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APPENDIX E

Numerical Estimates of Hydropower-Related Losses

I. Introduction

Any estimate of total losses of salmon and steelhead is limited by the lack and quality of data. A definitive judgment is impossible. Data are scarce for the era prior to 1850, the period before major development of the basin severely reduced fish runs. More recent data are more plentiful, but often are not comparable. For example, increased logging is known to have had a detrimental effect on salmon and steelhead habitat, but there is no definitive way to translate board feet or acres logged into fish lost. As a result, the data can be interpreted reasonably in several different ways.

Following are methods for numerically estimating the contribution of hydropower development and operation to losses of Columbia Basin salmon and steelhead. The focus is on the contribution of the hydropower system to losses of salmon and steelhead and their habitat and not on the precise contribution of each individual hydropower project in that system. In several parts of the discussion, there are references to the approximate contributions of groups of projects to salmon and steelhead losses. These are included only for the purpose of estimating system hydropower-related losses, not to determine particular responsibilities within that system for mitigating the losses.

II. Staff Numerical Estimates of Hydropower-Related Losses

The best way to estimate hydropower-related losses would be an approach that computed mortalities, by species and stock, from operation of each of the 136 hydropower projects in the basin annually since their development. These estimates would also compute the amount of production precluded by each project's blockage and inundation of habitat. Although probably the most accurate approach, this type of estimate is not possible because the extensive, specific data necessary to estimate hydropower-related losses in this manner is not now, and never will be, available.

The specific data necessary to assess losses caused by hydropower operation and development as comprehensively as noted above include the list of criteria that follows. This information would be needed for each stock of salmon and steelhead in the basin because life-history factors, such as migration timing, spawning timing and duration of freshwater rearing, differ among species and stocks. Information for each of the 136 hydropower dams would have to be assembled because each dam inundated varying amounts of habitat at different times, and each dam has affected the upstream and downstream migration of fish differently. Also, the information listed would have to be collected for all years since construction was initiated, because the effect of the dams and the size of the fish runs have fluctuated over time. Information requirements would be:

1. The numbers of smolts by stock produced above each hydropower dam from the date construction was initiated.

2. The rate of smolt mortality (direct and reservoir) by stock caused by each hydropower dam in the basin for every year since construction was initiated. (This would change as turbines were added.)

3. The ocean survival for each stock for every year since hydropower dam construction was initiated. (This is variable depending on each age class and on the availability of food. Individuals of the same stock may spend anywhere from one to five years rearing in the ocean.)

4. The rate of adult mortality by stock caused by each hydropower dam in the basin for each year since construction was initiated. (This also would change as turbines were added.)

5. The amount of salmon and steelhead habitat inundated or blocked by each dam and the effect of each dam on salmon and steelhead production directly below the site.

6. The amount of each dam's mortality rate attributable to hydropower, as opposed to irrigation, navigation, recreation or other specified purposes. (This also may have changed over time.)

If the above information were available, an annual accounting could be made for hydropower-caused losses for all hydropower dams in the Columbia Basin. The simple fact is that most of this information is not available because it was not collected at the time the losses occurred and currently is not being collected. Fish counts generally were not made until relatively recently. For example, adult fish counts were not made before Rock Island Dam and Bonneville Dam began operation in 1933 and 1938, respectively. Further, fish counts are only one indication of adult-run size. Estimates of numbers of fish caught below the dam, where the count is made, are necessary to represent the entire run size. Tools and methods for determining origin of fish caught in the ocean were not developed until the 1960s. Estimates of dam mortalities are available only for recent years and only for some of the 13 mainstem projects.

In short, the information needed to do this type of estimate of hydropower-related losses cannot be reconstructed with any degree of confidence. A simplified alternative clearly is necessary.

As a result, the Council staff developed two simplified alternatives. The first method estimates hydropower-related losses of about 7 million to 8 million fish. This approach primarily depends on assumptions about the state of salmon and steelhead when the hydropower projects were built and on the hypothetical capability of those fish to recover if it were not for the impacts of the hydropower system. One could assume that the runs could have recovered substantially to their 1850s levels if it were not for hydropower. Or one could assume that the runs were damaged and incapable of substantial recovery even without hydropower, but capable of significant partial recovery without hydropower. The second alternative method developed by the Council staff estimates a hydropower-caused loss of about 5 million to 11 million fish. This alternative uses the total loss caused by all developmental effects to determine hydropower-related losses.

A. Alternative 1

As identified above, specific information for all years and stocks is not available. However, use of a simplified version of this approach is possible. The following types of assumptions are integral to calculating an estimated hydropower contribution using this approach:

1. Most hydropower operational mortalities occur as fish pass through the mainstem Columbia and Snake river projects and associated reservoirs. Therefore, it may be appropriate for these purposes to assume that all operational mortalities are caused by mainstem projects.

