RECLAMATION
Managing Water in the West

Cle Elum and Bumping Lake Dams Fish Passage Facilities Biology Appendix

Storage Dam Fish Passage Study Yakima Project, Washington

Technical Series No. PN-YDFP-012

U.S. Department of the Interior
Bureau of Reclamation
Pacific Northwest Region
Boise, Idaho

January 2008

U.S. Department of the Interior

Mission Statement

The mission of the Department of the Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to Indian tribes and our commitments to island communities.

U.S. Bureau of Reclamation

Mission Statement

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

This document should be cited as follows:

Cle Elum and Bumping Lake Dams Fish Passage Facilities—Biology Appendix, Storage Dam Fish Passage Study, Yakima Project, Washington, Technical Series No. PN-YDFP-012, Bureau of Reclamation, Boise, Idaho, January 2008.

Table of Contents

List of Tables

List of Figures

Introduction

This appendix briefly describes and summarizes the assessments of production potential for coho and sockeye salmon in new habitat that will be accessible to these two anadromous salmonids when upstream and downstream passage is provided at Cle Elum Dam on the Cle Elum River and at Bumping Lake Dam on the Bumping River. Complete details of the assessments can be found in the referenced reports on the Yakima Storage Dam Fish Passage website; details of the supporting macroinvertebrate and limnological studies are also posted on the website.

Coho salmon *(Oncorhynchus kisutch)* and sockeye salmon *(O. nerka)* historically occupied the basins upstream from the two original lakes. Access to these basins was eliminated with the construction of dams across the outlets of the lakes in the early 20th century. Both species were extirpated from the Yakima River basin as a result of numerous anthropogenic activities; the Yakama Nation (YN) has been involved in a coho salmon reintroduction program since 1985, with some success. Sockeye salmon are still absent in the basin.

The Bureau of Reclamation (Reclamation) completed a Phase I Assessment Report in 2003 (Reclamation 2003). The Phase I assessment process examined a range of options and opportunities for providing fish passage and potentially reestablishing populations of anadromous salmonids in some tributaries of the five Yakima Project (YP) storage reservoirs. From this initial assessment, it appeared that some form of upstream and downstream passage would be technically possible at all the storage projects. The report indicated that a substantial amount of potential habitat would be accessible to anadromous salmonids if passage were restored. The Cle Elum River and several of its tributaries upstream from the lake had about 31.8 km of potential habitat while the Bumping River and Deep Creek upstream from Bumping Lake had about 9.6 km of potential habitat. Passage at the dams could also provide opportunities to reconnect isolated populations of bull trout.

The Yakima River basin fisheries co-managers developed a conceptual plan for a phased reintroduction of coho salmon and sockeye salmon in the Cle Elum and Bumping basins. Sockeye salmon are the preferred species for reintroduction, but some logistical and fish-cultural issues need to be resolved before sockeye salmon can be reintroduced, so coho salmon will be reintroduced initially.

Fish Population and Harvest Models

For this planning study, simple spreadsheet models were developed and used to accomplish three things.

1. First, we estimated a range of coho and sockeye salmon spawners that could be supported by the available habitat upstream from Cle Elum and Bumping Lake dams. These estimates were based on our evaluations of production potential using the best data available for lake and tributary habitat conditions at each dam site. There are a number of uncertainties associated with these estimates. We believe the assumptions made are reasonable and supported by literature values at other locations. These are the primary limiting factors that affect the population estimates:

- Coho – Population would be limited by the amount of available over-wintering habitat.
- Sockeye – Population would be limited by the amount of available spawning habitat.

2. Second, we calculated a buildup period to estimate the length of time and numbers of hatchery smolts that would be needed to reach the potential range of stabilized populations determined in step 1.
3. Third, we prepared a range of harvest estimates to be used in the economic analysis. The harvest estimates were developed from the numbers of returning spawners during the buildup period found in Step 2 and the number of spawners that could be supported on a long-term, self-sustaining basis by the available habitat determined in Step 1. The spreadsheets calculate the harvest breakdown for combined wild[1] and hatchery fish. The approach is not as sophisticated as that used in other studies[2], but it uses some of the same parameters, and gives reasonable harvest estimates for the limited purposes of this planning study.

The blue highlighted cells at the top of the harvest breakdown tables on pages 23 to 30 are the inputs. Any change in the blue input cells is automatically reflected in the calculated values in the cells below. All calculations are rounded to the nearest whole fish, so sometimes (especially at low harvest numbers) the total of the harvest breakdown numbers may be a fish short of the number shown in the total harvest column. The breakdown numbers should be used in the economic analysis and other associated studies.

Production Potential

Coho and Sockeye Salmon Spawner Summary Tables

The average number of wild fish returning each year after the population has stabilized is the estimated number of spawners from the production potential model, and represents a best estimate at a population that could be supported on a sustainable basis by the available habitat above the dams. These spreadsheet models do not attempt to portray yearly fluctuations in populations that are expected to occur. That level of detail is not warranted for this study. We simply based the estimated range of spawners on the available habitat and what percentage of that habitat might actually be used, considering competition from other species and other variables. The output from the production potential model uses smolt to adult return (SAR) rates and egg-to-smolt survivals that are attainable in the basin and supported by the literature. This indirectly addresses limiting factors found elsewhere in the basin that might affect production potential. Neither the production potential model nor the population growth model attempts to address annual population fluctuations caused by a multitude of environmental conditions.

[1] Wild fish are sustained through natural reproduction and rearing in natural habitats.
[2] e.g. Kennewick and Columbia Irrigation Districts' Pump Exchange Feasibility Study and Yakima River Basin Water Storage Feasibility Study.

Other studies are addressing limiting factors elsewhere in the basin, such as flow conditions and temperature conditions in certain river reaches. Successful implementation of projects that address these limiting factors would presumably benefit the Cle Elum and Bumping Lake fish passage project by improving lower river passage conditions and SARs. However, stabilized fish populations at Cle Elum and Bumping Lake will be limited by the available habitat upstream from the dams.

Table 1. Coho Salmon Spawner Estimates

Cle Elum and Bumping Lake Dams Fish Passage

Coho Salmon Spawner Estimates

Storage Dam Fish Passage Study
Yakima Project, WA

Cle Elum

Overwintering pool habitat = 123,267 m² 1/

Assumed SAR %	Required min. Egg to smolt %	Spawners @ 20 smolts/100 m^2	Spawners @ 25 smolts/100 m^2	Spawners @ 30 smolts/100 m^2	Spawners @ 50 smolts/100 m^2
3.5	2.3	863	1,079	1,294	2,157
4.0	2.0	986	1,233	1,479	2,465
4.5	1.8	1,109	1,387	1,664	2,774
5.0	1.6	1,233	1,541	1,849	3,082
5.5	1.4	1,356	1,695	2,034	3,390
6.0	1.3	1,479	1,849	2,219	3,698

Use most likely range of 900 - 1800 spawners

Bumping Lake

Overwintering pool habitat = 29,836 m² 2/

Assumed SAR %	Required min. Egg to smolt %	Spawners @ 20 smolts/100 m^2	Spawners @ 25 smolts/100 m^2	Spawners @ 30 smolts/100 m^2	Spawners @ 50 smolts/100 m^2
3.5	2.3	209	261	313	522
4.0	2.0	239	298	358	597
4.5	1.8	269	336	403	671
5.0	1.6	298	373	448	746
5.5	1.4	328	410	492	820
6.0	1.3	358	448	537	895

Use most likely range of 225 - 450 spawners

1/ Ref. BOR Technical Series PN-YDFP-007
Coho Salmon Production Potential in the Cle Elum River Basin

2/ Ref. BOR Technical Series PN-YDFP-009
Coho Salmon Production Potential in the Bumping River Basin

Table 2. Sockeye Salmon Spawner Estimates

Cle Elum and Bumping Lake Dams Fish Passage

Sockeye Salmon Spawner Estimates

Storage Dam Fish Passage Study
Yakima Project, WA

Cle Elum

Available spawning habitat = 159,160 m^2 1/

	Percent of Habitat Used			
	100%	70%	50%	33%
Sex Ratio	Spawners @ 1 redd per 7 m^2	Spawners @ 1 redd per 10 m^2	Spawners @ 1 redd per 14 m^2	Spawners @ 1 redd per 21 m^2
50% female	45,474	31,832	22,737	15,158
40% female	56,843	39,790	28,421	18,948

Use most likely range of 20,000 to 50,000 spawners

Bumping Lake

Available spawning habitat = 18,218 m^2 2/

	Percent of Habitat Used			
	100%	70%	50%	33%
Sex Ratio	Spawners @ 1 redd per 7 m^2	Spawners @ 1 redd per 10 m^2	Spawners @ 1 redd per 14 m^2	Spawners @ 1 redd per 21 m^2
50% female	5,205	3,644	2,603	1,735
40% female	6,506	4,555	3,253	2,169

Use most likely range of 2000 to 6000 spawners

Note: Assumes average fecundity of 2700 eggs per female, 4% SAR, and 1.85% egg to smolt survival.

1/ Ref. BOR Technical Series PN-YDFP-008
Assessment of Sockeye Salmon Production Potential in the Cle Elum River Basin

2/ Ref. BOR Technical Series PN-YDFP-010
Assessment of Sockeye Salmon Production Potential in the Bumping River Basin

Modeling Methods

The assessments of production potential were conducted to determine what level of fish production could be expected when these two anadromous salmonids had access to the habitat upstream from the lakes. To accomplish this, we reviewed the data from a series of U.S. Forest Service (USFS) stream surveys conducted during late summer low flow periods. We used these data to estimate the amount of suitable spawning habitat that was present for the two species as well as to estimate the extent of rearing/overwintering habitat for coho salmon. Sockeye salmon migrate downstream soon after emerging from the gravel to rear in lakes, so we used physical, chemical, and biological data from a recently completed limnological study of Cle Elum and Bumping lakes (Lieberman and Grabowski 2007) as well as other hydrological data to estimate potential production based on several lake parameters.

To estimate the number of smolts that could be produced in the estimated amount of suitable spawning habitat that was available, we used additional information from the literature on fecundity and size of redds for each species. For rearing/overwintering for coho salmon we looked at number and size of pools; we did not have sufficient information on side channels to include this potentially usable habitat in our analysis, nor did we have stream survey information from late fall and winter when river flows are generally higher, which would likely expand the amount of suitable pool and side channel habitat for overwintering coho salmon.

We estimated smolt production under various methods and approaches and from these estimates we calculated SAR rates of one to six percent. We estimated smolt production over a range of egg to smolt survival rates. As reported in the literature, both egg to smolt and SAR rates vary widely among fish populations by year, due to numerous and annually fluctuating environmental conditions, so we felt that a range of estimates should be developed to illustrate and emphasize the variation in production that could be expected. It is also important to realize that the watersheds upstream from these lakes are relatively unproductive and will remain so until there is an infusion of marine-derived nutrients from returning adult salmon. It will require initial human intervention to "jump-start" the population and there will be a substantial time lag until the full potential of the re-introduced population is realized.

Coho Salmon

Coho Salmon in the Cle Elum River Basin

For coho salmon in the Cle Elum River and its tributaries upstream from the lake, we estimated that 159,160 m^2 of riffle area had substrate within the size range suitable for spawning coho salmon. Based on 10 m^2 per redd, this amount of substrate could support 15,916 spawning females, and with fecundity of 2,500 at 1.5 percent egg to smolt survival (about a midrange value from the literature) would produce 596,817 smolts. At one to six percent SAR, these 596,817 smolts would produce 5,970 to 35,810 returning adults. The estimated production at high smolt abundance and high SAR are likely unrealistic.

Since rearing/overwintering habitat has been reported to limit coho salmon production, we estimated the amount of pool habitat available to juvenile coho salmon. In this case, we estimated that 123,267 m^2 of pool habitat would be available. We felt that this is a low and conservative estimate since we have insufficient information to estimate pool and side channel habitat in late fall and winter when river flows are greater. We estimated that at 0.25 smolts per m^2 of overwintering pool habitat, 30,818 smolts would be produced. These 30,818 smolts would produce 309 to 1,851 returning adults at from one to six percent SAR, respectively. These may be low estimates for numbers of overwintering coho salmon since we do not know the extent of habitat available with the increased late fall and winter river flows, and the quality of the habitat and food availability; 0.25 overwintering smolts per m^2 may be low. It is important to keep in mind that environmental conditions change annually, and the quality of the habitat can change annually as well.

Within this range of adult production based on rearing/overwintering habitat, and recognizing that this estimate is likely conservative, we estimate that over the long term, and after productivity of the Cle Elum River and its tributaries upstream from the lake improve with the infusion of marine-derived nutrients from salmon carcasses and any habitat improvement actions implemented by the management agencies, that a population of about 1,500 adult coho salmon can be sustained in the upper Cle Elum River basin.

The number of juvenile coho salmon estimated from the rearing/overwintering habitat approach is comparable to and falls within the range of values reported in the literature for number of smolts per 100 m^2 stream habitat, estimates based on stream length and latitude, and reported estimates of the number of spawning female fish per km needed for full smolt recruitment. We feel that the estimate of production potential presented here is reasonable and conservative, considering that the estimates were based on low streamflow conditions from stream surveys conducted in late summer, and the potential increase in habitat availability with increased fall and winter flows. This assessment of potential production indicates that a self-sustaining coho salmon population in the Cle Elum River would require an average 1.5 percent egg to smolt survival coupled with about a 5.5 percent SAR or some combination thereof. To illustrate this numerically, a return of 1,540 adult coho salmon with equal sex ratio would result in 770 females producing an estimated 1,925,000 eggs. A 1.5 percent egg to smolt survival would produce 28,875 outmigrants, and with a 5.5 percent SAR, 1,588 adults would be expected to return. The Yakima Coho Master Plan (Yakama Nation 2003) reported SARs up to 3.8 percent for wild coho salmon in 2001, but only 0.87 percent in 2002. Four percent SAR is the average interim SAR objective (ranging from two to six percent) in the Northwest Power and Conservation Council (NPCC) mainstem amendment for Snake River and upper Columbia River salmon and steelhead (NPCC 2003). A 5.5 percent SAR is optimistic, but if egg to smolt survival is greater than the average 1.5 percent used here, a lower SAR would result in a similar number of returning adults.

A return of 1,588 adult coho salmon to the upper Cle Elum River would not seem unreasonable, since recent returns to the Yakima River counted at Prosser Dam were as high as 6,138 adults in 2000, but dropped substantially to 818 in 2002 (Yakama Nation 2003). However, the low abundance of macroinvertebrate prey and warm summertime water temperatures, among other environmental factors, will limit coho salmon production in the Cle Elum River, at least until stream and lake productivity increases due to the infusion of marine-derived nutrients and any necessary habitat improvements are implemented.

Coho Salmon in the Bumping River Basin

For coho salmon in the Bumping River and its tributaries upstream from the lake, we estimated that 18,218 m^2 of riffle area had substrate within the size range for spawning coho salmon. Based on 10 m^2 per redd, this amount of substrate could support 1,822 spawning females, and with fecundity of 2,500, at a 1.5 percent egg to smolt survival (about a midrange value from the literature) would produce 68,364 smolts. At one to six percent SAR, these 68,364 smolts would produce 684 to 4,102 returning adults. The estimated production at high smolt abundance and high SAR are likely unrealistic.

Since rearing/overwintering habitat has been reported to limit coho salmon production, we estimated the amount of pool habitat available to juvenile coho salmon. In this case we estimated that 29,836 m^2 of pool habitat would be available. We felt that this is a low and conservative estimate since we have insufficient information to estimate pool and side channel habitat in late fall and winter when river flows are greater. We estimated that at 0.25 smolts per m^2 of overwintering pool habitat, 7,458 smolts would be produced. These 7,458 smolts would produce 75 to 447 returning adults at one to six percent SAR, respectively. These may be low estimates for numbers for production of overwintering coho salmon since we do not know the extent of habitat available with the increased late fall and winter river flows, and depending on the quality of the habitat and food availability, 0.25 overwintering smolts per m^2 may be low. It is important to keep in mind that environmental conditions change annually, and the quality of the habitat can change annually as well.

Within this range of adult production based on rearing/overwintering habitat, and recognizing that this estimate is likely conservative, we estimate that over the long term, and after productivity of the Bumping River and its tributaries upstream from the lake improve with the infusion of marine-derived nutrients from salmon carcasses and any habitat improvement actions implemented by the management agencies, that a population of about 300 adult coho salmon can be sustained in the upper Bumping River basin.

The estimate of smolt production based on the availability of spawning habitat seems optimistic compared to the estimates from the rearing/overwintering approach, especially in light of the closer correspondence of rearing/overwintering estimates to production values reported in the literature. The number of juvenile coho salmon estimated from the rearing/overwintering habitat approach is comparable to and falls within the range of values reported in the literature for number of smolts per 100 m^2 stream habitat, estimates based on stream length and latitude, and reported estimates of the number of spawning female fish per km needed for full smolt recruitment. We feel that our estimate of production potential is reasonable and conservative, considering the low streamflow conditions during which the stream surveys were conducted and on which this assessment is based, the presence of extensive side channels, for which physical data and macroinvertebrate abundance were not available, and the potential increase in habitat availability with increased fall and winter flows.

