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An Evaluation of the Potential Cumulative Bioeconomic Impacts of Proposed Small-Scale Hydro Development on the Fisheries of the Swan River Drainage, Montana[1]

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Abstract--Cumulative fisheries impacts of 20 small hydro projects proposed for tributary streams in the Swan River basin of northwestern Montana were investigated. Tributary fish populations consisted primarily of resident brook trout (Salvelinus fontinalis), resident westslope cutthroat trout (Salmo clarki lewisi), and juvenile bull trout (Salvelinus confluentus) from an adfluvial population residing in Swan Lake. The effects of total dewatering of project areas and increased stream sedimentation due to small hydro and forest development were predicted. Up to 4%, 18%, and 32% of drainage-wide populations of brook, cutthroat, and bull trout, respectively, could be lost if full development occurred, primarily because of dewatering. Individual stream populations could suffer losses as great as 50% for brook trout, 90% for cutthroat trout, and 84% for bull trout. Using creel and economic surveys, annual net values were estimated at $788,000 (travel-cost) for the entire Swan sport fishery and $232,000 (hedonic travel-cost) for the highly-valued migratory bull trout fishery. The estimated value to anglers of a 25% fish loss in the drainage varied from $250,000 (willingness-to-drive) to $2,600,000 (willingness-to-sell).

INTRODUCTION

Interest in developing small-scale hydropower generating facilities throughout the United States increased dramatically during the early 1980's following the passage of various federal and state legislative acts intended to stimulate the development of renewable energy sources. A nationwide "hydro-rush" soon followed and developers filed applications with the Federal Energy Regulatory Commission (FERC) for preliminary permits on nearly 90 hydropower sites in Montana alone during 1981 and 1982. Twenty of these preliminary permits were issued for sites on tributaries in the Swan River drainage.

The Northwest Power Planning Council (1982) recognized the potentially harmful cumulative effects of small hydro development (less than 5 megawatts) on fish and wildlife resources within individual river basins. In accordance, the Council recommended measures in the Columbia River Basin Fish and Wildlife Program to insure that potential cumulative effects of existing and proposed multiple hydroelectric developments are addressed by federal project operators and regulators, and to encourage development of criteria and methods for assessing these impacts.

Our study, funded by the Bonneville Power Administration (BPA), was designed to determine the potential cumulative biological and economic effects of small hydro development on the fisheries of the Swan River drainage. Recently, a study to develop methods for assessing cumulative fish and wildlife impacts of hydro development in the entire Columbia River Basin has been initiated by BPA. Also, FERC (1985) proposed a procedure to evaluate the cumulative effects of multiple small hydro project developments in three river basins in the northwestern United States. A more detailed account of our study may be found in Leathe and Enk (1985). The process which we used to assess cumulative impacts is summarized in figure 1.

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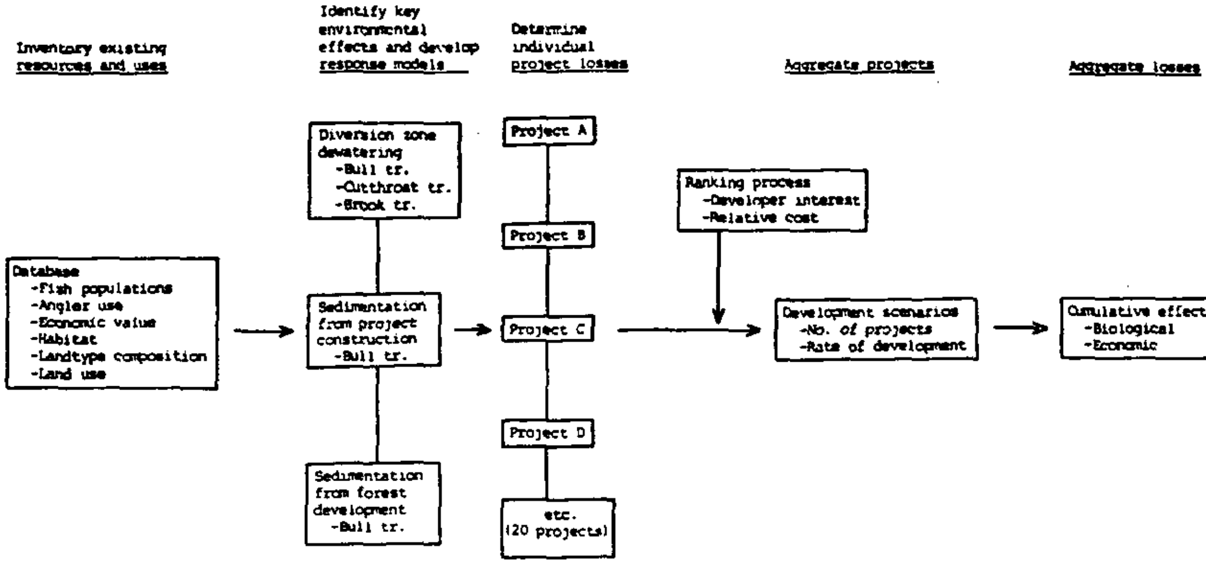

Figure 1.--Procedure for assessing cumulative impact of small hydro development in the Swan River drainage, Montana.