2. Maximum reservoir survival is generally estimated to be about 90 percent; average bypass efficiency is generally estimated to be about 50 percent; survival of bypassed fish is generally estimated to be about 98 percent; and survival of fish that travel through turbines is generally estimated to be about 85 percent. These estimates are from studies by the fish and wildlife agencies and hydropower project operators. These estimates were used by the Council's Mainstem Passage Advisory Committee to estimate downstream migrant survival. Using these figures, an optimistic per dam survival rate would be about 82 percent. Because present knowledge shows that reservoir survival decreases sharply as flows decrease, a survival rate of 80 percent is probably more appropriate. (See Attachment 1, Table 1.)

3. The Council's Mainstem Passage Advisory Committee estimates upstream passage survival per dam at 95 percent. This information appears to be the best available. (See Attachment 1, Table 1.)

4. Ocean survival is variable depending on the number of years the fish spends in the ocean. Some fish of the same stock (for example, fall chinook) spend from one to five years in the ocean. Because the proportion of the stock that spends varying times in the ocean itself varies by species, stock and years, an overall average survival is used here. The only estimates available for this factor are 2 percent for spring chinook; 4 percent for summer chinook; 8 percent for coho; and 10 percent for sockeye and steelhead.[1] Fall chinook are assumed to have the same survival rate as summer chinook for purposes of this issue paper because they have similar life histories and ocean migrations.

5. Most of the production that has been blocked occurred in areas above Grand Coulee and Hells Canyon dams. Therefore, for these purposes, it may be appropriate to account only for losses caused by blockage in these two areas.

6. Because blocked areas are permanently precluded by dams from producing salmon and steelhead, it may be appropriate to assume that all blocked-area loss is caused by dams.

1./ Testimony of D.W. Chapman in hearings before the Federal Energy Regulatory Commission on Rock Island Dam (Summer 1985). The Council staff is aware of no other overall estimates on this subject.

7. For purposes of this analysis, the congressional "repayment allocation" is used as the estimate of the percentage of dam loss attributable to hydropower for federal projects because this represents the amount of the project that is being paid for by hydropower ratepayers. Non-federal projects are not assigned repayment allocations, and the percent of loss attributable to hydropower is assumed to be different for different areas as explained below:

   a. The operational loss at the 13 mainstem Snake and Columbia river dams is assumed to be 89 percent of dam loss. This is the average of the repayment allocation for the federal dams and assumes 100 percent hydropower purpose for non-federal projects. (See Attachment 1, Table 5.)

   b. Above Grand Coulee Dam, the hydropower contribution for lost habitat is assumed to be equal to the repayment allocation for Grand Coulee Dam, which is 92 percent. (See Attachment 1, Table 5.)

   c. Above Hells Canyon Dam, the hydropower contribution for lost habitat is assumed to be 50 percent. This number cannot be estimated in a simplified manner because most of the projects in this area are non-federal, and the percentage of each of the dam's purposes is not clearly defined. The 50 percent figure assumes that the mainstem Snake dams above Hells Canyon are primarily operated for hydropower production and the numerous large tributary dams are primarily non-hydropower in purpose. This does not mean that hydropower dams do not exist on the tributaries and that the only purpose of mainstem dams is hydropower. It merely describes the primary purposes of the dams in a simplified fashion. As mentioned above, this estimate is for the purpose of determining the system contribution and not the precise contribution of each operator.

Using those assumptions, the basic calculation for hydropower contributions from operations is as follows:

Step 1. Average numbers of smolts produced in the area behind each mainstem Columbia and Snake river dam (the 13 dams below Chief Joseph and Hells Canyon dams)

X

Average survival of smolts at each mainstem Columbia and Snake river dam while migrating from the production areas to the ocean

X

Average overall ocean survival per species (or per race for chinook)

X

Average survival of adults migrating from the ocean to the production areas

=

Adults with dams

Step 2. Average numbers of smolts produced for the area behind each mainstem Columbia and Snake river dam (the 13 dams below Chief Joseph and Hells Canyon dams)

X

Average overall ocean survival per species
(or per race for chinook)

=

Adults without dams

Step 3. Adults without dams - adults with dams = dam loss

Step 4. Dam loss x average percent of hydropower purpose of dams

=

Salmon and steelhead loss attributable to hydropower system

Note: To compute blocked area hydropower contribution, only step 4 is necessary because all loss in the blocked areas is assumed to be dam-caused.

Recognizing the limitations of data, this approach appears to be the most technically based possible and uses the best scientific information available.

