Columbia Basin System Planning

SALMON and STEELHEAD PRODUCTION PLAN

KALAMA RIVER SUBBASIN

September 1, 1990

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Washington Department of Wildlife
600 Capitol Way North
Olympia, Washington 98501-1091

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Many individuals, agencies and sport groups have provided input to this particular subbasin plan. To list all the people involved would take several pages. The core of individuals putting the plan together are listed below.

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INTRODUCTION

The Northwest Power Planning Council's Columbia River Basin Fish and Wildlife Program calls for long-term planning for salmon and steelhead production. In 1987, the council directed the region's fish and wildlife agències, and Indian tribes to develop a systemwide plan consisting of 31 integrated subbasin plans for major river drainages in the Columbia Basin. The main goal of this planning process was to develop options or strategies for doubling salmon and steelhead production in the Columbia River. The strategies in the subbasin plans were to follow seven policies listed in the council's Columbia River Basin Fish and Wildlife Program (Appendix A), as well as several guidelines or policies developed by the basin's fisheries agencies and tribes.

This plan is one of the 31 subbasin plans that comprise the system planning effort. All 31 subbasin plans have been developed under the auspices of the Columbia Basin Fish and Wildlife Authority, with formal public input, and involvement from technical groups representative of the various management entities in each subbasin. The basin's agencies and tribes have used these subbasin plans to develop the Integrated System Plan, submitted to the Power Planning Council in late 1990. The system plan will guide the adoption of future salmon and steelhead enhancement projects under the Northwest Power Planning Council's Columbia Basin Fish and Wildlife Program.

In addition to providing the basis for salmon and steelhead production strategies in the system plan, the subbasin plans attempt to document current and potential production. The plans also summarize the agencies' and tribes' management goals and objectives; document current management efforts; identify problems and opportunities associated with increasing salmon and steelhead numbers; and present preferred and alternative management strategies.

The subbasin plans are dynamic plans. The agencies and tribes have designed the management strategies to produce information that will allow managers to adapt strategies in the future, ensuring that basic resource and management objectives are best addressed. Furthermore, the Northwest Power Planning Council has called for a long-term monitoring and evaluation program to ensure projects or strategies implemented through the system planning process are methodically reviewed and updated.

It is important to note that nothing in this plan shall be construed as altering, limiting, or affecting the jurisdiction, authority, rights or responsibilities of the United States, individual states, or Indian tribes with respect to fish, wildlife, land and water management.

PART I. DESCRIPTION OF SUBBASIN

Location and General Environment

The Kalama Subbasin begins on the southwest slope of Mount St. Helens and flows 44.5 milès west-southwest to enter the Columbia River below Bonneville Dam in southwest Washington at River Mile (RM) 73.1. Drainage is about 205 square miles and headwaters begin in Skamania County, although 98.9 percent of the basin is in Cowlitz County.

Topography is mountainous and averages 1,880 feet and climaxes with Mount St. Helens approaching 10,000 feet. Land varies from nearly level to strongly sloping terraces and includes valleys and moderate to steep foothills. Average river gradient is 217 feet per mile. Gradient for the first 10 river miles is flat to moderate, but then the valley closes in and continues as a narrow V-shaped drainage. Many tributaries to the Kalama have steep gradients and are inaccessible to anadromous fish. The 1980 eruption of Mount St. Helens had little affect on the Kalama Subbasin although there was a small mudflow near Kalama Springs.

Soils contain an extensive mudflow deposit made up of andesite and basalt lava flows and associated breccias and tuffs. The most widespread soils, the Olympic series, are derived from a combination of pumice, basalt, and andesite parent material. These soils are well drained, slightly to strongly acidic, and dark in color. Erosion potential is high on soils with vegetative cover removed.

Climate is typical of the West Coast marine type. Winters are mild, wet and cloudy while summers are relatively cool and dry. Annual precipitation varies from 35 inches near Kalama to over 120 inches in the headwaters. Most precipitation occurs between October 1 and March 31 in the form of rain although snow is present at higher elevations.

Above 3,500 feet, forests are generally Pacific silver fir with Douglas fir, western hemlock, western red cedar, noble fir, subalpine fir, mountain hemlock, and lodgepole pine as common associates. Understory is primarily huckleberry, fool's huckleberry and salal. Below 3,500 feet, climax species are western hemlock, Douglas fir, and western red cedar. Understory species include vine maple, huckleberry, salal, sword fern and devil's club. Hardwood species are concentrated in riparian areas along streams, creeks and rivers. The most common are alder, maple, willow and cottonwood.

Much of the subbasin riparian areas have been impacted through logging. In general, logging activities harvest and disturb vegetation that shade streams and reduce erosion, resulting in spawning and rearing habitat degradation. Logging also harvests trees destined to be large woody debris, important instream structures for fish.

Fisheries Resources

The Kalama River is managed for winter and summer steelhead, sea-run cutthroat, fall and spring chinook, and two stocks of coho (north and south). A power plant restricted distribution of anadromous salmonids and was operated at the lower Kalama Falls from 1915 until 1948 when it was dismantled. Fishway improvements in the 1950s allowed salmon and winter steelhead into the upper watershed. Presently, all salmon stocks are managed as hatchery stocks while steelhead are managed as mixed hatchery and natural stocks, and sea-run cutthroat are managed as a natural stock.

There are two hatcheries in the subbasin -- the Lower Kalama Salmon Hatchery (RM 4.3) and Kalama Falls Salmon Hatchery (RM 10). Lower Kalama has 28 double stacks of 14 Heath-type incubation trays with capacity of about 2 million eggs. Fourteen troughs are also used for incubation with a capacity of another 2 million eggs. Water source for incubation and rearing is pumped river water or Hatchery (Fallert) Creek water. There are also eight 20' x 80' raceways each with a flow of 600 gallons per minute (gpm); one 55' x 190' asphalt pond and one 55' x 190' gravel pond. The asphalt pond uses about 2,000 gpm fresh water and 1,200 gpm reused water. The gravel pond uses about 3,000 gpm fresh water.

The Kalama Falls Hatchery, built in 1959, uses Heath-type trays for egg incubation and has capacity for 13,440,000 eggs, but is water limited. Water for incubation is pumped river water or poor quality springs that produce about 400 gpm. Also present are 12 20' x 80' raceways using 500 gpm each pumped river water. The water is reused into five 40' x 60' ponds using about 1,000 gpm each and one 30' x 60' pond using about 800 gpm.

Gobar Pond, located about four miles up the Kalama tributary of Gobar Creek, is used for steelhead and often spring chinook rearing. The 1.5-acre dirt bottom pond is about 5 to 6 feet deep with a flow of about 2.5 cubic feet per second (cfs) using Gobar Creek water.

The Kalama Subbasin is intensively fished by sports anglers and is well noted for its summer steelhead, spring chinook, winter steelhead, fall chinook, coho and sea-run cutthroat fisheries. When fish are plentiful, the stream attracts a multitude of anglers.

Water Resources

Mean flow in the subbasin for 1953 through 1967 was 1,219 cfs. Because much of the subbasin is below the normal snow line, peak river flows correspond to midwinter warm rains and possible snowmelt from foothills (Table 1). Low flows are generally encountered in late summer and fall. Annual monthly high-flow-to-low-flow ratio was about 7-to-1. Low flows reduce juvenile salmonid production by limiting habitat.

Temperatures in the subbasin for 1960 through 1967 appeared amenable to salmonids, but have subsequently increased. Temperature records maintained at Lower Kalama Salmon Hatchery often exceeded 60 degrees Fahrenheit in July and August for 1986 through 1988.

Table 1. Kalama Subbasin flows (cfs) and temperatures (F) (USGS records). Flows (1953-1967) and temperatures (1960-1967) measured below Italian Creek #14223500.

Month	Flow	Temp.	Month	Flow	Temp.
January	2,152	39.7	July	409	56.5
February	1,954	39.7	August	305	56.7
March	1,702	42.1	September	306	54.3
April	1,566	46.0	October	680	50.5
May	1,063	50.5	November	1,645	45.9
June	688	54.1	December	2,157	41.9
			Average	1,219	

Gradient of the mainstem Kalama River was generally less than 1 percent while tributaries generally ranged from 1 percent to 7 percent. Most tributaries have moderate gradients in the lower sections and then become precipitous. Substrate near the subbasin mouth is generally sand and muck while upstream sections are a mixture of cobble, gravel and sand with some bedrock.

There are two barrier falls on the mainstem Kalama -- one at RM 10, which has been laddered at the Kalama Falls Hatchery site and one at RM 36.8, which is about 35 feet high and blocks anadromous fish migration. Major tributaries include Hatchery Creek, Little Kalama River, Wildhorse Creek, Gobar Creek, and North Fork Kalama.

Water chemistry in the subbasin has generally neutral pH and is low in dissolved solids and nutrients (Table 2). Turbidity fluctuates considerably.

Table 2. Water chemistry characteristics in the Kalama Subbasin, average of samples taken in 1963-1970 (USGS records).

pH	7.1
Specific conductivity	57
Phosphorus (mg/l as P)	.02

Land Use

Land use in the subbasin is dominated by forestry as reflected in a 1974 survey (SCS 1974) (Table 3). Creation of the legislative and administrative Mount St. Helens National Volcanic Monument has subsequently reduced acreage in commercial forest. With exception of some of the upper headwaters and other scattered tracts, the Kalama Subbasin is privately owned.

Table 3. Land use (%) in the Kalama Subbasin (USSCS 1974).

Land Use	Percent
Commercial forest	96.0
Non-commercial forest	1.3
Cropland	1.5
Other	1.1

Physical limitations of the land do not lend themselves to economic agricultural operations and irrigation. Consequently, water consumption in the subbasin is relatively low.

Local municipalities are limited to the town of Kalama, which is south of the river's mouth and may drain to the Columbia River. Population of Kalama was 1,120 people in 1974 (SCS 1974).

The subbasin contains part of the administrative and legislative Mount St. Helens National Volcanic Monument areas managed by the U.S. Forest Service. Only a small portion of the upper Kalama River is in the administrative monument. The pending land management plan for the administrative monument calls for regulated timber harvest along designated Class I, II, and III fishbearing streams with an objective of maximizing fish production.

A small part of the upper Kalama River is within the legislative National Volcanic Monument Area. Management of streams within the legislated monument is currently being addressed in a Fish and Wildlife Management Plan, which the Washington Department of Wildlife (WDW) and Washington Department of Fisheries (WDF) formulated. The Fish and Wildlife Management Plan will be amended to coordinate with other plans such as this subbasin plan. In the legislated monument, geological and ecological processes will be allowed to occur naturally for study and research, therefore fish habitat will not normally be enhanced. Timber harvest is not permitted.

The pending land management plan for the Gifford Pinchot National Forest is similar to that described for the administrative monument along with implementing habitat restoration and enhancement programs.

PART II. HABITAT PROTECTION NEEDS

History and Status of Habitat

Prior to active state and federal regulation of forest practices, fishery habitat was damaged. Indiscriminate logging around and through streams, use of splash dams to transport logs, and poor road construction with associated siltation reduced or eliminated anadromous fish from many streams. Other problems include destruction of riparian vegetation, land reclamation and non-point source pollution from agricultural development. Urbanization, port development, and flood control efforts further impacted stream habitat. Presently, numerous laws limit impacts, but the cumulative loss of habitat continues.

Fishery managers can influence fish habitat through management of the water and management of the physical habitat including the riparian edge. Since there are no dams and few water withdrawals in the Kalama Subbasin, management of the physical habitat is of primary importance.

Physical modification of aquatic habitat is controlled by state and federal statutes. Regulations overlap and are designed to limit impacts to public stream and shoreline resources. Laws addressing developments that could degrade stream and shoreline resources follow.

Federal

1. Clean Water Act, Section 404 and 10, U. S. Army Corps of Engineers, with State of Washington, Department of Ecology certification.

2. National Environmental Policy Act (NEPA), Federal Agency taking action.

State (Washington)

1. State Water Quality Laws RCW 90.48, Department of Ecology.

2. State Surface Water Codes RCW 90.03, Department of Ecology.

3. State Groundwater Codes RCW 90.44, Department of Ecology.

4. Shoreline Management Act, local government with state oversight by Department of Ecology.

5. Hydraulics Code RCW 75.20.100 and 103, Washington Department of Fisheries or Wildlife.

6. Minimum Flow Program, Department of Ecology.

7. State Environmental Policy Act (SEPA), local government or Department of Ecòlogy.

8. Flood Control Statutes, local government.

9. Forest Practices Act, Department of Natural Resources.

Constraints and Opportunities for Protection

Fish production in the Kalama Subbasin competes primarily with timber interests. Fishery agencies work with other agencies and landowners through various federal, state, and local laws and agreements to identify and reduce practices impacting fish habitat. Although fishery habitat laws and agreements are well intentioned, the inherent topography, geology, soils, and climate, and such would preclude most subbasin resource utilization without some habitat degradation.

In some cases, important factors affecting the quantity and quality of stream habitat are outside the direct regulatory authority of the fisheries management agencies. Interagency cooperation is important to address this difficult management situation. Good interagency communication of goals and objectives within watersheds and cooperative administration and enforcement could improve habitat protection.

Resource managers are currently cooperating to protect riparian habitat through a Timber/Fish/Wildlife Agreement. Harvest plans are reviewed by an interdisciplinary team and decisions are based on cooperative research, monitoring, and evaluation. The goal is to provide protection for wildlife, fish and water quality while allowing forest management activities to occur at reduced levels and under controlled operating conditions. Methods, among others, are to maintain adequate stream shading, leave trees that will later contribute large woody debris to streams, and to create silt traps to reduce silt entry into streams.

The following agencies have statutory or proprietary interests to salmon and steelhead production within the subbasin.