This assessment indicates that the Bumping River basin upstream from Bumping Lake could support a self-sustaining coho salmon population and would require a 1.5 percent egg to smolt survival coupled with about a 5.5 percent SAR, or some combination thereof. To illustrate, based on the juvenile rearing/overwintering habitat approach described above, a return of 410 adult coho salmon with equal sex ratio would result in 205 females producing an estimated 512,500 eggs. A 1.5 percent egg to smolt survival would produce 7,686 outmigrants, and with a 5.5 percent SAR, 422 adults would be expected to return. The Yakima Coho Master Plan (Yakama Nation 2003) reported SARs up to 3.8 percent for wild coho salmon in 2001, but only 0.87 percent in 2002. Four percent SAR is the average interim SAR objective (ranging from two to six percent) in the NPCC mainstem amendment for Snake River and upper Columbia River salmon and steelhead (NPCC 2003).

A return of 410 adult coho salmon to the Bumping River would not seem unreasonable, since recent returns to the Yakima River counted at Prosser Dam were as high as 6,138 adults in 2000, but dropped substantially to 818 in 2002 (Yakama Nation 2003). However, the low abundance of macroinvertebrate prey and warm summertime water temperatures, among other environmental factors, might limit coho salmon production in the Bumping River, at least until productivity in the streams and lake increases from the eventual infusion of marine-derived nutrients from returning adults.

Sockeye Salmon

Sockeye Salmon in the Cle Elum River Basin

For sockeye salmon in the Cle Elum River and its tributaries upstream from the lake, we estimated that 159,160 m^2 of riffle area had substrate within the size range for spawning coho salmon. Based on 7 m^2 per redd, this amount of substrate could support 22,737 spawning females, and with fecundity of 2,700, at 1, 2, and 5 percent egg to smolt survival would produce 613,899, 1,227,798, and 3,069,495 smolts, respectively. At one to six percent SAR, this range of smolts would produce 6,139 to 184,170 returning adults. The estimated production at high smolt abundance and high SAR are likely unrealistic.

Since juvenile sockeye salmon typically rear in lakes, we used three methods of estimating production reported by BioAnalysts (2000): 1) number of smolts per lake surface area, 2) lake euphotic volume, and 3) number of spawners per lake surface area. Where appropriate, we incorporated information from the September 2003 to October 2004 limnological study of Cle Elum Lake (Lieberman and Grabowski 2007). After estimating the number of smolts that could be produced by these methods, we estimated the number of adults that would return at SAR rates of one to six percent. We also considered some environmental constraints to sockeye salmon production in Cle Elum Lake, such as abundance of copepod and cladoceran prey, inter- and intra-specific competition, and the seasonal water level fluctuations and temperature regime that could influence production. We looked at several lake elevations and corresponding lake surface areas and focused on the median lake elevation and corresponding surface area for a recent 15-year period rather than the lake at full pool.

Using the number of smolts per lake surface area method and a lake surface area of 1,514.9 ha, we estimated that 1,190 to 1,835 smolts per ha, (1,802,731 to 2,779,842 smolts) would be produced, respectively. Estimated number of adults from these estimates of smolt production ranged from 18,027 to 166,791 for one to six percent SAR. The estimated production at high smolt abundance and high SAR are likely unrealistic.

Using lake euphotic volume (EV), and the surface area corresponding to median elevation and the average secchi depth (a measure of water clarity and a measurement used in this method) we estimated that 6,780 to 10,455 smolts per EV, or 2,310,624 to 3,563,064 smolts would be produced, respectively. Estimated number of adults from this smolt production ranged from 23,106 to 213,784, for one to six percent SAR. The estimated production at high smolt abundance and high SAR are likely unrealistic.

Using the number of spawners per lake surface area method, and the surface area corresponding to median elevation and 10 and 30 spawners per lake surface area, and one to five percent egg to smolt survival, we estimated that 204,512 to 3,067,673 smolts would be produced. Estimated number of adults from this smolt production ranged from 2,045 to 184,060, for one to six percent SAR, respectively. The estimated production at high smolt abundance and high SAR are likely unrealistic.

The estimated production of sockeye salmon adults in the historic lake, based on an estimated surface area of 802 ha and 38.8 spawners per lake surface area is about 31,125 adults. For contemporary Cle Elum Lake at median lake elevation and corresponding surface area of 1,515 ha, this number can be adjusted upward to 58,782. The estimated production of adults from the three lake-based methods ranges widely from a low of 2,045 to 184,060. Although these numbers are derived from the analysis, environmental conditions would have to be extremely favorable and survival very high for this level of production to occur, so we determine that very high levels of production are unlikely, especially in light of the oligotrophic status of the lake and the relative unproductive condition of the watershed. However, the analysis also indicated that about 30,000 to 50,000 adults could be produced assuming average survivals, conditions, and a median lake elevation.

Since the Cle Elum River basin supported sockeye salmon historically, it is likely that over time anadromous salmonid populations could be re-established as fish passage facilities are installed at the dam. The lake is oligotrophic, similar to other lakes in the Pacific Northwest, Canada, and Alaska that support viable sockeye salmon populations. Preferred prey items for rearing juvenile sockeye salmon are present in the lake but are in low abundance.

Some environmental factors may affect potential production. Summertime average daily water temperatures greater than 21°C in the Yakima River might delay adult sockeye salmon entry into the Yakima River. Water temperatures begin to exceed 21°C in the lower Yakima River about the time of peak passage of migrating adult sockeye salmon in the Columbia River. Inter- and intra-specific predator-prey interactions may influence production. Based on the range of estimated smolt production under average conditions, we estimate that Cle Elum Lake could eventually produce sufficient smolts to yield an adult return of 30,000 to 50,000 sockeye salmon.

Sockeye Salmon in the Bumping River Basin

For sockeye salmon in the Bumping River and its tributaries upstream from the lake, we estimated that 18,218 m^2 of riffle area had substrate within the size range for spawning coho salmon. Based on 7 m^2 per redd, this amount of substrate could support 2,602 spawning females, and 1, 2, and 5 percent egg to smolt survival would produce 70,254, 140,508, and 351,270 smolts, respectively. At one to six percent SAR, this range of smolts would produce 702 to 21,076 returning adults. The estimated production at high smolt abundance and high SAR are likely unrealistic.

Since juvenile sockeye salmon typically rear in lakes, we used three methods of estimating production reported by BioAnalysts (2000): 1) number of smolts per lake surface area, 2) lake EV, and 3) number of spawners per lake surface area. Where appropriate, we incorporated information from the September 2003 to October 2004 limnological study of Bumping Lake (Lieberman and Grabowski 2007). After estimating the number of smolts that could be produced by these methods, we estimated the number of adults that would return at SAR rates of one to six percent. We also considered some environmental constraints to sockeye salmon production in Bumping Lake, such as abundance of copepod and cladoceran prey, inter- and intra-specific competition, and the seasonal water level fluctuations and temperature regime that could influence production.

We looked at several lake elevations and corresponding lake surface areas and focused on the median lake elevation and corresponding surface area for a recent 15-year period rather than the lake at full pool.

Using the number of smolts per lake surface area method and a lake surface area of 424.7 ha, we estimated that from 1,190 to 1,835 smolts per ha, 505,381 to 779,306 smolts would be produced, respectively. Estimated number of adults from this smolt production ranges from 5,054 to 46,758 for one to six percent SAR. The estimated production at high smolt abundance and high SAR are likely unrealistic.

Using lake EV, and again in this case the surface area corresponding to median elevation and the average secchi depth (a measure of water clarity and a measurement used in this method) we estimated that at 6,780 to 10,455 smolts per EV, 688,170 to 1,061,183 smolts would be produced, respectively. Estimated number of adults from this smolt production ranges from 6,882 to 63,671, for one to six percent SAR. The estimated production at high smolt abundance and high SAR are likely unrealistic.

Using the number of spawners per lake surface area method, and again in this case the surface area corresponding to median elevation and 10 and 30 spawners per lake ha, and from one to five percent egg to smolt survival, we estimated that from 57,333 to 859,997 smolts would be produced. Estimated number of adults from this smolt production ranges from 573 to 51,600, for one to six percent SAR, respectively. The estimated production at high smolt abundance and high SAR are likely unrealistic.

The Bumping River basin supported sockeye salmon historically, and it is likely that over time a population could be re-established. The lake is oligotrophic, similar to other lakes that support viable sockeye salmon populations. Sockeye salmon smolt production estimated in Bumping Lake range from 43,736 to 1,682,210 using several methods and a range of assumptions. Similarly, the estimate of the number of returning adults ranged from 573 to 63,671. These estimates represent extreme low and high survivals and environmental conditions. A more reasonable estimate would be that obtained using mid-range values for survival and a median lake elevation with corresponding lake surface area. Using mid-range values, and considering the estimated historic production of perhaps 9,900 sockeye salmon adults in Bumping Lake, we estimate that Bumping Lake could produce from about 10,000 to 17,000 adult sockeye salmon when the species is fully restored there. Some factors that might limit a sockeye salmon population in the basin would be the low abundance of preferred prey items in the lake until marine-derived nutrients improve production, and summertime average daily water temperatures greater than 21°C that might delay adult sockeye salmon entry into the Yakima River.

Harvest Estimates for Economic Analysis

Fish Population Buildup Summary Tables

Table 3. Fish Population Buildup Summary - High Estimate

Cle Elum and Bumping Lake Dams Fish Passage

Fish Population Buildup Table

Storage Dam Fish Passage Study

Yakima Project, WA

Summary Sheet (High Est)

Year	Cle Elum coho (high)			Bumping Lake coho (high)			Cle Elum sockeye (high)			Bumping Lake sockeye (high)		
	Total Adults Returning	Hatchery	Wild	Total Adults Returning	Hatchery	Wild	Total Adults Returning	Hatchery	Wild	Total Adults Returning	Hatchery	Wild
1	0	0	0	0	0	0	0	0	0	0	0	0
2	600	600	0	150	150	0	0	0	0	0	0	0
3	600	600	0	150	150	0	7,308	7,308	0	870	870	0
4	600	600	0	150	150	0	12,474	12,474	0	1,485	1,485	0
5	1,200	600	600	300	150	150	12,600	12,600	0	1,500	1,500	0
6	1,200	600	600	300	150	150	12,600	12,600	0	1,500	1,500	0
7	1,200	600	600	300	150	150	16,834	12,600	4,234	2,004	1,500	504
8	1,800	600	1,200	450	150	300	22,821	12,600	10,221	2,717	1,500	1,217
9	1,800	600	1,200	450	150	300	25,083	12,600	12,483	2,986	1,500	1,486
10	1,800	600	1,200	450	150	300	25,186	12,600	12,586	2,998	1,500	1,498
11	1,800	0	1,800	450	0	450	27,641	12,600	15,041	3,291	1,500	1,791
12							32,844	12,600	20,244	3,910	1,500	2,410
13							36,649	12,600	24,049	4,363	1,500	2,863
14							37,695	12,600	25,095	4,488	1,500	2,988
15							39,182	12,600	26,582	4,665	1,500	3,165
16							43,204	12,600	30,604	5,143	1,500	3,643
17							47,564	12,600	34,964	5,662	1,500	4,162
18							49,780	12,600	37,180	5,926	1,500	4,426
19							51,109	12,600	38,509	6,084	1,500	4,584
20							54,058	12,600	41,458	6,436	1,500	4,936
21							50,939	5,292	45,647	6,064	630	5,434
22							48,883	126	48,757	5,819	15	5,804
23							50,478	0	50,478	6,009	0	6,009
24							52,753	0	52,753	6,280	0	6,280
25							52,167	0	52,167	6,210	0	6,210
							50,000		50,000	6,000		6,000
100	1800		1800	450		450	50,000		50,000	6,000		6,000

Table 4. Fish Population Buildup Summary - Low Estimate

Cle Elum and Bumping Lake Dams Fish Passage

Fish Population Buildup Table

Storage Dam Fish Passage Study

Yakima Project, WA

Summary Sheet (Low Est)

Year	Cle Elum coho (low)			Bumping Lake coho (low)			Cle Elum sockeye (low)			Bumping Lake sockeye (low)		
	Total Adults Returning	Hatchery	Wild	Total Adults Returning	Hatchery	Wild	Total Adults Returning	Hatchery	Wild	Total Adults Returning	Hatchery	Wild
1	0	0	0	0	0	0	0	0	0	0	0	0
2	300	300	0	75	75	0	0	0	0	0	0	0
3	300	300	0	75	75	0	2,900	2,900	0	290	290	0
4	300	300	0	75	75	0	4,950	4,950	0	495	495	0
5	600	300	300	150	75	75	5,000	5,000	0	500	500	0
6	600	300	300	150	75	75	5,000	5,000	0	500	500	0
7	600	300	300	150	75	75	6,680	5,000	1,680	668	500	168
8	900	300	600	225	75	150	9,056	5,000	4,056	906	500	406
9	900	300	600	225	75	150	9,954	5,000	4,954	995	500	495
10	900	300	600	225	75	150	9,995	5,000	4,995	999	500	499
11	900	0	900	225	0	225	10,969	5,000	5,969	1,097	500	597
12							13,033	5,000	8,033	1,303	500	803
13							14,543	5,000	9,543	1,454	500	954
14							14,958	5,000	9,958	1,496	500	996
15							15,549	5,000	10,549	1,555	500	1,055
16							17,144	5,000	12,144	1,714	500	1,214
17							18,875	5,000	13,875	1,887	500	1,387
18							19,754	5,000	14,754	1,975	500	1,475
19							20,281	5,000	15,281	2,028	500	1,528
20							21,452	5,000	16,452	2,145	500	1,645
21							20,214	2,100	18,114	2,021	210	1,811
22							19,398	50	19,348	1,940	5	1,935
23							20,031	0	20,031	2,003	0	2,003
24							20,934	0	20,934	2,093	0	2,093
25							20,701	0	20,701	2,070	0	2,070
							20,000		20,000	2,000		2,000
100	900		900	225		225	20,000		20,000	2,000		2,000