The most important factor in calculating hydropower-related losses using this approach is the fish run selected as a basis to calculate the average number of smolts produced for steps 1 and 2. Two alternative theories have been identified for this purpose: a) runs were damaged (by non-hydropower impacts) but were capable of substantial recovery to 1850s size if it were not for hydropower development and operations, or b) runs were damaged and incapable of substantial recovery to 1850s size, even without hydropower development and operations, but were capable of significant partial recovery without hydropower development and operation. Two levels of partial but significant recovery without hydropower operation and development can be identified as: 1) current run size without mainstem operational mortalities and without total production losses in blocked areas, or 2) current potential production of habitat now available plus hatchery production (lost potential) without mainstem operational mortalities and without total production losses in blocked areas. This potential may be greater, but the staff is aware of no certain means of determining whether it is or how much greater it might be.

Rationale and estimated hydropower contribution calculated for each of these bases follow.

1. <u>Alternative 1a</u> - Capable of Substantial Recovery if it were not for Hydropower Development and Operation

The theory underlying this approach is that non-hydropower development effects (e.g., irrigation, fishing, logging, mining, grazing, agriculture, urbanization, pollution and other effects) are largely reversible so hydropower caused all the mortalities that would occur if predevelopment run sizes existed. This is akin to saying the fish runs have been damaged, but they would be capable of complete, or nearly complete recovery, if it were not for hydropower development and operation. For example, the effects of irrigation diversions, poor logging practices and overgrazing in riparian zones may in time be reduced to an insignificant level, virtually eliminating their impact on salmon and steelhead runs.

The run size base used here is the average predevelopment run size of about 13 million fish. (The average of between 10 million and 16 million; see Compilation of Information on Salmon and Steelhead Losses in the Columbia River Basin, Chapter 2.) This run size base gives an estimate of hydropower-related losses of about 8 million salmon and steelhead. (See Attachment 1, Table 6.) The fish distribution used for this method is the predevelopment distribution identified in the losses report. (See Attachment 1, Table 2.)

1. <u>Alternative 1b</u> - Capable of Partial Recovery if it were not for Hydropower Development and Operation (Current Run)

The underlying theory to this approach is that the current run is what is actually occurring in the basin after all the development types have had their effects (destruction and rehabilitation of habitat and artificial production); therefore it reflects what has actually happened. This is akin to saying that the fish runs would be capable of partial recovery if it were not for hydropower development and operation.

The run that has partially recovered is defined here as the current run size of about 2.5 million fish (see Compilation of Information on Salmon and Steelhead Losses in the Columbia River Basin, Chapter 2) for operational loss and as the loss identified in Alternative 1a for blocked-area loss. This base provides an estimate of hydropower-related losses of about 7 million salmon and steelhead. (See Attachment 1, Table 7.) The distribution used for operational loss is the 1975 distribution. (See Attachment 1, Table 3.)

1. <u>Alternative 1c</u> - Capable of Partial Recovery if it were not for Hydropower Development and Operation (Current Potential Production)

The theory behind this approach is that the production potential of the habitat in the basin was limited after predevelopment times by activities such as irrigation, logging, mining, grazing and others. The effects of fishing are not considered in this approach, but current efforts by the fish managers are indicative that fishing may not currently limit production. (See Program Technical Appendix 2, Chapter 5.) This approach also is akin to saying that the fish runs' potential have been damaged but would be capable of partial recovery if it were not for hydropower development and operation.

The potential run that has partially recovered is defined here as the current potential production of the basin. In addition to natural potential, current hatchery releases are included as compensation for lost potential to determine operational loss. The hydropower-related losses computed in Alternative 1a are used for blocked areas. Natural potential is distributed according to the distribution identified in the Council's production planning data base, and hatchery potential is distributed by 1985 release sites. (See Attachment 1, Table 4.) It should be noted that the

Council's production potential data base, although complete for the most part, does not have estimates for minor production areas (areas where it may be possible to produce some fish, but where none are currently produced). This would tend to make this estimate conservative. Also, the addition of hatchery production may make the estimate a little high because some of the hatcheries' production may be compensation for blocked-area loss. This basis provides an estimated loss from hydropower of about 7 million salmon and steelhead. (See Attachment 1, Table 8.)

B. Alternative 2

The Alternative 1 approaches are complicated by the number of assumptions needed. Another approach would be to limit the number of assumptions to a minimum.

The equation for such an approach could be expressed as follows:

Total loss

X

Percent hydropower purpose of dams

=

Hydropower-related losses

The most difficult factor to identify in this equation is the percentage of hydropower purpose of dams. If it is assumed that one-third of the loss is attributable to each of the three areas that either currently or at one time produced salmon and steelhead, i.e., 1) the area currently accessible to salmon and steelhead, 2) the area above Grand Coulee Dam, and 3) the area above Hells Canyon Dam, then the average of the percents of the hydropower purpose identified in Alternative 1 is applicable here. This average is about 77 percent ([89% + 92% + 50%] , 3 = 77%). The resulting hydropower contribution range is then about 5 million to 11 million fish. (See Attachment 1, Table 9.)

