirement has a slight impact on power production. With a fixed withdrawal depth, a release of water during low flow periods to meet the requirement causes significant drops in water temperature in the Flathead River.

If a minimum flow of 700 cfs were implemented in the South Fork, Hungry Horse Reservoir refill ability would be affected. Annual inflows of less than 80 percent of normal would cause refill failure if present UBRC's were followed. Timing of refill would be delayed under higher inflow conditions. During less than average inflow years, reduced outflows required to refill the reservoir to the maximum extent could reduce flows in the main stem Flathead River to below 3,500 cfs at Columbia Falls. Tradeoffs between reservoir and river levels would be necessary during low inflow years.

Control of High Discharges into the Flathead River

Large, rapid fluctuations in discharges from Hungry Horse Dam into the South Fork and main stem Flathead River greatly affect water temperature and stream habitat. These temperature and volume changes strand fish and aquatic invertebrates, alter migration of certain fish species, reduce fish growth, and cause catastrophic drift of aquatic organisms from the substrate (Graham et al., 1980; McMullin and Graham, 1981; Fraley and Graham, 1982; Perry and Graham, 1981 and 1982; see discussion in Stanford, 1990). Rapid volume fluctuations also dewatered spawning beds of kokanee and mountain whitefish (McMullin and Graham, 1981; Fraley and Graham, 1982; Fraley et al., 1986).

Obviously, a return to a natural flow regime with spring freshest and summer/fall low water periods would be best for the health of the aquatic system. But, this option may not be practicable based on economics and operations of the power system. Limited changes in operations could achieve some biological gains. Options to achieve reductions in river fluctuations include ramping (restricting the rate of increase or decrease) or construction of a re-regulating dam and reservoir (U.S. BOR, 1986).

Graham et al. (1980) evaluated various scenarios under a re-regulating dam option and reported significant biological gains in the downstream river reach. We assessed the effectiveness of the proposed re-regulating dam (BOR, 1986) in smoothing flow fluctuations caused by peaking operations at Hungry Horse Dam. The proposed re-regulating dam has a usable storage of 3,263.5 acre feet. The pool elevation ranges from 3,030 to 3,083 msl. Pool length was reported to be 3.3 miles. The analysis assumes that the power house rewrap and unit uprate to 107 mw capacity are complete. Maximum turbine discharge was based on the 1954 Hungry Horse Unit 3 Gibson Test.

Four typical peaking scenarios, suggested by BPA and BOR power personnel, are shown in Figure 23. Between peaking discharges, flows decrease to the absolute physical minimum discharge (145 cfs) during hours of reduced energy demand. Although a multitude of peaking options exist, these examples provide insight into the potential of the proposed re-regulating dam to dampen flow fluctuations. The size of the basin and shape of the peaking operation influence the re-regulating basin's ability to moderate flow fluctuations. Water must be stored to reduce peak flows and released to augment flows during low discharge periods. Insufficient storage at either extreme will result in flow fluctuation.

Results indicate that the capacity of the proposed basin is large enough to smooth some peaking operations on a daily basis and that fluctuations can be moderated by ramping from one day to the next when operations change (Table 5). A constant outflow can be achieved by re-regulating scenarios 1, 3, and 4. However, capacity is insufficient to achieve a constant flow for 24 hours under peaking scenario 2. For example, assuming the re-regulating pool begins full at 11 p.m., a constant discharge of 5,786.2 cfs could be maintained from 11 p.m. through 6 a.m., by gradually emptying the re-reg. The re-reg would then be ready to store water when the peaking operation begins. Upon peaking, constant discharge must be increased to 9,870.7 cfs to avoid overfilling the re-reg, causing a discharge fluctuation. Selective withdrawal would eliminate negative thermal impacts, but flow fluctuations would continue to harm the riverine biota. Peaking without thermal control and re-regulation would cause harmful flow and temperature fluctuations.

Advantages

The potential is great for biological gains in the Flathead River downstream if a re-regulating dam was built. A re-regulating reservoir would increase power revenues (US BOR, 1986) and moderate flows in the South Fork Flathead River and main stem. Ramping would not achieve the full objective of moderating flows, but could reduce stranding of aquatic insects and fish. Restricting discharges during the summer and early fall months would partly achieve biological goals.