Federal
- U.S. Forest Service (USFS)
- U.S. Geological Survey (USGS)
- U.S. Soil Conservation Service (USSCS)
- U.S. Fish and Wildlife Service (USFWS)
- U.S. Army Corps of Engineers (COE)
- U.S. National Park Service (USNPS)
- Federal Energy Regulatory Commission (FERC)
- National Marine Fisheries Service (NMFS)

State
- Washington Department of Ecology (DOE)
- Washington Department of Fisheries (WDF)
- Washington Department of Wildlife (WDW)
- Washington Department of Natural Resources (DNR)
- Washington Department of Agriculture

Local
- Cowlitz County
- Skamania County

Habitat Protection Objectives and Strategies

In general, all fisheries management agencies subscribe to the concept of "no net loss" of existing habitat as a management goal. Even though this is difficult to attain, it is prudent policy and should be supported within the subbasin planning process for long-term production protection.

Objectives for habitat protection include:

1) No net loss of existing habitat.

2) No degradation of water quality.

3) No decrease of surface water quantity.

4) Increased security for existing habitat.

5) Increased salmonid use of underutilized habitat.

Strategies to protect habitat are not always easily implemented and as a result, the habitat portion of the subbasin process may not receive the attention it deserves. Prevention of cumulative loss of habitat is ultimately one of public policy.

Methods for implementing the guidelines mentioned are generally outside the normal activities of the Northwest Power Planning Council and the typical approach is through regulatory programs. However, this results in habitat protection being defensive whereby some habitat loss frequently occurs.

The combination of an effective public education program, an aggressive regulatory program with stiff penalties, tax incentives for riparian landowners, and demonstrated resource benefits to local residents is likely the only way to preserve and realize the production potential of the region's stream habitat resources. Within these broad categories, there is opportunity for the Northwest Power Planning Council to take a leadership and coordinating role. However, the daily business of protecting small habitat units will continue to be an agency burden. Effectiveness of these programs will depend on agency staffing levels of field management and enforcement personnel, public and political acceptance of program goals, local judicial support and importantly, the level of environmental awareness practiced by individual landowners.

The area of cumulative habitat loss is one which the Northwest Power Planning Council must be involved in for sake of the investments made in the Columbia River Basin Fish and Wildlife Program to date. The council could support the agencies' regulatory habitat protection work and become more involved by:

1) Continuing to broaden the public education and information program it already supports.

2) Purchasing riparian property adjacent to critical habitat.

3) Purchasing water rights if they can revert to instream uses.

4) Publishing additional inventories of important habitat for specific stocks.

5) Working with state and federal government for the development and passage of improved habitat protective legislation.

PART III. CONSTRAINTS AND OPPORTUNITIES FOR ESTABLISHING PRODUCTION OBJECTIVES

Systemwide Considerations

In terms of identifying objectives, general consideration should focus on the United States vs. Oregon document and the need to use this planning process as a means to fulfill the implementation of that decision. At the core of this agreement is the objective to rebuild weak runs at full productivity and to achieve fair sharing of the available harvest between Indian and non-Indian fisheries. A secondary objective is to rebuild upriver spring and summer chinook runs that would restore fisheries within 15 years. Harvests would be managed so that natural steelhead and other salmon runs also continue to rebuild. The rebuilding is to be accomplished through a systematic harvest management approach as well as implementation of appropriate production measures.

Consistent with United States vs. Oregon is the need to maintain flexible and dynamic plans that can be evaluated at defined intervals and modified whenever conditions change or new information becomes available. Long-term plans should also work to avoid disputes among the parties and attempt to resolve disagreements over fishing regulations and the collection and interpretation of management data.

As an extension of these objectives, subbasin plans should:

1) Achieve a balance with the stock of any given type (such as spring and fall chinook).

2) Work toward harvest stability within subbasins.

3) Provide equitable opportunity to each user group.

4) Maintain habitat and improve where possible.

5) Manage for the consistent escapement of escapement allowances.

6) Optimize production and maximize long-term net benefits.

7) Use indigenous stocks where feasible and maintain stock diversity of all species to ensure perpetual existence and ability to adapt to change.

Though the agreement focuses on above Bonneville stocks and the need to rebuild the natural components on the runs, it does not ignore the fish runs returning to tributaries below

Bonneville Dam. In some cases, such as Cowlitz spring chinook, it is intimately tied to providing upriver opportunities to tribal fisheries.

Lower Columbia River production acts as a major producer for ocean fisheries in helping to provide maximum opportunity on a consistent basis. The Pacific Salmon Treaty, negotiated in 1985, has a large influence on ocean harvest. The major principles of the treaty attempt to 1) prevent overfishing and provide for optimum production, and 2) provide for each party to receive benefits equivalent to the production of salmon originating in its waters.

In fulfilling their obligations, the parties will cooperate in management research and enhancement. In addition, the parties will take into account the following items.

1) The desirability, in most cases, of reducing interceptions.

2) The desirability, in most cases, of avoiding undue disruption of existing fisheries.

3) Annual variation in abundance of the stocks.

Local Considerations

Within the subbasin, constraints to objectives include water quantity and quality available for existing hatcheries, low summer flows in tributaries, and warm water temperatures. Existing rearing facilities are presently at capacity. The topography and hydrology of the subbasin may hamper location of sites and water sources for additional fish rearing facilities. Extensive timber harvest within the subbasin has resulted in stream siltation, warm water, reduced summer flows and reduced recruitment of large organic debris within streams.

PART IV. ANADROMOUS FISH PRODUCTION PLANS

WINTER STEELHEAD

Fisheries Resource

Natural Production

History and Status

Historically, winter steelhead were moderately abundant in the subbasin and were confined below the Kalama Falls Hatchery site at RM 10 (D. Lavier, retired biologist, Washington Game Department, pers. commun.). Punch-card harvest information (corrected for bias) indicated an average of 360 fish were sport caught in 1946 through 1953, years when no hatchery returns were expected. In the 1950s, ladder improvements around Kalama Falls were completed and winter steelhead gained new upstream access. For 1976 through 1986, run size of natural winter steelhead averaged 1,438 Kalama origin fish and 1,966 counting strays (Leider et al. 1987, revised 1989).

Life History and Population Characteristics

Adult time of entry is generally from mid-November through May with peak numbers in March and April (Table 4). Four-year average mean time of spawning in Gobar Creek, a Kalama River tributary, was April 14 with most spawning occurring from March through May (Leider et al. 1984). Emergence occurs from April through early July. Juvenile rearing generally lasts for two years prior to spring ocean emigration, although some juveniles emigrate after one or three years (Loch et al. 1985).

For 1976 through 1986 run size of natural winter steelhead was an estimated 1,438 Kalama fish and 1,966 counting strays.

Juvenile freshwater age structure of Kalama River steelhead smolts (winter and summer combined) was 6.1 percent, 80.6 percent, and 13.3 percent for ages I, II, and III, respectively (Loch et al. 1985). Mean fork length of smolts was 14.2 cm, 16.1 cm, and 17.2 cm for ages I, II, and III, respectively.

For adults, excluding repeat spawners, ocean age structure was dominated by 71.1 percent 2-year ocean fish (2-salts) followed by 25.7 percent 3-year ocean fish (Table 5) (Leider et al. 1986). Females made up 51.6 percent of initial spawners. Mean length of all initial spawners combined was 72.6 cm. Repeat spawners comprised 11.3 percent of the total, were 71.4 percent females, and averaged 77.4 cm (n=298). Mean length of all fish combined was 73.1 cm.

Table 4. Freshwater life history of subbasin winter steelhead. The developmental stage timing represents basinwide averages; local conditions may cause some variability.

Developmental Stages	Time of Year	Peak Occurrence
Adult immigration	November-May	March-April
Adult holding	December-May	March-April
Spawning	December-May	April
Egg/alevin incubation	December-June	May
Emergence	February-July	May-June
Rearing	Feb-April(26 mos.)	June-April(24 mos.)
Juvenile emigration	April-May	April-May

Table 5. Ocean age, sex, and length of Kalama natural steelhead (Leider et al. 1986).

	Ocean Age		
	1	2	3
Age Composition	3.2%	71.1%	25.7%
Percent Females	7.6%	47.5%	68.8%
Mean Length (cm) Male	52.0	70.8	85.8
Mean Length (cm) Female	59.0	69.2	80.5
Total number of fish	92	1,989	718

Kalama Subbasin fecundity data is meager. The Toutle River is fairly close in proximity to the Kalama and a total of 49 Toutle females live-spawned with a mean length of 70.4 cm provided a mean of 3,900 eggs per female in 1988 (R. Lucas, WDW, pers. commun.). Schuck and Kurose (1982) live-spawned 26 Toutle fish that had a mean fecundity of 2,251 eggs per female. Some eggs are retained in live spawning, so the above numbers underestimate actual fecundity. Fecundity of Cowlitz Hatchery kill-spawned steelhead, with lengths similar to Kalama fish, averaged 5,257 eggs per female. Beaver Creek Hatchery fish of 68.5 cm had a fecundity of 4,060 eggs per female (Randolph 1987). Based on the above, fecundity of Kalama steelhead is assumed to be 4,500 eggs per female.

Using the combined summer and winter steelhead smolt production estimate by Loch et al.(1985) (Table 6), a fecundity of 4,500 eggs per female, a male-female ratio of 1-to-1 and an adjusted hatchery versus natural reproductive success rate (28 percent from Chilcote et al. 1986), egg-to-smolt survival was 0.29 percent for winter and summer steelhead combined.

Smolt-to-adult survival of combined natural winter and summer steelhead was 12.3 percent (Leider et al. 1987, revised 1989).

As for habitat carrying capacity, the Northwest Power Planning Council's model estimated production at 129,179 combined winter and summer steelhead smolts. Smolt capacity was 34,850 fish using the Washington Department of Wildlife's gradient area flow methodology (GAFM). Using a large fyke net in 1978 through 1984, Loch et al. (1985) estimated an average of 28,259 smolts emigrated from the Kalama River. Because winter and summer steelhead are both present throughout the watershed, smolt capacity was split in half, resulting in 64,860 smolts via the Northwest Power Planning Council's model.

Table 6. Steelhead smolts produced and spawning escapement two years prior in the Kalama River (Loch et al. 1985).

		Spawning Escapement Two Years Earlier			
Year	Smolts	Hatchery winter	Natural winter	Hatchery summer	Natural summer
1978	36,166	389	762	1,966	909
1979	34,356	1,268	766	6,803	1,623
1980	23,804	233	461	4,187	775
1981	37,082	595	1,216	3,287	951
1982	10,953	961	2,160	16,033	5,423
1983	43,336	381	949	16,125	1,662
1984	12,113	424	542	7,640	1,464

Milner et al. (1980) did an electrophoretic profile of Kalama winter steelhead along with other Columbia River stocks to examine the feasibility of using biochemical genetic variation for estimating composition of mixed-stock fisheries. They concluded sufficient genetic differentiation existed to do so.

The Washington Department of Wildlife's Kalama River research group is examining the reproductive success of hatchery versus natural winter steelhead on the Kalama River. Genetic profiles using electrophoresis are being conducted but results are not yet available.

Supplementation History

Managers have planted considerable numbers of hatchery fish into the subbasin since 1938. However, plants were sporadic until annual plants began in 1955. From 1976 through 1988, managers planted an average of 93,158 smolts using Elochoman, Cowlitz, Chambers Creek and Bogachiel stocks with the goal of supplementing sport harvest of natural fish (Table 7). Smolt-to-adult survival of hatchery fish for 1978 through 1984 averaged 1.4 percent (Leider et al. 1987, revised 1989).

Table 7. Kalama Subbasin releases of hatchery winter steelhead.

Year	Smolts	Year	Smolts
1976	81,153	1982	99,501
1977	64,505	1983	106,363
1978	70,060	1984	94,376
1979	64,786	1985	125,150
1980	83,182	1986	125,920
1981	106,363	1987	85,417
		1988	103,945

Fish Production Constraints

In general, the Kalama Subbasin has limited natural production potential, especially for steelhead. The relatively few tributaries are generally short in length and have high gradients. Steelhead production, as measured by number of fish per square meter, is usually only moderate in river mainstems (WDW gradient area flow model for smolt production). For all species, production constraints include habitat degradation from riparian activities, lack of large organic debris, upstream passage difficulties, lack of good spawning gravel, and stressful temperatures. Riparian activities such as logging have resulted in sedimentation, increased water temperatures, loss of habitat and removal of future large woody debris (Table 8).

Hatchery Production

The 1.5-acre Gobar Pond is the only steelhead rearing facility in the subbasin. Winter and summer steelhead subsmolts are trucked in from Beaver Creek and Skamania hatcheries, respectively, usually in February. Smolts are released in late April to early May. Most smolts are trucked downstream to planting locations while some are often released directly into Gobar Creek. For 1986 through 1988, about 105,000 smolts (about 21,000 pounds) were reared in Gobar Pond of which about 56 percent were winter steelhead and the remainder summer steelhead. The goal of the facility is to acclimate steelhead prior to release so returns and subsequent sport harvest are enhanced. Also, Gobar allowed a greater number of fish to be released into the Kalama because Beaver Creek Hatchery becomes overcrowded in February. Additional smolts are planted from Beaver Creek Hatchery.

Table 8. Habitat constraints in the Kalama Subbasin.

Section of Subbasin	Species*	Habitat Constraints
Mouth to Hatchery Ck	1-6	Sediment, low gradient, temperature
Hatchery Ck	1-4,6	Passage blocked, gravel quality, channelized
Kalama from Hatchery Ck to Little Kalama	1-6	Passage difficulty, lack of woody structure
Little Kalama	1-3,6	High gradient, gravel quality
Kalama from Little Kalama to Falls	1-3,5,6	Gravel quantity and quality, lack of woody structure
Other tribs	1-3,6	High stream gradient, low flows, passage blocked, warm temperatures

* 1-Winter steelhead, 2-Summer steelhead, 3-Sea-run cutthroat, 4-Fall Chinook, 5-Spring Chinook, 6-Coho

Brood stock source is Beaver Creek Hatchery on the Elochoman River via hatchery rack returns, although Cowlitz, Chambers Creek, and Bogachiel hatchery eggs have been previously imported to Beaver Creek Hatchery. Fish selected for spawning are those sexually mature in December through February.

Hatchery run size of Kalama origin fish was estimated by Leider et al. (1987, revised 1989) to average 1,211 adults for 1977 through 1987 (Table 9). However, an additional 23 percent, strays from other rivers, also returned. Smolt-to-adult return was estimated at 1.4 percent for 1978 through 1984 Kalama origin fish (Leider et al. 1987, revised 1989).