Calculation of hydropower-related losses using this method is based on the premise that the predevelopment run size is the proper basis for this determination. This premise can be characterized as saying that the fish runs have been damaged, but that they would be capable of substantial recovery if it were not for hydropower development and operation. The estimated range for hydropower-related losses would be lower if the loss were based on a theory that runs have been damaged but are only capable of partial recovery. A loss based on this theory is not available.

III. Variations of the Council Staff Estimates

Alternative calculations for hydropower-related losses are possible by applying changes in assumptions and methods. All the alternatives suggested result in an estimate of hydropower-related losses within the 5 million to 11 million adult salmon and steelhead range estimated by the Council staff.

Although no commentors suggested that several variations be applied to calculate an alternative estimate, the staff recognizes that this might yield a hydropower-related losses estimate outside of the 5 million to 11 million range. The staff believes an estimate based on several variations is unreasonable because it would yield estimates outside the range that are either conservatively low or liberally high. In other words, the staff believes the range of 5 million to 11 million adult salmon and steelhead encompasses the most reasonable range for hydropower-related losses based on the available data. Suggested variations of the staff estimates were as follows:

1. A hydropower-related losses range can be calculated for the Alternative 1 predevelopment (substantial recovery if it were not for hydropower) run size basis. The point estimate is about 8 million. The estimated range around this point is about 6 million to 10 million. (See Attachment 1, Tables 10 and 11.)

2. In the issue paper, blocked-area, hydropower-related losses are calculated only using a predevelopment (substantial recovery if it were not for hydropower) basis. Hydropower-related losses can be calculated for the blocked areas using a current run size and a current potential run size (both are partial recovery if it were not for hydropower) basis if the assumption is that the percentage of production above and below the blocked areas is the same proportionally now as prior to 1850. These yield estimates of about 5 million, instead of 7 million, for a current run size basis, and 6 million, instead of 7 million, for a current potential run size basis. (See Attachment 1, Tables 12 and 13, respectively.)

3. It has been suggested that the percentage of dam use for hydropower should be calculated using "benefits" allocations, instead of repayment allocations. (See Attachment 1, Table 5.) Using benefits allocation, the estimated hydropower-related losses for the Alternative 1 calculations is about 7 million for a predevelopment run size (substantial recovery if it were not for hydropower) basis; about 6 million for a current run size (partial recovery if it were not for hydropower) basis; and about 6 million for a current potential run size (partial recovery if it were not for hydropower) basis. (See Attachment 1, Tables 14, 15, and 16, respectively.) The range for the Alternative 2 calculation is reduced at the upper end to 10 million. The lower end of the range remains about 5 million. (See Attachment 1, Table 17.)

4. If it is assumed that 100 percent of the operational dam loss is hydropower-caused because, in theory the system could be operated for fish passage if it were not for hydropower, then the Alternative 1 estimates of hydropower-related losses are about 8 million for a predevelopment run size (substantial recovery if it were not for hydropower), 7 million for a current run size (partial recovery if it were not for hydropower) basis, and 7 million for a current potential run size (partial recovery if it were not for hydropower) basis. (See Attachment 1, Tables 18, 19, and 20, respectively.) The Alternative 2 range estimate is 6 million to 11 million using this assumption. (See Attachment 1, Table 21.)

5. If some upstream and downstream migrant natural mortality is assumed in the "without dams" calculations for Alternative 1, then the estimated loss is about 6 million for a predevelopment run size (substantial recovery if it were not for hydropower) basis; about 6 million for a current run size (partial recovery if it were not for hydropower) basis; and about 6 million for a current potential run size (partial recovery if it were not for hydropower) basis. (See Attachment 1, Tables 22, 23, and 24, respectively.)

6. It was suggested that the summer chinook blocked-area distribution in the Alternative 1 estimate using a predevelopment run size (substantial recovery if it were not for hydropower) basis should be different. The distribution in the staff estimate is 16.6 percent above Chief Joseph Dam and 34.2 percent above Hells Canyon Dam. The suggested modification is that there was no summer chinook production above Hells Canyon Dam and 50.8 percent above Chief Joseph Dam. This change does not alter the hydropower-related losses estimate of about 8 million adult salmon and steelhead. (See Attachment 1, Table 25.)

7. It was suggested that the hydropower contribution for fall chinook loss above Hells Canyon Dam should be 100 percent in Alternative 1 calculations, because these fish are only affected by mainstem projects. This alternative does not change the estimates. (See Attachment 1, Tables 26, 27, and 28.)

8. It was suggested that a figure for delayed mortality should be added to the Alternative 1 calculations of hydropower-caused loss. Delayed mortalities are mortalities below the hydropower system (in the estuary and ocean) caused by a lowered survival rate from stress incurred on the fish by the hydropower system. In order to account for delayed mortality, a portion of the natural mortality in the estuary and ocean must be assigned to the hydropower system. Because delayed mortality has not been measured, estimates of its magnitude are speculative. Regardless, hydropower-related losses remain within the estimated range of 5 million to 11 million adult salmon and steelhead even if a plausible range of 0 percent to 25 percent delayed mortality is added to the Alternative 1 estimates.

