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DETERMINATION OF FISHERY LOSSES IN THE FLATHEADSYSTEM RESULTING FROM THE CONSTRUCTION OF HUNGRY HORSE DAM

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DETERMINATION OF FISHERY LOSSES
IN THE FLATHEAD SYSTEM
RESULTING FROM THE CONSTRUCTION OF HUNGRY HORSE DAM

FINAL,
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EXECUTIVE SUMMARY

This study is part of the Northwest Power Planning Council's resident fish and wildlife plan, which is responsible for mitigating damages to fish and wildlife resources caused by hydroelectric development in the Columbia River basin. The major goal of this study was to provide estimates of fishery losses to the Flathead system as a result of the completion of Hungry Horse Dam and to propose mitigation alternatives for enhancing the fishery.

Hungry Horse Reservoir (HHR) flooded approximately 57 km of the South Fork of the Flathead River and portions of 37 tributary streams with potential use for salmonids. Additionally, the dam blocked access to about 38 percent of the total drainage area available for spawning salmonids migrating upstream from Flathead Lake.

A total of 69 km of potential cutthroat tributary habitat was inundated by Hungry Horse Reservoir. Using stream order and gradient as indices of cutthroat densities, we estimated that potential habitat which would support an average of about 21,000 cutthroat juveniles was lost in these tributary streams. Based on the gradients of the streams inundated, we calculated that 89 percent of these fish were adfluvials destined for Flathead Lake and the rest resident tributary fish.

Based on population estimates from the river above HHR, we calculated that potential habitat for about 12,000 juvenile cutthroat was lost when the South Fork Flathead River was inundated. These fish were also adfluvials destined for Flathead Lake. Access to tributary habitat that would support approximately 165,500 adfluvial cutthroat juveniles was lost in the upper South Fork when the dam was completed. Based on migration rates for the Kootenai system, we calculated that about 65,500 adfluvial juvenile cutthroat were lost to Flathead Lake annually from the river and tributary system. Based on spawning gravel surveys and spawner escapement estimates from Hungry Horse Creek, potential recruitment of about 2,350 cutthroat juveniles were lost to the reservoir population if all problem road culverts identified were complete migration barriers.

By comparing spawning escapement estimates and drainage areas for the North and Middle Forks of the Flathead River, potential habitat for about 2,100 adult bull trout was lost to Flathead Lake annually from blocked access to the South Fork due to dam construction.

Construction of Hungry Horse Dam had the greatest adverse impacts on cutthroat and bull trout from Flathead Lake and mitigative measures should be taken to offset these losses, if biologically and economically feasible. Also, other losses to fish and wildlife have been documented in the Flathead basin due to hydroelectric facilities and their operation, Some of these

research projects will not be completed until 1989, when mitigation will be recommended using a basin-wide approach Since HHR is at the headwaters of the Columbia system, mitigative measures may also affect downstream projects. Therefore, we presented an array of possible mitigation alternatives for consideration by decision-makers, with suggestions on the ones we feel are the most cost effective. Possible mitigation measures included: (1) a feasibility/monitoring study to determine if the Bigfork fish ladder can be operated and maintained to pass fish upstream during all seasons and if the Swan drainage can significantly contribute to natural reproduction for Flathead Lake, (2) improve fish passage at barrier road culverts, (3) various stocking strategies using hatchery plants, (4) operation of Hungry Horse Dam to benefit game fish in the reservoir, (5) rehabilitation of spawning and rearing habitat in previously degraded Flathead basin tributaries, and (6) construction, operation and maintenance of spawning channels to enhance production. Monitoring should be initiated to determine the effectiveness of mitigation measures implemented and ensure a successful program.

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Many individuals and agencies contributed to the successful completion of this study, Terry Hightower spent many hours in the field and provided technical and computer assistance. Bruce May, Hungry Horse Reservoir Project biologist, provided information on the reservoir and its tributaries and valuable guidance on procedures and methods. Members of the Hungry Horse crew assisted with eiectrofishing and snorkeling. These included Tom Weaver, Steve Glutting, Gary Michael, Paul Suek, Beth Morgan, and Bob Braund. Scott Rumsey, Rick Adams, and John Cavigli also assisted with snorkel estimates. The dedication and efforts of these individuals were greatly appreciated.

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Fred Holm, BPA, Resident Fish Program Manager, provided many useful suggestions throughout the study, and also critically reviewed the manuscript.

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Dennice Hamman typed many drafts of the manuscript including the final.

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INTRODUCTION

The Pacific Northwest Electric Power Planning and Conservation Act passed in 1980 by Congress has provided a mechanism which integrates and provides for stable energy planning in the Pacific Northwest. The Act created the Northwest Power Planning Council and directed it to "promptly develop and adopt. . . a program to protect, mitigate, and enhance fish and wildlife, including related spawning grounds and habitat on the Columbia River and its tributaries."

Section 804(b)(4) of the Columbia River Basin Fish and Wildlife Program calls for the design, construction, operation and maintenance of mitigation projects in the Flathead River-Lake system to supplement natural propagation of fish as mitigation for habitat loss in the South Fork and Flathead River caused by construction and operationof Hungry Horse Dam and Reservoir. The measure also calls for this study to determine levels of production necessary to mitigate the effects of the hydroelectric system.

Construction of Hungry Horse Dam flooded approximately 57 km of the South Fork of the Flathead River (South Fork) and about 69 km of 37 tributary streams with potential for salmonid use. The dam also blocked access to 38 percent of the drainage area available to spawning salmonids migrating upstream from Flathead Lake. Isolation of migratory salmonids including westslope cutthroat (Salmo clarki lewisi), bull trout (Salvelinus confluentus) and mountain whitefish (Prosopium williamsoni.) from Flathead Lake was not mitigated by the creation of new lake habitat in Hungry Horse Reservoir (HHR). The reservoir captured fish destined for Flathead Lake and stopped recruitment from the South Fork to the Flathead Lake-River system. Spawning, juvenile trout rearing and resident fish habitat in the flooded portions of tributaries and the river was lost. The amount of potential salmonid habitat and numbers of fish lost was not quantified.

This study was initiated in August, 1985, to provide estimates of fishery losses in the South Fork of the Flathead River and its tributaries as a result of the completion of Hungry Horse Reservoir and to propose mitigation alternatives for enhancing the Flathead system fishery. The study was conducted with the following major objectives:

1. Assess the quality and quantity of game fish habitat lost in the South Fork and its tributaries flooded by the reservoir.

2. Estimate game fish losses:

   a. Populations that inhabited the river and tributaries before inundation.

b. Adfluvial fish losses due to dam construction.

3. Identify present fish passage problems, such as road culverts between Hungry Horse Reservoir and its tributaries.

4. Propose alternatives to mitigate for lost game fish production, and determine the most desirable cost-effective measures.

STUDY AREA

BACKGROUND

Hungry Horse Dam was constructed on the South Fork 8 km upstream from its confluence with the main stem of the Flathead River (Figure 1). This multipurpose project is situated at the headwaters of the Columbia basin power generating system and is utilized for both on-site power generation, water storage for downstream power generation, flood control and irrigation. Water released from HHR passes through an additional19 hydroelectric projects on its way to the Pacific Ocean. The dam is maintained and operated by the Bureau of Reclamation.

Construction of Hungry Horse Dam was authorized by Congress in 1944 under Public Law 329 (58 Stat. 270) primarily in response to a wartime need for power. The pool area was cleared under a series of logging and clearing contracts initiated during May, 1947; all clearing was completed by September, 1952. Approximately 90 million board-feet was removed from the pool area. Construction of the dam began in 1948 and water storage was initiated in 1951. The dam was completed in July, 1953 and the reservoir reached full pool in 1954. Today, the reservoir is 56 km long and covers 9,632 ha at full pool. The dam lies at the foot of the 4,403 km^2 South Fork drainage basin. No fish passage structures were installed in the dam and consequently access to approximately 38 percent of the total drainage area available for spawning salmonids migrating upstream from Flathead Lake was permanently blocked (Figure 2).

The upper South Fork originates at the junction of Danaher and Young's creeks and flows in a northerly direction for 95 km before entering Hungry Horse Reservoir. The average annual discharge into the reservoir (1964 to 1980) was 2,301 cfs with a maximum discharge of 30,200 and a minimum of 127 cfs. The upper 66 km lies entirely within the Bob Marshall Wilderness Area. The upper 84 km of the South Fork from its headwaters to the Spotted Bear River is classified a Wild River under the National Wild and Scenic Rivers Act of 1976 and downstream to HHR the South Fork is classified a Recreational River. Lands within the drainage are administered by the U.S. Forest Service as part of the Flathead National Forest, including portions of the Hungry Horse and Spotted Hear Ranger Districts.

FISH SPECIES

Historic Status

Very little data are available concerning the South Fork and the reservoir fishery before 1958. Prior to construction of Hungry Horse Dam, the South Fork drainage was considered the major