Table 9. Kalama Subbasin returns of Kalama origin hatchery winter steelhead (from Leider et al. 1987, revised 1989).

Year	Adult steelhead	Year	Adult steelhead
1977	691	1982	602
1978	1,981	1983	602
1979	398	1984	1,531
1980	1,147	1985	1,476
1981	819	1986	2,557
		1987	1,521

Although beginning and ending times are similar, peak adult time of return, time of spawning, incubation period, and emigration time is about two months sooner for hatchery fish than Kalama natural steelhead. Smolts emigrate after about 14 months, about one year sooner than natural fish. Saltwater age composition of adults was 2 percent, 86.8 percent, 11.3 percent for ages I, II, III, respectively (Table 10) (Leider et al. 1986). Females comprised 31.7 percent, 48.2 percent, and 73.4 percent of each age class, respectively, and 50.7 percent of the total. Repeat spawners comprised 5.8 percent of hatchery adult runs of which 71.6 percent were females. Mean length of all hatchery adults combined was 69.4 cm.

Length and fecundity of Elochoman hatchery steelhead, which are probably representative of hatchery returns to the Kalama, was 67.4cm - 3,910 eggs in 1983; 64.1cm - 3,459 eggs in 1984; and 68.5cm - 4,060 eggs in 1985 (Randolph 1986 and 1987).

Schreck et al. (1986) looked at stock identification of various Columbia River steelhead, including Beaver Creek stock, using cluster analysis of meristic and electrophoretic features and concluded geographical proximal stocks tend to be similar. Milner et al. (1980) also profiled Elochoman hatchery steelhead in a similar manner as that mentioned for Kalama natural fish.

No additional production facilities are planned in the Kalama Subbasin.

Table 10. Ocean age, sex, and length of initial migrant Kalama River hatchery steelhead (Leider et al. 1986).

	Ocean Age		
	1	2	3
Age Composition	2.0%	86.8%	11.3%
Percent females	31.7%	48.2%	73.4%
Mean Length (cm) Male	56.4	68.9	81.2
Mean Length (cm) Female	63.6	66. 8	79.2
Total number of fish	41	1,821	237

Harvest

For 1976 through 1986, sport harvest of hatchery and natural fish was estimated at 764 hatchery fish (48.8 percent harvest rate) and 1,048 natural fish (53.3 percent harvest rate), for an average total of 1,812 fish (Table 11). Harvest of natural fish will be prohibited under a regulation taking effect in 1990.

Few steelhead are harvested in the ocean although the ocean drift net fishery may have intercepted some in recent years. Harvest of winter steelhead in the Columbia River was estimated at 6.2 percent in the System Planning Model.

Harvest management goals in the subbasin are to maximize sport harvest hatchery fish while minimizing harvest of natural fish, with a target goal of 800 steelhead harvested.

Management procedures for harvest within the subbasin consist of regulation through Department of Wildlife harvest restrictions. Harvest is monitored through sport punch-card returns. Enforcement activities consist of Washington Department of Wildlife personnel checking anglers for compliance with harvest restrictions.

The Kalama has several regulations regarding areas open seasonally but, in general, has a two-fish limit. The season for winter steelhead opens in June and runs through March 31 above Kalama Falls up to Summers Creek. The river is open year-round below Kalama Falls. "Wild release" regulations were recently imposed on the Kalama, restricting harvest to hatchery fish only.

Table 11. Kalama Subbasin adult harvest and spawning escapement, winter steelhead (Leider et al. 1987, revised 1989).

	1977	1978	1979	1980	1981	1982
Spawning Escapement						
Hatchery fish	389	1,268	233	595	961	381
Natural fish	762	766	431	1,216	2,160	949
Subtotal	1,151	2,034	664	1,811	3,121	1,330
Subbasin Harvest (Recreational)						
Hatchery fish	433	1,088	242	762	670	643
Natural fish	855	1,041	654	1,023	1,806	1,562
Subtotal	1,288	2,129	896	1,785	2,476	2,205
TOTAL IN-RIVER RUN	2,439	4,163	1,560	3,596	5,597	3,535

	1983	1984	1985	1986	1987
Spawning Escapement					
Hatchery fish	424	1,176	574	1,868	954
Natural fish	542	900	598	851	918
Subtotal	966	2,076	1,172	2,719	1,872
Subbasin Harvest (Recreational)					
Hatchery fish	418	793	1,250	1,231	872
Natural fish	867	766	1,315	1,398	239
Subtotal	1,285	1,559	2,565	2,629	1,111
TOTAL IN-RIVER RUN	2,251	3,635	3,737	5,348	2,983

Specific Considerations

Steelhead management within the subbasin emphasizes sport harvest of hatchery steelhead and escapement of natural fish. "Wild release" regulations will minimize harvest of natural fish.

Production of hatchery fish within the subbasin is presently constrained at Gobar Pond by facility size. Smolt-to-adult survival of hatchery fish has averaged only 1.4 percent although in recent years it has improved to 1.8 percent, still a relatively low return rate.

Critical data gaps consist of winter steelhead fecundity data.

Objectives

Stock: Kalama Natural Winter Steelhead

Utilization Objective: Zero; catch and release only.

Biological Objective: Maintain biological characteristics of the existing natural population. The biological component has priority for this stock within the Kalama River.

Objectives for the Kalama natural stock are presently being met and consequently, no alternative strategies are offered. Subbasin returns for 1976 through 1986 averaged 1,438 fish. The System Planning Model indicated the recent "wild release" regulations will increase river returns by 459 fish at existing harvest rates.

Stock: Kalama Hatchery Winter Steelhead

Utilization Objective: 1,000 for sport fishery. The utilization component has priority for this stock within the Kalama River.

Biological Objective: Maintain differential run timing from natural stock.

Returns from an average release of 93,158 hatchery smolts resulted in 1,211 fish of which 764 were harvested. An additional 236 fish are needed for harvest which would require an additional subbasin return of 485 fish at existing harvest rates.

Alternative Strategies

Strategies to obtain objectives are generally first approached using the most natural techniques with least genetic impacts declining to less natural methods and ending with hatchery only. Steelhead in the Kalama River are managed as two separate stocks to minimize hatchery genetic impacts on the natural stock. Differential run timing is maintained and ideally, all hatchery fish would be harvested. Because the objectives involve a hatchery stock only, only hatchery alternatives are offered.

Modeling results for each strategy are presented in Table 12 as fish produced at "maximum sustainable yield" (MSY). The sustainable yield of a fish population refers to that portion of the population that exceeds the number of fish required to spawn and maintain the population over time. Sustainable yield can be "maximized," termed MSY, for each stock at a specific harvest level. The MSY is estimated using a formula (Beverton-Holt function) that analyzes a broad range of harvest rates. Subbasin planners have used MSY as a tool to standardize results so that decision makers can compare stocks and strategies.

In MSY management, managers set a spawning escapement level and the remaining fish (yield) could theoretically be harvested. In practice, a portion of the yield may be reserved as a buffer or to aid rebuilding. Thus, managers may raise the escapement level to meet a biological objective at the expense of a higher utilization objective.

The amount of buffer appropriate for each stock is a management question not addressed in the subbasin plans. For this reason, the utilization objective, which usually refers to harvest, may not be directly comparable to the MSY shown in Table 12. At a minimum, a strategy should produce an estimated MSY equal to or greater than the utilization objective. A MSY substantially larger than the subbasin utilization objective may be needed to meet subbasin biological objectives.

Estimated costs of the alternative strategies below are summarized in Table 13.

STRATEGY 1: Hatchery Production. This strategy seeks to achieve the objectives solely through traditional hatchery production. Only those actions necessary for maintenance of the hatchery program are included.

Hypothesis: Increasing the smolt production will increase number of adults produced.

Assumptions: This strategy assumes increased smolt production will result in commensurate adult returns.

Numeric Fish Increases: This strategy would add 556 fish to the subbasin at current harvest rates, thereby meeting objectives. Total production increase would be 402 fish at MSY.

ACTIONS: 1

1. Increase smolt production by 40,000 fish.

STRATEGY 2: Hatchery Production. This strategy seeks to achieve the objectives solely through traditional hatchery production. Only those actions necessary for maintenance of the hatchery program are included.

Hypothesis: Rearing pond smolt quality would be improved compared to raceway reared smolts and liberation would be less stressful.

Assumptions: This strategy was modeled with the assumption that the relative smolt survival of hatchery fish would be increased from 0.69 to 0.71. Currently, about half the smolts released are from Gobar Pond.

Numeric Fish Increases: This strategy would add 36 fish to the subbasin at current harvest rates. Total production increase would be 38 fish at MSY.

ACTIONS: 2

2. Construct a rearing pond in the lower Kalama River to rear needed hatchery smolts (in addition to Gobar Pond).

STRATEGY 3: Hatchery Production. This strategy seeks to achieve the objectives solely through traditional hatchery production. Only those actions necessary for maintenance of the hatchery program are included.

Hypothesis: Rearing pond smolt quality would be improved compared to raceway reared smolts and liberation would be less stressful. Increasing the smolt production will increase number of adults produced.

Assumptions: This strategy was modeled with the assumption that the relative smolt survival of hatchery fish would be increased from 0.69 to 0.71. This strategy assumes increased smolt production will result in commensurate adult returns.

Numeric Fish Increases: This strategy would add 570 fish to the subbasin at current harvest rates, thereby meeting objectives. Total production increase would be 418 fish at MSY.

ACTIONS: 1, 2

Recommended Strategy

The recommended strategy for Kalama winter steelhead is Strategy 3, constructing a rearing pond in the lower Kalama River and adding 40,000 smolts. A rearing pond would improve the smolt quality and would allow for an increase in numbers, up to 130,000 smolts. Other important associated benefits of a winter steelhead rearing pond in the lower Kalama will also occur: 1) Gobar Pond will be able to rear all the summer steelhead needed rather than trucking smolts directly from Skamania Hatchery thereby improving the relative smolt quality of that stock; 2) angler harvest rate on hatchery winter steelhead should increase as returning adults will concentrate near the area of release; and 3) the lower river homing site will help confine hatchery fish below much of the available juvenile rearing habitat thereby limiting possible negative genetic influences. Strategy 3 is also supported with the SMART analysis (Appendix B).

Table 12. System Planning Model results for winter steelhead in the Kalama Subbasin. Baseline value is for pre-mainstem implementation, all other values are post-implementation.

Utilization Objective:
1,000 hatchery fish for sport harvest. No harvest of natural fish.

Biological Objective:
Maintain run timing, size and age distribution of natural fish.

Strategy[1]	Maximum[2] Sustainable Yield (MSY)	Total[3] Spawning Return	Total[4] Return to Subbasin	Out of[5] Subbasin Harvest	Contribution[6] To Council's Goal (Index)
Baseline	1,424 -N	1,107	2,589	171	0(1.00)
All Nat	1,424 -N	1,107	2,589	171	0(1.00)
1	1,826 -N	1,256	3,148	208	596(1.22)
2	1,462 -N	1,091	2,610	172	22(1.01)
3*	1,842 -N	1,267	3,176	210	625(1.23)

*Recommended strategy.

[1]Strategy descriptions:

For comparison, an "all natural" strategy was modeled. It represents only the natural production (non-hatchery) components of the proposed strategies plus current management (which may include hatchery production). The all natural strategy may be equivalent to one of the alternative strategies below.

1. Add 40,000 hatchery smolts.
2. Baseline plus a rearing pond.
3. Strategy 1 and 2 combined.

[2]MSY is the number of fish in excess to those required to spawn and maintain the population size (see text). These yields should equal or exceed the utilization objective. C = the model projections where the sustainable yield is maximized for the natural and hatchery components combined and the natural spawning component exceeds 500 fish. N = the model projection where sustainable yield is maximized for the naturally spawning component and is shown when the combined MSY rate results in a natural spawning escapement of less than 500 fish.

[3]Total return to subbasin minus MSY minus pre-spawning mortality equals total spawning return.

[4]Total return to the mouth of the subbasin.

[5]Includes ocean, estuary, and mainstem Columbia harvest.

[6]The increase in the total return to the mouth of the Columbia plus prior ocean harvest (as defined by the Northwest Power Council's Fish and Wildlife Program), from the baseline scenario. The index () is the strategy's total production divided by the baseline's total production.

Table 13. Estimated costs of alternative strategies for Kalama winter steelhead. Cost estimates represent new or additional costs to the 1987 Columbia River Basin Fish and Wildlife Program; they do not represent projects funded under other programs, such as the Lower Snake River Compensation Plan or a public utility district settlement agreement. (For itemized costs, see Appendix C.)

	Proposed Strategies		
	1	2	3*
Hatchery Costs			
Capital[1]	184,000	0	184,000
O&M/yr[2]	20,000	0	20,000
Other Costs			
Capital[3]	0	250,000	250,000
O&M/yr[4]	0	5,000	5,000
Total Costs			
Capital	184,000	250,000	434,000
O&M/yr	20,000	5,000	25,000

* Recommended strategy.

[1] Estimated capital costs of constructing a new, modern fish hatchery. In some subbasins, costs may be reduced by expanding existing facilities. For consistency, estimate is based on $23/pound of fish produced. Note that actual costs can vary greatly, especially depending on whether surface or well water is used and, if the latter, the number and depth of the wells.

[2] Estimated operation and maintenance costs per year directly associated with new hatchery production. Estimates are based on $2.50/pound of fish produced. For consistency, O&M costs are based on 50 years.

[3] Capital costs of projects (other than direct hatchery costs) proposed under a particular strategy, such as enhancing habitat, screening diversions, removing passage barriers, and installing net pens (see text for specific actions).

[4] Estimated operation and maintenance costs per year of projects other than those directly associated with new hatchery production. For consistency, O&M costs are based on 50 years.