Disadvantages

A re-regulating dam would be expensive. Ecological impacts in the project area would be significant. The re-regulation pool could fluctuate from full pool to dead storage in a single day; these fluctuations would preclude establishment of any fishery and would produce an unsightly rereg basin. Three and one half miles of free flowing river would be inundated. Ramping would still be required to moderate fluctuations from one day to the next if the discharge schedule changed.

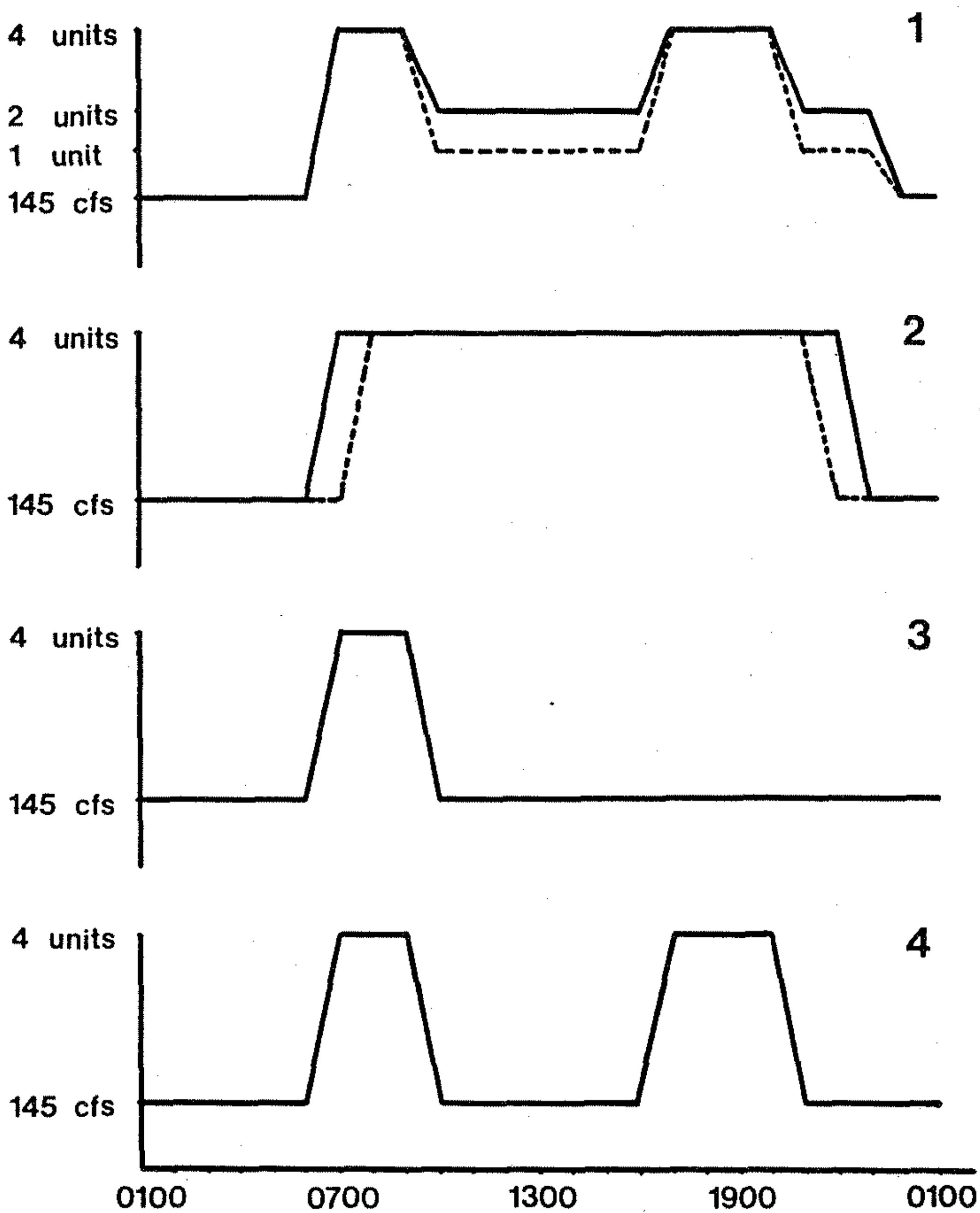

Figure 23. Typical 24-hour patterns of hydroelectric peaking operation. Peaking scenarios are identified in the text as 1 through 4, from the top down. The number of units corresponds with the number of turbines in use. Analysis assumes maximum turbine capacity (3,125.8 cfs per unit).