STUDY AREA

The Swan River is located in northwestern Montana, west of the Continental Divide (fig. 2). It flows north from its headwaters in the Mission and Swan mountains and enters Flathead Lake at the town of Bigfork, Montana which is 23 river kilometers (14 miles) downstream from Swan Lake. Drainage area of the Swan River is 1,738 km^2 (671 sq. mi.) measured at the outlet of Swan Lake. The river flows through a heavily forested glaciated valley that is relatively flat and five to ten kilometers wide. Mean annual flow is about 1,300 cfs immediately downstream from Swan Lake. Peak discharges of 5,000-6,000 cfs typically occur in May and June and are determined by the amount and rate of snowmelt in this mountainous watershed.

Most of the Swan drainage is part of the Flathead National Forest, but extensive "checkerboard" ownership exists in lower elevation areas. Other major landowners are Plum Creek Timber Company, Swan River State Forest, and small private holdings. Development in tributary basins consists primarily of road construction and associated timber harvest.

All proposed small hydro facilities were high-head tributary projects (fig. 2) with installed capacities ranging between 100 kilowatts and 1.5 megawatts. Water would be diverted into 12- to 20-inch diameter penstocks by the construction of three-foot high diversion dams. The diverted water would be transported 2,800 to 18,000 feet downslope in buried penstocks and released through high-pressure jets which would drive an impulse turbine (Pelton wheel) before being returned to the stream. Stream gradients within proposed diversion zones ranged from 3% to

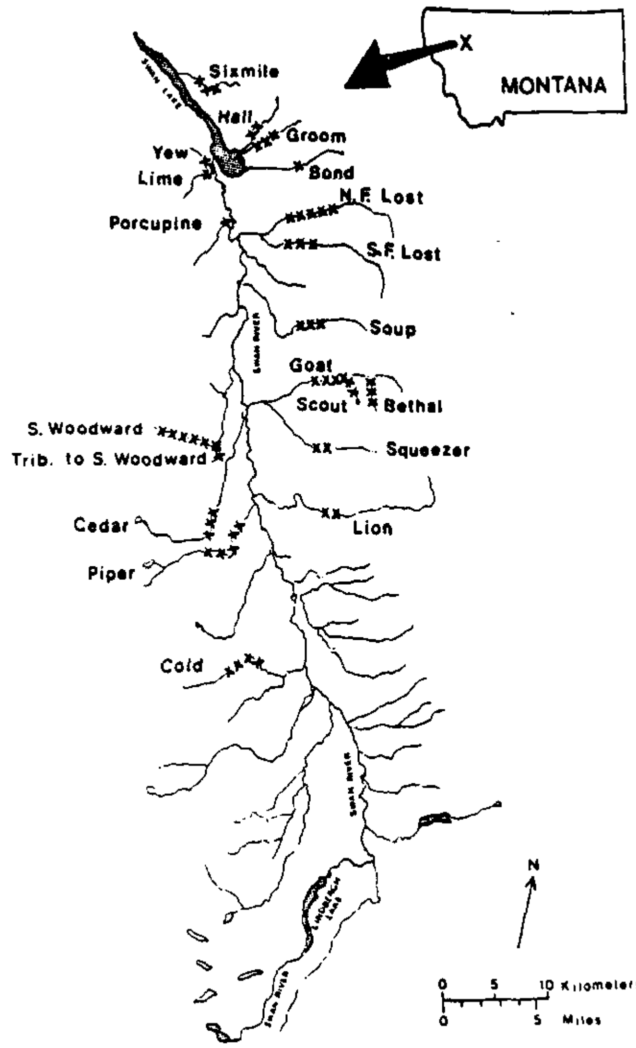

Figure 2.--Map of the Swan River drainage, with proposed locations of 20 small hydro sites.

21%. Gross head (vertical drop) of the proposed projects ranged between 90 and 527 m and averaged 227 m (774 feet).

The principal gamefish species in tributaries to the Swan River were brook trout (*Salvelinus fontinalis*), westslope cutthroat trout (*Salmo clarki lewisi*) and juvenile bull trout (*Salvelinus confluentus*). In the Swan River upstream from Swan Lake, brook trout and rainbow trout (*Salmo gairdneri*) were the predominant gamefish species. The predominant gamefish species in Swan lake were kokanee salmon (*Oncorhynchus nerka*), northern pike (*Esox lucius*), and bull trout. Of these, only westslope cutthroat trout and bull trout are native to the drainage, and both are listed as species of "special concern" in Montana due to their limited distributions and numbers.

Our study results indicated that bull trout were the only species that displayed a strong migratory tendency. During the summer, adult fish (400-850 mm long) migrate as far as 67 km upstream from Swan Lake to specific tributary streams where they spawn in the fall prior to returning to the lake. After emerging from the gravel in April, young bull trout spend from one to three years in the stream before migrating downstream to the lake where they mature at age five or six.

METHODS

Database

Habitat Inventory

Aerial pre-surveys of all streams were made to delineate reaches and identify representative survey sections using a helicopter technique similar to that developed in British Columbia (Chamberlin 1981). The aerial survey identified 49 tributaries that could support fish populations. These streams contained 416 km (258 miles) of habitat and were divided into 102 reaches.

To insure that overall study objectives were met, top priority was placed on obtaining ground survey information for the 37 stream reaches situated within or downstream from proposed small hydro project areas. The remainder of the 74 total reaches that were ground surveyed were randomly selected from a pool of all reaches stratified into 12 gradient/drainage area categories. Studies completed in other portions of the Flathead drainage and elsewhere have documented the importance of stream size and gradient in determining salmonid species abundance and distribution in mountainous watersheds (Hartman and Gill 1968, Griffith 1972, Platts 1979, Fraley and Graham 1981, Graham et al. 1981).