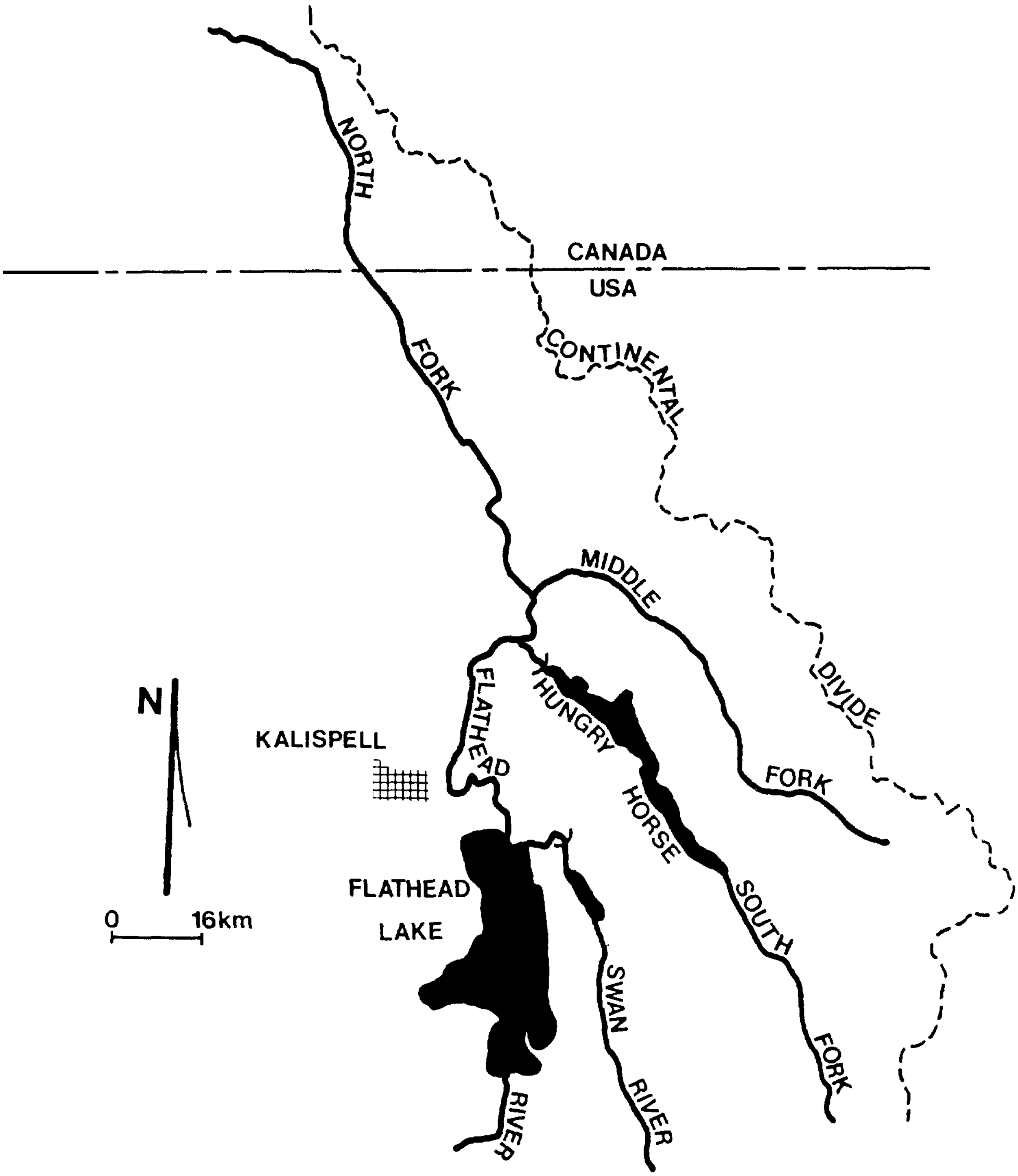

Figure 1. The upper Flathead drainage.

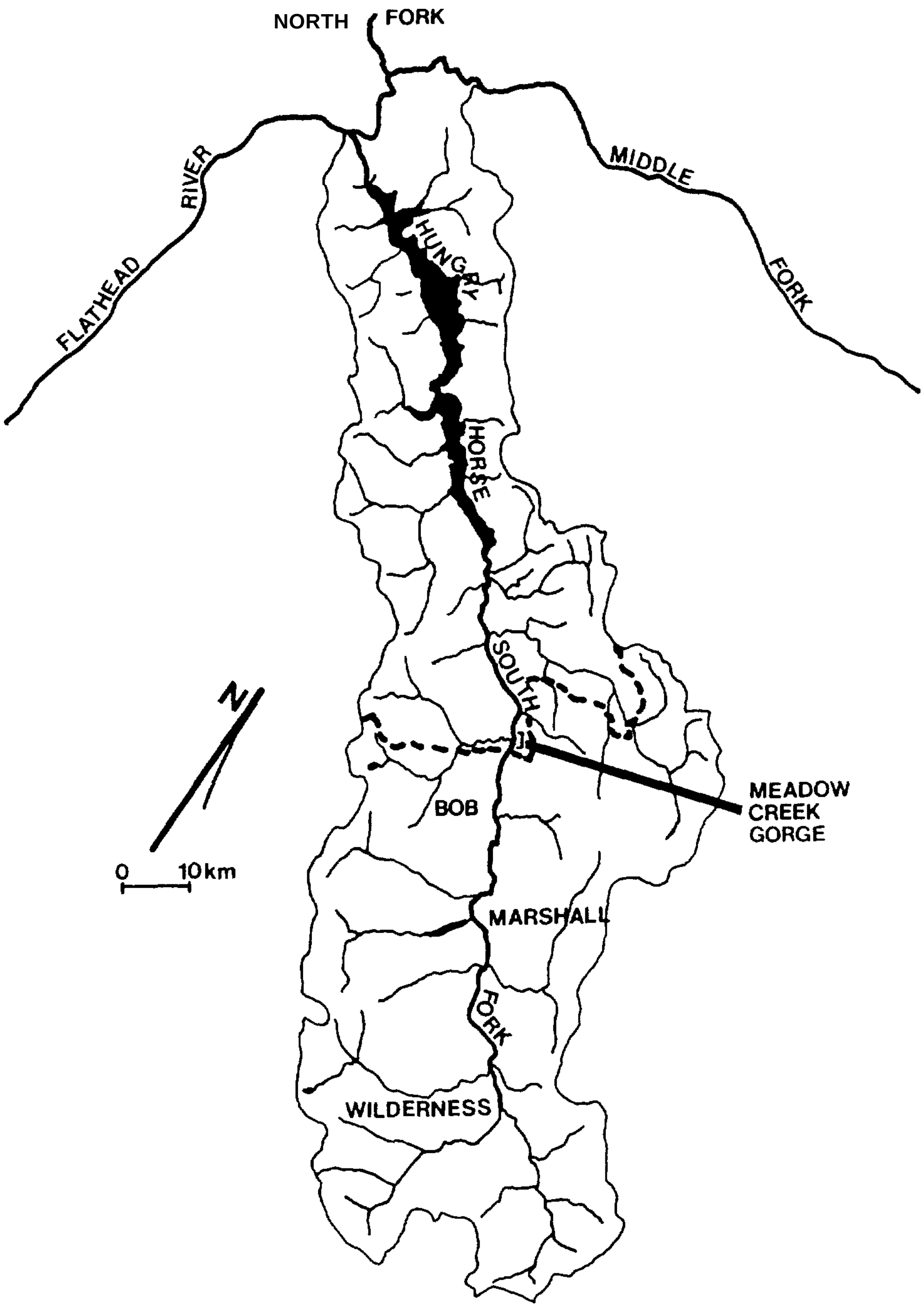

Figure 2. The South Fork of the Flathead River drainage including Hungry Horse Reservoir, major tributaries and Meadow Creek Gorge.

spawning area for adfluvial fish stocks from Flathead Lake. Substantial numbers of bull trout and westslope cutthroat trout spawned in the South Fork drainage along with smaller numbers of mountain whitefish and kokanee salmon (Oncorhynchus nerka). Native fish species in the South Fork drainage prior to dam construction included westslope cutthroat, bull trout, mountain whitefish, pygmy whitefish (Prosopium coulteri) northern squawfish (Ptychocheilus oregonensis), largescale sucker (Catostomus macrocheiles), longnose sucker (Catostomus catostomus), and sculpins (Cottus sp.). The fish species presently inhabiting the reservoir are native and non-native riverine and migratory fish from Flathead Lake trapped behind Hungry Horse Dam when it impounded the South Fork. The two major game fish species in the reservoir and river are westslope cutthroat and bull trout, both classified as a Species of Special Concern in Montana because of declines in abundance and distribution statewide. Exotic species which include yellowstone cutthroat (Salmo Clarki bouvieri), rainbow trout (Salmo gairdneri) and artic grayling (Thymallus arcticus) are present in the reservoir, but rarely collected. Pure westslope cutthroat are found in the South Fork River above the reservoir.

Life History

Three distinct life history patterns of westslope cutthroat commonly occur throughout their native range (Behnke 1979). Juvenile adfluvial cutthroat spend one to three years in the tributaries before emigrating to HHR. They generally reside in the reservoir for onetothree years, mature and returntotheir natal stream in June and July to spawn and complete the life cycle. Some repeat spawners have been found, but most are alternate-year spawners Fluvial westslope cutthroat trout are found in the main stem of the South Fork. These fish have a life cycle similar to the adfluvial strain, except that they grow and mature in a large river rather than a lake or reservoir. The resident strain of westslope cutthroat trout completes its entire life cycle in small headwater streams. Residents seldom reach total lengths greater than 200 mm, whereas fluvial and adfluvial cutthroat trout attain lengths up to 400-450 mm (Shepard et al. 1984) .

Bull trout populations also exhibit the adfluvial, fluvial and resident patterns. Bull trout in the South Fork drainage are primarily adfluvial and migrate from HHR to spawn in tributary streams. Repeat and alternate-year spawners have been found. They are fall spawners and eggs hatch in March compared to July and August for cutthroat trout. Bull trout live longer, grow larger and are much more piscivorousthan cutthroat, Adfluvial bull trout from HHR have attained lengths up to 700 mm (Shepard et al. 1984).

PHYSICAL CHARACTERISTICS

Nutrient-poor and transparent water are characteristic of the drainage because the area is underlain by Precambrian sedimentary rock which is frequently deficient in carbonates and nutrients. The geomorphic processes that shaped the area include alpine and continental glaciation as well as fluvial and gravitational processes associated with stream dissection and structural faulting.

Vegetation consists mostly of coniferous trees and includes warm, dry sites with ponderosa pine and douglas-fir communities at lower elevations; cool, moist sites with grand fir and western red cedar communities at moderate elevations; and cold, alpine sites with alpine fir, white bark pine and small remnants of alpine larch communities at the higher elevations.

Elevation ranges from 3,560 ft at the reservoir during full pool to mountain peaks over 10,000 feet high. Precipitation ranges from about 30 inches annually around the reservoir to more than 90 inches on the higher mountain ridgetops. The wider valleys of the upper South Fork and the "rainshadow effect" of the Mission Mountain range result in progressively drier climates moving upriver from the reservoir.

METHODS

LOSSES DUE TO DAM CONSTRUCTION

Predicting losses due to dam construction which occurred over 30 years ago is extremely difficult, especially with essentially no pre-impoundment data. Blockage of adfluvial fish migration from Flathead Lake is similar to that of anadromous fish in the lower Columbia River basin, where researchers have used two basic approaches to document lost production (Northwest Power Planning Council 1985):

1) Habitat-based methods which rely on known relationships between habitat and production;

2) Biologically-based methods which rely on escapement.