Table 5. Ability of the proposed re-regulating dam to moderate downstream fluctuations during a 24-hour period under differing peaking operations. Assumes maximum turbine capacity = 3,125.8 cfs per unit.

	Re-regulated Discharge (cfs)		
Peaking Scenario	Minimum	Maximum	Maximum Flow Fluctuation Below Re-regulating Dam
1a	4,991.5	4,991.5	0
1b	6,329.4	6,329.4	0
2a	5,786.2	9,870.7	4,084.5
2b	4,532.6	9,465.7	4,933.1
3	1,686.8	1,686.8	0
4	3,743.5	3,743.5	0

Benefit/Cost Ratios

The Bureau of Reclamation is presently re-evaluating the economics of constructing a re-regulating dam and reservoir which would extend 3.5 miles below Hungry Horse Dam. Bonneville Power Administration is calculating losses in firm power caused by holding reservoir levels at full pool from July through September, which would reduce discharges downstream. Until these analyses are completed, we are unable to calculate benefit/cost ratios. Benefits in the river system would have to be weighed against the impacts in the project area.

RECOMMENDED MITIGATION MEASURES

We consider the following recommended measures a conservative program designed to incrementally replace a practicable portion of identified losses. We designed these recommendations to complement actions under the Kerr Dam Mitigation Plan. Our approach recognizes uncertainty and is firmly based on principles of adaptive management (Hollings, 1980; Lee and Lawrence, 1986; Walters, 1986). We intend to prepare a detailed implementation plan addressing these measures after action by the NPPC.

Several factors will limit full mitigation of hydropower impacts. The spawning and rearing habitat lost to Flathead Lake, when Hungry Horse Dam blocked the South Fork, can not be replaced fully in quantity and quality. Flows in the Flathead River will not be returned to pre-dam conditions because of the operation of the power system and flood control constraints. Indeed, impacts have continued in areas upstream and downstream of the dam since 1951 until present with no mitigation.

At the level of spending estimated here a very long time will be required to reach the mitigation goals stated earlier. Scientists and citizens have pointed out that these mitigation actions will have the best chances of success if coupled with an aggressive program of predator control (eg. remove angling limits on small lake trout). The conservative approach we've followed should replace a practicable portion of what we consider the net losses attributable to the dam in the long term. Walters (1986) contends that resource managers must learn to live with substantial uncertainties. He further states that many key management decisions are in fact gambles or experiments. We recognize the uncertainty of the management actions recommended here. But, we feel these actions, coupled with a careful evaluation/monitoring program, will lead to success in the long term.

Our approach is generally consistent with the co-management plan agreed to by the Department and Tribes. The major departure is that we focus more on hatchery culture of kokanee and less on hatchery culture of native species. We take this approach based on input received since the approval of the management plan. The approach has several advantages for the native stocks. First, recreational fisheries focused on non-native species removes pressure from native species. Also, large plants of native fish directly into Flathead Lake (as outlined in the management plan) could harm the wild stocks through genetic changes, disease, or competition.

Non-operational Mitigation Actions

These recommended non-operational mitigation actions are based on our current knowledge and state of the biological system, and currently accepted fisheries techniques. These factors could change. The food web in Flathead Lake is fluctuating; mitigation technology will continue to evolve. Techniques in place 20 years from now may be completely different than these proposed here. Therefore, this plan must be considered flexible and based on adaptive management. Funding could be moved between categories of non-operational mitigation based on relative success of each technique. Costs should be considered working estimates. We plan to work with BPA to accomplish the work for the least possible cost.

These factors underscore the importance of continued cooperation and flexibility among the implementors of fisheries mitigation in the basin (ie. the MDFWP, CSKT, USFWS), and a broad group of advisors from the public sector. These recommended actions represent an initial blueprint; they do not represent an implementation plan. Because of the uncertainties described above, a long-term, peer reviewed implementation plan would be impracticable until the NPPC takes action on this plan and provides further direction.

We estimate, based on habitat affected and fish production per acre, that these non-operational measures will mitigate not more than 50 percent of the net fisheries losses and impacts attributable to Hungry Horse Dam (ie. non operational mitigation accounts mainly for losses caused by dam construction). This limitation is based on the level of opportunity available for mitigation sites in the basin, biological limitations of enhancement techniques, and continued impacts from dam operations. Operational mitigation actions would mitigate the remaining 50 percent of impacts (ie. from ongoing dam operations).