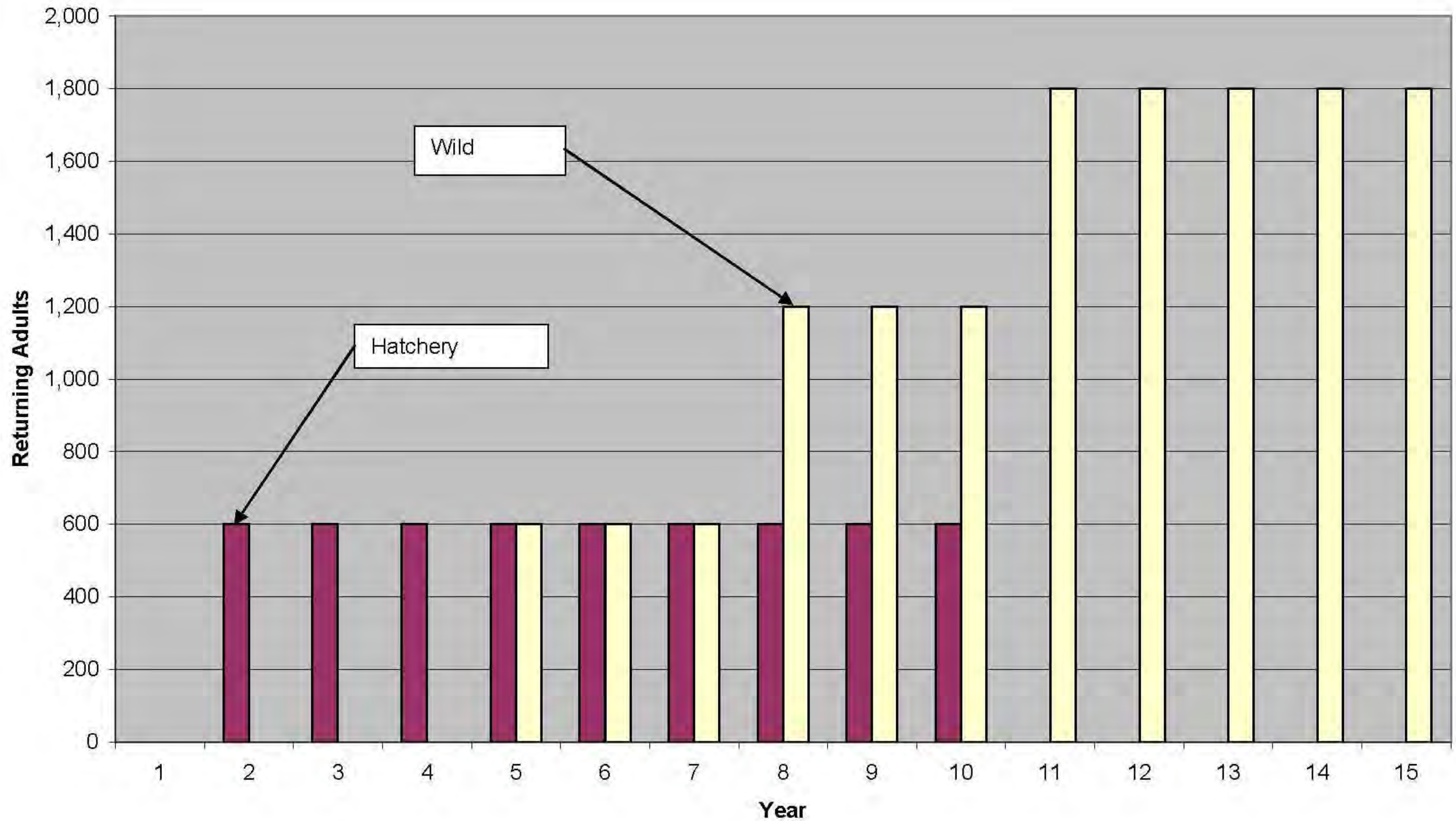

Figure 1. Coho Buildup Schedule – High Estimate

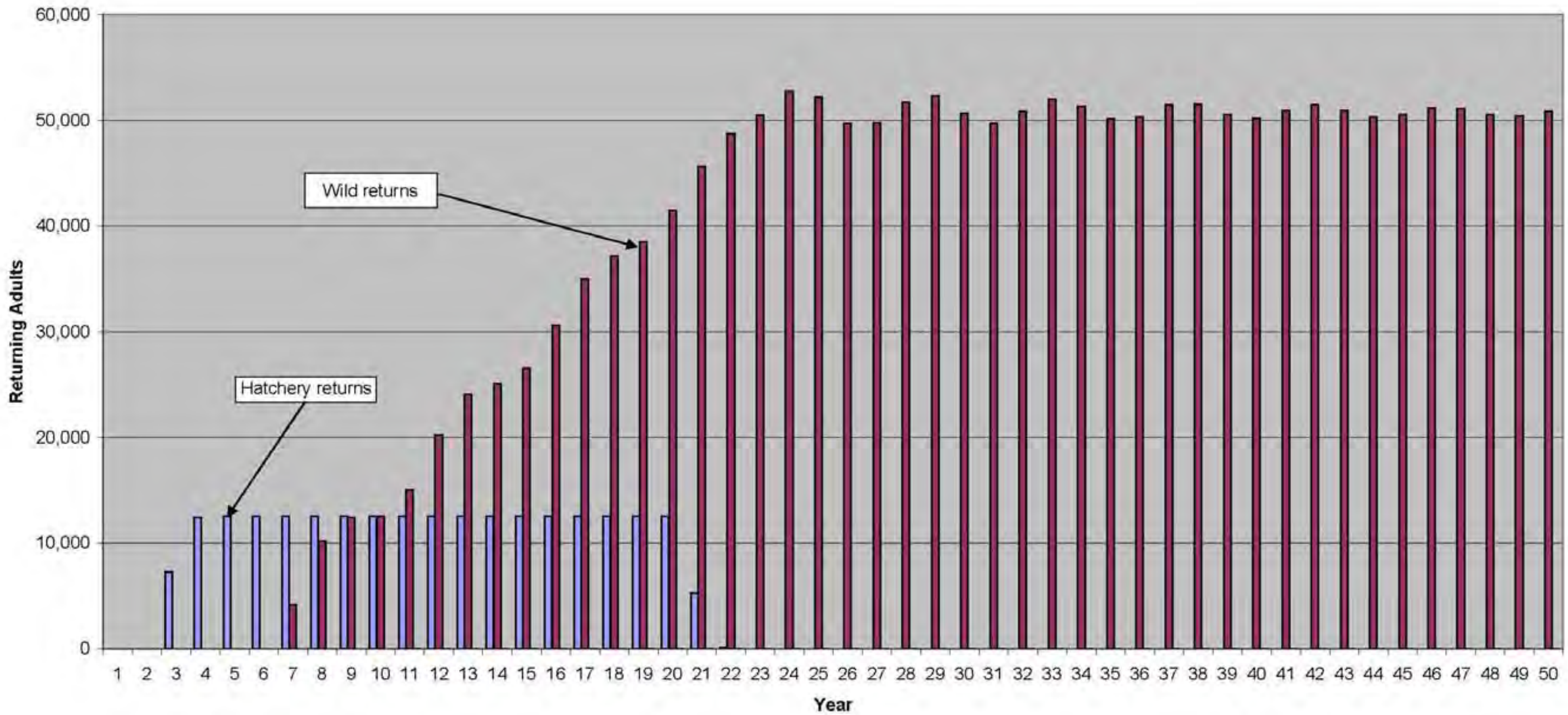

Figure 2. Sockeye Buildup Schedule – High Estimate

Buildup Period Assumptions

1. Once the passage project is authorized for construction, YN and Washington Department of Fish and Wildlife (WDFW) would begin releasing hatchery smolts at Cle Elum and Bumping Lake dams. The hatchery releases would commence about two or three years before construction of the passage facilities is completed. Returning hatchery-origin adults would be allowed to spawn upstream from the dams. The progeny of these hatchery-origin adults would rear in the natural habitat above the dams and would result in subsequent generations of naturally produced (wild) adults. Hatchery smolts will continue to be released over a period of several years until sufficient numbers of fish are returning to maintain a self-sustaining, stabilized population of wild fish. The figures are based on hatchery releases over a nine-year period for coho salmon, and over an 18-year period for sockeye salmon.

2. Most returning adults would be captured at the base of each dam and would be transported and released into the reservoir where they would then move to the upstream tributaries to spawn naturally.

3. Coho salmon life histories are fairly straightforward and consistent from year-to-year. We assumed coho salmon would typically spend one year in the lake and one year in the ocean and return as age-3 fish.

4. Sockeye salmon life histories are a bit more complex than the coho salmon. Based on Lake Wenatchee sockeye salmon data[3], we assumed that Cle Elum and Bumping Lake sockeye salmon would spend one or two years in the lake, and two or three years in the ocean, returning as age 4, age 5, and age 6 adults. The run of returning adults in any given year might include age classes 1.2, 2.1, 1.3, 2.2, and 2.3.[4] The population growth model accounts for these various combinations of over-lapping life histories by simply breaking up the adult returns for each generation of smolts and spreading them out over a three-year period. This is accomplished by using a 58 percent return of age 4 fish, a 41 percent return of age 5 fish, and a 1 percent return of age 6 fish. These percentages represent the average of the recorded Lake Wenatchee age-class estimates for the 2000 to 2006 reporting period as shown on Table 5. The actual recorded percentages varied a great deal from year-to-year. Attempting to account for these wide swings in age classes from year-to-year is beyond the scope of this study effort and is not necessary to achieve the purpose of the population growth model spreadsheet. The percentages could easily be changed but, as a practical matter, it won't make much difference in the end result. The object is simply to provide some kind of buildup schedule to get to the stabilized population that could be sustained by the available habitat.

5. Since there is currently no passage at the dams, the "without" population is zero. Therefore, all harvest numbers shown on the spreadsheet are attributable to passage at the dams.

[3] Columbia River Inter-Tribal Fish Commission (CRITFC) Technical Reports for years 2000 – 2006.

[4] European method for fish age description. The number of winters a fish spent in freshwater (not including the winter of egg incubation) is described by an Arabic numeral followed by a period. The numeral following the period indicates the number of winters a fish spent in the ocean. Total age is equal to one plus the sum of both numerals. (Fryer and Kelsey 2002).

Table 5. Sockeye Age Classes

Cle Elum and Bumping Lake Dams Fish Passage
Fish Population Buildup Table

Storage Dam Fish Passage Study
Yakima Project, WA

sockeye age classes

1/ Ages of returning adults at Tumwater Dam -- Wenatchee stock

	Year	3 yr	4 yr	5 yr	6 yr	Total
2/	1998	22.0%	11.0%	66.0%	1.0%	100.0%
2/	1999	8.7%	83.1%	7.4%	0.7%	99.9%
	2000	0.0%	98.9%	1.1%	0.0%	100.0%
	2001	0.0%	53.7%	46.4%	0.0%	100.1%
	2002	0.0%	41.9%	57.6%	0.4%	99.9%
	2003	0.0%	1.2%	91.5%	7.4%	100.1%
	2004	0.0%	97.8%	2.2%	0.0%	100.0%
	2005	0.0%	77.9%	21.8%	0.3%	100.0%
	2006	0.0%	37.0%	63.0%	0.0%	100.0%
	2007					0.0%
Average 1998-2006		3.4%	55.8%	39.7%	1.1%	100.0%
Average 2000-2006		0.0%	58.3%	40.5%	1.2%	100.0%
Use for population buildup			58.0%	41.0%	1.0%	100.0%

1/ Developed from data in CRITFC Technical Reports
2/ Bonneville Dam count -- mixed Wenatchee and Okanogan stock

Fish Harvest Breakdown Tables

Table 6. Fish Harvest Breakdown - Cle Elum Coho (high)

Cle Elum and Bumping Lake Dams Fish Passage

Fish Harvest Breakdown

Storage Dam Fish Passage Study
Yakima Project, WA

Cle Elum coho (high)

Total escapement = 1,800 1/

Harvest to Escapement ratio = 0.346 2/

	Ocean	Zone 1-5	Zone 6	Terminal
% of Harvest	60.3%	25.6%	11.1%	3.0%
Commercial =	40.0%	40.0%	95.0%	
Sport =	60.0%	60.0%		100.0%
C & S =			5.0%	

	Escapement (Returning Adults)			Total Harvest	Breakdown of Harvest by Zone and Category							
					Ocean		Zone 1-5		Zone 6		Terminal	
Year	Total	Hatchery	Wild	(Hatchery + Wild)	Comm.	Sport	Comm.	Sport	Comm.	C & S	Sport	C & S
1	0	0	0	0	0	0	0	0	0	0	0	0
2	600	600	0	208	50	75	21	32	22	1	6	0
3	600	600	0	208	50	75	21	32	22	1	6	0
4	600	600	0	208	50	75	21	32	22	1	6	0
5	1,200	600	600	415	100	150	42	64	44	2	12	0
6	1,200	600	600	415	100	150	42	64	44	2	12	0
7	1,200	600	600	415	100	150	42	64	44	2	12	0
8	1,800	600	1,200	623	150	225	64	96	66	3	19	0
9	1,800	600	1,200	623	150	225	64	96	66	3	19	0
10	1,800	600	1,200	623	150	225	64	96	66	3	19	0
11	1,800	0	1,800	623	150	225	64	96	66	3	19	0
12	1,800	0	1,800	623	150	225	64	96	66	3	19	0
13	1,800	0	1,800	623	150	225	64	96	66	3	19	0
14	1,800	0	1,800	623	150	225	64	96	66	3	19	0
15	1,800	0	1,800	623	150	225	64	96	66	3	19	0
16	1,800	0	1,800	623	150	225	64	96	66	3	19	0
17	1,800	0	1,800	623	150	225	64	96	66	3	19	0
18	1,800	0	1,800	623	150	225	64	96	66	3	19	0
19	1,800	0	1,800	623	150	225	64	96	66	3	19	0
20	1,800	0	1,800	623	150	225	64	96	66	3	19	0
yr 21 thru 100	1,800	0	1,800	623	150	225	64	96	66	3	19	0

1/ From Grabowski model - spawning population that could be sustained by available habitat above dam
2/ Based on KID model averages for coho

Table 7. Fish Harvest Breakdown - Cle Elum Coho (low)

Cle Elum and Bumping Lake Dams Fish Passage

Fish Harvest Breakdown

Storage Dam Fish Passage Study
Yakima Project, WA

Cle Elum coho (low)

Total escapement = 900 1/

Harvest to Escapement ratio = 0.346 2/

	Ocean	Zone 1-5	Zone 6	Terminal
% of Harvest	60.3%	25.6%	11.1%	3.0%
Commercial =	40.0%	40.0%	95.0%	
Sport =	60.0%	60.0%		100.0%
C & S =			5.0%	

Year	Escapement (Returning Adults)			Total Harvest (Hatchery + Wild)	Breakdown of Harvest by Zone and Category							
					Ocean		Zone 1-5		Zone 6		Terminal	
	Total	Hatchery	Wild		Comm.	Sport	Comm.	Sport	Comm.	C & S	Sport	C & S
1	0	0	0	0	0	0	0	0	0	0	0	0
2	300	300	0	104	25	38	11	16	11	1	3	0
3	300	300	0	104	25	38	11	16	11	1	3	0
4	300	300	0	104	25	38	11	16	11	1	3	0
5	600	300	300	208	50	75	21	32	22	1	6	0
6	600	300	300	208	50	75	21	32	22	1	6	0
7	600	300	300	208	50	75	21	32	22	1	6	0
8	900	300	600	311	75	113	32	48	33	2	9	0
9	900	300	600	311	75	113	32	48	33	2	9	0
10	900	300	600	311	75	113	32	48	33	2	9	0
11	900	0	900	311	75	113	32	48	33	2	9	0
12	900	0	900	311	75	113	32	48	33	2	9	0
13	900	0	900	311	75	113	32	48	33	2	9	0
14	900	0	900	311	75	113	32	48	33	2	9	0
15	900	0	900	311	75	113	32	48	33	2	9	0
16	900	0	900	311	75	113	32	48	33	2	9	0
17	900	0	900	311	75	113	32	48	33	2	9	0
18	900	0	900	311	75	113	32	48	33	2	9	0
19	900	0	900	311	75	113	32	48	33	2	9	0
20	900	0	900	311	75	113	32	48	33	2	9	0
yr 21 thru 100	900	0	900	311	75	113	32	48	33	2	9	0

1/ From Grabowski model - spawning population that could be sustained by available habitat above dam
2/ Based on KID model averages for coho

Table 8. Fish Harvest Breakdown - Bumping Lake Coho (high)

Cle Elum and Bumping Lake Dams Fish Passage

Fish Harvest Breakdown

Storage Dam Fish Passage Study
Yakima Project, WA

Bumping Lake coho (high)

Total escapement = 450 1/

Harvest to Escapement ratio = 0.346 2/

	Ocean	Zone 1-5	Zone 6	Terminal
% of Harvest	60.3%	25.6%	11.1%	3.0%
Commercial =	40.0%	40.0%	95.0%	
Sport =	60.0%	60.0%		100.0%
C & S =			5.0%	

Year	Escapement (Returning Adults)			Total Harvest (Hatchery + Wild)
	Total	Hatchery	Wild	
1	0	0	0	0
2	150	150	0	52
3	150	150	0	52
4	150	150	0	52
5	300	150	150	104
6	300	150	150	104
7	300	150	150	104
8	450	150	300	156
9	450	150	300	156
10	450	150	300	156
11	450	0	450	156
12	450	0	450	156
13	450	0	450	156
14	450	0	450	156
15	450	0	450	156
16	450	0	450	156
17	450	0	450	156
18	450	0	450	156
19	450	0	450	156
20	450	0	450	156
yr 21 thru 100	450	0	450	156

Year	Breakdown of Harvest by Zone and Category							
	Ocean		Zone 1-5		Zone 6		Terminal	
	Comm.	Sport	Comm.	Sport	Comm.	C & S	Sport	C & S
1	0	0	0	0	0	0	0	0
2	13	19	5	8	5	0	2	0
3	13	19	5	8	5	0	2	0
4	13	19	5	8	5	0	2	0
5	25	38	11	16	11	1	3	0
6	25	38	11	16	11	1	3	0
7	25	38	11	16	11	1	3	0
8	38	56	16	24	16	1	5	0
9	38	56	16	24	16	1	5	0
10	38	56	16	24	16	1	5	0
11	38	56	16	24	16	1	5	0
12	38	56	16	24	16	1	5	0
13	38	56	16	24	16	1	5	0
14	38	56	16	24	16	1	5	0
15	38	56	16	24	16	1	5	0
16	38	56	16	24	16	1	5	0
17	38	56	16	24	16	1	5	0
18	38	56	16	24	16	1	5	0
19	38	56	16	24	16	1	5	0
20	38	56	16	24	16	1	5	0
yr 21 thru 100	38	56	16	24	16	1	5	0

1/ From Grabowski model - spawning population that could be sustained by available habitat above dam
2/ Based on KID model averages for coho

Table 9. Fish Harvest Breakdown - Bumping Lake Coho (low)

Cle Elum and Bumping Lake Dams Fish Passage

Fish Harvest Breakdown

Storage Dam Fish Passage Study
Yakima Project, WA

Bumping Lake coho (low)

Total escapement = 225 1/

Harvest to Escapement ratio = 0.346 2/

	Ocean	Zone 1-5	Zone 6	Terminal
% of Harvest	60.3%	25.6%	11.1%	3.0%
Commercial =	40.0%	40.0%	95.0%	
Sport =	60.0%	60.0%		100.0%
C & S =			5.0%	

Year	Escapement (Returning Adults)			Total Harvest	Breakdown of Harvest by Zone and Category							
					Ocean		Zone 1-5		Zone 6		Terminal	
	Total	Hatchery	Wild	(Hatchery + Wild)	Comm.	Sport	Comm.	Sport	Comm.	C & S	Sport	C & S
1	0	0	0	0	0	0	0	0	0	0	0	0
2	75	75	0	26	6	9	3	4	3	0	1	0
3	75	75	0	26	6	9	3	4	3	0	1	0
4	75	75	0	26	6	9	3	4	3	0	1	0
5	150	75	75	52	13	19	5	8	5	0	2	0
6	150	75	75	52	13	19	5	8	5	0	2	0
7	150	75	75	52	13	19	5	8	5	0	2	0
8	225	75	150	78	19	28	8	12	8	0	2	0
9	225	75	150	78	19	28	8	12	8	0	2	0
10	225	75	150	78	19	28	8	12	8	0	2	0
11	225	0	225	78	19	28	8	12	8	0	2	0
12	225	0	225	78	19	28	8	12	8	0	2	0
13	225	0	225	78	19	28	8	12	8	0	2	0
14	225	0	225	78	19	28	8	12	8	0	2	0
15	225	0	225	78	19	28	8	12	8	0	2	0
16	225	0	225	78	19	28	8	12	8	0	2	0
17	225	0	225	78	19	28	8	12	8	0	2	0
18	225	0	225	78	19	28	8	12	8	0	2	0
19	225	0	225	78	19	28	8	12	8	0	2	0
20	225	0	225	78	19	28	8	12	8	0	2	0
yr 21 thru 100	225	0	225	78	19	28	8	12	8	0	2	0