9. It was suggested that the actual upstream and downstream mortality percentage for each dam be used for the Alternative 1 calculations instead of an average. Exact mortality rates are not known for most dams in the basin. The average mortalities used in the calculations are based on the best information available and represent the most accepted numbers used in the scientific community to assess mortality at Columbia Basin dams. Because the mortalities identified at each dam are an overall average, it should be noted that the hydropower-related losses cannot be assigned to specific projects or areas of the basin.

10. It was suggested that the percentage of dams used for hydropower purposes should be applied to each dam's losses instead of an average to the overall loss. This does not change the numbers calculated; it merely assigns different portions of the systemwide hydropower-related losses to specific projects and areas of the basin. As stated above, the mortalities identified at each dam are an overall average and cannot be assigned to specific projects or areas of the basin.

Attachment 1

Tables for Numerical Estimates of Hydropower-Related Losses

TABLE 1

CUMULATIVE AVERAGE MAINSTEM DAM SALMON AND STEELHEAD SURVIVAL RATE FOR THE COLUMBIA RIVER BASIN[1]

Number of Dams	Cumulative Downstream Survival Rate (average 80% per dam)	Cumulative Upstream Survival Rate (average 95% per dam)
0	100	100
1	80	95
2	64	90
3	51	86
4	41	81
5	33	77
6	26	74
7	21	70
8	17	66
9	13	63

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1 See Compilation of Information on Salmon and Steelhead Losses in the Columbia River Basin, Chapter 5, Section 5.3.

TABLE 2

PREDEVELOPMENT (PRE-1850) DISTRIBUTION OF SALMON AND STEELHEAD PRODUCTION IN THE COLUMBIA RIVER BASIN[1]

Areas of Production[3]	Spring Chinook	Summer Chinook	Fall Chinook	Coho	Steelhead	Sockeye[4]
	Percentage of Production by Species[2]					
Below Bonneville Dam	15.1	0.0	24.8	43.7	17.1	0.0
Between 1 and 2 Dams	0.9	0.0	1.0	4.9	2.2	0.0
Between 2 and 3 Dams	3.3	0.0	0.4	0.0	4.1	0.1
Between 3 and 4 Dams	4.5	0.0	0.4	0.0	5.2	0.0
Between 4 and 5 Dams	6.1	1.8	2.9	13.5	6.1	2.1
Between 5 and 6 Dams	0.0	0.0	2.2	0.0	0.0	0.0
Between 6 and 7 Dams	0.7	0.0	6.4	2.1	1.1	0.0
Between 7 and 8 Dams	2.6	1.2	2.2	2.7	1.1	0.8
Between 8 and 9 Dams	32.5	42.0	17.4	13.9	35.9	1.6
Above Wells and Below Chief Joseph dams	4.2	4.1	0.0	2.0	2.0	30.3
Above Chief Joseph Dam	14.7	16.6	14.0	17.3	10.5	64.7
Above Hells Canyon Dam	15.3	34.2	28.4	0.0	14.6	0.5

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1 Pacific Northwest Regional Commission 1976. Investigative Report of Columbia River Fisheries Project, Report G, Distribution of Salmon and Steelhead in the Columbia River Basin–1850 and 1975 by Dorien C. Lavier. Council staff used this report and the maps it summarized to determine distribution by area above each dam.

2 Percentages refer to the portion of production originating from an area as a portion of all the basin's predevelopment production.

3 Dams referred to are mainstem Snake and Columbia river dams.

4 Production of sockeye was distributed according to surface area of lakes used by sockeye. (See Compilation of Information on Salmon and Steelhead Losses in the Columbia River Basin, Appendix B, Table B-2.)

TABLE 3

CURRENT (1975) DISTRIBUTION OF SALMON AND STEELHEAD PRODUCTION IN THE COLUMBIA RIVER BASIN[1]

Area of Production[3]	Spring Chinook	Summer Chinook	Fall Chinook Hatchery[4]	Fall Chinook Natural	Coho	Steelhead	Sockeye[5]
	Percentage of Production by Species[2]						
Between 1 and 2 Dams	2.7	0.0	26.0	17.5	17.6	4.7	0.0
Between 2 and 3 Dams	12.8	0.0	0.0	23.4	10.9	5.4	0.0
Between 3 and 4 Dams	0.0	0.0	15.0	0.0	3.1	10.7	0.0
Between 4 and 5 Dams	8.4	4.7	51.0	50.8	24.4	9.5	0.0
Between 5 and 6 Dams	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Between 6 and 7 Dams	2.1	0.0	5.0	0.0	0.0	2.3	0.0
Between 7 and 8 Dams	3.3	1.9	0.0	2.0	4.0	2.2	21.0
Between 8 9 Dams	65.4	87.0	2.0	6.3	35.9	61.4	29.6
Above Wells and Below Chief Joseph dams	5.3	6.4	0.0	0.0	4.6	3.8	49.3

[1] Pacific Northwest Regional Commission 1976. Investigative Report of Columbia River Fisheries Project, Report G, Distribution of Salmon and Steelhead in the Columbia River Basin--1850 and 1975 by Dorien C. Lavier. Council staff used this report and the maps it summarized to determine distribution by area above each dam.