We chose a habitat-based approach to estimate fishery losses because the Montana Department Fish, Wildlife and Parks (MDFWP) has collected extensive habitat information and related it to cutthroat and bull trout populations. Our approach was based on sound biological principles, the best information possible and large data sets. Wherever practical, more than one method was used to compare estimates. We averaged these methods for the final estimates. Confidence intervals, where included, are at the 95 percent level.

Cutthroat trout are spring spawners and adults are difficult to trap effectively due to high stream flows. Therefore, complete estimates of spawning runs are often impossible to obtain. Fraley and Graham (1981) developed a habitat model to predict the abundance of Age I and older cutthroat and juvenile bull trout. This model used measures of trout cover, substrate size and stream order, We attempted to estimate cover prior to inundation from 1945 National Archives aerial photographs (1:22,500). Unfortunately, the resolution was not great enough to detect differences in cover types. Mostofthe study area was either under water or in the Bob Marshall Wilderness complex where extensive field surveys were impractical. Because of these circumstances, we divided tributary streams into reaches based on stream order and gradient. Reach lengths were measured from USGS 7.5 minute topographic maps with a Numonic 2,400 digitablet, and are on file in the MDFWP Special Projects office.

Cutthroat in Tributaries

In order to estimate juvenile cutthroat trout losses due to inundation, we electrofished 10 representative tributary reaches and used seven other tributary estimates collected by May and Zubik (1985) from HHR. We used the two-catch method and the

Petersen mark-recapture technique for streams less and greater than 20 cfs, respectively (Shepard and Graham 1983b) to estimate age I, II, and III fish greater than 75 mm. We combined these data with cutthroat estimates and habitat data collected from 152 tributary reaches from the North, Middle and Upper South Forks of the Flathead River (Montana Department of Fish, Wildlife and Parks, 1982a and 1982b). These combined data were then divided into stream order and gradient categories based on similar density estimates. An estimated cutthroat juvenile rearing potential loss was calculated by reach based on its density estimate for that stream order and gradient category and multiplied by the length of the reach. The estimated losses were summed by reach to predict the total potential juvenile cutthroat rearing loss.

We also used another method to calculate juvenile cutthroat losses whereby all tributary reach population estimates were summed and averaged. This mean was multiplied by the total length of tributary reaches lost. Assumptions used for both of these predictions were:

1. Stream reaches sampled were at carrying capacity for juvenile cutthroat.

2. South Fork streams of similar gradient and stream order supported similar numbers of juvenile cutthroat as North, Middle and South Fork streams surveyed from 1979-1982.

3. First order streams were too small, steep, and/or intermittent to support cutthroat.

4. Rearing capacity can be roughly estimated from important stream habitat characteristics (i.e. stream order and gradient).

5. We assumed that prior to dam construction the larger, more dominant adfluvial cutthroat spawned in the preferred habitats (less than six percent gradient) and that resident fish spawned in habitat with a gradient of six percent or greater.

6. To determine natural barriers to fish migration, we used helicopter survey information (Montana Department of Fish, Wildlife and Parks, 1982a and 1982b). Also, we interviewed long-time personnel from the USFS, outfitters, guides and trappers. Aaserude and Orsborn (1985) felt that adult inland cutthroat could not jump vertical heights greater than four feet and we used this as a cutoff for adfluvial cutthroat migration barriers.

Cutthroat in the Main River

In order to determine the number of cutthroat lost in the main river due to inundation we made a snorkel-Petersen estimate in the Harrison section of the South Fork above HHR (Zubik and Fraley, in press) and in the Whale Creek section of the North Fork. (The snorkel-Petersen method was derived and tested as part of this study and accepted with revision by the North American Journal of Fisheries Management). We applied the estimate to the total length of river inundated and made the following assumptions:

1. The Harrison and Whale Creek sections were similar to reaches of the South Fork inundated by HHR.

2. The reaches that we sampled were at carrying capacity.

Bull Trout

To estimate bull trout losses in the South Fork drainage, we took the 1980, 1981, 1982 and 1986 adult bull trout escapement estimates for the North and Middle Fork basins (Fraley and Shepard 1986, unpublished manuscript). We then calculated a potential bull trout run up the South Fork based on a percentage of the drainage area that the South Fork comprised versus the total Flathead basin drainage area. We assumed that drainage area was proportionalto bull trout escapement and that North and Middle Fork spawning and rearing habitat was similar to that in the South Fork.

ROAD CULVERTS

Road culverts that were possible fish migrationbarriersto reservoir tributaries were monitored by May and Zubik (19851, May and Fraley (1986) and May and Fraley (in press). Stream habitat surveys were also conducted on Hungry Horse tributaries during this time period. We averaged spawning cutthroat estimates for Hungry Horse Creek (May and Zubik 1985) which were calculated from trapping data. We divided this number into the potential spawning gravel above the trap site to calculate the area of spawning gravel per adult. We then divided the area of spawning gravel lost above the road culvert by this factor to calculate the potential number of spawning adults lost. We made the following assumptions:

1. Spawning gravel in other HHR tributaries was similar to that found in Hungry Horse Creek.

2. Hungry Horse Creek spawning potential was at or near carrying capacity.

RESULTS

LOSSES DUE TO DAM CONSTRUCTION

Cutthroat in Tributaries

Juvenile cutthroat density estimates in North, Middle and south Fork tributaries were highly variable (Appendix Table A). Stream order and gradient alone did not explain differences in juvenil cutthroat populations. In certain instances, estimates varied by a factor of 10 for the same stream order and gradient. We did find a general trend with low numbers of cutthroat in very low gradient reaches, high numbers in middle gradient reaches and low numbers in high gradient reaches for each stream order (Figure 3). As a result, we used two approaches to calculate and compare cutthroat juvenile losses. The first involved separating the 169 tributary reaches into similar stream order and gradient categories based on known density estimates (Table 1). We applyed the mean density estimate for that stream order gradient category to the length of tributary reach lost. The second method involved calculating a mean juvenile cutthroat estimate for all reaches sampled and multiplying it by the length of tributary reaches lost.

Total estimated losses were very similar for both methods. May and Fraley (in press) estimated an outmigration of 3,393 juvenile cutthroat from Hungry Horse Creek in 1986 based on trapping information and 2,726 based on stream order and gradient categories. We found an average of 45.5 and 33.4 cutthroat juvenile per 100 m for the 17 tributary reaches sampled around HHR based on actual electrofishing estimates and predictions based on stream order and gradient, respectively. Although the variances were high, we felt this was the best possible approach due to the large number of tributaries sampled, the agreement between methods, the agreement between actual and predicted losses, and that cutthroat habitat in North, Middle and South Fork tributaries appeared to be similar.

A total of 68,886 m of usable cutthroat tributary habitat was inundated by HHR (Appendix Table B). Based on stream order and gradient categories, habitat supporting 19,285 juveniles was lost (Table 2). Using the second method, we calculated an average of 31.9 juvenile cutthroat per 100 m of stream in the 169 North, Middle and South Fork tributary reaches sampled. Applying this mean to the length of tributary reaches inundated resulted in an estimated loss of 21,975 cutthroat juveniles, similar to the losses predicted with the stream order and gradient category method.

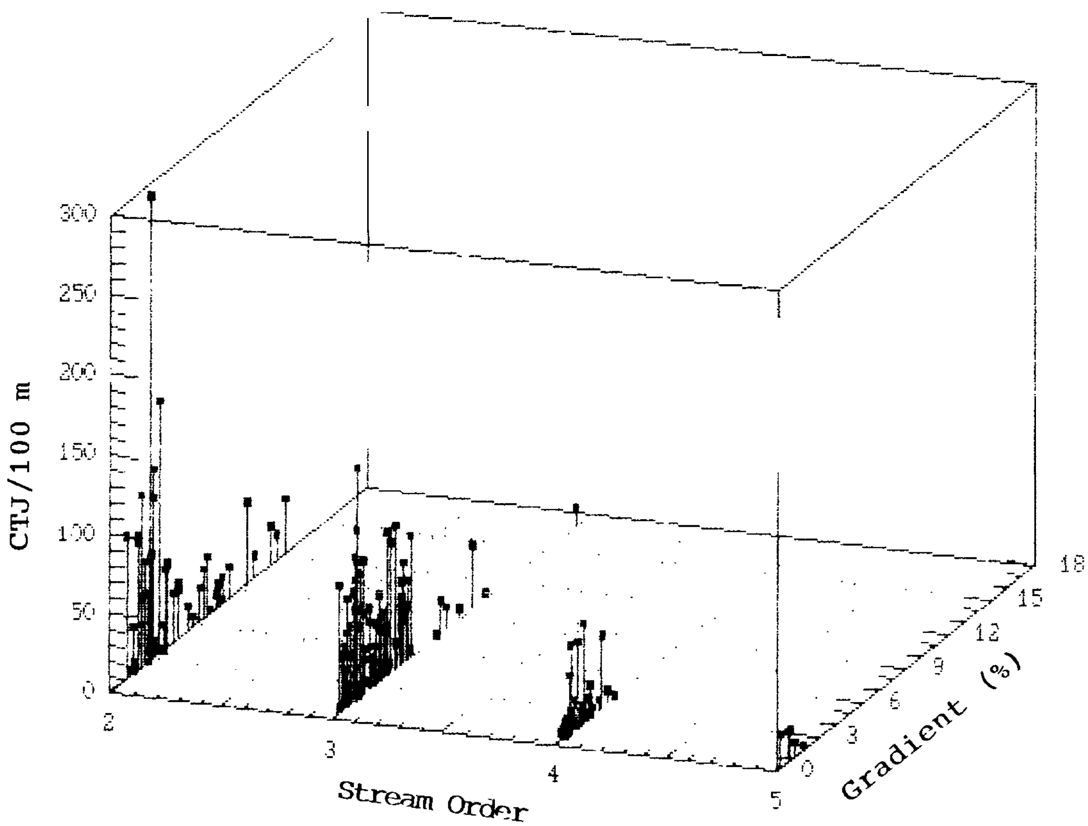

Figure 3. A three dimensional plot of juvenile cutthroat per 100 m versus stream order and gradient for 169 North, Middle and South Fork tributaries.

Table 1. Mean cutthroat estimates per 100 m of stream for juveniles greater than 75 mm by stream order and gradient categories for tributary reaches to the North, Middle and South Forks of the Flathead River.