1/ From Grabowski model - spawning population that could be sustained by available habitat above dam
2/ Based on KID model averages for coho

Table 10. Fish Harvest Breakdown - Cle Elum Sockeye (high)

Cle Elum and Bumping Lake Dams Fish Passage
Fish Harvest Breakdown
Storage Dam Fish Passage Study
Yakima Project, WA

Cle Elum sockeye (high)

Total escapement = 50,000 1/

Harvest to Escapement ratio = 0.288 2/

	Ocean	Zone 1-5	Zone 6	Terminal
% of Harvest		6.8%	46.4%	46.8%
Commercial =		92.3%	80.1%	
Sport =		7.7%		82.9%
C & S =			19.9%	17.1%

Year	Escapement (Returning Adults) Total	Hatchery	Wild	Total Harvest (Hatchery + Wild)	Breakdown of Harvest by Zone and Category: Ocean Comm.	Ocean Sport	Zone 1-5 Comm.	Zone 1-5 Sport	Zone 6 Comm.	Zone 6 C & S	Terminal Sport	Terminal C & S
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0
3	7,308	7,308	0	2,105	0	0	132	11	782	194	817	168
4	12,474	12,474	0	3,593	0	0	226	19	1,335	332	1,394	288
5	12,600	12,600	0	3,629	0	0	228	19	1,349	335	1,408	290
6	12,600	12,600	0	3,629	0	0	228	19	1,349	335	1,408	290
7	16,834	12,600	4,234	4,848	0	0	304	25	1,802	448	1,881	388
8	22,821	12,600	10,221	6,572	0	0	412	34	2,443	607	2,550	526
9	25,083	12,600	12,483	7,224	0	0	453	38	2,685	667	2,803	578
10	25,186	12,600	12,586	7,254	0	0	455	38	2,696	670	2,814	581
11	27,641	12,600	15,041	7,961	0	0	500	42	2,959	735	3,089	637
12	32,844	12,600	20,244	9,459	0	0	594	50	3,516	873	3,670	757
13	36,649	12,600	24,049	10,555	0	0	662	55	3,923	975	4,095	845
14	37,695	12,600	25,095	10,856	0	0	681	57	4,035	1,002	4,212	869
15	39,182	12,600	26,582	11,284	0	0	708	59	4,194	1,042	4,378	903
16	43,204	12,600	30,604	12,443	0	0	781	65	4,625	1,149	4,828	996
17	47,564	12,600	34,964	13,698	0	0	860	72	5,091	1,265	5,314	1,096
18	49,780	12,600	37,180	14,337	0	0	900	75	5,329	1,324	5,562	1,147
19	51,109	12,600	38,509	14,719	0	0	924	77	5,471	1,359	5,711	1,178
20	54,058	12,600	41,458	15,569	0	0	977	82	5,786	1,438	6,040	1,246
21	50,939	5,292	45,647	14,670	0	0	921	77	5,452	1,355	5,692	1,174
22	48,883	126	48,757	14,078	0	0	884	74	5,232	1,300	5,462	1,127
23	50,478	0	50,478	14,538	0	0	912	76	5,403	1,342	5,640	1,163
yr 24 thru 100	50,000	0	50,000	14,400	0	0	904	75	5,352	1,330	5,587	1,152

1/ From Grabowski model - spawning population that could be sustained by available habitat above dam
2/ Based on estimated harvest and estimated escapement of Wenatchee stock in 2001.

Table 11. Fish Harvest Breakdown - Cle Elum Sockeye (low)

Cle Elum and Bumping Lake Dams Fish Passage

Fish Harvest Breakdown

Storage Dam Fish Passage Study

Yakima Project, WA

Cle Elum sockeye (low)

Total escapement = 20,000 1/

Harvest to Escapement ratio = 0.288 2/

	Ocean	Zone 1-5	Zone 6	Terminal
% of Harvest		6.8%	46.4%	46.8%
Commercial =		92.3%	80.1%	
Sport =		7.7%		82.9%
C & S =			19.9%	17.1%

Year	Escapement (Returning Adults)			Total Harvest (Hatchery + Wild)	Breakdown of Harvest by Zone and Category							
					Ocean		Zone 1-5		Zone 6		Terminal	
	Total	Hatchery	Wild		Comm.	Sport	Comm.	Sport	Comm.	C & S	Sport	C & S
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0
3	2,900	2,900	0	835	0	0	52	4	310	77	324	67
4	4,950	4,950	0	1,426	0	0	90	7	530	132	553	114
5	5,000	5,000	0	1,440	0	0	90	8	535	133	559	115
6	5,000	5,000	0	1,440	0	0	90	8	535	133	559	115
7	6,680	5,000	1,680	1,924	0	0	121	10	715	178	746	154
8	9,056	5,000	4,056	2,608	0	0	164	14	969	241	1,012	209
9	9,954	5,000	4,954	2,867	0	0	180	15	1,066	265	1,112	229
10	9,995	5,000	4,995	2,878	0	0	181	15	1,070	266	1,117	230
11	10,969	5,000	5,969	3,159	0	0	198	17	1,174	292	1,226	253
12	13,033	5,000	8,033	3,754	0	0	236	20	1,395	347	1,456	300
13	14,543	5,000	9,543	4,188	0	0	263	22	1,557	387	1,625	335
14	14,958	5,000	9,958	4,308	0	0	270	23	1,601	398	1,671	345
15	15,549	5,000	10,549	4,478	0	0	281	23	1,664	413	1,737	358
16	17,144	5,000	12,144	4,938	0	0	310	26	1,835	456	1,916	395
17	18,875	5,000	13,875	5,436	0	0	341	28	2,020	502	2,109	435
18	19,754	5,000	14,754	5,689	0	0	357	30	2,114	525	2,207	455
19	20,281	5,000	15,281	5,841	0	0	367	31	2,171	539	2,266	467
20	21,452	5,000	16,452	6,178	0	0	388	32	2,296	570	2,397	494
21	20,214	2,100	18,114	5,822	0	0	365	30	2,164	538	2,259	466
22	19,398	50	19,348	5,587	0	0	351	29	2,076	516	2,168	447
23	20,031	0	20,031	5,769	0	0	362	30	2,144	533	2,238	462
yr 24 thru 100	20,000	0	20,000	5,760	0	0	362	30	2,141	532	2,235	461

1/ From Grabowski model - spawning population that could be sustained by available habitat above dam

2/ Based on estimated harvest and estimated escapement of Wenatchee stock in 2001.

Table 12. Fish Harvest Breakdown - Bumping Lake Sockeye (high)

Cle Elum and Bumping Lake Dams Fish Passage

Fish Harvest Breakdown

Storage Dam Fish Passage Study
Yakima Project, WA

Bumping Lake sockeye (high)

Total escapement = 6,000 1/

Harvest to Escapement ratio = 0.288 2/

	Ocean	Zone 1-5	Zone 6	Terminal
% of Harvest		6.8%	46.4%	46.8%
Commercial =		92.3%	80.1%	
Sport =		7.7%		82.9%
C & S =			19.9%	17.1%

Year	Escapement (Returning Adults)			Total Harvest (Hatchery + Wild)	Breakdown of Harvest by Zone and Category							
					Ocean		Zone 1-5		Zone 6		Terminal	
	Total	Hatchery	Wild		Comm.	Sport	Comm.	Sport	Comm.	C & S	Sport	C & S
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0
3	870	870	0	251	0	0	16	1	93	23	97	20
4	1,485	1,485	0	428	0	0	27	2	159	40	166	34
5	1,500	1,500	0	432	0	0	27	2	161	40	168	35
6	1,500	1,500	0	432	0	0	27	2	161	40	168	35
7	2,004	1,500	504	577	0	0	36	3	214	53	224	46
8	2,717	1,500	1,217	782	0	0	49	4	291	72	303	63
9	2,986	1,500	1,486	860	0	0	54	5	320	79	334	69
10	2,998	1,500	1,498	864	0	0	54	5	321	80	335	69
11	3,291	1,500	1,791	948	0	0	60	5	352	88	368	76
12	3,910	1,500	2,410	1,126	0	0	71	6	418	104	437	90
13	4,363	1,500	2,863	1,257	0	0	79	7	467	116	488	101
14	4,488	1,500	2,988	1,292	0	0	81	7	480	119	501	103
15	4,665	1,500	3,165	1,343	0	0	84	7	499	124	521	107
16	5,143	1,500	3,643	1,481	0	0	93	8	550	137	575	119
17	5,662	1,500	4,162	1,631	0	0	102	9	606	151	633	131
18	5,926	1,500	4,426	1,707	0	0	107	9	634	158	662	137
19	6,084	1,500	4,584	1,752	0	0	110	9	651	162	680	140
20	6,436	1,500	4,936	1,853	0	0	116	10	689	171	719	148
21	6,064	630	5,434	1,746	0	0	110	9	649	161	677	140
22	5,819	15	5,804	1,676	0	0	105	9	623	155	650	134
23	6,009	0	6,009	1,731	0	0	109	9	643	160	672	139
yr 24 thru 100	6,000	0	6,000	1,728	0	0	108	9	642	160	670	138

1/ From Grabowski model - spawning population that could be sustained by available habitat above dam
2/ Based on estimated harvest and estimated escapement of Wenatchee stock in 2001.

Table 13. Fish Harvest Breakdown - Bumping Lake Sockeye (low)

Cle Elum and Bumping Lake Dams Fish Passage
Fish Harvest Breakdown
Storage Dam Fish Passage Study
Yakima Project, WA

Bumping Lake sockeye (low)

Total escapement = 2,000 1/

Harvest to Escapement ratio = 0.288 2/

	Ocean	Zone 1-5	Zone 6	Terminal
% of Harvest		6.8%	46.4%	46.8%
Commercial =		92.3%	80.1%	
Sport =		7.7%		82.9%
C & S =			19.9%	17.1%

Year	Escapement (Returning Adults) Total	Hatchery	Wild	Total Harvest (Hatchery + Wild)	Breakdown of Harvest by Zone and Category: Ocean Comm.	Ocean Sport	Zone 1-5 Comm.	Zone 1-5 Sport	Zone 6 Comm.	Zone 6 C & S	Terminal Sport	Terminal C & S
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0
3	290	290	0	84	0	0	5	0	31	8	33	7
4	495	495	0	143	0	0	9	1	53	13	55	11
5	500	500	0	144	0	0	9	1	54	13	56	12
6	500	500	0	144	0	0	9	1	54	13	56	12
7	668	500	168	192	0	0	12	1	71	18	74	15
8	906	500	406	261	0	0	16	1	97	24	101	21
9	995	500	495	287	0	0	18	2	107	27	111	23
10	999	500	499	288	0	0	18	2	107	27	112	23
11	1,097	500	597	316	0	0	20	2	117	29	123	25
12	1,303	500	803	375	0	0	24	2	139	35	145	30
13	1,454	500	954	419	0	0	26	2	156	39	163	34
14	1,496	500	996	431	0	0	27	2	160	40	167	34
15	1,555	500	1,055	448	0	0	28	2	167	41	174	36
16	1,714	500	1,214	494	0	0	31	3	184	46	192	40
17	1,887	500	1,387	544	0	0	34	3	202	50	211	44
18	1,975	500	1,475	569	0	0	36	3	211	53	221	46
19	2,028	500	1,528	584	0	0	37	3	217	54	227	47
20	2,145	500	1,645	618	0	0	39	3	230	57	240	49
21	2,021	210	1,811	582	0	0	37	3	216	54	226	47
22	1,940	5	1,935	559	0	0	35	3	208	52	217	45
23	2,003	0	2,003	577	0	0	36	3	214	53	224	46
yr 24 thru 100	2,000	0	2,000	576	0	0	36	3	214	53	223	46

1/ From Grabowski model - spawning population that could be sustained by available habitat above dam
2/ Based on estimated harvest and estimated escapement of Wenatchee stock in 2001.

Harvest Assumptions

1. The total harvest figure is simply determined by applying a ratio to the escapement figure. The ratio of coho harvest to escapement is based on the average ratio obtained from the KID[5] coho salmon model. In the KID model, this ratio varies a bit from year-to-year as fish populations fluctuate. But the ratio fluctuates within a fairly narrow range, so the use of the average in this spreadsheet seems reasonable. For the sockeye salmon estimates, we used an estimated 2001 harvest to escapement ratio for Lake Wenatchee sockeye salmon stock[6]. There is limited information on recent sockeye salmon harvests in the Columbia River basin. In most years, the run under current conditions, is too small to allow any appreciable harvest. Sockeye salmon harvest in the Columbia River is typically constrained to protect ESA-listed Snake River sockeye salmon. We assumed the estimated 2001 Wenatchee harvest to escapement ratio would be representative of conditions that might be expected with restoration of sockeye salmon runs at Cle Elum and Bumping Lake dams.
2. The percent of coho salmon harvest figures by zone, and the percent of coho salmon harvest by commercial, sport, and C&S[7], are the same as the KID coho salmon model. The percent of sockeye salmon harvest figures by zone, and the percent of sockeye salmon harvest by commercial, sport, and C&S, are based on the 2001 harvest figures for Wenatchee sockeye salmon stock[6].

[5] Kennewick and Columbia Irrigation Districts' Pump Exchange Feasibility Study
[6] Developed from information in CRITFC Technical Report 02-2. (Fryer and Kelsey. 2002.)
[7] Tribal Ceremonial and Subsistence

Table 14. 2001 Wenatchee Sockeye Harvest

Cle Elum and Bumping Lake Dams Fish Passage
Development of Sockeye Harvest Percentages
Storage Dam Fish Passage Study
Yakima Project, WA

2001 Wenatchee sockeye harvest

Location	Type	2,001 Harvest	Estimated % Wenatchee stock		Estimated Wenatchee stock harvest
Zones 1-5	Commercial	1,558	34.0%		530
Zones 1-5	Sport	116	34.0% 1/		39
Zones 1-5	Sport	15	34.0% 2/		5
Zone 6	Tribal Commercial	5,580	56.0%		3,125
Zone 6	Tribal C&S	1,386	56.0% 3/		776
Downstream of Priest Rapids Dam	Wanapum Tribal	184	33.0%		61
Priest Rapids pool	Yakama Tribal	1,850	33.0% 4/		611
Lake Wenatchee	Sport	3,265	100.0%		3,265
Chief Joseph Dam Tailrace	Colville Tribal	<50	0.0%		
Okanogan River, Canada	Okanagan Tribal	unknown	0.0%		
				Total	8,412
2001 Bonneville Counts	Mixed stock	114,933	44.0%	=	50,571
2001 Tumwater Dam Counts	Wenatchee stock	32,482	100.0%	=	**32,482**
2001 Wells Dam Counts	Okanogan stock	74,490	0.0%		0

Zones 1-5		Zone 6		Terminal	
Commercial	Sport	Commercial	C&S	Sport	C&S
92.3%					
	6.8%				
	0.9%				
		80.1%			
			19.9%		
					1.5%
					15.5%
				82.9%	
92.3%	**7.7%**	**80.1%**	**19.9%**	**82.9%**	**17.1%**

These figures are used in the fish harvest breakdown spreadsheet.

Zones 1-5 % of total harvest	**6.8%**	
Zone 6 % of total harvest	**46.4%**	
Terminal % of total harvest	**46.8%**	5/
Estimated total harvest to escapement ratio	**28.8%**	6/

Note: All counts, harvest numbers, and percentages are 2001 data taken from CRITFC Technical Report 02-2.

1/ Incidental catch during steelhead sport fishery - assume same % as commercial
2/ Incidental catch during shad commercial fishery - assume same % as commercial
3/ Assume same % as Tribal Commercial
4/ Assume same % as Wanapum Tribal
5/ Includes Downstream of Priest Rapids Dam, Priest Rapids Pool, and Lake Wenatchee
6/ Assumes Lake Wenatchee escapement = Tumwater Dam count minus Lake Wenatchee harvest

Supporting Studies

Limnological Study of Cle Elum Lake

Physical, chemical, and biological information was required for Cle Elum and Bumping lakes to assess production potential for sockeye salmon. We used information obtained during the September 2003 to October 2004 portion of the study. We summarize the results below; the complete report can be found on the website at: http://www.usbr.gov/pn/programs/ucao_misc/fishpassage/activities/CleElumLimno.pdf.

Water Temperature and Dissolved Oxygen

Cle Elum Lake strongly thermally stratifies during the summer, typical of temperate dimictic lakes. Surface water temperature at midlake station CLE2 warms from April through July, then begins decreasing in the fall. Table 15 shows water temperature from June to September, 2004 from surface to 20m for Cle Elum Lake Station CLE2.

Table 15. Monthly water temperatures (C°) in 2004 at Cle Elum Lake station CLE2 from surface to 20 m.

Depth	June	July	August	September
Surface	14.9	21.1	19.3	13.8
10 m	12.9	18.8	15.4	13.3
20 m	9.8	13.3	6.3	5.8

Juvenile sockeye salmon rearing in lakes make diel vertical migrations to feed, metabolize and seek refuge from predators. The range of water temperatures documented during the limnological study should not impact diel migrations of juvenile sockeye salmon.