[2] Percentages refer to the portion of production originating from an area as a portion of the basin's production above Bonneville Dam in 1975.

[3] Dams referred to are mainstem Snake and Columbia river dams.

[4] Hatchery fall chinook distribution from Water Budget Center Weekly Report #85-2, March 18, 1985.

[5] Production of sockeye was distributed according to surface area of lakes used by sockeye. (See Compilation of Information on Salmon and Steelhead Losses in the Columbia River Basin, Appendix B, Table B-2.)

TABLE 4

CURRENT DISTRIBUTION OF SALMON AND STEELHEAD PRODUCTION POTENTIAL IN THE COLUMBIA RIVER BASIN[1]

(Numbers of Smolts Produced by Area)

Areas of Production[2]	Spring Chinook		Summer Chinook		Fall Chinook		Coho		Steelhead		Sockeye[3]	
	Hatchery	Natural	Hatchery	Natural	Hatchery	Natural	Hatchery	Natural	Hatchery	Natural	Hatchery	Natural
Between 1 & 2 Dams	4,985,397	863,522	---	---	4,431,200	---	1,750,400	268,710	96,000	197,133	---	---
Between 2 & 3 Dams	756,000	1,407,248	129,600	---	---	2,056,961	---	330,808	---	104,566	---	---
Between 3 & 4 Dams	48,000	4,272,578	---	---	2,580,000	2,024,606	---	---	---	457,564	---	---
Between 4 & 5 Dams	514,266	3,111,520	---	---	8,520,000	21,937,920	---	---	359,200	355,384	---	---
Between 5 & 6 Dams	---	---	---	---	---	---	---	---	---	---	---	---
Between 6 & 7 Dams	---	---	---	---	840,000	---	---	---	220,000	938	---	---
Between 7 & 8 Dams	1,640,000	887,035	---	556,176	---	---	---	---	---	94,387	---	316,250
Between 8 & 9 Dams	6,251,200	16,905,314	1,364,000	14,158,689	360,000	23,543	320,00	232,150	4,472,000	1,885,224	---	460,000
Above Wells and Below Chief Joseph dams	800,000	1,266,110	1,344,000	1,295,428	---	---	---	---	368,000	78,227	---	747,500

1 Natural potential from the Northwest Power Planning Council's production planning data base and artificial potential from the Water Budget Center Weekly Report #85-2, March 18, 1985. Note that hatchery releases have been reduced by 20 percent to account for release mortality.

2 Dams referred to are mainstem Snake and Columbia river dams.

3 Sockeye numbers are converted from predevelopment adult run sizes. Numbers were computed by assuming that the current potential was the proportion of remaining surface area of sockeye production lakes as a percentage of predevelopment surface area. These percentages were 1.1, 1.6 and 2.6 for 7, 8, and 9 dams respectively. These percentages were then applied to total predevelopment adult to determine current potential in adults. (See Compilation of Information on Salmon and Steelhead Losses in the Columbia River Basin, Chapter 2.) Then adults were divided by a 10 percent ocean survival to determine smolts.

TABLE 5

HYDROPOWER ALLOCATION METHODS

Projects	Repayment Allocations (%)	Benefits Allocations (%)
Bonneville	94	–[1]
The Dalles	86	93
John Day	74	79
McNary	80	93
Chief Joseph	99	100
Grand Coulee	92	36
Ice Harbor	76	83
Lower Monumental	82	94
Little Goose	80	89
Lower Granite	82	92
Operational Loss Average[2]	89	94
Blocked Loss Average[3]	96	68

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1 Not available.

2 Average of 13 dams where losses of salmon and steelhead occurs annually from operation of dams (Bonneville, The Dalles, John Day, McNary, Priest Rapids, Wanapum, Rock Island, Rocky Reach, Wells, Ice Harbor, Lower Monumental, Little Goose, Lower Granite). Allocations at the "non-federal" projects in assumed to be 100 percent.

3 Average of two dams where loss has occurred from blockage of access to habitat above Chief Joseph Dam (Chief Joseph, Grand Coulee). The percentage of losses caused in the blocked area above Hells Canyon Dam is considered to be 50 percent.