SUMMER STEELHEAD

Fisheries Resource

Natural Production

History and Status

The Kalama Subbasin historically had moderate numbers of summer steelhead. During 1956-1959 improvements on a 1936 fish ladder at the Kalama Falls Hatchery site, only natural fish were expected to return and 224 steelhead were captured in July and August 1956 (Lavier 1956). In 1958 and 1959, 119 and 558 fish, respectively, were counted at Kalama Falls from April through June, the peak run time (Lavier 1958 and 1959). Punch-card sport harvest for 1962, a year of few hatchery returns, was 473 summer steelhead. Run size of natural fish in the 1950s was probably less than 1,500 fish. Distribution was throughout the watershed up to the high falls at RM 35. Prior to construction of the fishway at the Kalama Falls Hatchery site, summer steelhead were thought to be the only salmonids to move above that site (D. Lavier, retired regional biologist, Washington Game Department, pers. commun.). The impacts of laddering the falls on summer steelhead is unknown.

Life History and Population Characteristics

Adult time of entry is generally April through October with peak numbers in July (Table 14). Spawning occurs from December through April with a peak at February 15 (Leider et al. 1984). Fry emerge from March through May. Juvenile rearing generally is two years prior to spring ocean emigration, although some juveniles emigrate after one or three years (Loch et al. 1985).

Run size of natural steelhead in the Kalama Subbasin for 1976 through 1986 averaged 2,420 fish although some were strays; number of Kalama origin fish was estimated at 1,672 fish (Leider et al. 1987).

Juvenile freshwater age structure of Kalama steelhead smolts (winter and summer combined) was 6.1 percent, 80.6 percent, and 13.3 percent for ages I, II, and III, respectively (Loch et al. 1985). Mean fork length of smolts was 14.2 cm, 16.1 cm, and 17.2 cm for ages I, II, and III, respectively.

Table 14. Freshwater life history of natural summer steelhead. The developmental stage timing represents basinwide averages, local conditions may cause some variability.

Developmental Stages	Time of year	Peak occurrence
Adult immigration	April-October	July
Adult holding	April-November	July-November
Spawning	December-May	February
Egg/alevin incubation	December-May	March-April
Emergence	March-May	April
Rearing	March-April(26 mos.)	April-April(24 mos.)
Juvenile emigration	April-May	April-May

For adults, excluding repeat spawners, ocean age structure was dominated by 78.9 percent 2-salts followed by 14.5 percent 1-salts and 6.6 percent 3-salts (Table 15) (Leider et al. 1986). Females made up 51.9 percent of initial spawners. Mean length of all initial spawners combined was 70.6 cm; 70.3 cm for males and 70.8 cm for females. Repeat spawners comprised 6 percent of the total, were 55.8 percent females, and averaged 78.2 cm (n=170). Mean length of all fish combined was 71 cm.

Table 15. Ocean age structure, length and sex of Kalama Subbasin natural summer steelhead (from Leider et al. 1986).

	Ocean Age		
	1	2	3
Age Composition	14.5 %	78.9 %	6.6 %
Percent Females	31.8 %	59.2 %	8.9 %
Mean Length (cm) Male	57.4	72.7	79.0
Mean Length (cm) Female	60.6	71.7	78.7
Number of Fish	368	2,004	168

No fecundity information was found for natural summer steelhead in the subbasin. Fecundity of Skamania stock steelhead after several generations of adaptation to the Cowlitz Hatchery had a mean length of 72.2 cm and 4,617 eggs per female (n=698).

Using the smolt productiôn estimate by Loch et al. (1985), a fecundity of 4,500 eggs, a male-female ratio of 1-to-1 and an adjusted hatchery versus natural reproductive success rate (28 percent from Chilcote et al. 1986), egg-to-smolt survival was 0.29 percent for winter and summer steelhead combined. Smolt-to-adult survival rates for combined natural summer and winter steelhead was estimated at 12.3 percent (Leider et al.1987).

Steelhead smolt capacity was estimated at 129,179 and 34,850 combined winter and summer steelhead smolts using the Northwest Power Planning Council's model and Washington Department of Wildlife's gradient area flow methodology (GAFM), respectively. Using a large fyke net in 1978 through 1984, Loch et al. (1985) estimated an average 28,259 smolts emigrated from the Kalama River. Because winter and summer steelhead are both present throughout the watershed, smolt capacity was split in half, resulting in 64,860 smolts via the Northwest Power Planning Council's model.

A Washington Department of Wildlife research group has worked on the Kalama River since 1975 in part to determine the reproductive success of hatchery and natural summer steelhead under natural conditions. Chilcote et al. (1986), through electrophoretic examination of juveniles for a specific genetic marker, found the success of hatchery fish in producing smolt offspring was 28 percent of wild fish. Also, they found 62 percent of naturally produced summer steelhead smolts were offspring of hatchery spawners due to hatchery spawners outnumbering wild spawners at least 4.5-to-1. They concluded the genetic integrity of wild populations may be threatened under such conditions and hatchery fish may be important contributors to spawner-recruitment of summer steelhead.

Milner et al. (1980) did an electrophoretic profile of Kalama summer steelhead along with other Columbia River stocks to examine the feasibility of using biochemical genetic variation for estimating composition of mixed stock fisheries. They concluded sufficient genetic differentiation existed to do so.

Supplementation History

Summer steelhead were planted as early as 1950, but from 1976 through 1988, an average of 94,794 smolts were planted using Skamania stock from Skamania Hatchery with the goal of supplementing sport catch of natural fish (Table 16). About half the smolts are released from Gobar Pond and the others are trucked from Skamania Hatchery. Smolt-to-adult survival of hatchery plants has averaged 8.7 percent for 1978 through 1984 releases (Leider et al. 1987). No additional supplementation is anticipated.

Fish Production Constraints

Production constraints for summer steelhead are similar to those previously mentioned (Table 8).

Hatchery Production

The previously described Gobar Pond is the only summer steelhead rearing facility on the Kalama River. For 1986 through 1988, about 105,000 smolts (about 21,000 pounds) were reared in Gobar Pond of which about 44 percent were summer steelhead and the remainder winter steelhead. No additional facilities are anticipated.

Additional smolts are planted from Skamania Hatchery, which is also the brood stock source for Gobar fish. Fish selected for spawning are those sexually mature in December through February. Ovarian fluid is tested from females for infectious hematopoietic necrosis (IHN) virus and eggs from positive females are usually discarded.

Table 16. Kalama Subbasin releases of hatchery summer steelhead.

Year	Smolts	Year	Smolts
1976	94,112	1982	64,776
1977	96,217	1983	76,264
1978	94,752	1984	112,524
1979	120,380	1985	93,936
1980	125,967	1986	130,354
1981	105,237	1987	58,201
		1988	59,595

Hatchery run size was estimated by Leider et al. (1987) to average 11,090 adults for 1977 through 1987 (Table 17). However, many of those were strays, particularly from the Cowlitz River after the eruption of Mount St. Helens, leaving an estimated average run size 7,800 fish. Smolt-to-adult return was estimated to be 8.7 percent for 1978 through 1984 releases (Leider et al. 1987).

Table 17. Returns of Kalama Subbasin hatchery summer steelhead (Leider et al. 1987).

Year	All steelhead	Kalama steelhead
1976	4,185	3,520
1977	10,924	9,187
1978	7,267	6,090
1979	5,309	4,486
1980	24,502	12,300
1981	23,314	13,709
1982	15,544	11,106
1983	4,028	3,133
1984	3,936	3,186
1985	7,636	6,301
1986	15,347	12,785

Although beginning and ending times are similar, time of spawning and incubation is about one month sooner for hatchery fish than Kalama natural steelhead. Hatchery smolts emigrate after about 14 months, about one year sooner than natural fish. Saltwater age composition of initial migrant adults was 4.5 percent, 85.7 percent, 9.8 percent for ages I, II, III, respectively (Table 18) (Leider et al. 1986). Females comprised 17.5 percent, 54 percent, and 32.9 percent of each age class, respectively, and 50.3 percent of the total. Repeat spawners comprised 2.8 percent of hatchery adult runs, had a mean length of 78.2 cm and were comprised of 50.7 percent females. Mean length of all hatchery adults combined was 72.7 cm. Fecundity of Skamania Hatchery fish was 4,170 eggs per female (Randolph 1987).

Table 18. Ocean age, sex, and length of initial migrant Kalama River hatchery summer steelhead (Leider et al. 1986).

	Ocean Age		
	1	2	3
Age Composition	4.5%	85.7%	9.8%
Percent Females	17.5%	54.0%	32.9%
Mean Length (cm) Male	57.9	72.8	85.2
Mean Length (cm) Female	60.8	71.2	79.7
Total number of fish	228	4,378	501

Harvest

For 1976 through 1986, sport harvest averaged 4,609 hatchery fish (41.6 percent harvest rate) and 1,106 natural fish (42 percent harvest rate) or 5,625 fish (41.6 percent harvest rate) overall (Leider et al. 1987) (Table 19). However, "wild release" regulations were adopted in 1986, which has minimized harvest of natural fish. Harvest management goals in the subbasin are to return enough hatchery fish to provide a sport harvest of about 3,000 fish.

Few steelhead are harvested in the ocean although the ocean drift net fishery may have intercepted some in recent years. Harvest of summer steelhead in the Columbia River was estimated at 2.4 percent in the System Planning Model.

Management procedures for harvest within the subbasin consists of regulation through Department of Wildlife sport harvest restrictions. General management is to emphasize harvest of hatchery fish and allow escapement of natural fish. Harvest is monitored through sport punch-card returns. Enforcement activities consist of Washington Department of Wildlife personnel checking anglers for compliance with harvest restrictions.

The Kalama has several regulations regarding areas open seasonally but, in general, has a two-fish limit with wild release regulations from April through October. The season for summer steelhead opens in June and runs through March 31 above

Kalama Falls up to Summers Creek. The river is open year-round below Kalama Falls.

Table 19. Kalama Subbasin adult summer steelhead harvest and spawning escapement (Leider et al. 1987).

	1976	1977	1978	1979	1980	1981
Spawning Escapement						
Hatchery fish	1,966	6,803	4,187	3,287	16,033	16,125
Natural fish	909	1,623	775	951	5,423	1,662
Subtotal	2,875	8,426	4,962	4,238	21,456	17,787
Subbasin Harvest (Recreational)						
Hatchery fish	2,219	4,121	3,080	2,022	8,469	7,189
Natural fish	784	812	626	639	2,936	949
Subtotal	3,003	4,933	3,706	2,661	11,405	8,138
TOTAL IN-RIVER RUN	5,878	13,359	8,668	6,899	32,861	25,925

	1982	1983	1984	1985	1986
Spawning Escapement					
Hatchery fish	7,640	1,778	1,664	3,837	7,971
Natural fish	1,464	398	537	639	1,059
Subtotal	9,104	2,176	2,201	4,476	9,030
Subbasin Harvest (Recreational)					
Hatchery fish	7,904	2,250	2,272	3,799	7,376
Natural fish	1,433	602	690	643	1,066
Subtotal	9,337	2,852	2,962	4,442	8,442
TOTAL IN-RIVER RUN	18,441	5,028	5,163	8,918	17,472

Specific Considerations

Steelhead management within the subbasin emphasizes sport harvest of hatchery steelhead and escapement of natural fish. "Wild release" regulations will minimize harvest of natural fish.

Production of hatchery fish is presently constrained at Gobar Pond by facility size. Smolt-to-adult survival of hatchery fish for 1978 through 1984 releases was an estimated 8.7 percent. Natural production is probably suboptimum due to habitat disturbances.

Critical data gaps consist of summer steelhead fecundity data.

Objectives

Stock: Kalama Natural Summer Steelhead

Utilization Objective: Zero; catch and release only.

Biological Objective: Maintain biological characteristics of the existing natural population. The biological component has priority for this stock within the Kalama River.

Objectives for the Kalama natural stock are presently being met and consequently, no alternative strategies are offered. Subbasin returns of Kalama natural summer steelhead averaged 1,672 fish for 1976 through 1986. The System Planning Model indicated an additional 66 fish will return to the subbasin under the "wild release" regulations at existing harvest rates.

Stock: Kalama Hatchery Summer Steelhead

Utilization Objective: 3,100 for sport fishery. The utilization component has priority for this stock within the Kalama River.

Biological Objective: Maintain differential run timing from natural stock.

Returns from average releases of 101,320 hatchery smolts provided 7,800 subbasin returns. At existing harvest rates, 3,200 fish are sport caught. Objectives for hatchery fish are presently being met and consequently, no alternative strategies are offered.

Alternative Strategies

Because objectives are currently being met, no actions or strategies are offered. Current returns are about 8,000 fish greater than historic levels.

SEA-RUN CUTTHROAT TROUT

Fisheries Resource

Natural Production

History and Status

Historical status of sea-run cutthroat trout in the subbasin is unknown. Distribution was thought to be confined below the Kalama Falls Hatchery site until the falls were successfully laddered in the 1950s (D. Lavier, retired regional biologist, Washington Game Department, pers. commun.). Rack counts at the Kalama Falls Salmon Hatchery were made for 1976 through 1986 and an average of 19 fish were counted. However, capture efficiency is unknown due to rack picket spacing; in 1976 only eight cutthroat were captured, but about 24 were later observed upstream in one section of Gobar Creek. Concern for inadequate Kalama sea-run cutthroat has resulted in closing the fishery.

Life History and Population Characteristics

Adult time of entry for the subbasin is generally from July though October with peak numbers in August and September (Table 20). Time of spawning occurs from January through March with emergence from March through June. Juvenile rearing generally lasts for two or three years prior to spring ocean emigration, although a few juveniles migrate after one year (Loch et al. 1985). Loch et al. (1985) observed that smolt migration peaked in mid-May in Gobar Creek, a little later than in the main Kalama River. Emigration appeared complete by mid-June.

Run size of naturally produced cutthroat is uncertain, but based on the estimated 7,737 smolts produced annually (Loch et al. 1985) and the 9.79 percent average smolt-to-adult survival for hatchery fish in the Cowlitz River, the Kalama population was estimated at 757 adults. Rack counts at the Kalama Falls Salmon Hatchery averaged 19 fish for 1976 through 1986, but capture efficiency of the rack is unknown.