Dissolved oxygen was near or above saturation in the lake, and exhibited a slight orthograde profile during thermal stratification. Dissolved oxygen was 8.4 mg/L at the surface in July and increased to 8.6 mg/L at 10 m, 9.4 mg/L at 20 m, and 10.6 mg/L at 30 m.

Secchi depth at midlake station CLE2 ranged from 6.9 to 10.2 m and averaged 8.35 m.

Nutrients

Epilimnetic nitrate-nitrite nitrogen levels in Cle Elum Lake ranged from 0.003 to 0.048 mg/L and generally remained less than 0.030 mg/L once the lake stratified. Hypolimnetic nitrate-nitrite nitrogen levels ranged from 0.024 to 0.083. Epilimnetic total Kjeldahl nitrogen (TKN) levels were generally low, averaging 0.19 mg/L and ranging from 0.05 to 0.47 mg/L. Hypolimnetic (TKN) levels were also low, averaging 0.18 mg/L and ranging from 0.05 to 0.57 mg/L (Lieberman draft report 2006).

Epilimnetic orthophosphorus levels were low, averaging 0.0028 mg/L and ranging from 0.001 to 0.005 mg/L. Hypolimnetic orthophosphorus levels were also low, averaging 0.0027 mg/L and ranging from 0.001 to 0.005 mg/L. Nutrient concentrations in the inflow and outflow were lower than those at midlake station. Phosphorus levels in the sediments of Cle Elum Lake after 1906 declined to 19 percent of their earlier levels, attributable in part to the elimination of marine-derived nutrients from returning adult salmon spawning in the Cle Elum Basin (Dey 2000).

Secchi Depth Transparency and Chlorophyll a *Concentrations*

Cle Elum Lake

Secchi depths in Cle Elum Lake at midlake site CLE2 ranged from 6.9 to 10.2 m and averaged 8.4 m in 2004, and ranged from 5.6 to 8.4 m and averaged 6.8 m during the 2005 sampling season. Water clarity in Cle Elum Lake in 2005 was reduced somewhat from 2004. Secchi depth transparency can be affected by algal abundance and turbidity from resuspension of fine sediments from wind or wave action.

Chlorophyll *a* (chl *a*) concentration, an estimate of total algal biomass, is typically used to estimate productivity in aquatic systems to assess trophic status (Likens 1975). Chl *a* concentrations were very low in Cle Elum Lake, as indicated by the mean chl *a* concentrations shown in Table 17. Chl *a* concentration at Cle Elum midlake site CLE2 ranged from 0.43 to 1.9 µg/L; greatest chl *a* levels tended to be present in the 10 to 20 m depth stratum during the period when the reservoir was strongly stratified. Chl *a* concentrations peaked at all stations in September 2004 and again in September 2005 except for the 0 to 10 m depth stratum where it peaked on October at CLE2. Chl *a* often correlates with secchi depth transparency; shallower secchi depths may coincide with greater chl *a* concentrations, indicating greater algal abundance.

Chl *a* concentrations in oligotrophic lakes range from 0.3 to 3.0 µg/L and from 2 to 15 µg/L in mesotrophic lakes (Likens 1975). According to this classification system, Cle Elum Lake would be classified as oligotrophic or unproductive.

Phytoplankton

Thirty-seven species of phytoplankton were identified in Cle Elum Lake. Chlorophyll *a* concentration is an indicator of phytoplankton abundance.

Zooplankton

Thirty-two species of zooplankton were collected from all stations in Cle Elum Lake. *Bosmina longirostris* and *Daphnia rosea* were the dominant cladocerans; *Acanthocyclops vernalis* and *Leptodiaptomus ashlandi* were the dominant copepods. Rotifers were abundant and seasonally comprised the major portion of the zooplankton. Maximum adult copepod density was about 12 individuals/L in May 2004 in the 0 to 10 m depth stratum; maximum cladoceran density was about 6.1 individuals/L in the 0 to 10 m depth stratum in August 2004. The combined densities of cladocerans and copepods, which together constitute the principal prey items for rearing juvenile sockeye salmon, were most abundant at about 13 individuals/L in 0 to 10 m depth stratum in May and 11 individuals/L in the 10 to 20 m depth stratum in April (Figure 3).

The water surface elevation during the September 2003 to October 2004 limnological survey varied from 2,139.25 feet on September 14, 2004 to 2,237 feet on June 16, 2004. More detailed analysis is provided in the report of the limnological study (Lieberman and Grabowski 2007).

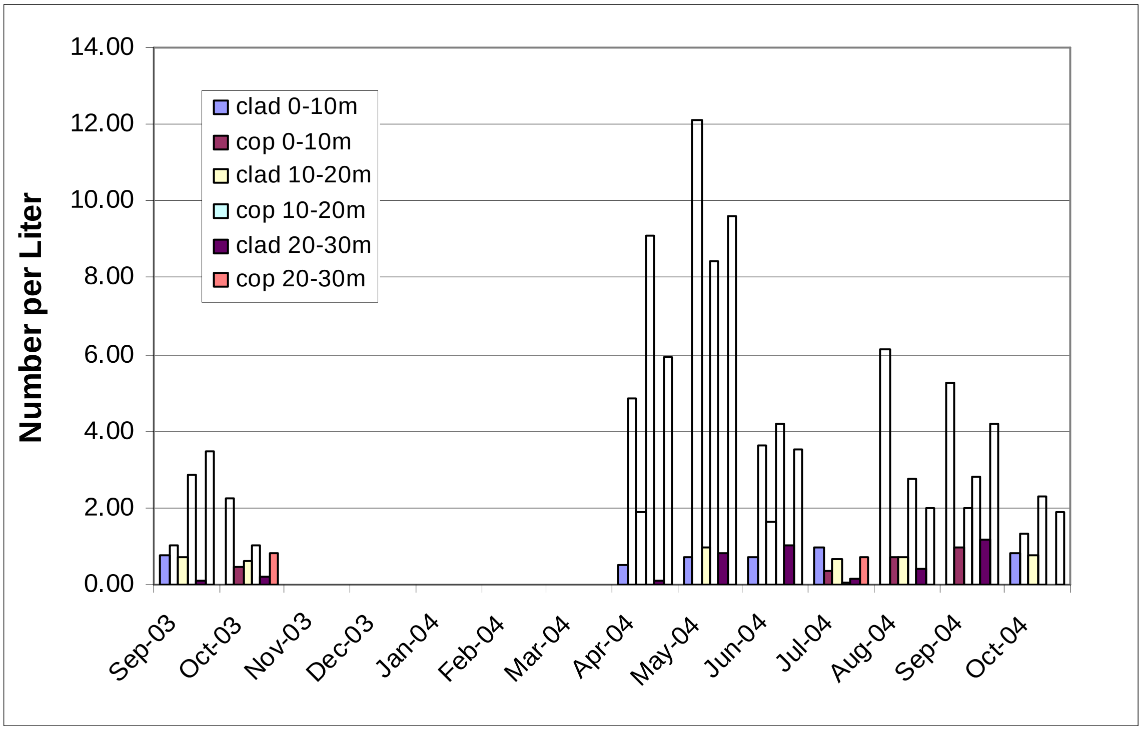

Figure 3. Seasonal abundance and distribution of cladoceran and copepod zooplankton in three depth strata at Cle Elum station CLE2 from September 2003 to October 2004.

Limnological Study of Bumping Lake

Water Temperature and Dissolved Oxygen

Bumping Lake strongly thermally stratifies during the summer, typical of temperate dimictic lakes. Surface water temperature at midlake station BMP2 warms from May through July, then begins decreasing up to the fall. The lake was inaccessible to sample in April 2004.

Table 16. Monthly water temperatures (C°) in 2004 at Bumping Lake station BMP2 from surface to 30 m.

Depth	May	June	July	August	September
Surface	8.6	13.4	20.4	18.4	14.5
10 m	5.5	7.5	10.8	9.7	9.9
20 m	5.2	5.8	6.1	6.1	6.1
30 m	4.9	5.4	5.6	5.5	5.6

Juvenile sockeye salmon rearing in lakes make diel vertical migrations to feed, metabolize, and seek refuge from predators. The range of water temperatures documented during the limnological study are not expected to impact diel migrations of juvenile sockeye salmon.

Dissolved oxygen was near or above saturation in the lake, and exhibited a slight orthograde profile during thermal stratification. Dissolved oxygen was 8.6 mg/L at the surface in July and increased to 11.2 mg/L at 10 m, and descreased to 9.98 mg/L at 20 m, and 8.85 mg/L at 30 m. pH at station BMP2 averaged 6.74 and ranged from about 5.89 to 7.59. Specific conductance average 29.3 and ranged from 25.0 to 35.1 µS/cm.

Secchi depth at midlake station BMP2 ranged from 5.9 to 11.2 m and averaged 8.85 m.

Nutrients

Epilimnetic TKN levels at midlake station BMP2 were generally low, with a sampling period average of 0.16 mg/L and ranging from 0.06 to 0.26 mg/L. Hypolimnetic (TKN) levels were also low, averaging 0.17 mg/L and ranging from 0.05 to 0.22 mg/L. Epilimnetic nitrate-nitrite nitrogen at BMP2 averaged 0.007mg/L, while near the bottom it averaged 0.018 mg/L. Nitrate-nitrite nitrogen concentrations in the Bumping River inflow was 0.010 mg/L and outflow was 0.006 mg/L.

Epilimnetic orthophosphorus levels were low, averaging 0.002 mg/L and ranged from 0.001 to 0.004 mg/L. Hypolimnetic orthophosphorus levels were also low, averaging 0.004 mg/L and ranged from 0.002 to 0.008 mg/L. Orthophosphorus concentrations in the Bumping River inflow was 0.003 mg/L and the outflow was 0.003 mg/L.

Secchi Depth Transparency and Chlorophyll a Concentrations

<u>Bumping Lake</u>

During 2003-2004, Bumping Lake secchi depths ranged from 5.9 to 11.2 m and averaged 8.9 m. Secchi depth was lowest (5.9 m) in October 2003 during a dry water year when the lake was drawn down to minimum pool and had begun to destratify. Secchi depth transparency can be affected by algal abundance and turbidity from resuspension of fine sediments from wind or wave action.

Mean chl *a* concentration in several depth strata at midlake site BMP2 are shown in Table 17. The lake supported phytoplankton production to 30 m, perhaps even deeper, as measured by chl *a* concentration, but chl *a* levels indicated relatively low productivity throughout the spring/summer/fall months of the survey.

Chl *a* concentrations in oligotrophic lakes range from 0.3 to 3.0 µg/L and from 2 to 15 µg/L in mesotrophic lakes (Likens 1975). According to this classification system, Bumping Lake would be classified as oligotrophic or unproductive.

Table 17. Mean chlorophyll *a* concentrations (µg/L) at midlake stations in Cle Elum and Bumping Lakes.

Depth/depth stratum	Cle Elum Lake, CLE2	Bumping Lake, BMP2
1 m	0.9	1.0
0-10 m	1.07	1.55
10-20 m	1.16	1.38
20-30 m	0.8	0.93

Phytoplankton

Forty-two species of phytoplankton were identified in Bumping Lake. The great majority of species collected were dinoflagellates (Division Pyrrhophyta) and diatoms (Division Chrysophyta). Some blue-green algae (Division Cyanophyta) were collected in September and October 2003. *Anabaena flos-aquae* and *Aphanocapsa* sp. were present in low levels.

Zooplankton

Twenty-seven species of zooplankton were collected from all stations in Bumping Lake. *Daphnia rosea*, *Bosmina longirostris,* and *Holopedium gibberum* were the dominant cladocerans; *Diacyclops thomasi* and *Hesperodiaptomus francisanus* were the dominant copepods. Rotifers were abundant and seasonally comprised the major portion of the zooplankton. Maximum cladoceran density was about 16.14 individuals/L in the 10 to 20 m depth stratum in July 2004; maximum adult copepod density was about 1.30 individuals/L in July 2004 in the 20 to 30 m depth stratum. The combined densities of cladocerans and copepods, which together constitute the principal prey items for rearing juvenile sockeye salmon, were most abundant at about 17.38 individuals/L in 10 to 20 m depth stratum in July and 9.43 individuals/L in the 0 to 10 m depth stratum, also in July (Figure 4).

The water surface elevation during the September 2003 to October 2004 limnological survey varied from 3.401.93 ft on 15 October 2003 to 3,426.68 ft on 12 May 2004.

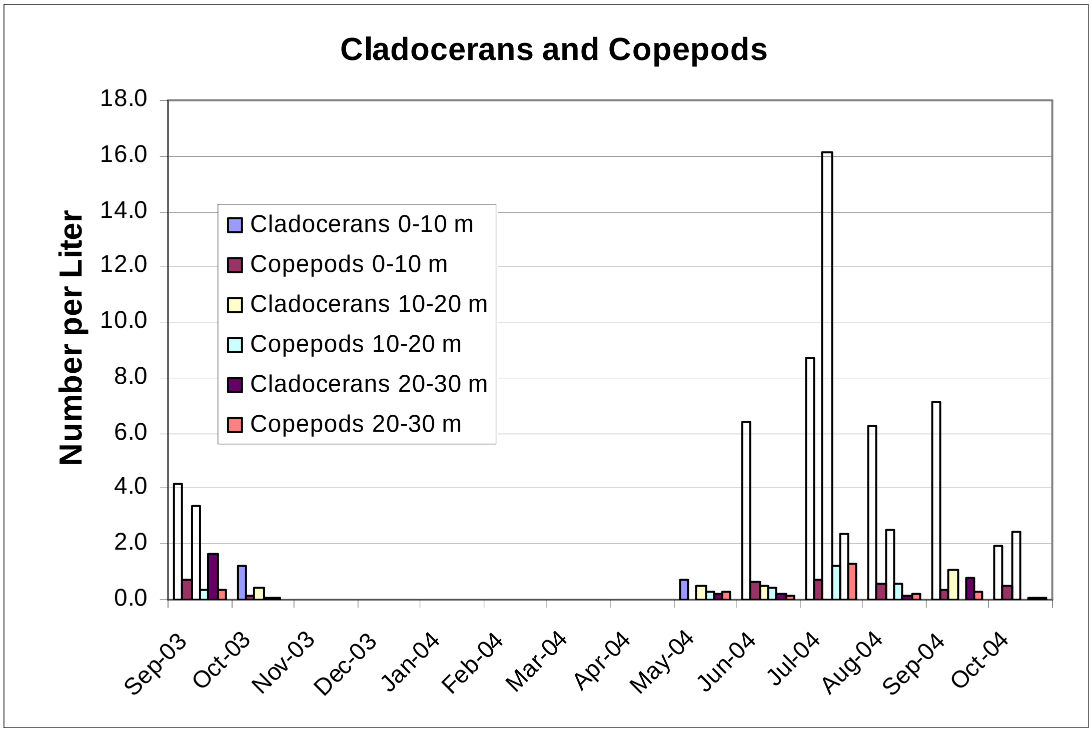

Figure 4. Seasonal abundance of cladoceran and copepod zooplankton in three depth strata at Bumping Lake station BMP2 from September 2003 to October 2004.

Stream Macroinvertebrate Surveys

Introduction

In large part, food resources for juvenile salmonids in lotic systems consist of invertebrates in the drift and benthos. A variety of invertebrates are important as food items for fishes, and changes in invertebrate communities may result in changes in condition of fish communities. Growth rates of salmonids are often linked to food availability and increased food may lead to increased growth rates and ultimately higher survival. Differences in the ability of streams to produce salmonids are often related to food availability rather than physical habitat. Reclamation required information on food availability to support potential reintroduced anadromous salmonids above Cle Elum and Bumping dams.

Reclamation biologists collected samples at 21 sites in September 2003, March/April 2004, and September 2004. Sampling occurred in the major tributaries flowing into Cle Elum and Bumping Lake reservoirs and in the rivers below the reservoirs. Environmental variables that may control macroinvertebrate assemblages was also collected and analyzed. The study is summarized here. The complete report is available on the web at: http://www.usbr.gov/pn/programs/ucao_misc/fishpassage/activities/macroinvertebratestudy.pdf. Literature references are not included in this summary, but are in the full report.

Methods

Sampling of Biological, Chemical, and Physical Variables

Most sampling occurred above the Cle Elum and Bumping reservoirs in the Cle Elum and Bumping watersheds. Some sampling occurred below the reservoirs.

A 3-minute kick method with a D-frame net was used for sampling benthic invertebrates along 25-m wadeable portions of the streams. Kick-net samples were enumerated and identified to lowest practical taxon under a binocular dissecting scope. Coarse-particulate-organic-matter (CPOM) was picked from the kick-net samples during processing for benthic invertebrates. Periphyton samples were collected from rocks or other solid, flat surfaces with a sampling device made from a modified 30-ml syringe.

Dissolved oxygen, conductivity, pH, and water temperature were measured with a portable meter. Water samples for alkalinity and hardness were analyzed with titration methods. Size composition of the substrate was visually estimated at each site in the area where macroinvertebrates were collected. Wet width of the stream was measured with a measuring tape or a range finder. Depth was measured with a calibrated rod. Water velocity at 10 cm above the substrate was measured at three discrete points in the invertebrate collection area. Habitat disturbance was estimated with Pfankuch's Index (Pfankuch 1975).