TABLE 6

STAFF ESTIMATE OF HYDROPOWER-RELATED LOSSES USING PRE-1850 RUN SIZE AS A BASIS

Fish Distribution (Percentage)

Area of Production	Spring Chinook	Summer Chinook	Fall Chinook	Coho	Steelhead	Sockeye
Below Bonneville	0.151	0.000	0.248	0.437	0.171	0.000
Between 1 & 2 Dams	0.009	0.000	0.010	0.049	0.022	0.000
Between 2 & 3 Dams	0.033	0.000	0.004	0.000	0.041	0.001
Between 3 & 4 Dams	0.045	0.000	0.004	0.000	0.052	0.000
Between 4 & 5 Dams	0.061	0.018	0.029	0.135	0.061	0.021
Between 5 & 6 Dams	0.000	0.000	0.022	0.000	0.000	0.000
Between 6 & 7 Dams	0.007	0.000	0.064	0.021	0.011	0.000
Between 7 & 8 Dams	0.026	0.012	0.022	0.027	0.011	0.008
Between 8 & 9 Dams	0.325	0.420	0.174	0.139	0.359	0.016
Between 9 & 10 Dams	0.042	0.041	0.000	0.020	0.020	0.303
Above Chief Joseph Dam	0.147	0.166	0.140	0.173	0.105	0.647
Above Hells Canyon Dam	0.153	0.342	0.284	0.000	0.146	0.005

TABLE 6 (cont.)

Calculation Parameters

	Spring Chinook	Summer Chinook	Fall Chinook	Coho	Steelhead	Sockeye
Total Adult Production (thousands)	1,449	3,569	1,971	1,342	959	2,722
Ocean Survival	0.02	0.04	0.04	0.08	0.10	0.10
Juvenile Downstream Survival (per dam passed)	0.80	0.80	0.80	0.80	0.80	0.80
Adult Downstream Survival (per dam passed)	0.95	0.95	0.95	0.95	0.95	0.95

CALCULATIONS

Number of Adults Without Dams (Thousands)

Spring Chinook	Summer Chinook	Fall Chinook	Coho	Steelhead	Sockeye
1,449	3,569	1,971	1,342	959	2,722

Number of Smolts Without Dams (Thousands)

Spring Chinook	Summer Chinook	Fall Chinook	Coho	Steelhead	Sockeye
72,450	89,225	49,275	16,775	9,590	27,220

TABLE 6 (cont.)

Numerical Distribution of Smolts Produced Without Dams (Thousands)

Area of Production	Spring Chinook	Summer Chinook	Fall Chinook	Coho	Steelhead	Sockeye
Below Bonneville	10,940	0	12,220	7,331	1,640	0
Between 1 & 2 Dams	652	0	493	822	211	0
Between 2 & 3 Dams	2,391	0	197	0	393	27
Between 3 & 4 Dams	3,260	0	197	0	499	0
Between 4 & 5 Dams	4,419	1,606	1,429	2,265	585	572
Between 5 & 6 Dams	0	0	1,084	0	0	0
Between 6 & 7 Dams	507	0	3,154	352	105	0
Between 7 & 8 Dams	1,884	1,071	1,084	453	105	218
Between 8 & 9 Dams	23,546	37,475	8,574	2,332	3,443	436
Between 9 & 10 Dams	3,043	3,658	0	336	192	8,248
Above Chief Joseph Dam	10,650	14,811	6,899	2,902	1,007	17,611
Above Hells Canyon Dam	11,085	30,515	13,994	0	1,400	136
Totals:	72,378	89,136	49,324	16,792	9,580	27,247

TABLE 6 (cont.)

Number of Smolts at River Mouth With Dams (Thousands)

Area of Production	Spring Chinook	Summer Chinook	Fall Chinook	Coho	Steelhead	Sockeye
Below Bonneville	10,940	0	12,220	7,331	1,640	0
Between 1 & 2 Dams	522	0	394	658	169	0
Between 2 & 3 Dams	1,530	0	126	0	252	17
Between 3 & 4 Dams	1,669	0	101	0	255	0
Between 4 & 5 Dams	1,810	658	585	928	240	234
Between 5 & 6 Dams	0	0	355	0	0	0
Between 6 & 7 Dams	133	0	827	92	28	0
Between 7 & 8 Dams	395	225	227	95	22	46
Between 8 & 9 Dams	3,950	6,287	1,438	391	578	73
Between 9 & 10 Dams	408	491	0	45	26	1,107
Above Chief Joseph Dam	0	0	0	0	0	0
Above Hells Canyon Dam	0	0	0	0	0	0
Totals:	21,358	7,661	16,274	9,539	3,208	1,477

TABLE 6 (cont.)