Sea-run cutthroat have a complex life cycle. For juveniles, Loch et al. (1985) found mean age composition of cutthroat in Gobar Creek, a Kalama tributary, to be 6.5 percent, 69.6 percent, and 23.9 percent for ages I, II, and III, respectively. Associated fork lengths were 12.6 cm, 15.5 cm and 17.5 cm, respectively. In the Kalama River, smolt age composition was found to be 2.2 percent, 73.1 percent, and 24.7 percent for ages I, II, and III, respectively, with an associated size of 12.3 cm, 16.3 cm, and 19.9 cm, respectively. Scale analysis of adult cutthroat found that 4.3 percent, 75.3 percent, 19.4 percent, and

1.1 percent had spent one, two, three, and four years in fresh water prior to migration, respectively.

Table 20. Freshwater life history of subbasin sea-run cutthroat. The developmental stage timing represents basinwide averages; local conditions may cause some variability.

Developmental Stages	Time of year	Peak occurrence
Adult immigration	July-October	August-September
Adult holding	August-January	August-January
Spawning	January-March	February-March
Egg/alevin incubation	January-May	March-April
Emergence	March-June	April-May
Rearing	Feb-April(26 mos.)	April-April(24 mos.)
Juvenile emigration	April-May	April-May

Adult cutthroat first return to fresh water in the fall after spring migration; some do not spawn, but do so in subsequent years. Maturity of initial migrant cutthroat was unknown in the subbasin, but was 64.3 percent and 53.3 percent for Cowlitz subbasin males and females, respectively (Tipping and Springer 1980). The following profile for Kalama Subbasin cutthroat is biased toward larger fish due to probable size selectivity associated with the picket spacing at the Kalama Falls Hatchery rack and the possibility that immature fish may not migrate up to the Kalama Falls site. For age profiles, summers spent in salt water were not differentiated for spawning or non-spawning fish (Table 21). Overall, females made up 24.7 percent of sampled fish, males 53.8 percent and unknown fish 21.5 percent. Mean length of males, females and unknown fish was 42.5 cm, 39 cm and 41.6 cm, respectively, and 41.4 cm overall.

Fecundity data was not found for naturally produced sea-run cutthroat in the Kalama Subbasin. Fecundity of cutthroat spawned at the Cowlitz Trout Hatchery from 1982 through 1986 averaged 1,044 eggs per female (n=1,878).

Egg-to-smolt and smolt-to-adult survival rates for the Kalama Subbasin are unknown.

Table 21. Age, length and sex of Kalama River natural sea-run cutthroat (Loch et al. 1985).

	Ocean Summers				
	1	2	3	4	5
Age composition	5.4%	45.0%	35.5%	5.4%	1.1%
Females	44.4%	24.4%	21.2%	20.0%	0.0%
Males	33.3%	51.1%	57.6%	80.0%	100.0%
Unknown	22.2%	24.5%	21.2%	- -	- -
Mean Length (cm) M	36.6	40.9	44.1	48.5	45.0
Mean Length (cm) F	36.4	37.1	42.3	47.0	--
Mean Length Unknown	30.8	41.7	44.5	--	--
Number of Fish	9	45	33	5	1

No estimate of habitat carrying capacity could be generated. Loch et al. (1985) estimated an average of 454 (range of 148 to 610) cutthroat smolts were produced from Gobar Creek in 1978 through 1984. They also estimated an average of 7,737 (range of 163 to 16,229) smolts were produced from the Kalama River for the same time period.

Supplementation History

Cutthroat have not been planted in the Kalama Subbasin since 1949 and it is doubtful plants in 1945, 1946, 1948, and 1949 were sea-run cutthroat, but more likely, resident cutthroat.

Fish Production Constraints

Production constraints for sea-run cutthroat in the subbasin are similar to that mentioned in Table 8. Because cutthroat use upper reaches of streams, they are sensitive to habitat degradation.

Hatchery Production

No hatchery production facility for sea-run cutthroat exists on the Kalama River and hatchery sea-run cutthroat are not planted in the Kalama. No facilities are anticipated.

Harvest

Harvest in the subbasin is unknown. Because of concerns that the population may be depressed, the fishery was closed in 1986. Harvest management goals in the subbasin are to build a run to provide a sport harvest of 200 natural fish.

Harvest of Kalama sea-run cutthroat in the ocean is thought to be minimal. An active sport harvest of cutthroat occurs in the Columbia River, but contribution of Kalama cutthroat is unknown. For the Cowlitz River, a total of 31.5 percent of the tags recovered from the sport fishery from the marked 1982 and 1983 releases were caught on the Columbia River (Tipping 1986).

Management procedures for harvest within the subbasin consists of regulation through Department of Wildlife sport harvest restrictions. General goal in management is to ensure adequate escapement of natural cutthroat. Enforcement activities consist of Washington Department of Wildlife personnel checking anglers for compliance with harvest restrictions.

Specific Considerations

Management goals allow adequate escapement of natural fish and protect habitat. Sea-run cutthroat use the upper reaches of mainstem tributaries and are quite susceptible to habitat disturbances. Protection of habitat in upper reaches of streams is vital.

A major problem in the subbasin is the lack of measured sport harvest; punch-card estimates of sport harvest are not available. Consequently, fluctuations in populations are not usually detected while hatchery rack returns are of uncertain validity for population trends. Also, run sizes have not been determined because of lack of spawning surveys.

Critical Data Gaps

A good measure of run strength is needed, perhaps an improved rack at the Kalama Falls Hatchery. Also, data was not found for egg-to-smolt survival and smolt-to-adult survival of natural fish for the subbasin. No catch estimates or spawning escapement data exists, consequently, run estimates are lacking. Smolt capacity estimates are needed.

Objectives

Utilization Objective

Provide 100 natural sea-run cutthroat for sport harvest.

Biological Objective

Maintain biological characteristics of the existing natural population. The biological component has priority for this stock within the Kalama River.

Based on the estimate of 7,737 smolts produced annually (Loch et al. 1985) and the 9.79 percent average smolt-to-adult survival for hatchery fish in the Cowlitz Subbasin, existing production was estimated at 757 fish. It is estimated that the run size needs to increase to 1,200 fish to allow a sport fishery.

Alternative Strategies

Strategies for sea-run cutthroat in this report have specific themes. Means to meeting the objectives are first attempted using natural methods followed by less natural techniques. Hatchery production of sea-run cutthroat is not desired in the Kalama River. Planners did not model the following strategies, nor did they estimate costs.

STRATEGY 1: Natural Production. This strategy seeks to achieve the objectives by eliminating sources of direct mortality to natural fish, answering management questions, and reducing risks of genetic modification of natural stocks.

This strategy provides for prudent stewardship of existing habitat and water quality in the historic distribution range through various existing laws and agreements. Streams in the subbasin need to be inventoried for summer temperature profiles; those exceeding temperature sensitivity criteria should be classified as such through the Department of Natural Resources so future impacts will be minimized. Water withdrawals on smaller streams should be reduced as possible. Riparian zones should be managed to provide a continuous recruitment of large organic debris (LOD) into the subbasin system. Stream typing should be reviewed and streams should be upgraded as needed. Fishways should be maintained.

Hypothesis: Existing habitat, if managed properly, should provide numbers of natural smolts needed to reach goals for natural fish. Rack improvements at the hatchery will verify run strength.

Assumptions: Strategy 1 assumes habitat is able to produce desired adults.

Numeric Fish Increases: Sea-run cutthroat were not modeled with the System Planning Model. Strategy 1 might reach the objective of 1,200 natural fish although this may or may not represent an increase in numbers.

ACTIONS: 1, 2

1. Maintain at least current level of stream habitat quality and quantity. Seek improved water quality via reduction of sedimentation and temperature.

2. Improve rack capture efficacy at the Kalama Falls Hatchery so run strength can be monitored.

STRATEGY 2: Habitat Base Increase. This strategy seeks to achieve the objectives by all the measures to increase productivity contained in Strategies 1, but also increases stock size by providing passage into inaccessible areas or release of fry into such areas.

Hypothesis: By making new habitat available, additional smolts would be produced.

Assumptions: It is assumed fish would fully utilize newly accessed waters. IHN virus in adult steelhead may be carried above the Lower Kalama Hatchery and contaminate the station. The falls on Elk Creek would be difficult to ladder due to access. This strategy would also assume no impact on resident fish in newly accessed areas.

Numeric Fish Increases: Based on observed production in Gobar Creek, increases would amount to about 102 smolts on Hatchery Creek, 127 smolts on Summers Creek, and 254 smolts on Elk Creek, a total of 483. At 9.79 percent smolt-to-adult survival, an additional 44 adults would be expected. Strategy 2 would meet objectives.

ACTIONS: 3

3. Expand historical distribution range via laddering falls, etc. Streams that could be laddered include Hatchery Creek (4 miles), Summers Creek (3 miles) and Elk Creek (4 miles).

Recommended Strategy

The recommended strategy for Kalama sea-run cutthroat is Strategy 1, aggressive habitat protection and improved population monitoring. Due to the habitat preferences of cutthroat in the upper reaches of streams, the fish are extremely sensitive to habitat disturbances and need aggressive habitat protection. Also, methods to monitor population size either, relative or absolute, is imperative to prudent management; an improved rack at the Kalama Falls Hatchery would aid in this need.

FALL CHINOOK SALMON

Fisheries Resource

Natural Production

History and Status

Fall chinook salmon in the subbasin were historically abundant. For many years, a fish trapping and canning operation existed about one mile above the river's mouth (Washington Department of Fisheries 1951). Run size prior to hatchery plants is difficult to determine because the Lower Kalama Salmon Hatchery began operation in 1895 when 4 million eggs were taken. The Washington Department of Fisheries (1951) estimated Kalama fall chinook escapement at 20,000 fish with three-quarters of the fish spawning in the lower three miles of river below hatchery racks, but above tidewater. Some fish were passed above the hatchery racks; their upstream movement terminated 10 miles up at the Kalama Falls Hatchery site where a 15-foot falls and an inefficient fishway presented a barrier to further migration. Although some of the returning adults spawn naturally due to the large hatchery programs, Kalama fall chinook are considered a lower Columbia hatchery stock. In some years, little natural reproduction occurs between the hatchery rack and the Kalama Falls Hatchery as few females are passed above the rack.

The two salmon hatcheries on the Kalama were used as an egg-bank temporarily from 1981 through 1986 for the Lyons Ferry upriver bright stock of fall chinook. That program and its returns will not be addressed herein due to its temporary status.

Life History and Population Characteristics

Fall chinook natural production of juveniles using the Northwest Power Planning Council's model was estimated at 428,670 fingerlings; another 162,200 could be produced above Kalama Falls Hatchery.

Run size of natural fish was estimated at 334 fish. This was based on Cowlitz River smolt capacity of 2,183,000 fingerlings producing 1,705 natural fish while the Kalama capacity of 428,670 smolts should produce about 334 fish, about 3.8 percent of the total run. An average of 3,498 fish spawned naturally in the Kalama between 1977 and 1986.

Supplementation History

Fall chinook have been planted into the Kalama Subbasin since 1895. For 1975 through 1986, a combined average of 5,931,000 fingerlings have been released from the two hatcheries (Table 22). Brood stock is taken from rack returns. The program goal is to contribute fish to`commercial and sport fisheries while returning enough fish to seed the river and fill hatchery needs. Performance of plants (catch plus escapement), based on marked 1978 through 1981 brood production fish averaged 0.17 percent with a range of 0.08 percent to 0.32 percent (A. Appleby, WDF, pers. commun.). Seidel and Mathews (1977) found survival at Lower Kalama Hatchery was a minimum of 2.25 percent versus 0.74 percent for early July released large (24 grams) and small (7 g) fingerlings, respectively. September releases of large (65 g) and small (19 g) fingerlings survived at a minimum of 6.52 percent and 0.99 percent, respectively. April released yearlings (78 g) survived at a minimum of 7.95 percent. At Kalama Falls Hatchery, Siedel and Mathews (1977) found two groups of 3-gram fingerlings survived at a minimum of 0.23 percent and 0.09 percent.

Fish Production Constraints

The major production constraint for natural fall chinook in the subbasin is amount of suitable habitat. Sedimentation and temperature increases associated with logging activity has degraded some spawning and rearing habitat. Some habitat exists above Kalama Falls Hatchery, but fish are not put above the hatchery.

Hatchery Production

There are two hatcheries on the Kalama River producing fall chinook -- Lower Kalama and Kalama Falls. At Lower Kalama, the program goal for 1989 was 1.5 million fall chinook at 80 fish per pound (18,750 pounds), 525,000 coho at 18 fish per pound (29,200 pounds), and 550,000 spring chinook at 10 fish per pound (55,000 pounds) -- a total of 102,950 pounds. Budget constraints temporarily reduced the hatchery program in 1988. In past years the hatchery program was comprised of 3.5 million fall chinook fingerlings and 525,000 coho yearlings. Brood stock is obtained from rack returns and, although a dominance of males has been observed at the rack, fish are spawned randomly at a 1-1 male-to-female ratio. Female chinook are tested for virus and eggs are treated with iodophor. No IHN virus positive chinook have been observed at this station. Egg-to-fry survival averaged 91.1 percent for 1985 through 1988 while fry-to-fingerling released survival averaged 99.1 percent, resulting in an egg-to-fingerling released survival of 90.3 percent. Production at the hatchery is at capacity and constraints in production are water quantity and facility size. Usually no severe disease problems are encountered at this facility.

The Kalama Falls Hatchery had a 1989 program of 3.5 million fall chinook at 70 fish per pound (50,000 pounds), 900,000 coho at 17 fish per pound (52,900 pounds), and 550,000 spring chinook at 20 fish per pound (27,500 pounds) transferred to Lower Kalama Hatchery in October -- a total of 130,400 pounds. Brood stock is obtained from rack returns downstream of the Lower Kalama Hatchery and fish are spawned randomly at a 1-1 male-to-female ratio. Female chinook are tested for virus and eggs are treated with iodophor. No IHN virus positive chinook have been observed at this station. Egg-to-fry survival for 1983 through 1987 broods averaged 93 percent while fry-to-planted-fish survival averaged 94.8 percent, resulting in egg-to-planted-fish survival of 88.1 percent. Loss of adults and eggs are sometimes severe due to high river water temperatures. Production at the hatchery is at capacity and constraints in production are facility size and water quality and quantity. Disease problems have been primarily routine and include Costia sp., low temperature disease (Cytophaga psychrophilia), and furunculosis (Aeromonas salmonicida).