Aquatic Habitat Improvement and Stabilization

We recommend the allocation of an estimated $220,000 annually for the mitigation period for aquatic habitat improvement. With these funds, we will be able to improve the equivalent of 31 acres of habitat annually. Assuming an average structure life of 30 years, this ongoing investment would partly offset the loss of spawning and rearing grounds caused by the construction of Hungry Horse Dam. This level of work could be reasonably accomplished through an aggressive program with some volunteer labor and volunteer planning (see cost-effectiveness discussion earlier in this report). The equivalent value of $220,000 in 1990 dollars must be maintained to produce lasting results.

Potential sites for stream habitat improvement work exist through the basin (Table 6). Initially, we recommend focusing on East Spring Creek, by entering into a cooperative program with the Flathead Conservation District. Other sections of Mill Creek are available for improvement. Paladin Spring Creek (see Appendix Report) represents an excellent candidate for stream habitat improvement and imprint planting. The Rose Creek site, owned by MDFWP, could potentially be improved and established as a spawning return stream and egg-taking station for cutthroat or bull trout.

Table 6. Some potential sites for stream habitat improvement in the Flathead Valley.

Stream	Approximate Low Flow (cfs)	Miles of Stream Available for Improvement	Potential
East Spring Creek	10 cfs (plus 10 cfs additional diverted from the River	8	Moderate
Paladin Spring Creek	12	1.5	High
Rose Creek	3 cfs	2	Moderate
Whitefish River	≈ 100	18	Moderate
Stillwater River	≈ 120	16	Moderate
Siderius Spring Creek	30	1.5	Moderate
Brenneman's Slough	15	2.5	Low-Moderate
Garnier Creek	5	10	Low-Moderate

The Whitefish/Stillwater River complex offers an opportunity for stream habitat improvement work targeted at westslope cutthroat in a large system. We recommend work in this drainage after techniques have been tested and experience gained on the aforementioned smaller systems. Examples of structures and techniques now being used in stream habitat improvement are found in the Appendix Report. Part of our efforts during the initial years of the mitigation period would focus on identifying the best sites available for habitat improvement.

Pilot habitat improvement work is underway in Hungry Horse Reservoir. Tree bundle structures will be tested in the spring of 1991. Other potential lake habitat improvement work could include living dikes, seeding of dewatered area for juvenile fish cover, other structures designed for fish cover, willow plantings, and other methods (see Appendix Report). Drawdown severely limits establishment of fish cover along the shoreline of Hungry Horse Reservoir. These techniques are practical ways to establish resting, holding, and feeding areas for fish and aquatic invertebrates.

Fish Passage Improvements

We recommend allocating an estimated $50,000 per year for fish passage improvement in the basin. This figure represents a reasonable level of improvement work that could be accomplished and evaluated annually. These dollars would be used to replace culverts or to install fish passage structures in existing culverts, or create fish passage over natural barriers. This work would help offset loss of spawning and rearing habitat caused by the construction of Hungry Horse Dam.

Many opportunities exist to improve fish passage in streams around Hungry Horse Reservoir which have been partly or completely blocked by relocation of the road above the reservoir pool, or by drawdown of the reservoir (Table 7). We would begin work immediately on identified priority sites. Natural barriers to fish migration could be removed or bypassed. Other potential sites for fish passage improvements exist around the basin (ie. tributaries in the Middle and North fork drainages).

The most cost-effective way to use these dollars would be to install and maintain passage structures wherever possible. This method should work in streams of low to moderate gradient. Even using complete replacement of culverts, this method is cost-effective. The value of $50,000 annually in 1990 dollars must be maintained to provided a viable, lasting program.

Hatchery Fish Production and Fish Planting

Hatchery fish are required to replace production from some of the lost or damaged spawning and rearing habitat caused by the construction and operation of Hungry Horse Dam. These fish will be used for imprint planting to establish new runs in specific stream areas or direct plants in lake environments designed to increase the fishery and pioneer general spawning runs. Our emphasis for native species will be to establish new spawning runs in restored stream habitats.

Table 7. Potential sites for fish passage improvement in tributaries to Hu

WEST SIDE

Priority[a]	Stream Name	Reach No.	Stream Order	Barrier location km from stream origin	Accessible[b] Y/N/P	Length above barrier (km)	Gradient (%)	Spawning gravel (m^2/km) (r=rearing potential)	Barrier Type	Remo modi rati 1. E 2. M 3. D
2	Doris	3	3	5.5	N	2.3	12.4	r	Waterfalls	
2/3	Lost Johnny	2	3	2.0	N	6.3	5.6	r	Bedrock Chutes	
2	Clayton	1	3	0.1	N	6.3	8.3	r	Boulder Falls	
2	Knieff	1	3	0.4	N	2.0	8.3	r	Culvert @ <3,535 Falls above culvert	
	Graves	1	3							
2	Wheeler	3	2	10.0	N	4.9	12.1	r	Waterfalls	
2	Quintonken	2	3	5.2	N	11.1	5.0	r	Waterfalls	

Continued on next page.