Stream Order	Gradient (%)	Number Reaches	Mean Estimate	Standard Deviation
2	1.2- 1.9	6	22.7	34.4
2	2.0- 2.7	8	56.9	34.4
2	2.8- 3.8	10	77.6	93.8
2	3.9- 6.9	10	31.0	14.2
2	7.0-12.3	11	18.8	13.9
3	0.5- 1.0	9	22.3	26.1
3	1.1- 1.6	15	38.9	28.8
3	1.7- 2.2	12	62.9	42.3
3	2.3- 4.0	30	25.4	19.7
3	4.1- 5.3	12	43.9	24.2
3	5.4-17.0	9	19.2	24.3
4	0.4- 1.0	10	5.2	3.8
4	l.l- 1.6	8	24.0	21.2
4	1.7- 4.2	14	13.5	18.2
5	0.2- 1.8	5	14.3	7.8
	Mean	169	31.9	36.5

Table 2. Estimated number of cutthroat juveniles lost by stream order and gradient categories for South Fork tributary reaches inundated by Hungry Horse Reservoir.

Stream Order	Gradients (%)	Number Reaches	Length (m)	Mean/ 100 m	Total Lost
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- 6.7	11	7,532	31.0	2,335
2	7.1-12.3	7	5,291	18.8	995
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- 5.3	4	3,369	43.9	1,479
3	5.9-12.8	6	3,327	19.2	639
4	0.9- 0.9	1	3,956	5.2	206
4	2.0- 6.7	5	13,191	13.5	1,781
	TOTAL	55	68,886		19,285

Residents/Adfluvials

We felt that adfluvial adult cutthroat probably used almost all of the preferred spawning habitat since their large body size would give them a competitive advantage in obtaining and holding this habitat over the smaller residents where both exist. From his work on cutthroat trout in tributaries to Lake Koocanusa and HHR, May (MDFWP pers, comm) felt this habitat was primarily found in gradients of less than six percent. As a result of dam construction, 58,254 m of tributary reaches withgradients of less than six percent were inundated (85 percent of the total potential habitat). By using stream order and gradient categories, we calculated that potential habitat was lost for 17,186 adfluvial juveniles destined for Flathead Lake (Table 3). By calculating a mean juvenile cutthroat estimate for reach gradients of less than six percent (33.8 juveniles per 100 m) an estimated 19,690 (90 percent of the total estimated loss) were probably adfluvials which would have emigrated to Flathead Lake.

When Hungry Horse Dam was constructed it not only flooded portions of the river and its tributaries but also blocked access to the South Fork Flathead River. The South Fork drainage comprises about 4,403 km^2 , or 38 percent of the total drainage area available for spawning salmonids from Flathead Lake. We calculated there were 1,075,987 m of potential tributary habitat in the South Fork drainage above full pool (Appendix Table C) which did not include tributary reaches above possible barrier road culverts, Approximately 526,931 m of tributary reaches were less than six percent gradient and no longer accessible to adfluvial cutthroat spawners from Flathead Lake (Table 4). Based on stream order and gradient categories (less than six percent), habitat which would support about 158,297 adfluvial juvenile cutthroat trout was lost to Flathead Lake in South Fork tributaries above full pool. Based on mean population estimates for tributary reaches with gradients less than six percent, about 178,103 adfluvial juvenile cutthroat were lost. The combined loss to Flathead Lake due to dam construction was 585,185 m of potential tributary habitat above and below full pool. This resulted in a potential loss of 170,058 adfluvial cutthroat juveniles based on stream order and gradient categories or 197,793 based on mean population estimates for gradients less than six percent (Table 5).

River Losses

Hungry Horse Dam also flooded 57 km of the South Fork Flathead River The major problem in determining river losses was whether cutthroat juveniles lost were residents, fluvials, adfluvials or a mixed population. Based on tag returns, trapping and snorkeling data Fraley and Graham (1982)felt that juvenile cutthroat in the Middle Fork up to Bear Creek (87 km above the mouth of the South Fork) and in the North Fork up to Trail Creek (96 km above the

Table 3. Estimated number of adfluvial cutthroat juveniles lost by stream order and gradient categories (for gradients less than six percent) in tributary reaches inundated by Hungry Horse Reservoir.

Stream Order	Gradients (%)	Number Reaches	Length (m)	Mean/ 100 m	Total Lost
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

Table 4. Estimated number of adfluvial cutthroat juveniles lost by stream order and gradient categories (for gradients less than six percent) in tributary reaches to the South Fork above full pool (includes the upper South Fork in the Bob Marshall Wilderness Area).

Stream Order	Gradients (%)	Number Reaches	Length (m)	Mean/ 100 m	Total Lost
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

Table 5. Potential adffuvial juvenile cutthroat rearing losses to the Flathead Lake System when Hungry Horse Dam was constructed. Estimates are based on stream order and gradient categories and mean population estimates for South Fork tributaries with gradients less than six percent.

Area	Number of reaches	Length (m)	Number Lost: Stream order & gradient	Number Lost: Mean pp. estimate
Tributaries inundated by HHR	39	58,254	57,185	19,690
HHR tributaries above full pool	35	101,330	39,964	34,250
South Fork tributaries upstream of HHR	86	425,601	112,909	143,853
TOTAL	160	585,185	170,058	197,793

mouth of the South Fork) were almost entirely adfluvials. Based on tag return data May and Fraley (in press) felt that cutthroat juveniles in the main South Fork River are primarily adfluvials below Meadow Creek Gorge and fluvials or residents upstream. The Gorge is located 99 km above the mouth of the South Fork (Figure 2: similar to the distances found for adfluvial juveniles in the North and Middle Fork. As a result, we assumed that all juvenile cutthroat lost in the inundated portion of the South Fork River were probably adfluvials destined for Flathead Lake.

Zubik and Fraley (in press) estimated there were 215 (±29) cutthroat per km in the Harrison section of the South Fork immediately below Meadow Creek Gorge. Applying this figure to the 57 km of river inundated, we estimated that 12,255 (±1,653) juvenile cutthroat were lost to the Flathead Lake system. For comparison, we used a snorkel-expansion estimate conducted on the Whale Creek section of the North Fork (60 km above the mouth of the South Fork) collected in 1985. Based on this estimate, we calculated that 11,571 adfluvial cutthroat juveniles were lost, similar to the Harrison estimate.

Bull Trout Losses

During 1980, 1981, 1982, and 1986, Department personnel made basin-wide bull trout redd counts for the North and Middle Forks (Fraley and Shepard 1986, unpublished manuscript). Based on these counts, they estimated that between 3,004 and 4,877 adult bull trout entered spawning tributaries to the North and Middle Forks, respectively on an annual basis. Since the South Fork above Hungry Horse Dam comprises 38 percent of the drainage area of the Flathead basin, we derived a proportion and estimated that potential spawning habitat for between 1,840 and 2,089 adult bull trout from Flathead Lake were lost when Hungry Horse Dam blocked access to the South Fork.

CULVERT BARRIERS

May and Zubik (1985), May and Fraley (1986) and May and Fraley (in press) monitored possible barrier road culverts on tributaries to HHR for spawning cutthroat trout. These roads were relocated when the pool was flooded. Total and partial barriers were identified (Table 6). May and Zubik (1985) found that there were an average of 752 adult cutthroat in the spawning run for Hungry Horse Creek and 913 m^2 of spawning gravel above the trap for an average of 1.21 m^2 of spawning gravel per adult. By dividing the estimated 484 m^2 of potential spawning gravel above the problem road culverts by this factor, we estimated that habitat which would support 400 potential cutthroat spawners was lost if all habitat could be utilized (Table 6). However, only Felix Creek was a complete barrier to cutthroat spawners. May and Zubik (1985) determined that Riverside, North Fork Logan,

Table 6. Complete or partial culvert barriers to spawning cutthroat in HHR tributaries and the maximum potential losses. Partial barriers are listed in descending order (most to least severe).

Classification	Stream	Potential spawning gravel (m^2)	No. of adults lost
Total barrier	Felix	195.0	161
Partial barrier	Riverside	22.0	18
Partial barrier	N.F. Logan	26.9	22
Partial barrier	Murray	8.0	7
Partial barrier	Harris	64.1	53
Partial barrier	McInernie	167.9	139
TOTAL		483.9	400

Murray, Harris and McInernie Creek road culverts were partial barriers during part of the spawning season. Therefore, the actual number of spawners lost may be less than those predicted, Only Felix Creek contained possible suitable spawning habitat for bull trout, but Huston (MDFWP pers. comm.) felt that none of these tributaries were used by bull trout prior to dam construction.

DISCUSSION

LOSSES

We estimated that potential habitat for about 21,000 age I, II and III cutthroat juveniles was lost in South Fork tributaries inundated by HHR. Based on assumed gradient preferences, 89 percent of these were adfluvials destined for Flathead Lake (Table 7). Habitat for another 12,000 adfluvial juvenile cutthroat destined for the Flathead Lake was lost when the South Fork Flathead River was inundated. Also, habitat for about 165,500 adfluvial cutthroat juveniles were lost to Flathead Lake from South Fork tributaries above full pool when the dam blocked access to the river and its tributaries. We calculated the combined total potential rearing habitat loss for age I, II and III cutthroat juveniles at about 200,000 fish with 98 percent of these adfluvials destined for Flathead Lake. May and Huston (1975) found that about one third of juvenile adfluvial cutthroat out-migrated from Young Creek to Lake Koocanusa annually. Applying this factor to the total adfluvial juvenile loss estimate, we calculated that about 65,287 adfluvial juvenile cutthroat were lost to Flathead Lake annually. Survival rates of cutthroat trout in the lake are not known. However, the majority of the mortality probably occurs in tributary streams during the early life stages.

We estimated a potential spawning habitat loss for about 400 adult cutthroat spawners to the reservoir population if all problem road culverts identified were complete migration barriers. May and Fraley (1986) found a 1:2.4 male to female sex ratio in HHR from gillnet catches which would result in a loss of 233 females. May (MDFWP pers. comm.) calculated that one female would produce about 8 to 12 juveniles to the lake system annually. This would result in potential habitat loss for about 1,900 to 2,800 adfluvial juveniles to Hungry Horse Reservoir on an annual basis.

Based on spawning escapement estimates for the North and Middle Fork of the Flathead River, potential spawning habitat for about 2,100 adult bull trout migrants from Flathead Lake was lost because of blocked access to the South Fork due to dam construction.