Habitat surveys were conducted by crews of two technicians on one- or two-kilometer representative sections of selected reaches using a transect method described by Leathe and Enk (1985). In addition to numerous other variables, a modified version of substrate score (Crouse et al. 1981) was estimated for 80 to 120 sampling points in each reach by summing the ranks for dominant particle size, subdominant particle size, and embeddedness of dominant-sized particles (table 1).

Fish Populations

Fish population estimates were made in a 100- to 150-m section within each habitat survey section. Gas-powered backpack electrofishing gear was used in smaller streams and bank electrofishing gear was used on larger (20 cfs or more) accessible streams. Population estimates were calculated for fish 75 mm and larger using the two-sample removal method, or occasionally using three-sample or mark-recapture techniques (Seber 1973).

An estimate of the total number of each species of trout inhabiting the tributary system was made to facilitate cumulative impact assessment. For the 74 reaches actually electrofished, this simply involved expanding the population estimates over the entire length of the reach. The 28 reaches not surveyed were classified into the gradient and drainage area categories used in our subsampling scheme. The population of each trout species in these reaches was then estimated using average fish densities from electrofished reaches in the same gradient/area category (table 2), except where other data indicated the species was absent.

Table 1.--Substrate characteristics and associated ranks for calculating substrate score (modified from Crouse et al. 1981).

Rank	Characteristic
	Particle size class (range)
1	Silt and/or detritus
2	Sand (<2.0 mm)
3	Small gravel (2.0-6.4 mm)
4	Large gravel (6.5-64.0 mm)
5	Cobble (64.1-256.0 mm)
6	Boulder and bedrock (>256.0 mm)
	Embeddedness[1/]
1	Completely embedded (or nearly so)
2	3/4 embedded
3	1/2 embedded
4	1/4 embedded
5	Unembedded

[1/] Extent to which dominant-sized particles are buried in sand and silt.

Table 2.—Average fish population size (number of fish 75 mm and longer per 300 m of stream) in reaches within various gradient and drainage area categories in Swan River drainage tributaries.

Gradient %	Drainage area (km²)	Number reaches sampled	Ave. no. fish ≥75 mm per 300 m (±SD) Cutthroat Trout	Brook Trout	Bull Trout
0-3%	0-20	3	11(±14)	490(±103)	0(±0)
	>20-50	13	6(±12)	154(±89)	22(±36)
	>50	11	5(±10)	164(±177)	59(±73)
3-6%	0-20	8	104(±86)	49(±69)	0(±1)
	>20-50	9	42(±55)	22(±60)	59(±89)
	>50	1	0	0	108
6-13%	0-20	14	81(±85)	1(±2)	8(±21)
	>20-50	5	73(±116)	44(±65)	24(±54)
	>50	1	39	129	39
>13%	0-20	9	57(±58)	3(±8)	0(±0)
	>20-50	—	—	—	—
	>50	—	—	—	—

Angler Use

The creel census designs for Swan Lake and the Swan River were modified versions of the method described by Neuhold and Lu (1957). Sampling days and times were selected at random within two-week sampling intervals. Angler counts on Swan Lake were made twice daily from a boat during times of open water or from vantage points during the iced-in period. Angler counts on the 85-kilometer (53-mile) section of the Swan River were made once from a low-flying airplane on each selected sampling day. Tributary fishing pressure was calculated indirectly as a percentage of river pressure based on the relative amount of fishing effort sampled at checking stations established along a roadway that bisected the study area. This estimate was cross-checked using the results of a statewide mail survey of anglers made by MDFWP during the 1982-83 fishing season.

Economics

Economic survey information was obtained by creel census clerks during the course of angler interviews. A series of 14 questions was used to gather information from party leaders concerning angler origin, demographic and income information, scenic qualities, and other waters fished. The simple travel-cost method was used to estimate the total value to anglers of the fishery resource in the Swan River drainage. This approach is a practical and accepted method for estimating the total value of recreational sites (Palm and Malvestuto 1983), but it is not well suited for estimating the economic value of specific characteristics of a fishing site.

Since small-hydro development in the Swan drainage would likely cause a partial loss of fish rather than a total loss of site, four techniques were used to estimate the value to anglers of these losses. The first three were contingent-valuation methods that focused on anglers' willingness-to-pay (WTP), willingness-to-sell (WTS), and willingness-to-drive (WTD) in response to hypothetical 25% fish losses. The fourth technique, hedonic travel cost, used multiple regression in conjunction with travel-cost analysis to determine the value of individual site characteristics.

A total of 376 fishing parties were interviewed in the Swan drainage. Interviews of 544 fishing parties in eight other areas of Montana were also conducted by cooperating MDFWP biologists to add diversity to the economic database. A more detailed explanation of the economic evaluation may be found in ECO Northwest (1984).

Impact Modeling

Evaluation Criteria

A number of potential environmental impacts including dewatering, interference with upstream and downstream fish passage, turbine mortality, streambed sedimentation, temperature alterations, and gas supersaturation were considered in the development of cumulative fisheries impact models. Life histories and habitat requirements of fish species inhabiting project streams were also considered.