Combined production from both hatcheries from 1975 through 1986 averaged 5,931,000 spring-released fingerling fall chinook (Table 22). Marked production fish had 0.26 percent and 0.21 percent fingerling-to-adult survival for 1977 through 1981 broods at the Lower Kalama and Kalama Falls hatcheries, respectively. Recent data (P. Seidel, WDF, pers. commun.) indicates greater returns with releases of larger (more than 7.6 grams) fingerlings in June. Fingerlings released to adult returns to the river averaged 0.19 percent for 1975 through 1981 broods.

Table 22. Kalama Subbasin releases of hatchery fall chinook.

Brood Year	Fry	Fingerlings	Fall releases
1975	88,000	4,628,939	
1976		2,504,325	89,074
1977		5,542,573	145,406
1978		8,514,150	
1979	870,000	7,244,185	
1980		6,609,997	
1981		8,814,388	
1982		1,608,200	
1983		3,510,000	
1984		7,446,510	
1985	15,000	7,676,100	
1986		7,068,900	

Run size of hatchery fish for 1977 through 1986 averaged 8,498 adults and 612 jacks; jacks comprised 25 percent of the sports catch, 5.8 percent of hatchery returns and 6.7 percent of total returns (Table 23).

Table 23. Kalama Subbasin hatchery fall chinook returns (escapements from Kreitman and LeFleur memorandums, WDF; sport catch from WDF punch cards).

Year	Sport Catch		Spawning Escapement		Hatchery Escapement		Total Return	
	Jacks	Adults	Jacks	Adults	Jacks	Adults	Jacks	Adults
1977	982	224	65	6,484	43	1,568	1,090	8,276
1978	30	441	74	3,637	319	2,808	423	6,886
1979	158	166	27	2,704	286	4,218	471	7,088
1980	219	1,523	175	5,675	622	8,161	1,016	15,359
1981	211	580	77	1,840	235	5,752	523	8,172
1982	46	1,196	25	4,570	139	1,572	210	7,338
1983	113	359	41	2,681	50	4,516	204	7,556
1984	151	716	88	2,955	44	5,241	283	8,912
1985	213	533	204	1,055	650	4,736	1,067	6,324
1986	113	671	374	2,227	342	6,167	829	9,065
MEAN	224	641	115	3,383	273	4,474	612	8,498

Adult time of return is generally August and September while spawning occurs from late September into November. Fecundity for 1977 through 1986 averaged 4,774 eggs per female (n=17,937). Emergence occurs from January through March and juvenile rearing generally lasts through June although some fish rear into fall. Juvenile emigration peaks in June through August although some emigration occurs through December.

Freshwater age scale analysis for 1982 through 1987 hatchery fish found all fish had migrated to the ocean as age-0 fingerlings. Saltwater age composition indicated most males returned after two years in salt water and most females returned after three years (Table 24). Mean lengths for saltwater ages II, III, and IV were 77.1 cm, 87.6 cm, and 94.3 cm, respectively. Fish are collected at a 1-1 male-to-female ratio for hatchery use although returning males outnumber females at the rack in the lower river.

Table 24. Mean saltwater age composition of Kalama fall chinook (from scale analysis 1982-1987, WDF Battleground office).

	Ocean Age				
	I	II	III	IV	V
Age Composition	7.1%	38.3%	46.1%	8.4%	0.1%
Percent Females	0.0%	13.6%	50.0%	69.0%	50.0%
Number of fish	685	3,666	4,417	807	8

Milner et al. (1980) did an electrophoretic profile of Kalama fall chinook along with other Columbia River stocks to examine the feasibility of using biochemical genetic variation for estimating composition of mixed-stock fisheries. They concluded sufficient genetic differentiation existed to do so. Schreck et al. (1986) looked at stock identification of various Columbia River fall chinook, including Kalama stock, using cluster analysis of meristic and electrophoretic features and concluded geographical proximal stocks tend to be similar.

Harvest

Kalama fall chinook are a lower Columbia River hatchery stock that contributes to ocean commercial and recreational fisheries from Alaska to the Columbia River. Mainstem Columbia River gill net and recreational fisheries also harvest this stock. During 1983 through 1987, the overall harvest rate was 81 percent. Escapement requirements at Oregon and Washington hatcheries has occasionally restricted mainstem fisheries and is actively managed for, however, natural escapement is not.

Harvest within the subbasin for 1977 through 1986 averaged 641 adults and 224 jacks for a combined harvest rate of 9.5 percent. Harvest management goal is to allow only enough fish back to the hatchery to maintain production. Because the inriver sport fishery is not harvest effective, most fish are intended for ocean and Columbia River harvest.

Management procedures within the subbasin consists of regulation through Washington Department of Fisheries sport harvest restrictions. On the Kalama River, the daily limit is six salmon of 12-inch minimum size of which two may exceed 24 inches. The area downstream of the Kalama Falls Hatchery is open the entire year although from September 1 to October 31 between the Lower Kalama Hatchery pump house intake downstream to the natural gas pipeline crossing at Mahaffey's Campground is open to fly-fishing only. From October 1 to December 31, chinook over 28 inches in the previously described area must be released. All other waters in September and October are limited to bait or lures with one single-pointed hook measuring no more than 0.5 inch from point to shank. When the Washington Department of Fisheries temporary rack is installed just below Modrow Bridge, that portion of the river 200 feet above the rack to 1,500 feet below the rack is closed to salmon angling.

Above Kalama Falls Hatchery, from Summers Creek upstream to Road 6420, the area is open from the last Saturday in May through November 30 to fly-fishing only. From Summers Creek downstream to the Kalama Falls Hatchery, the area is open from last Saturday in May through November 30. Enforcement activities consist of Washington Department of Fisheries and Washington Department of Wildlife personnel checking anglers for compliance with harvest restrictions.

Specific Considerations

The Kalama Subbasin is managed as a lower Columbia River hatchery stock. Most harvest of subbasin fish is intended to occur outside the subbasin since the inriver sport harvest rate is only 9.5 percent.

The present production constraint is hatchery capacity, which is currently at full production. Smolt-to-adult survival of marked hatchery fingerlings averaged 0.17 percent. Recent data indicates improved survival of hatchery juveniles by releasing large fingerlings in June. Natural production potential was estimated at 428,670 fingerlings and an average of 3,498 fish spawned naturally in 1977 through 1986. However, fish are not passed above Kalama Falls Hatchery so some habitat is not utilized.

Objectives

Utilization Objective

Provide 1,340 fall chinook for sport harvest and support out of basin harvest. The utilization component has priority for this stock within the Kalama River.

Biological Objective

Maintain biological characteristics of the existing population.

At existing harvest rates, this objective requires increasing subbasin returns by 5,000 fish for a total of 14,110 fish. For 1977 through 1986 an average of 9,110 fish returned to the subbasin.

Alternative Strategies

Strategies for fall chinook in this report have specific themes. Means to meeting the objectives are first attempted using natural methods followed by less natural techniques and finally, hatchery production. Actions identified under each strategy are closely related to the theme. Strategy 1 has a natural production theme seeking to improve the productivity of the existing natural stock. Strategy 2 is a "benign" supplementation strategy, emphasizing actions to develop a single supplemented run with yet higher productivity. Strategy 3 employs all the actions to improve stock productivity, but also includes any opportunities to increase stock size by providing passage into inaccessible habitat or releasing fry into such areas to make use of additional natural rearing potential. Strategy 4 relies on a traditional hatchery program to meet objectives. Only those actions necessary for the success of a hatchery program would be included in Strategy 4.

Modeling results for each strategy are presented in Table 25 as fish produced at "maximum sustainable yield" (MSY). The sustainable yield of a fish population refers to that portion of the population that exceeds the number of fish required to spawn and maintain the population over time. Sustainable yield can be "maximized," termed MSY, for each stock at a specific harvest level. The MSY is estimated using a formula (Beverton-Holt function) that analyzes a broad range of harvest rates. Subbasin planners have used MSY as a tool to standardize results so that decision makers can compare stocks and strategies.

In MSY management, managers set a spawning escapement level and the remaining fish (yield) could theoretically be harvested. In practice, a portion of the yield may be reserved as a buffer or to aid rebuilding. Thus, managers may raise the escapement level to meet a biological objective at the expense of a higher utilization objective.

The amount of buffer appropriate for each stock is a management question not addressed in the subbasin plans. For this reason, the utilization objective, which usually refers to harvest, may not be directly comparable to the MSY shown in Table 25. At a minimum, a strategy should produce an estimated MSY equal to or greater than the utilization objective. A MSY substantially larger than the subbasin utilization objective may be needed to meet subbasin biological objectives.

Estimated costs of the alternative strategies below are summarized in Table 26.

STRATEGY 1: Natural Production. This strategy seeks to achieve the objectives by eliminating sources of direct mortality to natural fish, answering management questions, and reducing risks of genetic modification of natural stocks.

This strategy provides for prudent stewardship of existing habitat and water quality in the historic distribution range through various existing laws and agreements. Streams in the subbasin need to be inventoried for summer temperature profiles; those exceeding temperature sensitivity criteria should be classified as such through the Department of Natural Resources so future impacts will be minimized. Riparian zones should be managed to provide a continuous recruitment of large organic debris into the subbasin system.

Hypothesis: Existing habitat, if properly managed, should provide near optimum numbers of smolts.

Assumptions: This strategy assumes relative egg-to-smolt survival would be increased by 10 percent.

Numeric Fish Increases: The System Planning Model indicated two additional fish would return to the subbasin at current harvest rates. Total production would increase by 78 fish at MSY.

ACTIONS: 1

1. Maintain at least current level of stream habitat quality and quantity. Seek improved water quality via reduction of sedimentation.

STRATEGY 2: Supplementation. This strategy seeks to achieve the objectives by supplementing natural production with an appropriate existing hatchery stock or natural stock. Any actions identified in Strategy 1 necessary for the success of the supplementation program are also required.

Hypothesis: Increased fingerling production numbers and survival would result in increased adult returns.

Assumptions: This strategy assumes relative smolt survival can be improved from 0.5 to 0.55 and that water and space to accommodate 3,850,000 smolts can be found.

Numeric Fish Increases: The System Planning Model indicated this strategy would increase subbasin returns by 6,196 fish at current harvest rates. Total production increase would be 52,209 fish at MSY. This strategy would meet objectives.

ACTIONS: 1, 2, 4

1. -

2. Improve hatchery smolt quality. Conduct research to determine if hatchery fingerling survival can be improved through size at release, etc.

4. Construct rearing facilities to accommodate 3,850,000 hatchery fingerlings.

STRATEGY 3: Supplementation and Habitat Base Increase. This strategy seeks to achieve the objectives by all the measures to increase productivity contained in Strategies 1 and 2, but also increases stock size by providing passage into inaccessible areas or release of fry into such areas.

Hypothesis: Access to new habitat would result in increased fingerling production.

Assumptions: This strategy assumes all available habitat would be fully utilized. An estimated 162,200 fingerlings could be produced by utilizing habitat above Kalama Falls.

Numeric Fish Increases: The System Planning Model indicated an additional 6,321 fish would return to the subbasin at current harvest rates. Total production increase would be 52,919 fish at MSY.

ACTIONS: 1-4

1. -
2. -

3. Modify adult fish holding facilities at the Kalama Falls Hatchery to reduce adult pre-spawning mortality so adult or fry excesses could be passed upstream of the Kalama Falls Hatchery to seed that section of the subbasin.

4. -

STRATEGY 4: Hatchery Production. This strategy seeks to achieve the objectives solely through traditional hatchery production. Only those actions necessary for maintenance of the hatchery program are included.

Hypothesis: Increased fingerling production numbers and survival would result in increased adult returns.

Assumptions: This strategy assumes relative smolt survival can be improved from 0.5 to 0.55 and that water and space to accommodate 3,850,000 smolts can be found.

Numeric Fish Increases: The System Planning Model indicated an additional 6,195 fish would return to the subbasin at current harvest rates. Total production increase would be 52,132 fish at MSY. This strategy would meet objectives.

ACTIONS: 2, 4 (see above)

Recommended Strategy

The recommended strategy for Kalama fall chinook is Strategy 2, aggressive habitat protection and supplementation. By attempting to improve hatchery smolt survival, rearing additional hatchery fingerlings, and attempting to improve natural egg-to-smolt survival through aggressive habitat protection, numbers of fish produced will increase considerably. Fall chinook are managed as a lower Columbia River hatchery stock with high out-of-basin harvest rates and minimal genetic concern of impacting a system with hatchery fish. This strategy is consistent with that management practice. The SMART analysis (Appendix B) also supports Strategy 2 although Strategy 4, which excludes the aggressive habitat protection, was a close second.

Table 25. System Planning Model results for fall chinook in the Kalama Subbasin. Baseline value is for pre-mainstem implementation, all other values are post-implementation.

Utilization Objective: 1,340 for sport harvest.

Biological Objective: Maintain biological characteristics of lower Columbia River hatchery stock.

Strategy[1]	Maximum[2] Sustainable Yield (MSY)	Total[3] Spawning Return	Total[4] Return to Subbasin	Out of[5] Subbasin Harvest	Contribution[6] To Council's Goal (Index)
Baseline	1,820 -N	6,554	9,102	67,613	0(1.00)
All Nat	92 -N	8,215	9,220	68,486	991(1.01)
1	1,912 -N	6,473	9,104	67,627	16(1.00)
2*	5,353 -N	8,947	15,294	113,610	52,190(1.68)
3	4,317 -N	9,991	15,418	114,527	53,230(1.69)
4	4,894 -N	9,360	15,294	113,609	52,188(1.68)

*Recommended strategy.

[1]Strategy descriptions:

For comparison, an "all natural" strategy was modeled. It represents only the natural production (non-hatchery) components of the proposed strategies plus current management (which may include hatchery production). The all natural strategy may be equivalent to one of the alternative strategies below.