Number of Adults at River Mouth With Dams (Thousands)

Area of Production	Spring Chinook	Summer Chinook	Fall Chinook	Coho	Steelhead	Sockeye
Below Bonneville	219	0	489	586	164	0
Between 1 & 2 Dams	10	0	16	53	17	0
Between 2 & 3 Dams	31	0	5	0	25	2
Between 3 & 4 Dams	33	0	4	0	26	0
Between 4 & 5 Dams	36	26	23	74	24	23
Between 5 & 6 Dams	0	0	14	0	0	0
Between 6 & 7 Dams	3	0	33	7	3	0
Between 7 & 8 Dams	8	9	9	8	2	5
Between 8 & 9 Dams	79	251	58	31	58	7
Between 9 & 10 Dams	8	20	0	4	3	111
Above Chief Joseph Dam	0	0	0	0	0	0
Above Hells Canyon Dam	0	0	0	0	0	0
Totals:	427	306	651	763	321	148

TABLE 6 (cont.)

Number of Adults at Spawning Grounds With Dams (Thousands)

Area of Production	Spring Chinook	Summer Chinook	Fall Chinook	Coho	Steelhead	Sockeye
Below Bonneville	219	0	489	586	164	0
Between 1 & 2 Dams	10	0	15	50	16	0
Between 2 & 3 Dams	28	0	5	0	23	2
Between 3 & 4 Dams	29	0	3	0	22	0
Between 4 & 5 Dams	29	21	19	60	20	19
Between 5 & 6 Dams	0	0	11	0	0	0
Between 6 & 7 Dams	2	0	24	5	2	0
Between 7 & 8 Dams	6	6	6	5	2	3
Between 8 & 9 Dams	52	167	38	21	38	5
Between 9 & 10 Dams	5	12	0	2	2	70
Above Chief Joseph Dam	0	0	0	0	0	0
Above Hells Canyon Dam	0	0	0	0	0	0
Totals:	379	207	611	731	288	98

All Species Total: 2,314,000

TABLE 6 (cont.)

Number of Adults at Spawning Grounds Without Dams (Thousands)

Area of Production	Spring Chinook	Summer Chinook	Fall Chinook	Coho	Steelhead	Sockeye
Below Bonneville	219	0	489	586	164	0
Between 1 & 2 Dams	13	0	20	66	21	0
Between 2 & 3 Dams	48	0	8	0	39	3
Between 3 & 4 Dams	65	0	8	0	50	0
Between 4 & 5 Dams	88	64	57	181	58	57
Between 5 & 6 Dams	0	0	43	0	0	0
Between 6 & 7 Dams	10	0	126	28	11	0
Between 7 & 8 Dams	38	43	43	36	11	22
Between 8 & 9 Dams	471	1,499	343	187	344	44
Between 9 & 10 Dams	61	146	0	27	19	825
Above Chief Joseph Dam	213	592	276	232	101	1,761
Above Hells Canyon Dam	222	1,221	560	0	140	14
Totals:	1,448	3,565	1,973	1,343	958	2,725

All Species Total: 12,012,000

TABLE 6 (cont.)

Dam Produced Salmon and Steelhead Loss (Thousands)

Area of Production	Spring Chinook	Summer Chinook	Fall Chinook	Coho	Steelhead	Sockeye
Below Bonneville	0	0	0	0	0	0
Between 1 & 2 Dams	3	0	5	16	5	0
Between 2 & 3 Dams	20	0	3	0	17	1
Between 3 & 4 Dams	37	0	4	0	28	0
Between 4 & 5 Dams	59	43	38	121	39	38
Between 5 & 6 Dams	0	0	32	0	0	0
Between 6 & 7 Dams	8	0	102	23	9	0
Between 7 & 8 Dams	32	37	37	31	9	19
Between 8 & 9 Dams	419	1,332	305	166	306	39
Between 9 & 10 Dams	56	134	0	25	18	755
Above Chief Joseph Dam	213	592	276	232	101	1,761
Above Hells Canyon Dam	222	1,221	560	0	140	14
Totals:	1,068	3,359	1,362	613	670	2,626

All Species Total: 9,698,000

TABLE 6 (cont.)

Hydropower-Related Salmon and Steelhead Loss (Thousands)

Area of Production	Spring Chinook	Summer Chinook	Fall Chinook	Coho	Steelhead	Sockeye
Below Bonneville	0	0	0	0	0	0
Between 1 & 2 Dams	3	0	4	14	5	0
Between 2 & 3 Dams	18	0	3	0	15	1
Between 3 & 4 Dams	33	0	4	0	25	0
Between 4 & 5 Dams	52	38	34	107	35	34
Between 5 & 6 Dams	0	0	29	0	0	0
Between 6 & 7 Dams	7	0	91	20	8	0
Between 7 & 8 Dams	29	33	33	28	8	17
Between 8 & 9 Dams	372	1,186	271	148	272	34
Between 9 & 10 Dams	50	119	0	22	16	672
Above Chief Joseph Dam	196	545	254	214	93	1,620
Above Hells Canyon Dam	111	610	280	0	70	7
Totals:	871	2,531	1,002	552	545	2,385

All Species Total: 7,886,000

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