RESERVOIR HABITAT

When Hungry Horse Dam was constructed, it trapped adfluvial salmonids destined for Flathead Lake. The dam created 9,632 hectares of new "lake" habitat at full pool. However, reservoir operation adversely affects the habitat for fish and fish food organisms including reductions in reservoir volume, volume in the zone, surface area, wetted bed area of the littoral zone

Table 7. The mean potential habitat losses to cutthroat and bull trout populations in the Flathead System due to the construction of Hungry Horse Dam.

Area	CUTTHROAT TROUT			
	Juveniles			Adults
	Residents	Adfluvial	Total	
South Fork tributaries inundatedby HHR	2,184	18,438	20,622	—
South Fork tributaries above full pool (lost access)	- -	165,488	165,488	—
South Fork River inundated by HHR	--	11,913	11,913	—
Culvert barriers to HHR tributaries		2,350	2,350	—
TOTAL	2,184	198,189	200,373	---
	BULL TROUT			
Dam construction blocking access to South Fork tributaries	--	---	---	2,110

and weakening of the thermal structure (May and Fraley 1986). As a result, fish populations are below the potential carrying capacity if the reservoir remained at full pool on an annual basis.

Fish produced at Hungry Horse Reservoir are not comparable to those produced at Flathead Lake on an individual basis. Flathead Lake receives 11.7 times more fishing pressure from anglers than does Hungry Horse Reservoir on an annual basis (McFarland 1986). Consequently, Flathead Lake fish are much more valuable both to the angler and to the private sector economically, due to the easy accessibility and recreational opportunities the lake provides compared to Hungry Horse Reservoir. Through the MDFWP planning process, fisheries managers identified the interconnected Flathead Lake and River system fishery as the highest priority in Region 1 for the state's strategic fish management plan. Flathead Lake receives the second highest amount of fishing pressure of any lake in the state and is very important to the local economy.

MITIGATION ALTERNATIVES

Because the construction of Hungry Horse Dam had the greatest impacts on cutthroat and bull trout from Flathead Lake, mitigative measures should be taken to offset these losses, if biologically and economically feasible. The MDFWP fisheries policy is to encourage natural reproduction wherever possible and only stock hatchery fish where there is insufficient natural reproduction. Therefore, we feel the ideal situation would be one where mitigative measures would primarily enhance natural reproduction of cutthroat and bull trout and secondarily benefit other species of game fish as well in the Flathead system.

Other losses to fish and wildlife have also been documented in the Flathead basin because of the construction and operation of hydroelectric facilities. Some of these research projects will not be completed until 1988 when mitigation will be recommended using a holistic approach for the entire Flathead basin. Mitigative measures implemented in the basin may also affect downstream projects since HHR is at the headwaters of the Columbia system. Additionally, the future of kokanee salmon, the primary game fish in the basin, is unknown at this time. By 1989, biologists will better understand its needs and what mitigative measures will benefit this species. It is our intent to document fishery losses due to Hungry Horse Dam construction and present an array of possible mitigation alternatives for consideration. The alternatives are listed in order of preference with suggestions on which we feel are the most desirable (Table 8).

In 1902, the 3.7-m high Bigfork Dam was constructed about 2.4 km above the mouth of the Swan River (Figure 1). It blocked access to the Swan drainage for migratory salmonids from Flathead Lake. A multi-step fish ladder was installed in the dam during

Table 8. Possible mitigation alternatives, the species and fishery affected, the potential returns to that fishery, the cost effectiveness of proposed mitigation and desirability of implementation.

Mitigation Alternative	Species Affected[a]	Fishery Affected	Potential Returns	cost Effectiveness	Desirability
Modify/ Reconstruct Bigfork fish ladder	WCT DV KOK	Flathead Lake	High	High	High
Correct road culvert barriers	WCT DV	Flathead Lake	Low	Moderate	Moderate
Rehabilitate tributary streams	KOK WCT DV	Flathead Lake	Moderate	Moderate	*
Artificial propagation	WCT DV	Flathead Lake	High	Low	Moderate
HHR operation	WCT	HHR	?	High	High
Correct road culverts and improve/Enhance old structures	WCT	HHR	Moderate	Low	Moderate
Hatchery or increased capacity	WCT KOK	Flathead Lake	Moderate	Low	*

* Depends on future management recommendations
a/ WCT=westslope cutthroat; DV=bulltrout; KOK=kokanee

the early 1930's and was modified in 1960 to improve upstream fish passage. Currently this hydroelectric project is owned and operated by Pacific Power and Light (PP&L). MDFWP and PP&L personnel found limited fish passage through the ladder from periodic seining and trapping efforts (Rumsey 1986). Leathe and Enk (1985) considered the Swan drainage to be isolated from the Flathead drainage based on bull trout tagging data.

We feel that the Bigfork fish ladder has the potential to pass migratory fish upstream during all seasons and flows with minor modification, proper operation and maintenance. It would provide access to 1,813 km of drainage area for migratory salmonids from Flathead Lake. This would encompass about 40 percent of the drainage area lost to migratory salmonids from Flathead Lake when Hungry Horse Dam blocked access to the South Fork drainage. Cutthroat and bull trout could potentially access and use spawning and rearing habitat in the river and its tributaries throughout the drainage. Rehabilitation of some tributary streams may be required since brook trout have become established in many of the lower gradient tributary reaches in the drainage (Leathe and Enk 1985). Removal or substantial reduction of this exotic species would increase the availability of spawning and rearing habitat for cutthroat and bull trout in the drainage. Imprint plants could be introduced to hasten the establishment of adfluvial cutthroat and bull trout.

After ascending Bigfork Dam, kokanee salmon could potentially spawn in the 8.5 km of Swan River between the outlet of Swan Lake downstream to the mouth of Bear Creek and along the shoreline of Swan Lake. Improved fish passage could enhance and diversify kokanee reproduction for Flathead Lake. Imprint kokanee plants could be introduced at the outlet of Swan Lake to encourage adult returns to the river and lake.

Downstream cutthroat adult, juvenile cutthroat and bull trout, and kokanee fry mortality would probably be minimal since most of the water passes over the spillway during this time period (March through the end of July). Also, there is only a 3.7-m drop in spillway elevation. Downstream bull trout adult survival may be adversely impacted since they outmigrate to Flathead Lake in the fall (September through October). During this time period, most or all of the flow is diverted through the conduit (500 cfs) while a minimum flow of 40 cfs remains in the river channel. Intake grates probably prevent adult bull trout from becoming entrained or entrapped in the diversion or generators.

Another possibility is to improve passage at barrier road culverts to increase natural reproduction by opening access to new tributary habitat in the Flathead system. This could be done by using deflectors, gabions or replacing culverts with bridges depending on the severity of the problem and the potential fishery returns that would be realized. Introduction (imprinting) of cutthroat and/or bull trout could be implemented once the corrections have been made to hasten the recovery of the tributary fishery.

Weaver et al. (1983) identified the Montana State Highway #2 culvert on Tunnel Creek in the Middle Fork drainage as a complete barrier to upstream fish migration. Reach 1 and 2 are 1.4 and 4.3 km long with gradients of 4.2 and 0.9 percent, respectively. Historically, migratory fish from Flathead Lake were found in Tunnel Creek before culvert construction. They also identified the Stanton Creek road culvert on Montana State Highway #2 as a partial barrier to fish migration in the Middle Fork drainage. Stanton Creek is 2.4 km long with a gradient of 3.4 percent and has a partial natural barrier 0.6 km above the road culvert. Since this reach is short and contains a partial barrier, corrective measures would probably not be cost-effective in this instance. Read et al. (1982) identified no man-made barriers to fish migration in the North Fork drainage.

May and Fraley (1986) identified six problem road culverts in the South Fork drainage. Only the Felix Creek road culvert is a total barrier to fish migration and would sustain an estimated 160 spawning cutthroat if corrected. It may be desirable to keep this creek a barrier to Hungry Horse Reservoir fish due to its genetically pure resident cutthroat population. We estimated that McInernie Creek could sustain about 140 potential spawners based on available spawning gravel. May and Fraley (1986) identified this culvert as the least severe partial barrier and corrective measures may or may not contribute significantly to the Hungry Horse population.

Today, there are fewer barriers to fish migration than when Hungry Horse Dam was first constructed due to modification/ replacement of road culvert barriers in the mid 1960's and early 1970's (May and Zubik 1985). Many of these structures are over 20 years old and may need replacement and/or reconditioning. These culverts would need to be inventoried and identified to be considered for possible mitigation. Although these tributaries are very important to the Hungry Horse population, corrective measures would not contribute to the Flathead Lake fishery where the primary fish losses occurred.

Stocking strategies using hatchery plants are many and varied One possibility would be to increase the capacity for raising salmonids at the MDFWP Rose Creek Fish Hatchery for plants in Flathead Lake. Kokanee salmon could be reared to the smolt stage and released directly into Flathead Lake. Construction of an access channel from Flathead River to the MDFWP Creston Hatchery may be desirable since spawn could be collected and fish released directly from the hatchery site. If it were not feasible to rear these fish at the MDFWP Rose Creek Hatchery, a cooperative agreement could possibly be arranged with the Creston National Fish Hatchery (USFWS). MDFWP has initiated supplemental stocking of cutthroat in HHR to augment natural fish production. Monies could possibly be used to defray these costs and/or increase production Management decisions have to be made on the level of production, fish species desired and where and how these fish would be planted.

Operation of Hungry Horse Dam adversely affects the game fish population in Hungry Horse Reservoir. BPA Project No. 83-465 (Quantification of Hungry Horse Reservoir Water Levels Needed to Maintain or Enhance Reservoir Fisheries) will be completed in 1988 and recommend operating procedures that will ultimately benefit game fish in the reservoir and predict increases in fish numbers. These improved operations could be used as partial mitigation.

Another consideration is the improvement of spawning and rearing habitat in Flathead basin tributaries. One option would be rehabilitating Spring Creek, a 13 km tributary to the lower Flathead River (Spratt 1986). The fish habitat of Spring Creek has deteriorated substantially as a result of agricultural and residential practices. Numerous stream crossings with undersized road culverts have restricted the natural flow. As a result, pools have formed and have become sediment traps. Domestic livestock and irrigation have degraded the habitat and dewatered the channel, respectively (Decker-Hess 1986). Domrose (MDFWP pers. comm.) found that kokanee historically used this creek. It could be a prime kokanee spawning tributary due to its potentially favorable water temperatures, spawning gravel and gradient. Another possible rehabilitation site is Brenneman Slough, a 2.4 km spring fed tributary to the lower Flathead River (Decker-Hess 1986). Clancey and Fraley (1986) found that kokanee salmon spawn in portions of this tributary, but production is limited by excessive siltation primarily due to grazing practices. Rehabilitation (fencing) could significantly increase the potential to produce more kokanee in this stream. Also, cutthroat trout could potentially become established in Spring Creek and Brenneman Slough. Beattie (MDFWP pers. comm.) has identified four tributary streams to Flathead Lake that have been degraded by human-related activities. Production of kokanee could be increased in these smaller tributaries through habitat enhancement. Corrective measures, if designed and implemented properly, should either be a one-time process or require minimal additional maintenance and cost.