(Table 7 Continued)

EAST SIDE

Priority[a/]	Stream Name	Reach No.	Stream Order	Barrier Location km from Stream Origin	Accessible[b/] Y/N/P	Length Above Barrier (km)	Gradient (%)	Spawning Gravel (m^2/km)	Barrier Type	Removal or Modificatio Rating[c/]
								(r=rearing potential)		1. Easy 2. Moderate 3. Difficul
2/3	Riverside	2	3	1.3	P	3.2	9.8	r	Culvert	2
3	Murray	1	2	0.2	P	1.1	6.8	7.3	Gabion/ Culvert	1
3	McInernie	1	2	0.5	P	2.2	5.0	76.3	Culvert	1
2	Harris	1	2	0.3	P	1.8	8.2	35.6	Culvert	2
4	Felix	1	3	0.2	N	3.8	2.5	51.3	Culvert	2/3
3	Paint	1	1	0.2	N	4.7	6.4	r	Culvert	2/3
3	N. Logan	1	2	0.5	P	2.8	4.8	9.6	Culvert	2
1	Upper Twin	2	4	7.8	N	12.7	3.5	r	Natural Falls	3

[a/] 0 = not feasible; 1 = not practical; 2 = fair potential; 3 = good potential; 4 = excellent potential

[b/] Y = yes; N = no; P = passage possible during lower flows

[c/] 1 = easy; 2 = moderate; 3 = difficult

[d/] 1 = fair; 2 = good; 3 = excellent

As we implement the hatchery portion of this plan, we will consider the overall structure of the fish population in Flathead Lake. Dual-beam acoustic estimates in 1989 showed 15.2 million fish greater than one inch in the limnetic zone (375 fish/hectare). Based on confirmation sampling, bull trout comprised 6-28 percent of the limnetic fish community. Lake trout comprised 5-38 percent; lake whitefish made up 45-89 percent (Montana Dept. of Fish, Wildlife and Parks, 1990). Reductions in lake trout and lake whitefish by encouraging more harvest by anglers may be necessary to enhance bull trout, kokanee, and cutthroat in the system.

The production capacity of state and federal hatcheries is currently planned and utilized. Therefore, we have two options: build new hatcheries or expand and upgrade existing hatcheries.

We recommend refurbishment and expansion of the Somers State Hatchery and Creston National Fish Hatchery to supply eggs and fish for the mitigation efforts. Also, some dollars could be used to create a low-capital outdoor raceway system for the state's Rose Creek site. Construction of new hatcheries would cost three to five times more than upgrade of existing hatcheries. Currently, production from Creston National Fish Hatchery supplements fisheries outside the Flathead Basin. Under this plan, the USFWS has committed to dedicating all production to the Flathead system.

We recommend allocating an estimated $2,675,000 in capital funds to upgrade, modernize, and expand the Somers State Hatchery (see cost estimates, Appendix Report). The MDFWP will contribute $500,000 towards the total cost of $3,175,000. This upgrade would make it possible for Somers Hatchery to produce kokanee or other species required for mitigation. We plan to work with BPA to reduce capital costs as much as possible. BPA could provide engineering and design, which would save significant amounts of money.

We recommend allocating an estimated $2,075,000 for the upgrade and expansion of the Creston National Fish Hatchery (see Appendix Report for a summary of cost estimates). A small portion of these funds could be used for improvements at the nearby state-owned Rose Creek site. Funds from Montana Power Company, through Kerr Dam mitigation, would be coupled with these funds to complete the upgrade at Creston. Capital costs could be reduced through consultation with BPA engineers.

We recommend allocating an estimated $180,000 per year for annual hatchery operation and maintenance. Some areas and some species could require continual hatchery fish planting for the mitigation period. If natural runs develop, some hatchery funds could be shifted to other techniques. These dollars will be coupled with dollars from Montana Power Company through mitigation for Kerr Dam to provide adequate annual operating funds. Disease testing and control, genetic testing, and brood stock evaluation will be an important part of the hatchery program.