1. Aggressive Habitat Protection.
2. Strategy 1 plus improve smolt quality, add 3,850,000 hatchery smolts.
3. Pass adults into new habitat upstream.
4. Improve smolt quality, add 3,850,000 hatchery smolts.

[2]MSY is the number of fish in excess to those required to spawn and maintain the population size (see text). These yields should equal or exceed the utilization objective. C = the model projections where the sustainable yield is maximized for the natural and hatchery components combined and the natural spawning component exceeds 500 fish. N = the model projection where sustainable yield is maximized for the naturally spawning component and is shown when the combined MSY rate results in a natural spawning escapement of less than 500 fish.

[3]Total return to subbasin minus MSY minus pre-spawning mortality equals total spawning return.

[4]Total return to the mouth of the subbasin.

[5]Includes ocean, estuary, and mainstem Columbia harvest.

[6]The increase in the total return to the mouth of the Columbia plus prior ocean harvest (as defined by the Northwest Power Council's Fish and Wildlife Program), from the baseline scenario. The index () is the strategy's total production divided by the baseline's total production.

Table 26. Estimated costs of alternative strategies for Kalama fall chinook. Cost estimates represent new or additional costs to the 1987 Columbia River Basin Fish and Wildlife Program; they do not represent projects funded under other programs, such as the Lower Snake River Compensation Plan or a public utility district settlement agreement. (For itemized costs, see Appendix C.)

	Proposed Strategies			
	1	2*	3	4
Hatchery Costs				
Capital[1]	0	885,500	885,500	0
O&M/yr[2]	0	96,250	96,250	0
Other Costs				
Capital[3]	0	0	2,000,000	2,000,000
O&M/yr[4]	30,000	33,000	63,000	33,000
Total Costs				
Capital	0	885,500	2,885,500	2,000,000
O&M/yr	30,000	129,250	159,250	33,000

* Recommended strategy.

[1] Estimated capital costs of constructing a new, modern fish hatchery. In some subbasins, costs may be reduced by expanding existing facilities. For consistency, estimate is based on $23/pound of fish produced. Note that actual costs can vary greatly, especially depending on whether surface or well water is used and, if the latter, the number and depth of the wells.

[2] Estimated operation and maintenance costs per year directly associated with new hatchery production. Estimates are based on $2.50/pound of fish produced. For consistency, O&M costs are based on 50 years.

[3] Capital costs of projects (other than direct hatchery costs) proposed under a particular strategy, such as enhancing habitat, screening diversions, removing passage barriers, and installing net pens (see text for specific actions).

[4] Estimated operation and maintenance costs per year of projects other than those directly associated with new hatchery production. For consistency, O&M costs are based on 50 years.

SPRING CHINOOK SALMON

Fisheries Resource

Natural Production

Historically, few spring chinook were found in the subbasin (WDF 1951). Spring chinook were established at Kalama Falls Hatchery after its completion in 1959. Presently, the run is considered a hatchery stock although an average of 711 fish spawned naturally from 1977 through 1987. Spring chinook are distributed primarily below Kalama Falls Hatchery although some have been passed upstream in large return years.

The Northwest Power Planning Council's model estimated a subbasin capacity of 111,192 smolts below Kalama Falls plus another 465,160 smolts above Kalama Falls.

Based on the habitat capacity and numbers of fish spawning naturally, run size of natural fish was roughly estimated at 300 fish, about 10 percent of the total.

For 1977 through 1987, an average of 299,349 smolts were released from Kalama hatcheries. For the same time period, 499,000 fry were released only in 1981. Some fingerlings were released in the falls of 1977, 1978, 1979, 1982, and 1984, but this is not a current program (Table 27). The purpose of plants was to contribute adult fish to sport and commercial fisheries. Smolt-to-adult survival averaged 3.05 percent for the 1971 and 1974 brood years, and ranged from 0.02 percent to 5.16 percent (A. Appleby, WDF, pers. commun.). Smolt-to-adult survival is anticipated to increase with a recent program change allowing an April release versus a February release. Smolt-to-adult returns to the Kalama for the 1975 through 1982 broods averaged 1.73 percent. Seidel and Mathews (1977) found September-released fingerlings (18 grams) had a minimum of 0.47 percent survival while yearlings (65 g) had a minimum of 2.70 percent survival.

Production constraints for natural spring chinook are similar to that listed in Table 8. Sedimentation and temperature problems commonly associated with logging activities are thought to be constraints. Also, the historic small run size might suggest a habitat constraint.

Hatchery Production

The previously described Kalama Falls and Lower Kalama hatcheries are the facilities currently producing spring chinook in the subbasin. Lower Kalama Hatchery receives spring chinook fingerlings (about 200 fish per pound) from Kalama Falls in about

May. Lower Kalama rears them until release the following April at seven to 10 fish per pound. In prior years, Kalama Falls transferred fingerlings in October at 20 fish per pound to Gobar Pond for release in February at 10 per pound. This program change is anticipated to increase smolt-to-adult survival by releasing smolts in April rather than February. Recent hatchery programs at Lower Kalama Hatchery include 550,000 spring chinook yearling smolts (55,000 pounds) out of a current program of 103,000 pounds; coho make up 29,200 pounds and fall chinook, 18,750 pounds. The hatchery is felt to be at capacity.

Spring chinook smolts are usually not released from Kalama Falls Hatchery although eggs are taken at the station and reared until about May. About 160,000 smolts were reared in 1989 for release in the Washougal River. The program goal at Kalama Falls Hatchery for 1990 includes 550,000 spring chinook fingerlings (2,750 pounds) transferred to Lower Kalama in May at about 200 fish per pound. Brood stock source is rack returns and pre-spawning mortality has sometimes been severe. Brood stock is spawned randomly at a 1-1 ratio and eggs are treated in iodophor to destroy possible virus contamination; no IHN positive females have been detected to date. Egg-to-fry survival averaged 90.6 percent for 1982 through 1986 broods while fry-to-smolt survival averaged 84.0 percent, resulting in an egg-to-smolt survival of 76.1 percent. Smolt-to-adult survival averaged 3.05 percent for the 1971 and 1974 brood years, the most recent marked groups. Other programs at Kalama Falls include coho (58,800 pounds) and fall chinook (50,000 pounds). The hatchery is felt to be at capacity.

Constraints at the hatchery are primarily water quality and quantity followed by facility size. Disease problems have been primarily routine and include Costia sp., low temperature disease (Cytophaga psychrophilia), and furunculosis (Aeromonas salmonicida). Actions that could increase production would be to improve the existing water quality and quantity and reduce adult holding losses.

Run size averaged 2,997 fish from 1977 through 1987 (Table 28). Assuming 300 fish were natural origin, hatchery run size averaged 2,667 fish. Hatchery rack returns comprised 42.8 percent of subbasin returns while sport catch averaged 33.4 percent and natural spawning 24.2 percent. Smolt-to-adult survival was estimated at 3.05 percent (A. Appleby, WDF, pers. commun.).

Table 27. Kalama Subbasin releases of hatchery spring chinook.

Brood Year	Fry	Fall Releases	Smolts
1975		220,000	283,704
1976		332,200	276,200
1977		474,800	152,437
1978			116,506
1979			600,800
1980		272,500	160,000
1981	499,000		228,000
1982			325,900
1983			569,300
1984		55,000	404,000
1985			176,000
Average			299,349

Table 28. Kalama Subbasin hatchery spring chinook returns (WDF records, Battleground, WA; catch records from punch cards).

	Sports catch		Natural Escapement		Hatchery Escapement		Total Return	
Year	Jacks	Adults	Jacks	Adults	Jacks	Adults	Jacks	Adults
1977	166	419	N/A	500	0	518	166	1,437
1978	42	554	N/A	564	0	250	42	1,368
1979	39	891	N/A	708	68	989	107	2,588
1980	41	349	42	298	261	1,830	344	2,477
1981	151	936	127	721	284	1,608	562	3,265
1982	271	2,212	180	2,712	232	3,496	683	8,420
1983	116	2,093	141	1,009	246	1,755	503	4,857
1984	46	871	1	133	4	803	51	1,807
1985	37	242	0	0	11	96	48	338
1986	72	438	16	165	47	474	135	1,077
1987	92	916	56	471	124	1,031	272	2,418
AVE	98	902	51	660	116	1,168	265	2,732

Adult time of return generally ranges from March through July (Table 29). Fish are held through the summer prior to spawning. Adult mortality from fungus infection due to warm water and stress has been severe in some years. Spawning time is August and September with fry emergence in November through March. Yearling fish are reared through the following March and released in April through June. Fecundity of spring chinook spawned from 1977 through 1986 averaged 4,491 eggs (n=1,600).

Table 29. Freshwater life history of Kalama spring chinook. The developmental stage timing represents basinwide averages; local conditions may cause some variability.

Developmental Stages	Time of year	Peak occurrence
Adult immigration	March-July	May-June
Adult holding	March-September	May-August
Spawning	September-October	September
Egg/alevin incubation	September-January	September-December
Emergence	December-February	December-January
Rearing	Dec-April (17 mos.)	Jan-April (16 mos.)
Juvenile emigration	April-June	April-May

Nearly all adult fish had spent one year in fresh water prior to ocean migration. Saltwater age composition of spring chinook returning to the hatchery in 1980 through 1988 was 9.2 percent age-I ocean, 66 percent age-II, and 24.8 percent age-III and age-IV. Male-female ratio was 1.21-to-1 for 1978 through 1986. Length profiles were not available, but are probably similar to Cowlitz Subbasin spring chinook (Table 30).

The genetic work described for fall chinook by Milner et al. (1980) and Schreck et al. (1986) was also done for Kalama hatchery spring chinook.

Table 30. Cowlitz Hatchery spring chinook length profile, 1982-1987 (Lavoy, WDF, pers. commun.).

	Saltwater Age				
	0	1	2	3	4
Male Length (cm)	31.6	55.2	73.2	85.7	86.9
Female Length (cm)	--	64.6	74.6	82.7	87.1

Harvest

Subbasin sport harvest averaged 1,000 fish (33.4 percent) for 1977 through 1987. Harvest rate on adults was 33 percent and 37 percent on jacks.

Ocean and Columbia River fisheries on Kalama spring chinook account for 45 percent of production (from the System Planning Model). Relatively little harvest occurs in the ocean while Columbia River commercial and sport comprise most of the harvest.

In the Kalama River, management goals have been to provide fish for sport and commercial harvest in the ocean and Columbia River, and for sport harvest within the subbasin. Also, fish are needed for the hatchery program and natural spawning. Harvest management within the subbasin consists of regulation through Washington Department of Fisheries sport harvest restrictions. The Kalama River daily limit is six salmon of 12-inch minimum size of which two may exceed 24 inches. The area downstream of the Kalama Falls Hatchery is open the entire year, although from September 1 to October 31 the area between the Lower Kalama Hatchery pump house intake downstream to the natural gas pipeline crossing at Mahaffey's Campground is open to fly-fishing only. Above Kalama Falls Hatchery, from Summers Creek upstream to Road 6420, the area is open from the last Saturday in May through November 30 to fly-fishing only. From Summers Creek downstream to the Kalama Falls Hatchery, the area is open from last Saturday in May through November 30. Enforcement consists of Washington Department of Fisheries and Washington Department of Wildlife personnel checking anglers for harvest regulation compliance.

Specific Considerations

Spring chinook in the subbasin are an introduced stock and are managed as a hatchery stock. Consequently, relatively few are needed for spawning escapement. Kalama habitat carrying capacity was estimated at 111,192 smolts below Kalama Falls and 576,400 smolts overall. Natural spawners averaged 711 fish. Because of brood stock needs and adult holding problems at the hatchery, few spring chinook are passed above Kalama Falls Hatchery.

Sport anglers prize Kalama spring chinook as a premier sport and food fish. Harvest rate in the Kalama averaged 33.4 percent. Smolt-to-adult survival averaged 3.05 percent although this is anticipated to increase with the recent change in smolt release timing.

Spring chinook were fairly well accounted for in the subbasin although better knowledge of natural fish contribution is desirable.

Objectives

Utilization Objective

Provide 2,000 spring chinook for sport harvest. The utilization component has priority for this stock within the Kalama River.

Biological Objective

Maintain the biological characteristics of the existing population.

Subbasin returns for 1977 through 1987 averaged 2,997 fish, representing a total run size of 5,445 fish. The System Planning Model was calibrated using a hatchery smolt level of 299,349 fish, which represented 1975-1985 production. Hatchery smolt levels were then increased to 550,000 smolts to reflect recent program increases. The System Planning Model estimated an additional 2,281 fish would return to the subbasin at existing harvest rates. Therefore, the objective is to return 943 fish to the subbasin above the recent program increase.

Alternative Strategies

Strategies for spring chinook in this report have specific themes. Means to meeting the objectives are first attempted using natural methods followed by less natural techniques and finally, hatchery production. Actions identified under each strategy are closely related to the theme. Strategies 1 has a natural production theme seeking to improve the productivity of the existing natural stock. Strategy 2 is a "benign" supplementation strategy, emphasizing actions to develop a single supplemented run with yet higher productivity. Strategy 3 employs all the actions to improve stock productivity, but also includes any opportunities to increase stock size by providing passage into inaccessible habitat or releasing fry into such areas to make use of additional natural rearing potential. Strategy 4 relies on a traditional hatchery program to meet objectives. Only those actions necessary for the success of a hatchery program would be included in Strategy 4. Strategy 5 is similar to Strategy 3.

Modeling results for each strategy are presented in Table 31 as fish produced at "maximum sustainable yield" (MSY). The sustainable yield of a fish population refers to that portion of the population that exceeds the number of fish required to spawn and maintain the population over time. Sustainable yield can be "maximized," termed MSY, for each stock at a specific harvest level. The MSY is estimated using a formula (Beverton-Holt function) that analyzes a broad range of harvest rates. Subbasin planners have used MSY as a tool to standardize results so that decision makers can compare stocks and strategies.

In MSY management, managers set a spawning escapement level and the remaining fish (yield) could theoretically be harvested. In practice, a portion of the yield may be reserved as a buffer or to aid rebuilding. Thus, managers may raise the escapement level to meet a biological objective at the expense of a higher utilization objective.