Our investigations indicated that fish populations within diversion zones of proposed small hydro project areas were comprised primarily of resident westslope cutthroat trout and migratory juvenile bull trout. Bull trout were chosen as the primary species of concern because of their extensive use of project areas, sensitivity to streambed sedimentation (Shepard et al. in press), and importance to the Swan Lake and River sport fisheries. Cutthroat trout were of lesser importance because of their minor contribution to the sport fishing catch, small size (seldom larger than 200 mm), and limited movements within project streams. Although brook trout comprised more than 90% of the sport fishery harvest in the tributary system, they received lowest priority in our analysis. This was due to their limited use of project diversion zones and their apparent tolerance of streambed sedimentation, which was judged to be the most significant factor influencing downstream areas.

Because no small hydro projects were constructed in the study area during our investigations, we were unable to quantify the effect of project operation on fish passage, turbine mortality, temperature alterations, and gas supersaturation. Limited measurements made at two high-head small hydro projects outside of the study area suggested that effects of project operation on water temperature and gas supersaturation could be detrimental to fish populations.

However, the magnitude of these impacts was judged to be dependent upon project size, location, and operational characteristics (Leathe and Enk 1985). Turbine mortality and interference with fish passage were judged to have minimal impacts on fish populations in project streams. This was because migratory bull trout seldom used areas upstream from proposed diversion structures for spawning or rearing, and movements of resident cutthroat trout were limited (on the order of 150 meters or less).

Dewatering was considered a key factor in our analysis because developers proposed to divert up to the entire streamflow during the low flow period. This would effectively remove 13% of the tributary mileage from the Swan drainage if all 20 projects were developed. Sediment production and subsequent streambed degradation from construction of access roads, penstocks, and transmission lines was the other key factor considered in our study. Many of these routes would be built in steep terrain and in close proximity to stream channels. Although not included in our analysis, the risk of penstock rupture and subsequent slope failure should also be acknowledged.

Response Models

Two strategies of project operation were modeled to evaluate dewatering effects. If recommended instream flows were maintained in project diversion zones, no significant fish losses would be expected. According to the developer, however, the Swan projects would not be profitable with this requirement since most, if not all, of the streamflow during winter months would be needed for power generation. Under such severe dewatering conditions, there can be no guarantee that stream diversion zones would not dehydrate or freeze up. Complete loss of fish habitat was predicted for this operational strategy because diversion zones could not support trout during the critical winter period (MDFWP 1984). Fish losses in these areas were estimated based on existing populations of cutthroat and brook trout, and on projected populations of bull trout as described later.

A comprehensive watershed model was developed to estimate sediment delivery to streams from small hydro as well as other forest development (road building and timber harvest). Annual sediment loads were calculated using erosion coefficients developed by soil scientists and hydrologists of the Flathead National Forest. The coefficients were derived from a landtype classification system which was based on vegetation, soil, and slope characteristics (USDA, Forest Service 1980). Both natural and man-induced erosion were simulated.

Roads, timber harvest, and hydro development constituted man-made sediment sources. Road sediment coefficients were based on ground exposed in road surface, cut slope, fill slope, and drainage ditches. Logging-related sediment was estimated by considering skid trail, landing, and fireline requirements for various size clearcuts. Sediment from small hydro development was predicted by estimating ground disturbance which would result from construction of access roads, penstocks, and transmission lines described in preliminary study permits for the projects. All sediment coefficients were adjusted to reflect lower erosion rates as disturbed sites recover with age. Sediment routing to downstream reaches was simulated using delivery ratios based on drainage area (Cline et al. 1981).

Relationships between estimated annual sediment loads and streambed composition in 46 tributary reaches were established by linear regression. Percent increase in sediment over natural levels due to road construction and maintenance was significantly correlated with percent streambed fines observed in habitat surveys during 1983. However, a higher coefficient of determination (r^2=0.56) was obtained by regressing percent increase in sediment over natural due to roads and a logarithmic transformation of stream gradient against substrate score (fig. 3). Logging-related

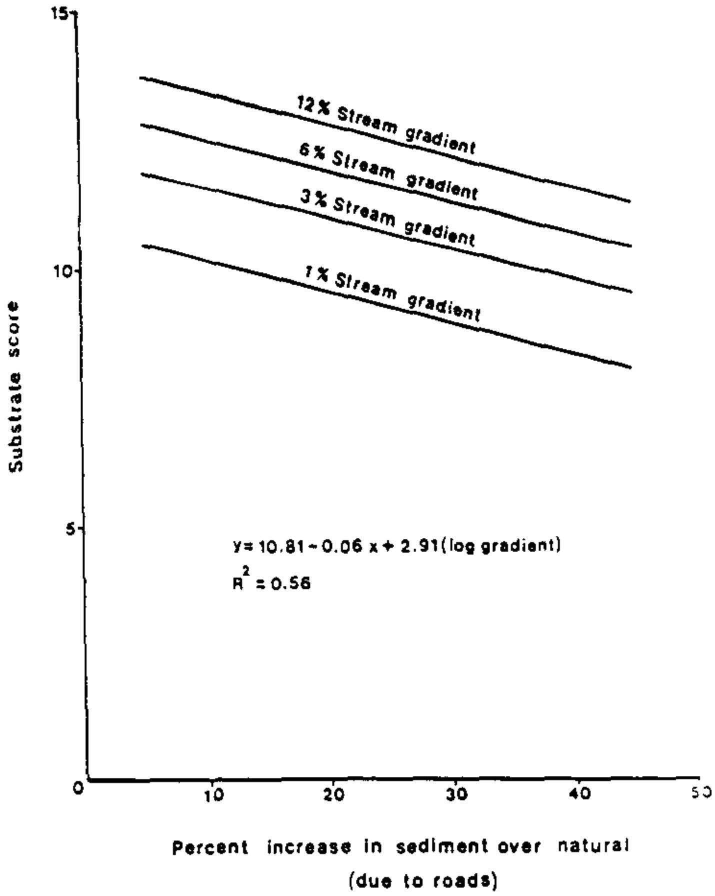

Figure 3.—The relationship between streambed substrate score and sediment loading rates (percent over natural levels) resulting from road construction and maintenance in Swan tributary drainages.