Section 804 (b)(4) of the Columbia River Basin Fish and Wildlife Program originally called for construction, operation and maintenance of a spawning channel in the South Fork below the dam. Another possible site for a spawning channel is immediately below Bigfork Dam (Rumsey1985). Spawning channels would probably be suitable for production of kokanee salmon only since fry immediately emigrate downstream. Cutthroat and bull trout rear for onetothree years in tributary streams before entering the lake system and these channels would not provide the needed rearing space and cover for juvenile fish. Without this rearing habitat, cutthroat and bull trout juveniles may be flushed through the system with no gains realized. Also, these channels are usually expensive to construct and often require constant maintenance.

RECOMMENDATIONS

Based on best estimates of fishery losses due to the construction of Hungry Horse Dam and the possible mitigation alternatives, we feel that proper operation and maintenance of the Bigfork fish ladder has the potential to be one of the most cost-effective and desirable. Prior to the construction of Hungry Horse and Bigfork dams, adfluvial salmonids could access approximately 13,000 km^2 of drainage area in the North, Middle, South Fork and Swan drainages. Construction of Hungry Horse and Bigfork dams blocked or significantly reduced access to about 46 percent of this original drainage area available to migratory salmonids. Although the total ramifications of lost access are not known, significant impacts to the natural reproductive potential for migratory salmonids from Flathead Lake must have occurred, especially for adfluvial fish.

Making the Bigfork fish ladder passable is desirable because mitigation would be off-site and no changes in dam operations would be required. We feel the present structure could be easily modified to pass fish and therefore potential costs could be minimal. A commitment would be needed to ensure proper flows through the ladder. Natural reproduction would partially replace documented losses versus costly hatcheries or spawning channels. This is consistent with the MDFWP philosophy of encouraging natural reproduction wherever the potential exists.

Losses to kokanee salmon due to Kerr Dam operation have been documented (Decker-Hess and Clancey 1984, Fraley and Decker-Hess, in press). Presently, MDFWP feels that increased production of kokanee is needed in Flathead Lake. Access to the Swan system could potentially increase kokanee production and mitigate for some of the kokanee losses in Flathead Lake. Presently, there is no established adfluvial cutthroat population in the Swan drainage despite an intensive stocking program (Leathe 1985). Another potential benefit may be the establishment of a viable adfluvial cutthroat fish stock in the Swan drainage.

A feasibility/monitoring study should be initiated and consist of two parts:

Part 1: Feasibility

a. Document the potential habitat available and possible production for migratory salmonids in the Swan drainage.

b. Determine the best design, operation and potential costs involved to improve fish passage up the Bigfork fish ladder during all seasons and flows.

Part 2: Monitoring/Evaluation

a. If there is significant potential habitat available which has the capability to substantially increase reproduction in Flathead Lake, implement the design and operational changes in the Bigfork ladder.

b. Monitor (through trapping) the movement of migratory salmonids through the Bigfork fish ladder. Tag these fish to determine movement and use patterns in the Swan drainage.

c. Remove or significantly reduce brook trout from selected prime potential adfluvial cutthroat and bull trout juvenile habitat.

d. Introduce imprint plants to hasten the recovery of lost migratory fish reproduction to Flathead Lake.

e. Monitor (trap) downstream juveniles and young-of-the-year fish to ensure that the Swan drainage is making a significant contributon to the Flathead Lake system.

The Swan drainage has the potential to replace some of the spawning and rearing habitat lost in the South Fork drainage. How improved access would affect the Swan system fishery, it's carrying capacity and the actual production to and its effects on the Flathead Lake fishery are not known at this time. A feasibility study would be imperative to ascertain that all fish species could be passed upstream and that adequate habitat is available to significantly increase reproduction in Flathead Lake. The feasibility study should be accomplished prior to the completion of the other mitigation studies. If the project is deemed feasible, it should be implemented as partial mitigation and be included with other selected alternatives in a basin-wide holistic plan. A monitoring program must be initiated to determine that once the Swan drainage reaches carrying capacity that it will significantly contribute to the Flathead Lake fishery,

Once all the mitigation studies have been completed a mitigation "package" should be prepared for the entire basin and involve all affected agencies and organizations, including the public. These mitigative measures, once initiated, should be monitored, evaluated and adjusted, if necessary to ensure a successful mitigation program.

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APPENDIX A

The reach, stream order, gradient and juvenile cutthroat estimates for tributaries to the North, Middle, and South Forks of the Flathead River.

Appendix A. The reach, stream order, gradient and juvenile cutthroat (WCC) estimates (>75mm) for tributaries to the North, Middle, and South Forks of the Flathead River.

Drainage	Stream	Reach	Stream Order	Gradient(%)	WCT Juveniles per 100m
North Fork	Kintla	1	2	1.7	29.3
	Starvation	2	2	1.8	7.3
	Dutch	2	2	2.0	80.5
	Moose	3	2	2.8	291.4
	Mathias	1	2	2.8	6.8
	Akokala	2	2	2.9	66.6
	Langford	2	2	3.0	119.0
	Langford	1	2	3.0	101.0
	Moose	2	2	3.5	158.9
	Cummings	1	2	6.6	30.7
	Coal	4	2	7.5	8.8
	Hay	4	2	7.6	14.8
	Red Meadow	3	2	7.9	16.1
	Dutch	3	2	10.1	14.5
	Anaconda	2	2	11.7	16.7
	Long Bow	1	2	12.3	34.2
	Coal	2	3	0.7	35.0
	Camas	2	3	1.0	10.9
	Yakinikak	4	3	1.3	48.8
	Hay	2	3	1.5	69.2
	Hay	1	3	1.5	28.9
	Tuchuck	1	3	1.6	76.0
	Logging	1	3	1.6	28.6
	Ketchikan	1	3	1.6	90.7
	Bowman	1	3	1.7	145.6
	Red Meadow	2	3	1.7	87.6
	Dutch	1	3	1.8	79.2
	Anaconda	1	3	2.0	75.6
	Red Meadow	1	3	2.2	84.0
	Spruce	1	3	2.3	20.9
	Spruce	2	3	2.6	50.0
	Moose	1	3	2.6	51.8
	Coal	3	3	2.7	18.0
	Cyclone	1	3	2.9	15.5
	Ford	2	3	2.9	14.1
	South Fork Coal	1	3	3.0	2.4
	Starvation	1	3	3.1	14.0
	Ketchikan	3	3	3.1	37.6
	Ford	1	3	3.4	39.2
	Hay	3	3	3.4	31.0
	Coal	3	3	3.8	28.0
	Moran	1	3	3.9	89.9
	Parke	2	3	4.9	28.0
	Parke	1	3	4.9	41.6
	Ketchikan	2	3	4.9	51.3

Drainage	Stream	Reach	Stream Order	Gradient(%)	WCT Juveniles per 100m
North Fork (continued)	Moran	3	3	5.5	3.7
	Kletomas	1	3	7.3	0.9
	Moran	2	3	7.6	20.1
	Werner	1	3	8.0	13.2
	McGinnis	1	3	8.9	6.0
	Kimmerly	1	3	9.8	38.9
	Yakinikak	5	3	10.7	2.7
	Ford	3	3	17.0	11.1
	Whale	2	4	0.7	7.8
	Coal	1	4	1.2	13.5
	Akokala	1	4	1.4	18.7
	Big	1	4	1.5	1.4
	Granite	1	4	1.7	4.3
	Hallowat	1	4	1.7	1.4
	Quartz	1	4	2.0	62.1
	Coal	1	4	2.4	12.1
	Canyon	1	4	3.7	7.5
Middle Fork	Gateway	4	2	1.2	89.8
	Whistler	1	2	1.6	4.2
	Bergsicker	1	2	1.7	2.4
	Long	2	2	1.8	3.1
	Essex	1	2	2.2	108.4
	Charlie	1	2	2.2	28.0
	Basin	3	2	2.2	44.6
	Walton	2	2	2.5	55.5
	Argosy	2	2	2.7	43.3
	Charlie	2	2	2.7	1.2
	Long	3	2	3.2	4.9
	Miner	2	2	3.3	10.1
	South Fork Trail	1	2	3.8	15.4
	Bowl	5	2	3.8	0.6
	Park	4	2	4.5	31.0
	Gateway	3	2	4.8	30.5
	Schafer	4	2	5.5	15.6
	Argosy	1	2	5.8	6.5
	Clack	3	2	7.0	3.1
	Cox	1	3	0.6	2.5
	Lake	2	3	0.7	4.3
	Park	2	3	0.9	39.5
	Schafer	3	3	1.0	24.2
	Strawberry	4	3	1.0	2.6
	Dolly Varden	1	3	1.0	2.0
	Lodgepole	1	3	1.1	3.1
	Basin	2	3	1.1	32.2
	Basin	1	3	1.1	67.9
	Ole	2	3	1.1	45.1
	Miner	1	3	1.3	4.3
	Schafer	2	3	1.3	12.1
	cox	2	3	1.5	55.7