Data Analysis

Multivariate analysis (CANOCO 4.0), taxa richness and abundance measures, and biomass were used to compare invertebrate assemblages. Ordination techniques were used to examine patterns in the macroinvertebrate data and to identify physical and chemical variables that were most closely associated with invertebrate distributions. After an initial analysis of the data set, the canonical correspondence analysis (CCA) model was selected for analysis. Initial environmental variables used in the CCA model included conductivity, temperature, width, pH, Pfankuch index, S.I., percent sand, periphyton biomass, CPOM mass, and depth.

Data from invertebrate sampling were compared to water quality biological criteria developed by the Washington State Department of Ecology (Merritt et al. 1999). The California Tolerance Value (CTV) was also calculated as a general index of tolerance to human disturbance.

Standing crop categories promulgated by Mangum (1989) were used to relate biomass data collected in this study to other stream values.

Five types of sites were sampled:

- Bumping drainage below the dam
- Bumping drainage above the dam
- Cle Elum drainage below the dam
- Cle Elum drainage above the dam
- Pool habitats (including the slow water habitat at Reach +7 of the Cle Elum)

Results

A total of 126 macroinvertebrate taxa were found in the study area.

Invertebrate food resources

CPOM differed among the sites. Amounts of CPOM were higher at lotic sites above the dams and very low at Cle Elum sites below the dam and at pool sites. Sites above the dam in the Bumping drainage had the greatest amounts of CPOM. Conversely, periphyton biomass was greatest at sites below the dams and at the pool sites, and lowest at lotic sites above the dams.

Substrate also varied among sites with the percent of substrate containing boulders much higher at Cle Elum sites above the dam while the percent of substrate that was sand was higher in pool sites. Velocity was similar at most types of sites, with the exception of pool sites where it was much lower. Stream width was greatest at sites below the dams and smallest at sites above Bumping reservoir. Sites above Bumping reservoir were relatively shallow and deepest sites were those associated with pools. Temperatures were highest at sites below the reservoirs and lowest at sites found in the Bumping drainage above the reservoir.

Benthic Invertebrate Distributions and Relationship with Environmental Variables

CCA analysis with all samples suggested differences between aquatic invertebrate communities. Invertebrates associated with pools were those that are tolerant of fine sediment and associated with increased water depths. Sites above reservoirs contained more shredders and scrapers. The large river sites below the reservoirs were numerically dominated by collector-filterer functional feeding groups. This longitudinal pattern of shredders and scrapers giving way to collector-filterers is a typical pattern for streams in the northwest.

Some rare taxa that were present at Bumping drainage sites have hyporheic affinities suggesting that cold groundwater is upwelling at these sites. The high abundance of shredders associated with pool habitat was from large numbers of *Hyalella* present at Cle Elum R +7. This is an anomalous site that consists of a long stretch of marsh-like, slow-velocity habitat.

Standing Crop

The majority of these sites would be described by Mangum’s criteria (Mangum 1989) as being poor for standing crop with dry weight biomass < 0.5 g/m^2. Several sites in the Bumping drainage, however, would be placed in the fair category as was a single Cle Elum site (Cle Elum R+2). Mean dry weight biomass at lotic sites upstream of Bumping Reservoir was higher than that found at sites above Cle Elum Reservoir.

Particular invertebrates such as midges and baetid mayflies, perhaps because of their strong presence in the drift, may be especially important in the diet of juvenile salmonids. Abundance of these invertebrates varied with types of locations with mean values highest in the Bumping drainage above the reservoir.

Organic Matter

CPOM was highest at sites above Bumping Reservoir. Lotic sites above the reservoirs were similar in having relatively low amounts of periphyton biomass.

Biological Criteria

CTVs indicated that, with the exception of Cle Elum R +7, all sites had good-excellent water quality. Cle Elum R +7 was from a long section of more lentic character and almost marsh-like. The CTV of 6.9 would suggest that this is fairly poor water quality. Tubificid worms, implicated in whirling disease transmission, were collected only from this site.

Sites above the reservoirs tended to have higher water quality, with those below Bumping having higher quality than those below Cle Elum.

Discussion

Benthos Distribution and Water Quality

Benthic macroinvertebrates showed some of the same patterns described by the River Continuum Concept (RCC) as described by Vannote et al. (1980) where a gradient of physical variables from upstream to downstream result in a continuum of biotic adjustments. This pattern was found at sites along the Bumping and Cle Elum drainages and is typical of the northwest. Pools were not part of this gradient and contained invertebrates that were tolerant of depth, low velocity, and fine sediment.

Sites in the Cle Elum drainage above the reservoir may be atypical, with low numbers of shredders and depauperate in invertebrate biomass and CPOM. Temperature and substrate were important variables in structuring the invertebrate community between upper Bumping and Cle Elum sites.

Benthos metrics suggested that water quality was suitable and not a concern at most of the sampled sites.

Organic Matter

Often there is a link between organic matter and productivity of a stream's food web. Litter exclusion has resulted in some of the lowest secondary production estimates reported for stream ecosystems. The decreased CPOM in the upper Cle Elum drainage may be related to the larger size substrate found there. Other factors may also decrease CPOM standing crop including hydrology, riparian characteristics, stream size and depth, and past history of logging.

In this study, periphyton biomass was similar between the upper portions of Cle Elum and Bumping river drainages, while CPOM was higher in the Bumping. CPOM was positively correlated with a variety of biological variables, while periphyton biomass was not. Absent from both of these drainages, at this time, are salmon carcasses. These could be very important in enhancing the food web. Wipfli et al. (1998) found that biofilm and macroinvertebrate abundance increased in natural streams where salmon carcasses were introduced, suggesting an increase in stream productivity.

Linkages with Fish

Richardson (1993) suggests that productivity of salmonids is controlled by lower trophic level production, resulting in "bottom-up" regulation of salmonid production. Mangum (1989) suggests that invertebrate biomass levels below 0.5 g/m^2 result in poor fisheries. Weng et al. (2001) found that juvenile salmonids experienced higher growth rates when streams were enriched to the point where benthic invertebrate biomass was in the range of 0.6 to 0.8 g/m^2. This is similar to Hetrick et al. (1998) who found that salmon streams contained 0.5 to 1.0 g/m^2 dry weight of invertebrate biomass.

Sites that had the highest biomass in the present study were mostly found in the Bumping River drainage. A single site from the Cle Elum drainage had biomass that Mangum (1989) would describe as fair for fisheries production.

It should be noted that benthos data from the present study were limited to a single sampling occasion, from samples collected only from the surface of the stream bottom. Hyporheic invertebrates from deep within the substrate may make up a large portion of stream productivity that is susceptible to fish predation (such as during emergence). Also, while standing crop is often related to production, short-lived species can have low standing crop but high turnover and yearly production (Waters 1988) that could provide for increased fish food. These issues could modify conclusions drawn from standing crop data.

Water Temperature Monitoring – U.S. Forest Service

Cle Elum River Water Temperature

Some additional water temperature information was collected in the Cle Elum River at several locations in 2004, to supplement earlier information. Average, minimum, and maximum water temperatures recorded at eight locations from July to October 2004. At these locations, maximum water temperature exceeded the state water temperature standard of 16.1°C for some time during the summer (

Table 18). Water temperature for below Scatter Creek and above Cooper River in the Cle Elum River are shown in Figure 5 and Figure 6. Maximum water temperature downstream from Scatter Creek exceeded 21.1°C in August and most likely reflects the warming of shallow Tucquala Lake. Further downstream, maximum water temperatures approached but did not exceed 21.1°C. Average water temperatures generally exceeded the 15°C upper optimum range for rearing juvenile coho salmon from about mid July to the third week in August, and slightly later at the Scatter Creek location. Maximum water temperature generally dropped below 15°C by about the end of August. A few areas of groundwater upwelling have been identified by USFS biologists, but the flow from these, even though they may have a localized cooling effect on the river, are apparently insufficient to offset the apparent larger effect of warm water from Tucquala Lake. For comparison, water temperatures were 11.3°C and 11.5°C in Cle Elum River reaches C-2 and C-3, respectively, during the benthic macroinvertebrate sampling in September 2003.

Table 18. Water temperature for several locations in the Cle Elum River from July to October 2004.

Site	River Mile	Recording dates	Maximum Temperature °C	Days Exceeding 16.1°C	Max 7-day Average Maximum Temperature	Days Where 7-day Average Exceeded 14.4°C
Cle Elum River at Deception Pass	32.53	7/18/04 - 10/3/04	21.40	38	20.65	43
Cle Elum River above Lake Tucquala	30.10	7/18/04 - 10/3/04	20.65	38	20.21	43
Cle Elum River at Scatter Creek	29.20	7/18/04 - 10/3/04	22.32	40	21.54	44
Cle Elum River below Fortune Creek	26.90	7/18/04 - 10/3/04	20.61	30	20.10	36
Cle Elum River at South End of Goat Mountain	26.10	7/19/04 - 10/3/04	20.46	34	19.86	42
Cle Elum River at Huckleberry Mt. Spawning Area	25.30	7/19/04 - 10/3/04	20.44	35	20.09	40
Cle Elum River at Salmon la Sac	19.90	7/17/04 - 10/4/04	20.59	41	19.76	46
Cle Elum River above French Cabin Creek	17.50	7/13/04 - 10/4/04	20.61	41	19.82	45
Source: U.S. Forest Service, Wenatchee National Forest, Cle Elum Ranger District, 2005						

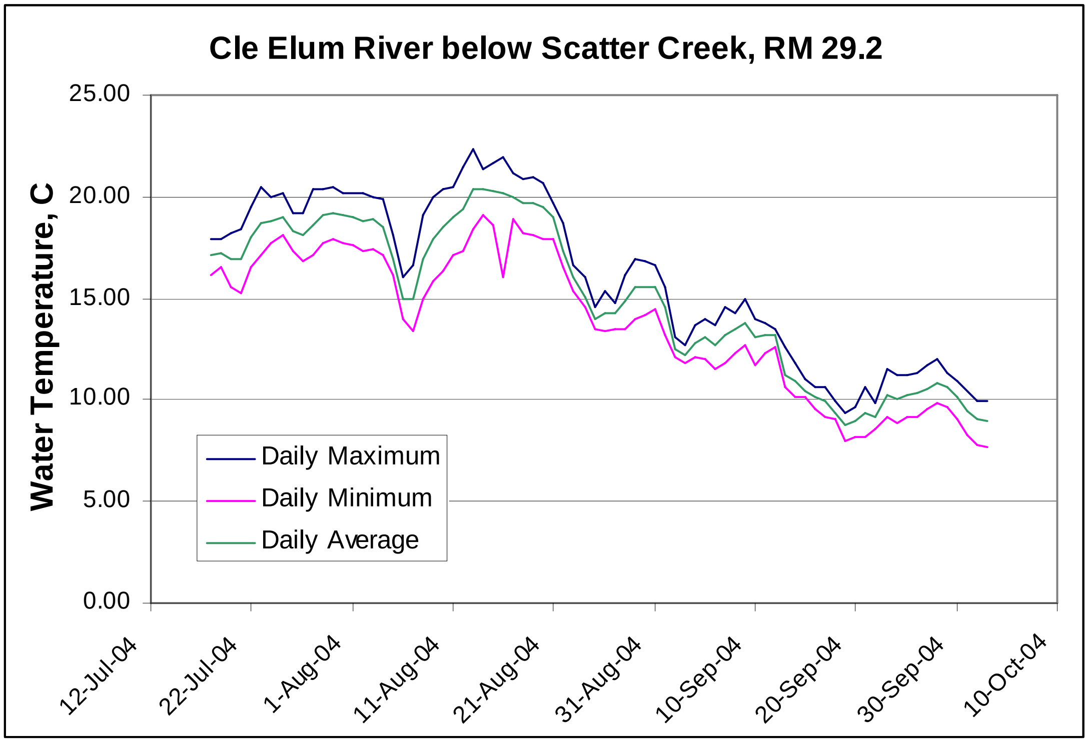

Figure 5. Water temperatures on the Cle Elum River downstream from Scatter Creek from July to October 2004.

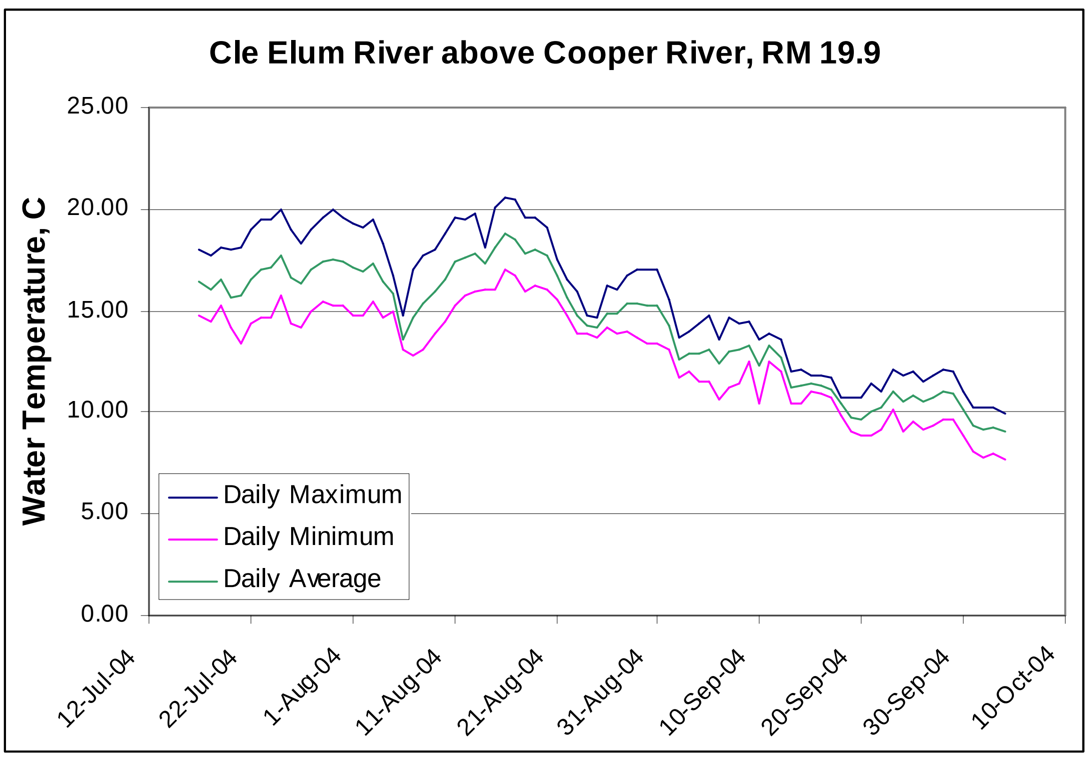

Figure 6. Water temperatures on the Cle Elum River upstream from the Cooper River from July to October 2004.

Sediment Surveys – U.S. Forest Service

Introduction

Fine sediment is a natural component of streambeds, but sediment levels are often elevated in streams affected by roads, logging, or mining. Increased sediment load in streams can adversely affect salmonid spawning and rearing success by facilitating suffocation and metabolic waste-poisoning of eggs (Chapman 1988), decreasing egg survival to emergence (Reiser and White 1988), and increasing entrapment and suffocation of fry (Chapman and McLeod 1987). Accelerated sedimentation can lead to channel widening and loss of pool habitat (Peterson et al. 1992), and is often correlated with higher stream temperatures.

In 2003, a Washington Conservation Corps crew sampled reaches in the Cle Elum River for bed composition. This river historically provided spawning and rearing habitat for Chinook salmon (*Oncorhynchus tshawytscha*), coho salmon (*O. kisutch*), and steelhead (*O. mykiss*), as well as rainbow trout (*O. mykiss*) and bull trout (*Salvelinus confluentus*).

The Lake Cle Elum Dam has blocked the upstream migration of anadromous fish into the upper Cle Elum River for nearly a century. In the next five years, Reclamation intends to move migrating fish beyond the dam, and at that point the upper Cle Elum River will be available as spawning habitat for salmon and steelhead.

The Wenatchee National Forest Land and Resource Management Plan (WNF LRMP 1990) states that spawning gravel will consist of no more than 20 percent fine sediment (less than 1.0 mm). Watershed Analysis ratings (Schuett-Hames et al. 1999) are based on the percent of a gravel sample that is less than 0.85 mm in diameter. Samples with less than 12 percent fine sediment are considered "Good", samples with 12 to 17 percent fine sediment are considered "Fair", and samples with greater than 17 percent fine sediment are consider "Poor". Research has indicated that the geometric mean diameter (Dg) of spawning gravel is the most sensitive measure of salmonid survival to emergence, and percentage of particles less than 0.85 mm is the most sensitive indicator of changes to substrate induced by land management activities (Young et al. 1991).

Methods

Sampling methods followed the techniques described in the Schuett-Hames et al. (1999). Sampled stream segments were identified using the techniques described in the protocol, with attention paid to stream gradient. Samples were taken with a McNeil core sampler. The crew took four samples in each riffle. Sampling took place between August 15, 2003 and September 4, 2003.

Samples were processed at the Cle Elum Ranger Station according to the protocol in Schuett-Hames et al. (1999). The stacked sieves were of the following sizes: 76.1, 25.4, 12.7, 9.5, 6.3, 2.8, 2.0, 1.2, 1.0, 0.85, and 0.50 mm. Silts (<0.5 mm) were collected beneath the sieves and poured into Imhoff cones, where they settled out and were measured. Data entry and statistical analysis were done using Microsoft Excel.