sediment was not a significant variable in either regression. As a measure of substrate quality, substrate score incorporates indices of size composition as well as embeddedness level, both of which influence habitat suitability for spawning and rearing trout (Shepard et al. in press, Griffith 1979).

In stepwise multiple regression analysis, streambed substrate score was found to be the most important variable relating juvenile bull trout density to habitat characteristics in Swan tributaries. Therefore, predicted changes in reach substrate score due to forest and small hydro development could be used to model impact on the migratory bull trout fishery, based on the correlation shown in figure 4. The equations used in this two-step process were the following:

1) $Y = 10.81 - 0.06(X_1) + 2.91(X_2)$

where Y = streambed substrate score,

X_1 = sediment load due to roads, expressed as percent above natural levels, and

X_2 = logarithm of reach gradient;

2) $\text{Log } Y = 0.14(X) - 1.39$

where Y = number of bull trout ≥75 mm per 100 m^2, and

X = streambed substrate score.

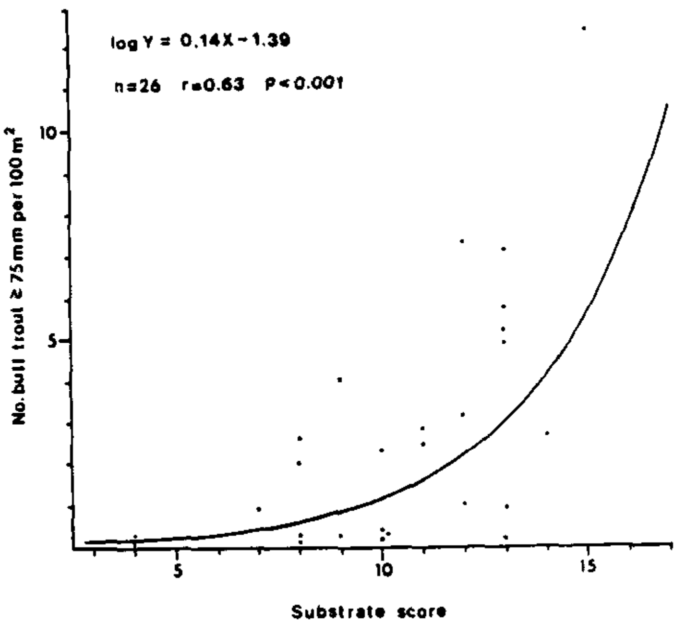

Figure 4.—The relationship between average substrate score and juvenile bull trout density (number of fish 75mm and longer per 100 square meters of stream) for 26 tributary reaches in the Swan River drainage during 1982 and 1983.

Predicted bull trout losses were expressed as a percentage of the potential population which these streams could support if their basins were undeveloped. Potential populations were calculated by assuming no increase over natural sediment in Equation 1 above. Resulting substrate scores were then used in Equation 2 to compute potential bull trout densities in all reaches supporting migratory populations. The effect of increased sediment on resident cutthroat and brook trout in Swan tributaries was not modeled because stepwise multiple regression failed to identify streambed sedimentation as a significant factor influencing their abundance. However, other studies have documented many detrimental effects of sediment on stream salmonids (Reiser and Bjornn 1979).

Development Scenarios

The effects of individual as well as multiple small hydro construction were evaluated. Individual project impacts were considered along with concurrent planned forest development for five possible construction years: 1986 - 1990. Impacts from sediment production were assumed to begin the year after project construction. For multiple development, six scenarios with varying numbers of projects and rates of development were simulated (table 3). To establish a logical sequence of construction, projects were ranked according to developer interest (based on status of FERC permits) and cost factors (Cunningham 1982).

RESULTS AND DISCUSSION

Database

Fish Populations

Cutthroat and brook trout were the most widely distributed species in the tributary system, being found in 45 and 40 reaches, respectively, while bull trout were present in 31 reaches. Maximum

Table 3.--Description of small hydro development scenarios for Swan River drainage. Construction would begin in 1986.

Scenario	Number of projects developed[1]	Rate of development
Low incremental	Four	1 project/yr
Low immediate	Four	4 projects/yr
Moderate incremental	Ten	2 projects/yr
Moderate immediate	Ten	10 projects/yr
Full incremental	Twenty	4 projects/yr
Full immediate	Twenty	20 projects/yr

[1]Order of development determined by rank.

observed brook trout density (609 fish >75 mm per 300 meters of stream) was much higher than peak cutthroat or bull trout densities (285 and 270 fish per 300 meters, respectively). With the exception of adult bull trout on spawning runs, most tributary fish were relatively small, ranging between 50 and 200 mm. Tagging and movement studies indicated that cutthroat and brook trout were resident in tributaries while bull trout were, for the most part, migratory.