Drainage	Stream	Reach	Stream Order	Gradient(B)	WCT Juveniles per 100m
Middle Fork (continued)	Trail	1	3	1.6	2.1
	Ole	1	3	1.6	16.3
	Morrison	3	3	1.7	20.5
	Harrison	1	3	1.9	6.8
	Strawberry	3	3	1.9	0.5
	Ole	3	3	2.0	43.7
	Park	3	3	2.2	50.5
	Calbic	1	3	2.3	27.7
	Morrison	2	3	2.3	7.0
	Pinchot	2	3	2.6	41.8
	Trail	2	3	2.7	3.4
	Lodgepole	2	3	2.8	18.1
	Lake	1	3	2.9	16.3
	Lincoln	2	3	3.0	24.6
	Challenge	1	3	3.3	54.0
	Bowl	4	3	3.4	4.1
	Stanton	1	3	3.5	8.2
	Muir	2	3	3.8	31.3
	West Fork Schafer	1	3	3.8	31.9
	Gateway	1	3	3.8	3.6
	Gateway	2	3	4.0	6.1
	Muir	3	3	4.4	90.2
	Pinchot	1	3	4.5	15.6
	Walton	1	3	4.8	22.4
	Twentyfive Mile	3	3	4.9	34.3
	Muir	1	3	5.0	62.6
	E. Fk. Strawberry	1	3	5.2	33.9
	Strawberry	1	4	0.7	1.3
	Schafer	1	4	0.7	0.8
	Shorty	1	4	0.9	9.9
	Tunnel	2	4	0.9	1.1
	Bowl	1	4	1.0	2.0
	Granite	2	4	1.0	9.6
	Bowl	3	4	1.0	3S.3
	Strawberry	2	4	1.1	54.1
	Morrison	1	4	1.1	2.1
	Park	1	4	1.7	12.9
	Lincoln	1	4	2.0	8.3
	Bowl	2	4	2.2	2.2
	Nyack	2	4	2.5	1.8
	Giefer	1	4	2.5	19.7
	Sear	3	4	2.6	4.5
	Skyland	1	4	3.1	6.1
	Tunnel	1	4	4.2	0.8
	McDonald	1	5	0.2	20.9
	Bear	2	5	0.9	18.9
	Trail	1	5	1.2	9.0
	Bear	1	5	1.8	3.1

Drainage	Stream	Reach	Stream Order	Gradient(%)	WCT Juveniles per 100m
South Fork	Emery	1	2	2.0	84.1
	Clark	1	2	3.9	49.9
	McInernie	1	2	4.0	53.2
	Bent	2	2	4.8	34.4
	South Fork Logan	1	2	6.3	21.3
	Murray	1	2	6.8	37.3
	Dead Horse	2	2	7.9	3.6
	Ryle	1	2	8.4	19.1
	Deep	1	2	9.6	51.1
	Devil's Corkscrew	1	2	11.3	24.4
	Gordon	3	3	0.5	80.0
	Gordon	4	3	1.7	106.7
	Wounded Buck	1	3	2.0	53.7
	Quintonkon	2	3	2.3	27.2
	Tent	1	3	3.6	41.9
	Dead Horse	1	3	3.8	3.2
	Lost Johnny	1	3	4.1	81.8
	Wounded Buck	3	3	4.5	16.7
	Riverside	1	3	5.3	48.9
	Forest	1	3	5.5	76.0
	Gordon	1	4	0.4	4.9
	Little Salmon River	1	4	0.6	5.5
	Youngs	1	4	0.8	9.6
	White River	1	4	1.1	12.9
	Sullivan	2	4	1.6	52.9
	White River	2	4	3.3	45.6
	Danaher	1	5	0.7	19.6

APPENDIX B

The reach, stream order, gradient and length of potential salmonid habitat lost for tributary reaches to the South Fork inundated by Hungry Horse Reservoir.

Appendix B. The reach, stream order, gradient and length of Potential salmonid habitat lost for tributary reaches to the South Fork inundated by Hungry Horse Reservoir.

Stream	Reach	Stream Order	Gradient(%)	Length(m)
Harris	1	2	0.4	2792
East Hungry Horse	1	2	1.4	853
Clark	1	2	1.7	620
Betty	1	2	1.8	505
Deep	3	2	2.2	1692
Murray	1	2	2.6	2312
Goldie	1	2	2.8	2689
McInernie	1	2	2.9	772
Clark	2	2	3.4	534
Logan	2	2	3.6	704
Deep	2	2	3.6	671
Deep	1	2	4.0	767
Dry Park	1	2	4.5	405
Goldie	2	2	4.5	543
Hoke	1	2	4.6	1033
South Fork Logan	1	2	5.3	487
Murray	2	2	5.4	734
McInernie	2	2	5.7	638
East Hungry Horse	2	2	5.8	501
Canyon	1	2	6.0	1412
Lion Hill Gorge	2	2	6.1	697
Brush	1	2	6.7	315
Deadhorse	1	2	7.1	485
Fire	1	2	7.4	1647
Lid	1	2	8.1	1040
Mazie	1	2	8.6	670
Devils Corkscrew	1	2	10.3	475
Betty	2	2	12.1	379
Anna	1	2	12.3	595
Graves	1	3	0.6	8692
Wounded Buck	3	3	2.6	1626
Emery	1	3	2.6	2143
Logan	1	3	2.9	1222
Dudley	1	3	3.1	741
Lost Johnny	2	3	3.3	550
Wheeler	2	3	3.4	646
Doris	4	3	3.5	524
Clayton	1	3	3.6	1525
wounded Buck	1	3	3.8	407
Knieff	1	3	4.3	1057
Flossy	1	3	4.6	1456
Riverside	2	3	4.9	433
Forest	1	3	5.3	423
Knieff	2	3	5.9	727

Stream	Reach	Stream Order	Gradient(%)	Length(m)
Graves	2	3	6.4	287
Flossy	2	3	6.8	539
Doris	3	3	7.7	711
Clayton	2	3	9.1	539
Wounded Buck	2	3	12.8	524
Sullivan	1	4	0.9	3956
Hungry Horse	1	4	2.0	6770
Wheeler	1	4	2.1	1457
Riverside	1	4	2.4	3600
Doris	1	4	3.5	1047
Doris	2	4	6.7	317
Total				68886

APPENDIX c

The reach, stream order, gradient and length
of potential adfluvial habitat for
South Fork tributaries above full pool.

Appendix C. The reach, stream order, gradient and length of potential adfluvial habitat for South Fork tributaries above full pool. (NN = unnamed tributary)

Stream	Reach	Subreach	Stream Order	Gradient(%).	Length(m)
East HHR NN1	1		2	20.9	640
Emery	1		3	2.0	10000
Emery	1	1	2	17.1	1411
Emery	1	2	2	5.8	261
Emery	1	3	2	16.6	771
Emery Loop	1	4	2	2.2	1624
Emery Loop	1	5	2	5.9	1501
Emery Loop	2		2	2.2	684
Emery Loop	2	1	2	11.2	1498
Strife	1		2	5.4	424
Hungry Horse	1		3	1.7	6264
Hungry Horse	1	1	3	4.4	415
Hungry Horse	1	2	2	14.5	1180
Hungry Horse	2		2	4.5	2150
Hungry Horse	3		2	7.9	1001
Lost Mare	1		2	5.7	1199
Lost Mare	2		2	18.3	2100
Tiger	1		2	3.3	1906
Tiger	2		2	3.7	976
Turmoil	1		2	12.2	2702
Margaret	1		2	8.0	6575
East HHR NN2	1		2	10.6	1821
East HHR NN3	1		2	6.3	725
Fire	1		2	7.9	2791
Spring Meadow	1		2	11.0	2240
Ada	1		2	7.9	464
Tent	1		3	3.2	717
Tent	2		2	6.8	693
Ryle	1		2	8.9	960
Ryle	2		2	12.2	1225
Dudley	1		2	4.3	2659
Riverside	1		3	5.9	1237
Riverside	2		3	10.2	2861
Riverside	3		2	10.8	1575
Riverside	3	1	2	25.3	1011
East HHR NN4	1		2	8.3	1032
Murray	1		2	6.8	1100
Murray	2		2	15.1	4361
McInernie	1		2	4.6	1864
McInernie	2		2	19.0	3265
Deep	1		2	9.6	1399
Canyon	1		2	7.8	1100
Canyon	2		2	17.1	2000
Harris	1		2	8.2	1800
Harris	2		2	21.4	2499
Logan	1		2	4.8	2499

Stream	Reach	Subreach	Stream Order	Gradient(%)	Length(m)
Logan	2		2	12.1	2499
South Fork Logan	1		2	6.3	2900
South Fork Logan	2		2	21.3	2499
Devil's Corkscrew	1		2	11.3	2100
Hoke	1		2	6.3	1900
Hoke	2		2	23.0	2600
Baptiste	1		2	5.4	1399
Baptiste	2		2	22.5	2399
Deadhorse	1		2	6.3	1365
Deadhorse	2		2	10.1	2531
Peters	1		2	10.2	2700
Peters	2		2	3.9	620
Brush	1		2	26.4	2499
Dry Park	1		2	23.2	1900
East HHR NN5	1		2	15.9	1382
Beta	1		2	23.8	3000
Mamie	1		2	19.8	369
Doris	1		3	3.5	2100
Doris	2		3	5.8	340
Seneca	1		2	25.2	2177
Endor	1		2	27.9	1605
Lost Johnny	1		3	4.1	1000
wounded Buck	1		4	2.1	4709
Wounded Buck	2		3	3.9	2512
Elya	1		2	15.1	1299
Flossy	1		3	15.8	1470
Flossy	2		2	13.3	1374
Flossy	2	1	2	15.7	1084
Goldie	1		2	8.3	2358
Mazie	1		2	17.5	3200
Forest	1		3	8.3	4200
Forest	2		2	15.4	1700
Forest	2	1	2	19.9	658
Quintonkon	1		3	3.3	5200
Clark	1		2	3.9	2500
Clark	2		2	6.8	3000
Sullivan	1		4	1.2	10800
Sullivan	2		3	2.2	8346
Sullivan	3		2	7.5	3025
Slide	1		2	5.5	2100
Slide	2		2	8.4	1600
Connor	1		3	3.3	4800
Connor	1	1	2	5.5	4721
Connor	2		2	8.8	2108
Connor	2	1	2	8.0	804
Branch	1		3	5.3	1542
Branch	2		2	3.6	2261
Branch	2	1	2	7.6	1166
Wheeler	1		3	2.8	1700
Wheeler	2		3	2.6	8300