Specifically, we plan to focus on the following hatchery programs:

Kokanee: Initial hatchery efforts will focus primarily on kokanee. This species is considered a very desirable sport fish and an important component of lake trout diet in Flathead Lake. Also, kokanee enhancement carries little genetic risk because the species is already in the system and Flathead kokanee were the original source of other populations from which we plan to obtain eggs. Hatchery culture of kokanee is well established and cost effective. In conjunction with mitigation efforts for Kerr Dam, we will plant from 10-20 million kokanee annually in Flathead Lake to fully test the recovery potential and overcome the assumed predation trap. We recognize the difficulty of securing this level of egg sources. Initially, operation funds will be directed to developing egg sources, collecting eggs, and obtaining eggs from sources outside Montana.

The size of the effort planned here should be a large enough test to meet the guidelines of adaptive management, and to fully test the hypothesis that predation of kokanee by lake trout in Flathead Lake can be overcome by a large enough plant of two-inch fish. This level of enhancement has achieved some success in Lake Pend Oreille, which has similar conditions to Flathead Lake. If this effort is unsuccessful, we will shift major emphasis to native species enhancement, particularly in off-site areas.

Cutthroat trout: We will plant hatchery cutthroat trout juveniles and eggs experimentally to test relative success in the following order of priority:

1. Imprint planting in blocked areas;

2. Imprint planting in habitat improvement sites;

3. Supplementation of juveniles or eggs in areas with low populations;

4. Release of cutthroat into the Flathead Lake/River or forks for imprinting;

5. Release of cutthroat directly into Flathead Lake; and

6. Release of cutthroat directly into Hungry Horse Reservoir.

Juvenile fish will be marked or otherwise made identifiable and followed with an intensive monitoring program. A strong evaluation/feedback program will help test the hypotheses that each of these techniques can be successful for cutthroat trout at a given planting level and technique.

Bull trout: The culture of bull trout is less established than for cutthroat trout. Initially, work will be directed towards evaluating hatchery culture techniques and disease testing. The Creston National Fish Hatchery, MDFWP, and CSKT are working cooperatively to evaluate culture potential of bull trout eggs. Managers in British Columbia have successfully cultured bull trout for the Arrow Lakes system.

We will utilize eggs and fry with the same prioritized techniques listed for westslope cutthroat trout. The fish will be marked, or otherwise made identifiable, and the techniques will be evaluated through an intensive monitoring program. Eventually, it would be desirable to replace the estimated 250,000 young bull trout lost by the construction of Hungry Horse Dam, by a combination of these non-operational techniques.

Off-site Mitigation

Off-site mitigation could be used if excellent opportunities are identified in the Flathead area for fishery improvements. Also, we may find there are not enough opportunities to fully mitigate losses on site. ***We recommend allocating an estimated $50,000 per year for the mitigation period specifically to off-site projects.*** One example of a reasonable use of off-site funds would be to enhance an off-site fish stock from which we plan to obtain eggs for planting on site (eg. kokanee in Lake Mary Ronan). Another example would be to rehabilitate a closed basin lake and create a new westslope cutthroat fishery. If insufficient opportunities are identified in a given year, these funds could be shifted to other categories.

Operational Mitigation Actions

We recommend that these operational changes take place as quickly as possible. Reservoir level fluctuations and downstream changes in water volume and temperature have continued to the detriment of the biological resource since 1953. Our analyses show that selective withdrawal requires no changes in volume of water discharged and benefits to the aquatic resource in the Flathead River are substantial, so we recommend the process to achieve this measure should be initiated immediately. Logically, other operational recommendations should be referred to the Columbia Basin System Operation Review, being conducted by the USBOR, BPA, and USACOE so that all projects can be examined together. ***We ask the Power Planning Council to reaffirm the interim operational guidelines for protection of resident fish in the Flathead system outlined in the 1987 Fish and Wildlife Program until the completion of the System Operation Review.***

Our reservoir model represents a viable tool for working with system operators to evaluate biological/power/flood control tradeoffs. We plan to work with operators in using our model to make continual adjustments in recommendations as system operations change. ***We offer our model as a tool for use in the System Operation Review.***

Reservoir Surface Elevation Control

Drawdown from full pool should begin no earlier than September 15 for maximum terrestrial insect deposition and maximum volume of optimal temperature during the period of trout biomass increase. Drawdown may occur to meet 3,500 cfs combined flows in the main

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