Fish species abundance and distribution within tributaries to the Swan River appeared to be strongly influenced by channel gradient (fig. 5). Brook trout were by far the most abundant species in low gradient (0 to 3%) reaches while cutthroat trout predominated in higher gradient headwater reaches. Bull trout were not a dominant species in any gradient category but tended to be most abundant in reaches having gradients of six percent or less.

It was estimated that the tributary system within the study area supported approximately 107,000 brook trout, 65,000 cutthroat trout, and 31,000 bull trout. The bull trout estimate included migratory and suspected resident fish. For evaluating project impacts, populations of juvenile bull trout in tributaries known to support migratory runs were estimated independently, using habitat and fish population response models described previously.

Angler Use

Anglers expended approximately 48,000 hours or 16,300 angler-days sport fishing in the Swan River drainage during the 1983-84 fishing season.

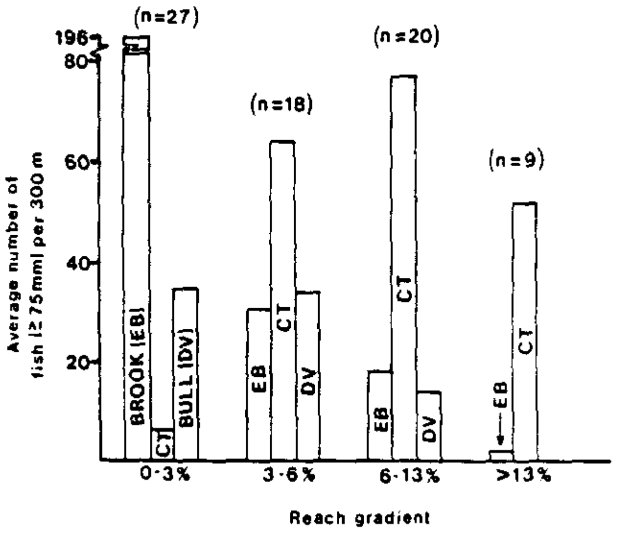

Figure 5.—Average population density (number of fish 75 mm and longer per 300 m stream) of three trout species in tributaries to the Swan River in relation to channel gradient. Sample sizes (number of reaches electrofished) are in parenthesis.

This total was comprised of 21,700, 16,500, and 9,900 hours in Swan Lake, Swan River, and tributaries, respectively. Bull trout comprised approximately four percent of the total Swan Lake harvest (table 4). However, about 16% of lake fishing pressure was directed specifically at bull trout and they were the primary species sought during the winter ice-fishing season (December through March). Approximately six percent of Swan River fishing pressure was directed solely at bull trout. These anglers sought "trophy-sized" fish (up to 850 mm) during the spring/summer spawning migration out of Swan Lake.

Cutthroat trout were abundant in proposed small hydro project areas but did not comprise a significant portion of the sport fishery in any portion of the system (table 4). Brook trout were important to the tributary and river fisheries, but were not abundant in proposed project areas. Rainbow trout, kokanee salmon, and northern pike were caught primarily in the Swan River or Swan Lake and seldom used the tributary system.

Impact Modeling

Individual Projects

If recommended instream flows were maintained, development of individual projects would result in losses of only 2% to 10% of potential bull trout production in individual streams (table 5, left side). With additional sediment from forest development, estimated losses ranged from 8% to 22% in project drainages. If diversion zones were dewatered, bull trout losses would increase dramatically for all projects listed except three which would not dewater rearing habitat. Piper Creek would experience the greatest impact, with 72% of its juvenile bull trout production lost. Considering the

Table 4.--Harvest estimates for the principal gamefish species in three segments of the Swan River drainage, Montana during the 1983-84 fishing season. Ninety-five percent confidence intervals (when calculated) are in parenthesis.

Species	Estimated total harvest: Swan Lake	Swan River	Tributaries
Bull trout	740 (±260)	560 (±260)	300
Cutthroat trout	240 (±150)	240 (±150)	300
Brook trout	0	2,400 (±1,000)	9,700
Rainbow trout	290 (±180)	1,770 (±670)	400
Kokanee salmon	14,430 (+3,390)	0	0
Northern pike	1,240 (±460)	0	0
Total	16,940	4,970	10,700

additional effect of forest roads, losses would increase to 84% in Piper Creek and range from 11% to 76% in other drainages.

The relative importance of each project stream becomes apparent when losses are expressed as a percentage of the total migratory bull trout production in the Swan drainage (table 5, right side). If instream flows are maintained through diversion zones, no small hydro project by itself would cause more than 1% loss to the Swan bull trout fishery. However, with dewatered diversion zones, losses range up to 7% for a single project (Cold Creek) with up to 8% lost altogether because of road construction in that drainage.

The effects of diversion zone dewatering on cutthroat and brook trout populations varied widely among sites. Percent loss of individual stream fisheries would be substantial in many cases: up to 90% of the cutthroat trout in Soup Creek and up to 50% of the brook trout in Porcupine Creek. In terms of the entire Swan tributary fishery, single project impacts would be less significant. Losses would range up to 5% of the cutthroat and 2% of the brook trout population.

Table 5.—Cumulative percentage loss of potential juvenile bull trout production due to forest and small hydro development (average year-after losses for five possible construction years: 1986-1990). First number given is loss due to all development; number in parenthesis is loss attributable solely to hydroproject development. Only projects which would affect migratory bull trout rearing streams are listed.