Results

In the Cle Elum River (Figure 7), the mean percent fines in Reach 1 was 10.24 percent (SD 4.20) and the mean geometric mean diameter was 5.73mm (SD 1.43). In Reach 2, the mean percent fines was 14.12 percent (SD 7.16), while the mean geometric mean diameter was 5.66mm (1.01).

Discussion

The results of sampling in each riffle, and the averages for each reach, are presented in Table 19. We choose riffles that allowed for four samples each. The variability between samples makes it clear that replicates are needed to calculate a representative mean. However, it is also true that sediment deposition is spatially variable, and calculating a mean may always be a poor representation of the physical reality. The results of percent fines for all the reaches surveyed this year are summarized in Table 19.

Reach 1 of the Cle Elum River is considered "good" spawning habitat, while Reach 2 is considered "fair". Further reduction of sediment inputs to the river will improve habitat quality for both resident and anadromous fish. We will monitor these reaches for habitat quality as restoration work is done in the watershed.

Table 19. Mean percent fines and mean geometric mean diameter of McNeil core samples from the Cle Elum River in September of 2003.

	Mean Percent Fines	SD	Mean Geometric Mean (mm)	SD	Samples
Cle Elum River					
Reach 1 -- Averaged	*10.24%*	*4.20%*	*5.73*	*1.43*	*12*
Riffle 1	15.38%	2.39%	5.36	1.78	4
Riffle 2	8.50%	1.49%	6.43	1.18	4
Riffle 3	6.84%	1.46%	5.42	1.41	4
Reach 2 -- Averaged	*14.12%*	*7.06%*	*5.66*	*1.01*	*12*
Riffle 1	11.83%	4.57%	6.18	1.03	4
Riffle 2	12.72%	8.04%	4.66	0.28	4
Riffle 3	17.81%	9.30%	5.58	1.02	4

Table 20. Percent fines in each McNeil core sample taken in each riffle of Cle Elum River in September of 2003.

			Percent Fines					
Stream Name:	**Reach No.**	**Riffle No.**	**Sample 1**	**Sample 2**	**Sample 3**	**Sample 4**	**% Avg. of Riffle**	**% Avg. of Reach**
Cle Elum	1	1	17.7	12.73	14.01	17.06	15.4	
Cle Elum	1	2	6.41	9.18	9.84	8.59	8.5	
Cle Elum	1	3	5.53	8.24	7.98	5.63	6.8	10.2
Cle Elum	2	1	17.89	8.89	12.75	7.78	11.8	
Cle Elum	2	2	10.27	11.28	24.11	5.24	12.7	
Cle Elum	2	3	16.75	25.2	7.37	20.87	17.8	14.1

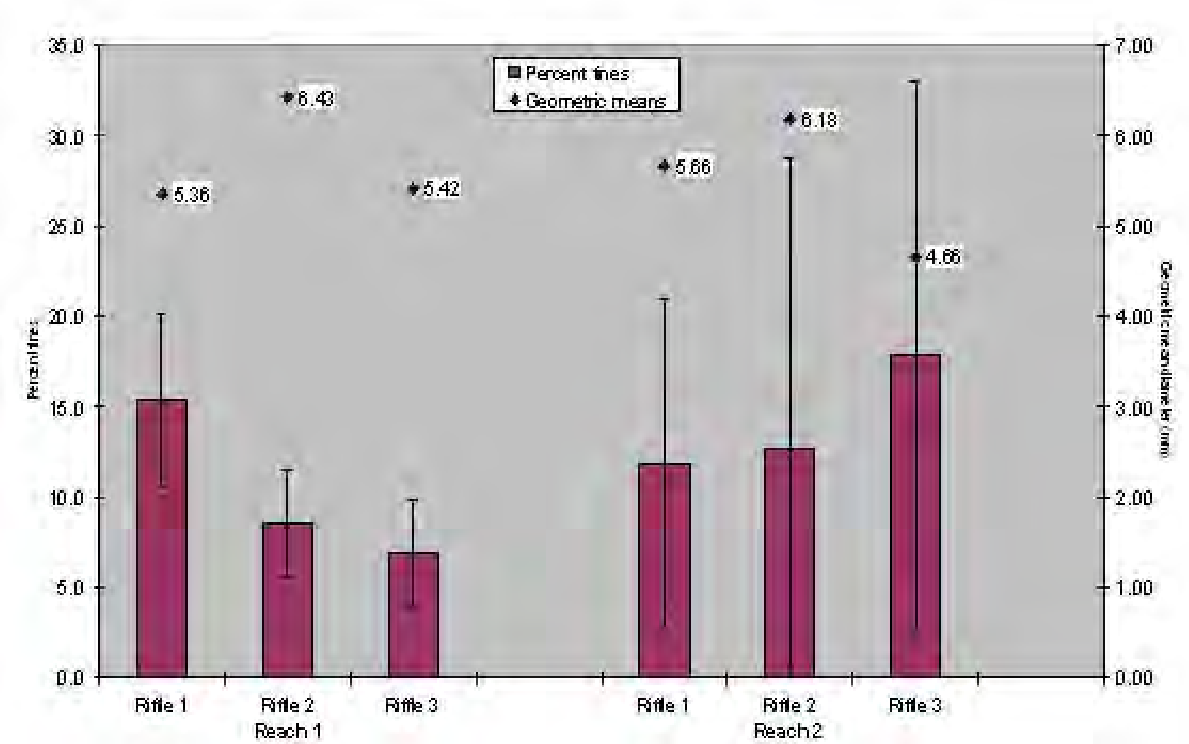

Figure 7. Percent fines and geometric means of McNeil core samples from the Cle Elum River in September 2003. Error bars indicate twice the standard deviation fromt he mean (n=4).

Stream Surveys – U.S. Forest Service

Numerous stream surveys have been conducted by USFS staff biologists from the Cle Elum and Naches Ranger districts as part of ongoing habitat assessments. Information collected by USFS biologists from 1991 on was available for some of the tributaries entering the Cle Elum River and Bumping River above the dams, and this information was used in the production potential assessment for coho and sockeye salmon. However, additional information was needed for Deep Creek, a tributary of Bumping Lake, to complete the production potential assessment of the Bumping River basin above the dam. With funding from Reclamation, USFS Cle Elum Ranger District staff Tina Mayo, Rebecca Wassell, Derrick Bawdon, Noel Ferguson, and Joan St. Hilaire surveyed Deep Creek upstream from its confluence with Bumping Lake 5.36 miles to a 35-foot-high waterfall that is a barrier to migrating fish from July through October 2005. Table 21 summarizes physical habitat data for Deep Creek, from which, along with additional data on stream substrate size and composition, was used to estimate the amount of spawning habitat for coho and sockeye salmon and juvenile rearing habitat for coho salmon.

Table 21. Summary Data for Deep Creek

	Reach 1	Reach 2	Reach 3
Begin elev. (ft)	3435	3500	3590
End elev. (ft)	3500	3590	3840
Change in elevation (ft) (from topo map)	65	90	250
Valley length (ft)	4118	7392	12,144
Measured channel length (ft)	4804	8792	13,868
Average riffle gradient (measured)	1.4	1.0	1.8
Sinuosity	1.09	1.19	1.12
Length in riffles (ft)	2054	5717	7087
Length in pools (ft)	2684	3075	6717
Length in side channels (ft)	2010	6496	1800
Length in culverts (ft)	66	0	64
Percent riffle	32.3%	47.9%	44.8%
Percent pool	49.9%	26.0%	52.2%
Percent side channels	16.5%	26.1%	1.9%
Riffles/mile	30.8	24.0	24.0
Pools/mile	34.1	27.6	32.7
Length of unstable banks	100	3	721
Percent of banks that are unstable	1.0%	0.0%	3.0%
Average bankfull channel width (ft)	45.3	45.3	47.8
Average bankfull depth in riffle (ft)	5.5	2.5	2.2
Avg. floodprone width (ft)	567	604	118
Bankfull width/depth ratio	8.2	18.1	21.7
Bankfull width/floodprone	0.08	0.08	.41
Wood (large & medium)/mile	219	144	176
Wood (all)/mile	389	275	296

Cle Elum Dam Interim Fish Passage Operations

One component of the planning study is to provide interim (temporary, experimental) passage features at Cle Elum Dam to test the ability of juvenile salmonids to find the fish passage features and move out of the reservoir under their own volition. Uniquely marked fish are monitored as they exit the reservoir, migrate downstream, and return as adults. The interim passage protocols use Passive Integrated Transponder (PIT) tags implanted in the test fish to monitor their movement through the system. PIT tag detectors located at Cle Elum, Prosser, McNary, and Bonneville dams record the passage of these juveniles as they migrate downstream, and when they return as adults.

Results of these interim passage experiments over a period of 5 to 8 years will be used as one indicator of the feasibility of reintroducing anadromous fish species above the dam and reservoir.

Installation and Testing of PIT Tag System–2005

In the early spring of 2005, Reclamation completed construction of the interim (temporary, experimental) downstream juvenile fish passage facility at Cle Elum Dam. The passage features include a stop-logged overflow section and plunge pool installed in the second radial gate bay from the left side of the spillway, and a temporary plywood and lumber framed flume built on the existing spillway. Two PIT tag detectors were installed in the flume by Biomark, Inc., Boise, Idaho. The interim passage facility is designed to pass a maximum flow of about 400 ft^3/s. The overflow section can pass flows whenever the reservoir pool is at least two feet above the spillway crest (elevation 2223).

Low reservoir levels in 2005 caused by drought conditions, precluded the planned release of 10,000 PIT-tagged coho salmon smolts into the reservoir. Instead, the fish were released in April at several points downstream from Cle Elum Dam (1/3 below Cle Elum, 1/3 in Roza pool, 1/3 below Roza). Cle Elum Reservoir reached spillway crest elevation of 2223.00 on May 17, 2005. It rose to a maximum elevation of 2225.70 on May 26, 2005 and then dropped back below the spillway crest elevation on June 6, 2005. This very short period of time when the pool was above the spillway crest combined with the shallow depth of flow over the crest, limited fish passage and PIT tag testing activities in 2005. Nevertheless, Reclamation was able to operate the passage flume for several days, and the YN and Biomark were able to test the functionality and efficiency of the PIT tag system by releasing several groups of PIT tagged coho salmon smolts directly into the flume on June 2 and June 3, 2005.

The reservoir pool elevation limited flow in the passage flume to less than 100 ft^3/s. Flow depth in the flume was only about 0.6 ft ± (flume designed for maximum flow depth of about 4 ft). The flume functioned properly with no vibration and minimal turbulence. Even under this low flow operating condition, the PIT tag detectors performed well. A total of about

1,800 smolts were released into the flume in various sized groups. The combined detection was over 97 percent on single groups of up to 5 fish released at once. More detail on installation and testing of the PIT tag system in 2005 is summarized in the report Cle Elum Dam Juvenile PIT Tag Fish Bypass System Report, Technical Series No. PN-YDFP-004, Bureau of Reclamation, Boise, ID, 2005.

Other Interim Passage Activities in 2005

The YN released 3,000 PIT-tagged coho salmon parr into the Cle Elum River above Cle Elum Reservoir in August 2005. The purpose of this release was to test rearing and overwintering survival, and outmigration in the spring of 2006. The PIT tag detectors were taken back to the laboratory for testing and adjustment. Modifications such as sun shades and spillway flow deflectors were installed at the detector locations and other modifications to monitoring and control equipment and other physical features were made.

Interim Passage Activities in 2006

In 2006, YN biologists released about 10,000 PIT tagged coho salmon smolts into the reservoir from a net pen located about ½ mile upstream from the spillway. Several hundred of these fish were recorded by the PIT tag detector in the spring of 2006 as they passed through the interim flume. About 5 percent of the fish counted were from the coho parr released the previous year (2005). These preliminary results are encouraging and seem to confirm that the basic concept proposed for downstream passage may work to effectively move juvenile fish downstream. The biologists also released about 1,000 PIT-tagged coho salmon smolts downstream from the dam as controls, and another 1,000 fish directly into the passage flume to check the efficiency of the PIT tag detectors.

Reservoir levels didn't reach spillway elevation until early June. This is late in the coho salmon season of migration, but did allow for 32 days of downstream passage and a reasonable testing both of the passage facility and the PIT tag detectors. The passage facilities were operated from June 6 through July 9, 2006, at which time pool elevations again dropped below spillway level.

Even though the period of operation was late in the season and of relatively short duration, 617 PIT-tagged coho salmon smolts were recorded passing through the passage flume. Thirty of these fish were from the group of 3,000 coho salmon parr released in the summer of 2005 at Tucquala Lake in the Cle Elum River about 12.9 miles upstream from the reservoir. The remaining fish were from a group of 10,000 coho salmon smolts released into the reservoir in late May 2006, about ½ mile upstream from the dam. The coho salmon were late in their season of migration which normally is late winter or early spring.

Most of the PIT-tagged coho salmon were detected during the period of June 16 to July 9, 2006; the prime time of travel was between 0600 hrs to 1200 hrs Zulu[8].

---

[8] All time in the operations log are PST or PDT. However, the times noted in the PIT tag files are GMT or Zulu times (PST=GMT-8, PDT=GMT-7).

Flow depths of 18 to 24 inches were consistently maintained over the stoplogs as the reservoir levels changed. Reclamation operations staff reported that it is challenging to maintain fish passage flows at Cle Elum and meet target flows at Parker at the same time. At times, fish passage flows of 400 ft^3/s ± were a substantial part of the total releases from Cle Elum Dam. However, remote control enabled the operators to make good release patterns.

Interim passage stoplog operations went smoothly, although Reclamation staff resources were stretched thin because of Keechelus Dam refill operations. The stoplogs functioned properly. There were no debris problems. Operation of the stoplogs to follow water surface levels as the reservoir filled and receded, did put some strain on limited operation and maintenance staff resources. The Project operators will try to maintain as much carryover in Cle Elum Reservoir as possible to help operations in 2007.

Interim Passage Activities in 2007

In 2007, YN biologists again released about 10,000 PIT tagged coho salmon smolts into the reservoir, and about 3,000 coho salmon parr into the Cle Elum River at Tucquala Lake. The PIT tag detectors at the Cle Elum interim passage flume counted 3,450 of the smolts as they exited the reservoir and passed downstream. Another 954 juvenile fish from the 2006 releases were also counted as they passed through the flume in 2007. Many of the smolts were also detected at downstream locations as they migrated out to the ocean. Several PIT-tagged coho salmon adults from previous year's releases were detected as they returned to the Yakima River.

The detection in 2007 of 954 PIT-tagged coho salmon smolts from the 2006 smolt release into the lake was interesting since it represents almost 10 percent of the overall number released and indicated that the fish can survive for a year in the reservoir. We assume that these juvenile fish summered and overwintered in the reservoir, although some might have moved up into the Cle Elum River or tributary streams to overwinter. There are no data available to determine what these fish actually did, but the fact that 954 fish were detected a year after release is encouraging.

Yakama Nation and Washington Department of Fish and Wildlife Conceptual Reintroduction Plan

This section of the appendix presents a suggested sequence and methodology for reintroduction of anadromous fish species above Reclamation storage dams in the Yakima Basin. This plan is based on extensive discussions between the fisheries co-managers–YN Fishery Resource Management and WDFW. Since this re-introduction plan was developed in 2004, it does not reflect some of the recent major accomplishments of the fish passage program.

The anadromous fish species being considered for reintroduction above the storage dams in order of preference include sockeye salmon (*Onchorynchus nerka*), coho salmon (*O. kisutch*), spring Chinook salmon (*O. tshawytscha*), summer steelhead (*O. mykiss*), and Pacific lamprey (*Lampetra tridentata*). An additional objective is to provide two-way passage for resident bull trout to restore genetic connectivity between landlocked adfluvial populations in the storage reservoirs and fluvial (riverine) bull trout that reside downstream from the dams. Bull trout and steelhead are listed as "threatened" under the Endangered Species Act.

During the Phase I Assessment, the inter-agency work group and Reclamation selected two dams for detailed feasibility/engineering study. The two selected projects are Cle Elum Dam (Cle Elum River, Kittitas County) and Bumping Lake Dam (Bumping River, Yakima County) Other YP storage dams may be considered for future fish passage facility construction based on the success of the interim passage facilities and the fish reintroduction plan at these two projects. This proposed reintroduction plan currently addresses only the Cle Elum Dam juvenile fish passage project.

Considering the significant costs involved in planning, engineering, construction, operation and maintenance of even temporary fish passage facilities at this project, waiting for existing fish populations downstream from the dams to colonize or "pioneer" newly accessible upstream habitat is unacceptable to the fisheries co-managers and Reclamation. It could take three or four salmon generations (15 to 20 years) or more to realize significant use of habitat above the reservoirs even if fish reintroduction, especially for sockeye salmon, is aided by human intervention.

The YN and WDFW developed this conceptual re-introduction plan based on using five species available in the near-term, mid-term, or long-term. Near-term efforts began using hatchery coho salmon smolts in 2005 that are readily and reliably available for testing the efficacy of modified interim (temporary, experimental) juvenile passage facilities at Cle Elum Dam. However, the primary benefit to re-establishing anadromous salmonid passage upstream of YP storage dams will be the re-introduction of the sockeye salmon, which use the lake environment for juvenile rearing.