Stream	Reach	Subreach	Stream Order	Gradient(%)	Length(m)
Trapper	1		2	12.0	4166
Soldier	1		2	6.4	6539
Lower Twin	1		3	2.2	6736
Lower Twin	1	1	2	29.7	430
Lower Twin	1	2	2	16.7	346
Twin	1		4	1.3	6807
North	1		3	7.0	2379
Tin	1		3	4.0	1494
Tin	2		3	7.1	3097
Tin	3		2	13.1	2889
Spotted Bear River	1		5	0.3	29485
Spotted Bear River	2		4	2.0	3503
Bent	1		2	4.0	1542
Bent	2		2	4.8	3848
Bent	3		2	2.9	2083
Trail	1		2	8.4	5084
Sergeant	1		3	4.4	4704
Sergeant	1.	1	2	4.4	1353
Sergeant	2		2	10.9	2605
Sergeant	2	1	2	4.0	686
Big Bill	1		2	14.0	1102
Big Bill	2		2	11.9	2058
Deer	1		2	19.3	711
Whitcomb	1		3	6.7	457
Milk	1		2	5.0	245
Silvertip	1		3	4.8	1814
Dean	1		4	4.8	3893
Dean	1	1	2	19.5	1622
Dean	2		3	3.0	3206
Dean	2	1	2	17.5	1801
Dean	2	2	3	15.8	675
Dean	2	3	2	35.6	531
Dean	2	4	2	23.2	1183
Dean	3		2	2.3	5749
Dean	3	1	2	16.2	1667
Spotted Bear NNl	1		2	13.3	791
Slim	1		2	7.3	2419
Addition	1		4	4.2	2639
Jungle	1		3	7.9	2255
Jungle	2		3	18.5	2255
Jungle	3		2	21.0	1047
Larch	1		2	15.0	2655
South Fork NNl	1		2	14.6	1814
Harrison	1		4	3.8	5486
Harrison	1	1	3	12.2	1051
Harrison	1	2	2	12.4	1568
Harrison	2		3	5.9	1897
Harrison	2	1	3	8.4	2502
Harrison	2	2	2	13.0	280
Harrison	3		2	15.8	'2466

Stream	Reach	Subreach	Stream Order	Gradient(%)	Length(m)
Harrison	3	1	2	14.6	2176
Corporal	1		2	3.8	2189
Bunker	1		5	0.6	8170
Bunker	1	1	2	23.3	1191
Bunker	2		4	4.6	529
Gorge	1		4	2.1	5656
Gorge	1	1	3	2.1	893
Gorge	1	1	3	21.7	893
Gorge	1	2	2	19.7	977
Gorge	2		3	1.3	7357
Gorge	2	1	2	17.2	3103
Gorge	2	2	2	18.4	2809
Gorge	2	3	2	26.2	1233
Gorge	3		3	7.9	2149
Gorge	4		2	1.5	877
Gorge	4	1	2	15.9	961
Inspiration	1		2	7.4	4858
Stadim	1		4	3.4	4433
Stadium	2		3	5.8	1844
Stadium	3		2	7.6	3353
Stadium	3	1	2	26.6	1285
Trickle	1		2	6.9	5999
Cannon	1		3	5.0	6630
Cannon	2		2	10.3	653
Feather	1		3	12.6	4109
Feather	2		2	18.3	518
Willow	1		2	4.0	1051
Willow	2		2	19.1	1568
South Fork NN2	1		2	19.0	1503
Mid	1		3	3.7	10171
Mid	1	1	2	16.0	1679
Mid	1	2	2	10.4	1335
Mid	1	3	2	22.0	1218
Mid	2		2	11.1	2720
Mid	2	1	2	14.6	2042
Picture	1		3	11.0	2128
Picture	2		2	13.5	1713
Black Bear	1		4	3.3	6358
Black Bear	2		3	4.2	1285
Black Bear	3		2	9.0	2872
Rambler	1		3	6.3	2688
Slick	1		3	7.6	3029
Slick	2		2	8.6	2710
Hungry	1		2	6.8	5013
snow	1		3	8.0	2425
snow	2		2	13.3	1371
Snow	2	1	2	10.6	979
Helen	1		3	5.4	5556
Helen	2		2	12.8	2619
North Fork	1		2	11.2	4027

Stream	Reach	Subreach	Stream Order	Gradient(%)	Length(m)
Damnation	1		3	7.7	4418
Damnation	1	1	2	24.2	1715
Damnation	1	2	2	15.2	2040
Damnation	2		2	20.5	1547
Damnation	2	1	2	20.7	1235
Little Salmon	1		4	1.1	19342
Little Salmon	1	1	2	25.3	1556
Little Salmon	1	2	2	23.5	1481
Little Salmon	1	3	2	23.4	1563
Little Salmon	2		3	3.3	3202
Little Salmon	2	1	2	16.6	1800
Little Salmon	2	2	2	20.2	2544
Little Salmon	3		2	4.7	4996
Little Salmon	3	1	2	6.1	1127
Palisade	1		3	8.0	4366
Palisade	1	1	2	29.2	964
Palisade	2		2	7.8	560
Palisade	2	1	2	17.2	1447
Gill	1		2	8.7	4866
Combat	1		3	16.3	2419
Con-bat	2		2	15.1	1693
Combat	2	1	2	20.3	1141
Highrock	1		2	14.8	3809
Chasm	1		2	11.9	4362
Big Salmon River	1		4	1.3	1300
Big Salmon River	2		4	0.6	7309
Spud	1		2	9.7	5588
Sappho	1		2	14.1	3885
Sappho	1	1	2	13.7	1801
Brownie	1		2	16.9	2994
Casey	1		2	8.8	6247
Charlotte	1		2	37.4	890
Phil	1		3	6:0	5505
Phil	1	1	2	10.2	803
White River	1		4	1.7	13254
Straight	1		2	13.1	2412
South Fork	1		3	5.0	3966
South Fork	2		2	18.8	2468
South Fork	2	1	2	18.8	5432
Holbrook	1		3	3.4	9013
Holbrook	2		2	4.5	4573
Scarface	1		3	6.4	2594
Scarface	2		2	10:6	778
Scarface	2	1	2	7.9	346
Burnt	1		3	4.7	8079
Burnt	1	1	2	25.7	1420
Burnt	2		2	8.4	2883
Burnt	2	1	2	18.6	1637
South Fork NN3	1		2	9.9	2555
Bartlett	1		3	2.6	7849

Stream	Reach	Subreach	Stream Order	Gradient(%)	Length(m)
Bartlett	1	1	2	22.4	2387
Bartlett	1	2	2	25.3	964
Bartlett	1	3	2	10.1	5432
Bartlett	2		2	8.4	3429
Cluster	1		3	4.3	2427
Cluster	2		3	14.9	716
Cluster	2	1	2	9.9	1606
Cluster	3		2	17.0	1021
Cluster	3	1	2	29.5	672
Una	1		2	11.9	5376
Brownstone	1		3	11.2	41015
Brownstone	2		2	11.8	568
Brownstone	2	1	2	14.8	661
Cayuse	1		3	1.0	4473
Cayuse	2		2	8.7	5446
Catchem	1		2	5.0	2509
Francois	1		2	3.5	739
Francois	2		2	16.9	3901
Gordon	1		4	0.6	16863
Gordon	1	1	2	11.0	981
Gordon	1	2	2	20.8	2858
Gordon	1	3	2	23.9	1736
Gordon	1	4	2	21.0	1280
Gordon	1	5	2	21.4	1273
Gordon	1	6	2	15.0	1851
Gordon	1	7	2	18.1	1924
Gordon	2		3	0.7	6443
Gordon	2	1	2	22.8	1567
Gordon	3		3	2.6	3075
Gordon	4		2	9.3	2403
Lick	1		3	3.6	2277
Lick	2		2	19.7	958
Lick	2	1	2	8.9	1113
Doctor	1		2	5.9	4005
George	1		2	4.5	5078
Shaw	1		2	6.7	4373
Cardinal	1		3	9.2	2698
Cardinal	2		2	18.9	2716
Cardinal	2	1	2	19.5	875
Gabe	1		3	22.2	2150
Gabe	2		2	19.1	1788
Elk	1		2	24.5	1569
Youngs	1		4	0.5	2774
Youngs	2		4	1.3	2088
Youngs	3		4	1.9	9023
Youngs	4		3	1.4	2541
Youngs	5		2	2.8	3751
Ross	1		3	2.8	652
Ross	2		2	7.5	3398
Spruce	1		2	19.8	1093

Stream	Reach	Subreach	Stream Order	Gradient(%)	Length(m)
Jenny	1		3	5.5	2017
Jenny	2		2	4.2	2687
Marshal	1		3	2.9	7445
Marshal	2		2	9.6	1277
Marshal	2	1	2	8.3	1685
Boulder	1		2	14.4	2229
Babcock	1		3	2.1	13382
Babcock	1	1	2	24.3	1106
Babcock	1	2	2	29.2	1148
Babcock	2		2	2.2	1682
Furious	1		2	14.4	3238
Cabin	1		3	4.6	3616
Cabin	2		2	6.8	4939
Otter	1		2	8.6	4142
Kid	1		2	18.8	1670
Hahn	1		3	4.1	5789
Hahn	1	1	2	22.2	972
Hahn	2		2	6.0	6237
Hahn	2	1	2	17.3	369
Jumbo	1		2	12.1	2740
Danaher	1		5	0.7	15565
Danaher	2		4	0.3	12017
Danaher	3		3	1.7	4411
Limestone	1		3	3.7	5044
Limestone	2		2	11.3	2460
Limestone	2	1	2	8.4	3313
Helib	1		2	8.9	3619
Limestone NNl	1		2	8.0	3771
White	1		2	5.7	1858
Bar	1		3	2.2	1886
Bar	2		2	6.3	1644
Bar	2	1	2	4.3	3137
Bar	3		2	9.3	1701
Calf	1		3	3.5	2951
Calf	2		2	7.8	5075
Little Calf	1		2	5.1	2255
Spring	1		2	3.9	2568
Spring	2		2	12.1	2211
Alloy	1		2	7.7	4507
Rapid	1		4	1.9	5277
Rapid	2		3	7.2	3898
Rapid	3		2	12.7	624
Rapid	3	1	2	13.7	625
Foolhen	1		3	3.3	4760
Foolhen	1	1	2	10.4	2369
Foolhen	2		2	4.6	2803
Foolhen	2	1	2	10.9	1175
Ayres	1		2	4.8	2872
Ayres	2		2	13.5	1401
Basin	1		4	1.8	4018

Stream	Reach	Subreach	Stream Order	Gradient(%)	Length(m)
Basin	2		2	4.4	7083
Basin	2	1	2	10.7	2385
Basin	3		2	20.2	618
Stadler	1		3	4.9	5240
Stadler	2		2	11.7	780
Camp	1		3	4.8	3467
Camp	1	1	2	11.2	2668
Camp	2		3	7.2	800
Camp	3		2	11.5	1825
Wigwam	1		2	9.8	2521
Total					1075987