Project stream	Percentage loss in affected streams: With IFR[1] in diversion zone	Percentage loss in affected streams: Dewatered diversion zone	Percentage loss of Swan drainage production: With IFR[1] in diversion zone	Percentage loss of Swan drainage production: Dewatered diversion zone
Bethal	11.6 (2.9)	11.6 (2.9)	0.9 (0.2)	0.9 (0.2)
Cold	21.0 (9.2)	76.0 (64.2)	2.2 (1.0)	8.0 (6.8)
Goat	10.8 (2.1)	45.1 (36.4)	0.9 (0.2)	3.7 (3.0)
Lion	7.7 (3.7)	13.6 (9.6)	1.3 (0.6)	2.3 (1.6)
N.F. Lost	9.2 (2.9)	56.9 (50.6)	0.7 (0.2)	3.5 (3.0)
Piper	22.4 (10.5)	84.2 (72.3)	1.5 (0.7)	5.6 (4.8)
Scout	11.3 (2.6)	11.3 (2.6)	0.9 (0.2)	0.9 (0.2)
S.F. Lost	11.0 (3.0)	42.3 (34.3)	1.1 (0.3)	4.3 (3.5)
S. Woodward	21.8 (9.4)	24.1 (11.7)	1.7 (0.7)	1.9 (0.9)
S. Woodward trib.	14.2 (1.8)	14.2 (1.8)	1.1 (0.1)	1.1 (0.1)
Squeezer	7.6 (2.3)	37.0 (31.7)	0.5 (0.1)	2.4 (2.0)

[1] IFR = instream flow recommendation.

Multiple Projects

The cumulative effects of forest and multiple small hydro development on migratory juvenile bull trout production in the Swan drainage would be significant (fig. 6). Projected losses varied among levels of development (low vs. moderate vs. full) and, to some extent, between rates of development (immediate vs. incremental). Losses due to sediment from forest development (roads) were estimated at 6% to 7% of potential

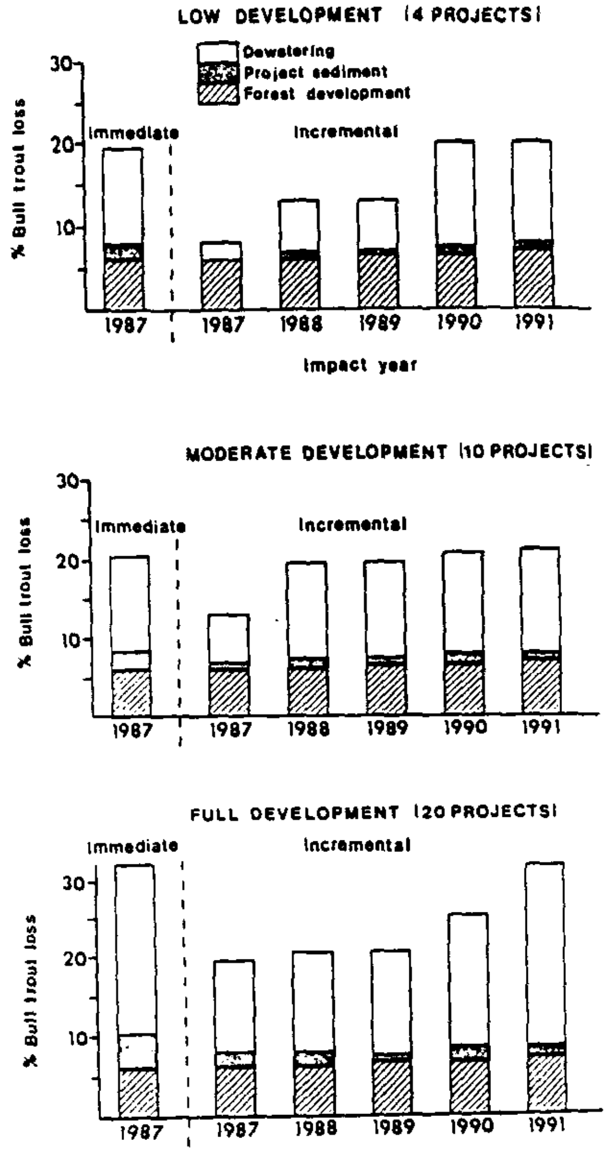

Figure 6.—Predicted losses in potential migratory bull trout production in the Swan River drainage due to forest development and three levels of small hydro development. Effects of immediate (all projects built in one year) and incremental (construction phased over five years) scenarios are shown for each level of development.

bull trout production for the modeled years. Additional sediment from small hydro construction would cause losses of up to 4% of the total Swan migratory bull trout production. Therefore, if instream flows were protected, cumulative losses would not exceed 11% under any scenario.

Dewatering of hydroelectric diversion zones would be responsible for the greatest bull trout losses (up to 23%). As a result, the ultimate impact of an "incremental" scenario was very similar to an "immediate" scenario for a given level of development. However, incremental development reduced the impact of project-related sediment, which would be an important consideration in more sediment-sensitive areas or where dewatering is less significant.

Without minimum flow maintenance, even a low level of development would eventually result in the loss of about 13% of juvenile bull trout production, with an additional 7% lost due to forest roads. The total loss (20%) is substantial because three of the four projects to be built would involve rearing streams. These streams ranked high in developer interest, most likely because of sizeable winter flows which also made them optimal for rearing bull trout.