Sockeye salmon reintroduction is considered to be a "mid-term" effort because there are only two potential donor stocks in the upper Columbia Basin, even though it's the preferred species and coho salmon will serve as surrogates to evaluate the interim passage facilities. Both of these sockeye salmon stocks are wild or naturally produced populations that exhibit highly variable abundance from year-to-year. The co-managers must be satisfied that the passage facilities are functional and efficient before attempting re-introduction with these valuable native sockeye salmon stocks. There are also some fish culture and disease issues related to sockeye salmon that must be addressed prior to reintroduction. Sockeye salmon spawning and incubation is more complicated because adult fish may carry IHN virus and to date the Yakima River is IHN virus-free. Adults cannot be tested for IHN virus until the spawning parents are killed, so isolation techniques for each pair of spawned parents are required.

Steelhead re-introduction above the dams is considered a “long-term” objective because steelhead are an existing native, wild stock that is listed under the Endangered Species Act (ESA). Steelhead are currently not fully using all of the accessible spawning and rearing habitat downstream of the YP storage dams. Therefore, it is premature to attempt to expand their distribution. Spring Chinook salmon are considered a “long-term” objective for re-introduction above YP storage dams because all smolts produced at the Cle Elum Supplementation and Research Facility are fully allocated to a sophisticated experimental design and cannot be used for reintroduction experiments at this time. Pacific lamprey are very rare in the Yakima Subbasin and little is known about their life history, historic distribution, or current limiting factors, hence re-introduction of this species is also considered a long-term objective at this time.

Near-Term (2005): Coho Salmon

Coho salmon are the most suitable species for early feasibility research regarding juvenile passage at the existing storage dams in the Yakima system. Coho salmon smolts are currently being imported into the Yakima basin for the Yakima-Klickitat Fisheries Project (YKFP) coho salmon reintroduction feasibility study. However, adult coho salmon returns to the basin are not sufficient to adequately seed currently available spawning and rearing habitat downstream from the storage reservoirs (hence the ongoing YKFP coho salmon reintroduction feasibility study). Therefore, adult coho salmon will not be available to trap elsewhere in the basin and haul above Cle Elum Dam to initiate natural spawning and juvenile production.

Cle Elum Dam Interim Juvenile Passage

Sufficient numbers of hatchery coho salmon smolts are readily available every year, and therefore are a reliable source of smolting salmonids for evaluation of juvenile passage modifications at Cle Elum Dam. The expansion of the YKFP coho salmon reintroduction study can easily provide 12,000 or more coho salmon smolts imported from a lower Columbia River hatchery for release into Cle Elum Lake. All of these smolts will be tagged with PIT tags to passively evaluate downstream passage survival using the PIT tag detection capability in the interim fish passage flume of the modified gate structure at Cle Elum Dam.

The use of out-of-basin coho salmon smolts will be the most assured and biologically acceptable source for releasing sufficient numbers of salmon smolts for interim passage facility evaluation. Evaluating the infrastructure modifications and juvenile passage efficiency is the immediate priority of the interim passage study at Cle Elum Dam. The released smolts will be 100 percent PIT tagged.

Evaluations also include other release locations in Cle Elum Lake and tributary releases to evaluate smolt migration through the reservoir and homing of returning adults to release tributaries. Smolts surviving from the reservoir releases in the spring of one year will return as adults in the fall of the next year.

Mid-Term: Sockeye Salmon

Sockeye salmon are the only species of salmon whose juveniles are almost always associated with lake rearing for some period of time during their juvenile life stages. This species was present in all of the natural lakes in the Yakima system prior to construction in the early 1900s of timber crib dams without fishways at the natural outlets of Keechelus, Kachess, and Cle Elum lakes, and construction of Bumping Lake Dam in 1910 (Davidson 1953). We could potentially implement a reintroduction program for sockeye salmon if fish passage could be developed at the existing reservoirs.

Sockeye salmon would be less suitable than coho for the near-term evaluation of interim juvenile passage research at the two dams. This is because the availability of sockeye salmon smolts for research is much less reliable than coho salmon smolts. However, we should proceed with the development of a sockeye salmon reintroduction program as rapidly as possible to evaluate their ability to migrate downstream from the reservoirs, as they may have different migration patterns (depth, velocity, timing, etc.) from the coho salmon smolts.

There is some question as to the appropriate donor stock of sockeye salmon to use for this reintroduction study. Donor stock would likely come from Lake Wenatchee or Lake Osoyoos (Canadian fish). A preliminary research effort to evaluate the feasibility of reintroduction of sockeye salmon into Cle Elum Lake used Lake Wenatchee stock in the late 1980s and early 1990s (Flagg et al. 2000). The Lake Wenatchee stock is the closest stock to the Yakima (next river basin to the north), but the Lake Osoyoos stock may be the better stock for reintroduction into the Yakima Basin. The Lake Wenatchee stock spawn in late September and Lake Osoyoos stock spawn in early October. The Lake Osoyoos adult fish have to migrate up a very warm section of the Okanogan River to reach their spawning grounds. This environmental condition may be more similar to the lower Yakima River, as opposed to the cooler migration corridor through the lower Wenatchee River. However, Lake Wenatchee is oligotrophic, similar to Cle Elum Lake, while Lake Osoyoos is more productive. It is unknown how the juvenile rearing history would affect Lake Osoyoos sockeye salmon reared in Cle Elum Lake. WDFW and YN will continue to evaluate the two available stocks to determine donor stock suitability, availability and the potential for spawning, incubating, and rearing juvenile sockeye salmon to the smolt life stage for release in Bumping and Cle Elum reservoirs.

Implementation of sockeye salmon reintroduction research could or should include:

1. The release of radio-tagged adults in the reservoirs to monitor the location and timing of any spawning activities in the streams above the dams. The number of adults released will likely be limited by the abundance and availability of the donor stock and also the number of radio-tags.

2. The release of smolts (10 percent PIT tagged; 100 percent coded wire tag) to evaluate the outmigration success and survival of juveniles. Cle Elum Lake sockeye salmon smolt production capacity (and the corresponding adult spawning escapement) will be estimated to determine optimum escapement.

All disease prevention protocols prescribed by State and Federal fish health officials will be followed in selecting and importing donor sockeye salmon eggs, juveniles, and adults. Concern exists among the co-managers and the U.S Fish and Wildlife Service regarding reintroduction of sockeyesalmon into the Yakima basin due to the disease status of existing Columbia Basin sockeye stocks. Careful monitoring and selection of disease-free brood stock would be essential in a reintroduction effort to protect the other existing species of salmon currently in the Yakima watershed. The main disease of concern is Infectious Hematopoietic Necrosis (IHN) caused by the IHN virus.

Returning adults from smolt releases would be collected at the Roza adult trap and transported above Cle Elum Dam for release, or captured at the base of Cle Elum Dam if interim adult passage facilities are constructed there. Interim adult passage would be necessary to provide access for Bumping Lake returning sockeye salmon adults since there are no suitable adult collection facilities in the lower Naches Basin.

Mid-Term: Spring Chinook Salmon

The YKFP is presently supplementing spring Chinook salmon in the basin using a complex, statistically-rigorous experimental design to evaluate new supplementation techniques (Busack et al. 1997). We could possibly trap and haul adults at the Cle Elum River “Green Bridge” a short distance below the dam, but we would need to evaluate impacts on the YKFP program. The impacts would probably be minor if we only take about 100 adults to place above Cle Elum Dam. There is also the concern that we would not be able to determine adults destined to return to the Cle Elum at the Roza trap. Thus all spring Chinook salmon would be released upstream at Roza trap and we would have to re-trap at the base of the Cle Elum Dam and haul adult fish attempting to return to the upper Cle Elum.

Long-Term: Steelhead

It is not likely that we would attempt to reintroduce steelhead above Cle Elum Dam anytime soon. Only about 100 to 200 steelhead adults pass Roza Dam annually. There are too few steelhead in the upper Yakima to include them in a directed reintroduction experiment at this time. Current efforts to improve steelhead status in the upper Yakima basin will focus on increasing the status and productivity of the existing steelhead population in the mainstem and tributaries downstream of storage reservoirs. There are also ESA issues involved in trapping and handling listed fish at both the juvenile and adult stages that are a significant obstacle to active, “hands-on” supplementation. There is currently no YKFP program to supplement natural production of steelhead with hatchery-reared smolts. For the foreseeable future, steelhead restoration will be limited to the experimental “kelt reconditioning” program located at the Chandler Hatchery at Prosser. At this time, reconditioned kelts will not be trucked and released above Bumping or Cle Elum Dam.

Long-Term: Pacific Lamprey

The YN is currently undertaking development of a Pacific lamprey reintroduction plan for the entire Yakima basin. The areas above the reservoir dams will be considered and included in these plans as they are being developed.

Fish Health Issues

All introduced stocks and/or populations transported to Lake Cle Elum or above the current supplementation facilities must be inspected for presence of salmonid viruses, and the presence, prevalence, and magnitude of *Renibacterium salmoninarum, Flavobacterium psychrophilus, Aeromonas salmonicida,* and *Yersinia ruckeri*. In addition, a host of external and internal parasites, especially *Ichthyophthirius,* could be amplified and spread downstream. Although some of these pathogens are wide spread and may be difficult to eliminate from some introduced stocks, each introduction should withstand the scrutiny of risk assessment (including the possibility of drug resistance) in perspective to potential impacts to native and cultured fish below the point of introduction.

Any introduced juvenile stocks that will be confined for a period of time must be monitored periodically during their captivity. Health and pathogen status must be communicated to the YKFP and Cle Elum Supplementation and Research Facility staff during this period and prior to any releases.

During any captive holding of introduced stocks, if any mortality, morbidity, or infection occurs that is deemed hazardous to native or cultured stocks below the point of captivity, those fish must be destroyed and the holding facility properly sanitized or disinfected.

Specific Procedures and Comments

All sockeye salmon introductions must include preventative measures to reduce the probability of spreading Infectious Hematopoietic Necrosis Virus (IHNV), or *Renibacterium salmoninarum* (the causative agent for bacterial kidney disease or BKD) This species of fish is extremely sensitive to these pathogens and will readily amplify them to the detriment of other susceptible salmonids (i.e., steelhead, rainbow trout, and Chinook salmon). It is highly recommended to introduce only fish/eggs that have been individually screened to be free of IHN and have extremely low levels of the antigen for BKD. Note that BKD may already be present in Chinook salmon.

Literature Cited

BioAnalysts 2000	BioAnalysts. 2000. *Potential Sockeye Smolt Yield from Lake Chelan.* Prepared for: Public Utility District No. 1 of Chelan County, Wenatchee, WA. 22 p.
Busack et al. 1997	Busack, C., T. Pearsons, C. Knudsen, S. Phelps, B. Watson, and M. Johnston. 1997. Yakima Fisheries Project Spring Chinook Supplementation Monitoring Plan. U.S. Dept. of Energy, Bonneville Power Administration, Final Report, 185 p.

Chapman 1988	Chapman, D.W. 1988. Critical review of variables used ot define effects of fines in redds of large salmonids. Trans. Am. Fish. Soc. 117(1): 1-21.
Chapman and McLeod 1987	Chapman, D.W. and K.P. McLeod. 1987. Development of criteria for fine sediment in the northern rockies ecoregion. EPA report no. 910/9-87-162. Environmental Protection Agency, Washington, DC. 279p.
Davidson 1953	Davidson, F.A. 1953. *The Development of the Yakima River Basin for Irrigation and It's Effect on the Migratory Fish Population in the River.* Yakama Nation, Toppenish, Washington. 17pp.
Dey 2000	Dey, D. 2000. *Section III: Cle Elum Lake Productivity and Fertilization Potential.* In Flagg, Thomas A., T. E. Ruehle, L. W. Harrell, J. L. Mighell, C. R. Pasley, A. J. Novotny, E. Slatick, C. W. Simes, D. B. Dey, Conrad V. W. Mahnken. National Marine Fisheries Service, Seattle WA. 2000. *Cle Elum Lake Anadromous Salmon Restoration Feasibility Study: Summary of Research, 2000 Final Report to Bonneville Power Administration,* Portland, OR. Contract No. 86A164840, Project No. 86-045, 118 electronic pages. BPA Report DOE/BP-64840-4).
Flagg et al. 2000	Flagg, Thomas A., T.E. Ruehle, L.W. Harrel, J.L. Mighell, C.R. Pasley, A.J. Novotny, E. Slatick, C.W. Sims, D.B. Dey, Conrad V.W. Mahnken – National Marine Fisheries Service, Seattle, WA. 2000. Cle Elum Lake Anadromous Salmon Restoration Feasibility Study: Summary of Research, 2000 Final Report to Bonneville Power Administation, Portland, OR. Contract No. 86AI64840, Project No. 86-045, 118 electronic pages (BPA Report DOE/BP-64840-4).
Fryer and Kelsey 2002	Fryer, Jeffrey K. and Denise A. Kelsey. 2002. *Identification of Columbia Basin Sockeye Salmon Stocks Using Scale Pattern Analyses in 2001, Technical Report 02-2.* Columbia River Inter-Tribal Fish Commission, Portland, OR. [Also similar reports for 1999, 2000, 2001, 2003, 2004, 20005, 2006, and 2007.]
Hetrick et al. 1998	Hetrick, N.J., M.A. Brusven, T.C. Bjornn, and R.M. Keith. 1998. *Effect of canopy removal on invertebrates and diet of juvenile coho salmon in a small stream in southeast Alaska.* Transactions of the American Fisheries Society 127:876-888.
Koenings and Kyle 1997	Koenings, J.P. and G.B. Kyle. 1997. *Consequences to Juvenile Sockeye Salmon and the Zooplankton Community Resulting from Intense Predation.* Alaska Fishery Research Bulletin 4(2):120-135.
Lieberman and Grabowski 2007	*Lieberman, D. and S.J. Grabowski. 2007. Physical, Chemical, and Biological Characteristics of Cle Elum and Bumping Lakes in the Upper Yakima River Basin, Washington: September 2003 to October 2005. Bureau of Reclamation, Denver, CO. 74 p.*
Mangum 1989	Mangum, F.A. 1989. *Aquatic Ecosystem Inventory, Macroinverebrate Analysis.* In: Fisheries Habitat Surveys Handbook (R-4 FSH 2609.23) Chpt. 5.

Merritt et al. 1999	Merritt, G.D., B. Dickes, and J.S. White. 1999. *Biological Assessment of Small Streams in the Coast Range Ecoregion and the Yakima River Basin.* Publication No. 99-302. Washington State Department of Ecology, Olympia, Washington.
NPCC 2003	*Mainstem Amendments to the Columbia River Basin Fish and Wildlife Program.* Council Document 2003-11. Northwest Power and Conservation Council, Portland, OR.
Peterson et al. 1992	Peterson, N.P., A.. Hendry, and T.P. Quinn. 1992. *Assessment of cumulative effects on salmonid habitat: some suggested parameters and target conditions.* Timber/Fish/Wildlife Program Report No. TFW-F3-92-001. Washington Department of Natural Resources, Olympia. 78p.
Pfankuch 1975	Pfankuch, D.J. 1975. *Stream Reach Inventory and Channel Stability Evaluation.* U.S. Department of Agriculture, Forest Service, Region 1, Missoula, Montanta.
Reclamation 2003	*Phase I Assessment Report, Storage Dam Fish Passage Study, Yakima Project, Washington, Technical Series No. PN-YDFP-001.* Bureau of Reclamation, Boise, Idaho. February 2003.
Reiser and White 1988	Reiser, D.W. and R.G. White. 1988. Effects of two sediment size-classes on survival of steelhead and Chinook salmon eggs. N. Am. J. Fish. Mgt. 8:432-437.
Richardson 1993	Richardson, J. S. 1993. *Limits to productivity in streams: evidence from studies of macroinvertebrates.* Pages 9-15 In R.J. Gibson and R.E. Cuttings (eds.) Production of juvenile Atlantic salmon, *Salmo salar*, in natural waters. Can. Spec. Publ. Fish. Aquat. Sci. 118.
Schuett-Hames et al. 1999	Schuett-Hames, D., R. Conrad, A. Pleus, and M. McHenry. 1999. TFW Monitoring Program method manual for the salmonid spawning gravel composition survey. Prepared for the Washington State Dept. of Natural Resources under the Timber, Fish, and Wildlife Agreement. TFW-AM9-99-006. DNR #108. March. http://www.nwifc.org/tfw/documents/TFW_Salmonid_Spawning_Gravel_Composition.pdf.
Vannote et al. 1980	Vannote, R.I., G.W. Minshall, K.W. Cummins, J.R.Sedell, and C.E. Cushing. 1980. The river continuum concept. Can. J. Fish. Aquat. Sci. 37:130-137.
Waters 1988	Waters, T.F. 1988. *Fish production-benthos production relationships in trout stream.* Pol. Arch. Hydrobiol. 35(3-4):545-561.
Weng et al. 2001	Weng, Z., N. Mookerji, and A. Mazumber. 2001. *Nutrient-dependent recovery of Atlantic salmon streams from a catastrophic flood.* Can. J. Fish. Aquat. Sci. 58:1672-1682.
Wipfli et al. 1998	Wipfli, M.S., J. Hudson, and J. Caouette. 1998. *Influence of salmon carcasses on stream productivity: response of biofilm and benthic macroinvertebrates in southeastern Alaska, U.S.A.* Can. J. Fish. Aquat. Sci. 55:1503-1511.

Yakama Nation 2003 *Yakima Coho Master Plan*. Yakima/Klickitat Fisheries Project, Toppenish, WA. 64p. plus addendix.