A moderate level of development (10 projects) with dewatering would ultimately result in only a slightly greater loss than would a low level. The difference between the two levels is minor because only two of the projects added in moderate scenarios affect bull trout. Predicted fish losses for low and moderate development levels would vary if different projects were selected for these scenarios.

Full development of all 20 small hydro projects with subsequent dewatering of diversion zones would cause considerable damage to the migratory bull trout fishery of the Swan drainage. Losses of up to 26% of the potential production were predicted. Considering the additional impact of forest development, over 30% of the bull trout fishery would be lost.

Cutthroat trout populations in Swan River tributaries would also be significantly affected by stream dewatering associated with multiple project development. Cumulative losses of 7%, 12%, and 18% were predicted for low, moderate, and full development levels, respectively. Brook trout were less abundant than cutthroat in proposed diversion zones. As a result, estimated impact on this species was small, ranging from 2% of the total tributary population lost with a low level of small hydro development to 4% lost with full development.

Economic Valuation

Travel-cost results placed the net economic value of the Swan River drainage sport fishery at $788,000 per year (ECO Northwest 1984). This sum was comprised of $455,000, $265,000 and $68,000 for the Swan River, Swan Lake, and tributary fisheries, respectively. Dividing the total net value by the 16,300 angler days estimated for the 1983-84 fishing season yielded an average value of $48.30 per angler-day. Average angler-day values ranged between $21.00 for tributary anglers to $76.00 for river anglers.

Responses to contingent-valuation questions revealed that Swan River anglers consistently attributed a higher value to a hypothetical 25% fish loss than did anglers on Swan Lake or the tributaries (table 6). Anglers fishing various parts of the drainage reported they would pay from $13 to $76 annually to prevent a 25% loss, while they would sell their rights to these fish for $79 to $580 per year. Anglers reported being willing to drive 53 to 127 one-way miles to get to an area equal in quality to the Swan, which amounts to $27 to $64, based on travel costs of 25 cents per mile (table 6).

Estimates of the total value of a 25% fish loss were derived using creel census estimates of the total number of anglers fishing Swan Lake, River, and tributaries. As displayed in table 7, the resulting contingent values were substantial, ranging between $250,000 (based on WTD) and $2.6 million (based on WTS) annually. the difference between WTS and the other two contingent-valuation methods (WTP and WTD) is apparently commonplace in the literature. Variances around contingent-valuation responses were quite large. For example, mean WTP (average response to the WTP question) for the Swan River and tributaries and mean WTS for Swan Lake were not significantly different from zero (table 6).

The hedonic travel-cost method was used to determine the net economic value of the bull trout fishery in the Swan River drainage. Bull trout were found to be significantly more

Table 6.--Average responses of anglers in the Swan River drainage to contingent-valuation questions designed to determine the value of a hypothetical 25% fish loss (ECO Northwest 1984). Numbers of valid responses are in parenthesis.

Area	Willingness-to-pay ($/year)	Willingness-to-sell ($/year)	Willingness-to-drive (miles/trip)1/
Swan Lake	$29* (80)	$241 (82)	89* (173)
Swan River	$76 (111)	$580* (72)	127* (192)
Swan tributaries	$13 (12)	$ 79* (19)	53* (33)

1/ These are one-way miles. Multiply by $0.50 to obtain dollar value.

* Asterisks denote responses significantly different from zero at the 0.05 significance level.

Table 7.--Aggregate valuation (dollars per year) of a hypothetical 25% fish loss in the Swan River drainage using three contingent-valuation techniques. Adapted from ECO Northwest (1984).

Area	Willingness-to-pay	Willingness-to-sell	Willingness-to-drive
Swan Lake	$108,300	$ 899,700	$110,800
Swan River	204,700	1,562,000	114,000
Swan tributaries	18,300	111,000	24,800
TOTAL	$331,300	$2,572,700	$249,600

valuable than "trout" to anglers. Anglers were willing to pay an estimated $450 per party-visit to fish specifically for bull trout as compared to $30 to fish for "trout". However, there was a large amount of variance associated with these value estimates (ECO Northwest 1984).

Multiplying the estimated number of bull trout fishing trips (from creel census data) by $450 resulted in net values of $183,600 and $48,600 annually for the bull trout fishery in Swan Lake and the Swan River, or $232,000 total. Similar calculations (using $30 per trip) resulted in an estimated value of $87,000 for non-specific "trout" fishing (including kokanee salmon) in the lake, river, and tributaries.

The hedonic travel-cost results indicated that the bull trout fishery has a substantially greater net value than the "trout" fishery in the Swan River drainage, even though bull trout comprised only about 5% of the total harvest and were the target of about one-sixth of the fishing pressure. Consequently, small hydro and forest development in tributary drainages could have significant effects on the value of the migratory bull trout fishery in downstream areas (Swan River and Swan Lake).

The bioeconomic impacts of small hydro development on the tributary sport fishery would be small due to the distribution of brook trout, which formed the basis of that fishery. Assuming that dewatering constitutes a loss of site and that the total value of the tributary fishery to anglers is due to the presence of brook trout, the travel-cost estimate was used to assess the net value of brook trout losses. If all small hydro projects were developed, associated brook trout losses (4%) would have an estimated value of $2,700 (0.04 x $68,000). This is not to say that westslope cutthroat trout losses (up to 18% at full development) are of no value. This species is important from a genetic standpoint and may at some future time be more avidly sought by tributary anglers. The question of future value was also raised by Gordon et al. (1973).

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