The amount of buffer appropriate for each stock is a management question not addressed in the subbasin plans. For this reason, the utilization objective, which usually refers to harvest, may not be directly comparable to the MSY shown in Table 31. At a minimum, a strategy should produce an estimated MSY equal to or greater than the utilization objective. A MSY substantially larger than the subbasin utilization objective may be needed to meet subbasin biological objectives.

Estimated costs of the alternative strategies below are summarized in Table 32.

STRATEGY 1: Natural Production. This strategy seeks to achieve the objectives by eliminating sources of direct mortality to natural fish, answering management questions, and reducing risks of genetic modification of natural stocks.

This strategy provides for prudent stewardship of existing habitat and water quality in the historic distribution range through various existing laws and agreements. Streams in the subbasin need to be inventoried for summer temperature profiles; those exceeding temperature sensitivity criteria should be classified as such through the Department of Natural Resources so future impacts will be minimized. Riparian zones should be managed to provide a continuous recruitment of large organic debris into the subbasin system.

Hypothesis: Existing habitat, if properly managed, should provide near optimum number of smolts.

Assumptions: This strategy assumes egg-to-smolt survival would be increased by a relative 10 percent.

Numeric Fish Increases: The System Planning Model indicated this strategy would return four additional fish to the subbasin at current harvest rate. Total production increase would be 19 fish at MSY.

ACTIONS: 1

1. Maintain at least current level of stream habitat quality and quantity. Seek improved water quality via reduction of sedimentation and temperatures.

STRATEGY 2: Supplementation. This strategy seeks to achieve the objectives by supplementing natural production with an appropriate existing hatchery stock or natural stock. Any actions identified in Strategy 1 necessary for the success of the supplementation program are also required.

Hypothesis: Increased smolt production would result in increased adult returns.

Assumptions: This strategy assumes increased smolt production will result in commensurate adult returns. Strategy 2 also assumes a suitable water supply, space, and such would be available for rearing facilities.

Numeric Fish Increases: The System Planning Model indicated this strategy would increase subbasin returns by 1,091 fish at current harvest rates. Total production would increase by 2,007 fish at MSY. This strategy would meet objectives.

ACTIONS: 1, 4

1. -

4. Construct new or expand existing hatchery facilities to produce 120,000 yearling smolts. One alternative would be to expand Lower Kalama Hatchery and another would be to construct a rearing pond on Wildhorse Creek or the Little Kalama River.

STRATEGY 3: Supplementation and Habitat Base Increase. This strategy seeks to achieve the objectives by all the measures to increase productivity contained in Strategies 1 and 2, but also increases stock size by providing passage into inaccessible areas or release of fry into such areas.

Hypothesis: Increased habitat access would result in increased smolt production.

Assumptions: This strategy would assume adults or fry would fully utilize available habitat. Natural smolt capacity would be increased by 465,160 fish.

Numeric Fish Increases: The System Planning Model indicated this strategy would increase of 2,146 fish to the subbasin (165 more than Strategy 2) at current harvest rates. Total production would increase by 3,115 fish at MSY. This strategy would meet objectives.

ACTIONS: 1-3

1. -

2. Improve survival of adults held at Kalama Falls Hatchery. Would require the adult fish trapping system at the hatchery be improved to include fish ladder modifications and an adult holding pond with a sorting distribution system rather than the present stressful brail method. Adults in excess of spawning needs would be passed upstream of the Kalama Falls Hatchery.

3. Improve survival of adults held at Kalama Falls Hatchery as in Action B and fry plant habitat above Kalama Falls Hatchery.

Modifying the ladder to include an adult holding pond with a sorting distribution system and improved water supply would assist in reducing stress and subsequent mortality on adults held at Kalama Falls Hatchery. Adult mortality has generally resulted in all brood stock being required for hatchery needs. Improved survival of held adults would create an excess of adults or fry (resulting from those adults) to be placed above the hatchery to utilize habitat. Action 2 would result in increased recreational opportunity while Action 3 does not.

STRATEGY 4: Hatchery Production. This strategy seeks to achieve the objectives solely through traditional hatchery production. Only those actions necessary for maintenance of the hatchery program are included.

Hypothesis: Increased smolt production would result in increased adult returns.

Assumptions: This strategy assumes increased smolt production will result in commensurate adult returns. Strategy 4 also assumes a suitable water supply, space, and such would be available for rearing facilities.

Numeric Fish Increases: The System Planning Model indicated 1,088 additional fish would return to the subbasin at current harvest rates. Total production would increase by 1,987 fish at MSY.

ACTIONS: 4 (see above)

STRATEGY 5: This strategy is similar to Strategy 3 except Actions 2 and 3 stand by themselves.

Numeric Fish Increases: The System Planning Model indicated subbasin returns would increase by 973 fish at current harvest rates. Total production would increase by 1,077 fish at MSY. This strategy would meet objectives.

ACTIONS: 2, 3 (see above)

Recommended Strategy

The recommended strategy for Kalama spring chinook is Strategy 5, improving adult holding survival at the hatchery to minimize the adults required to meet the hatchery egg requirements thereby allowing excess adults to be passed upstream where most of the habitat is found. This is a more natural enhancement method of increasing returns that would also create recreational opportunity for sport anglers. This strategy should also be a relatively low cost method of adding up to 456,000 natural smolts, with the natural influence possibly adding to the genetic integrity of the hatchery stock. The SMART analysis (Appendix B) also supports Strategy 5.

Table 31. System Planning Model results for spring chinook in the Kalama Subbasin. Baseline value is for pre-mainstem implementation, all other values are post-implementation.

Utilization Objective: 2,000 for sport harvest.

Biological Objective: Maintain biological characteristics of existing population.

Strategy[1]	Maximum[2] Sustainable Yield (MSY)	Total[3] Spawning Return	Total[4] Return to Subbasin	Out of[5] Subbasin Harvest	Contribution[6] To Council's Goal (Index)
Baseline	2,627 -N	2,101	5,253	4,290	0(1.00)
All Nat	2,122 -N	3,295	6,241	5,095	1,792(1.19)
1	2,681 -N	2,061	5,257	4,293	6(1.00)
2	3,361 -N	2,385	6,342	5,180	1,978(1.21)
3	2,940 -N	3,528	7,351	6,002	3,808(1.40)
4	3,296 -N	2,434	6,339	5,178	1,973(1.21)
5*	2,237 -N	3,181	6,213	5,072	1,742(1.18)

*Recommended strategy.

[1]Strategy descriptions:

For comparison, an "all natural" strategy was modeled. It represents only the natural production (non-hatchery) components of the proposed strategies plus current management (which may include hatchery production). The all natural strategy may be equivalent to one of the alternative strategies below.

1. Aggressive habitat protection.
2. Strategy 1 plus 120,000 hatchery smolts.
3. Strategy 2 plus pass adults into upstream unused habitat.
4. Add 120,000 smolts.
5. Pass adults upstream into unused habitat.

[2]MSY is the number of fish in excess to those required to spawn and maintain the population size (see text). These yields should equal or exceed the utilization objective. C = the model projections where the sustainable yield is maximized for the natural and hatchery components combined and the natural spawning component exceeds 500 fish. N = the model projection where sustainable yield is maximized for the naturally spawning component and is shown when the combined MSY rate results in a natural spawning escapement of less than 500 fish.

[3]Total return to subbasin minus MSY minus pre-spawning mortality equals total spawning return.

[4]Total return to the mouth of the subbasin.

[5]Includes ocean, estuary, and mainstem Columbia harvest.

[6]The increase in the total return to the mouth of the Columbia plus prior ocean harvest (as defined by the Northwest Power Council's Fish and Wildlife Program), from the baseline scenario. The index () is the strategy's total production divided by the baseline's total production.

Table 32. Estimated costs of alternative strategies for Kalama spring chinook. Cost estimates represent new or additional costs to the 1987 Columbia River Basin Fish and Wildlife Program; they do not represent projects funded under other programs, such as the Lower Snake River Compensation Plan or a public utility district settlement agreement. (For itemized costs, see Appendix C.)

	Proposed Strategies				
	1	2	3	4	5*
Hatchery Costs					
Capital[1]	0	276,000	276,000	276,000	0
O&M/yr[2]	0	30,000	30,000	30,000	0
Other Costs					
Capital[3]	0	0	2,000,000	0	2,000,000
O&M/yr[4]	30,000	30,000	60,000	0	30,000
Total Costs					
Capital	0	276,000	2,276,000	276,000	2,000,000
O&M/yr	30,000	60,000	90,000	30,000	30,000

* Recommended strategy.

[1] Estimated capital costs of constructing a new, modern fish hatchery. In some subbasins, costs may be reduced by expanding existing facilities. For consistency, estimate is based on $23/pound of fish produced. Note that actual costs can vary greatly, especially depending on whether surface or well water is used and, if the latter, the number and depth of the wells.

[2] Estimated operation and maintenance costs per year directly associated with new hatchery production. Estimates are based on $2.50/pound of fish produced. For consistency, O&M costs are based on 50 years.

[3] Capital costs of projects (other than direct hatchery costs) proposed under a particular strategy, such as enhancing habitat, screening diversions, removing passage barriers, and installing net pens (see text for specific actions).

[4] Estimated operation and maintenance costs per year of projects other than those directly associated with new hatchery production. For consistency, O&M costs are based on 50 years.

Spring Chinook - 78

COHO SALMON

Fisheries Resource

Natural Production

Coho were historically present, but not in great abundance in the subbasin; the Washington Department of Fisheries (1951) estimated about 3,000 fish. Both early-returning (September to October) and late-returning (November) fish were present, but distribution was confined below the Kalama Falls Hatchery site until the falls were laddered in 1936. By 1951, coho were observed above Kalama Falls, but numbers were unknown and distribution was probably throughout the watershed (WDF 1951). Presently, both Type-S (early) and Type-N (late) coho are present and managed as hatchery stocks while a relatively small amount of natural production occurs. The Type-S stock has a more southerly ocean distribution than the Type-N, which has a more northerly ocean distribution.

Kalama life history data was not available for natural coho, but is presumed similar to hatchery fish and is presented in that section.

The Northwest Power Planning Council's model indicated the subbasin has a capacity of 53,758 smolts of which about 67 percent is above Kalama Falls Hatchery. Run size of natural fish in the Kalama was estimated by using the 9 percent natural fish found in the Cowlitz River (Devore 1987) and the observation that 78 percent of Cowlitz coho returned to the hatchery rack. Therefore, since 6,776 fish returned to the hatchery racks, total coho run was 8,687 of which 9 percent were natural in origin, resulting in an estimated 782 natural fish.

Hatchery coho have been planted in the subbasin since at least 1942 from the Lower Kalama Hatchery. However, through 1950, plants were limited and most were fry. For the 1975 through 1985 brood years, an average of 171,700 fry, 95,400 fingerlings and 701,900 smolts of the Type-N stock were planted. Also, an average of 191,400 fry, 90,000 fingerlings, and 539,200 smolts of the Type-S stock were planted. Purpose of releases was to provide fish for sport and commercial harvest. No evaluation of fry and fingerling plants to adult returns has been done. Smolt-to-adult survival of N stock fish averaged 4.67 percent (range: 0.56 percent to 7.71 percent) for the 1983 through 1985 brood releases while S stock survival ranged from 6.10 percent to 7.50 percent and averaged 6.80 percent for the 1973 brood year (A. Appleby, WDF, pers. commun.).

General production constraints for coho are listed in Table 8. Coho are primarily tributary spawners and few lengthy tributaries of low to moderate gradients exist. Sedimentation and temperature problems commonly associated with logging activities were present. Most production capacity in the subbasin exists above Kalama Falls Hatchery where sometimes few adults are passed.

Hatchery Production

The previously described Lower Kalama and Kalama Falls salmon hatcheries both produce coho. At Lower Kalama, program goal for 1989 is 525,000 coho at 18 fish per pound (29,200 pounds) in addition to the aforementioned fall and spring chinook programs, all totaling 102,950 pounds. Most eggs are obtained from rack returns at Kalama Falls Hatchery where fish are spawned randomly at a 1-1 male-to-female ratio. For the past several years, the S stock of coho has been reared at this station although the N stock was used in previous years. Female coho are tested for virus and eggs are treated with iodophor. No IHN virus positive coho have been observed at this station. Egg-to-fry survival averaged 90.6 percent and fry-to-smolt survival was 99.2 percent, resulting in an egg-to-smolt survival of 89.9 percent. Hatchery production is at capacity and constraints are facility size and water quantity.

The Kalama Falls Hatchery had a 1989 program of 900,000 coho at 17 fish per pound (53,000 pounds), 3.5 million fall chinook at 70 fish per pound (50,000 pounds), and 550,000 spring chinook at 200 per pound (2,750 pounds, transferred to Lower Kalama in May) -- a total of 105,800 pounds. Brood stock is obtained from rack returns and fish are spawned randomly at a 1-1 male-to-female ratio. Female coho are tested for virus and eggs are treated with iodophor. No IHN virus positive coho have been observed at this station. Egg-to-fry survival for 1982 through 1986 broods averaged 85 percent while fry-to-planted-fish survival averaged 85 percent, resulting in egg-to-smolt survival of 72.3 percent.

Production at the hatchery is at capacity and constraints are facility size and water quality and quantity. Disease problems have been primarily routine and include Costia sp., low temperature disease (Cytophaga psychrophilia,) and furunculosis (Aeromonas salmonicida).

An average of 1,354,000 smolts were planted annually for the 1975 through 1985 brood years (Table 33). In addition, an average of 1,193,700 unfed fry were planted from 1979 through 1982. The unfed fry program changed to a fingerling program with an average of 302,800 planted from 1984 through 1986. Most of the fry and fingerlings went into Gobar, Wildhorse, and Arnold creeks and the Little Kalama River, which combined received an average of 252,000 fingerlings. Most of the tributaries are above the Kalama Falls Hatchery while Wildhorse Creek is above a coho barrier. Performance of unfed fry and fingerling plants is uncertain. Smolt-to-adult survival of N stock fish averaged 4.67 percent (range: 0.56 percent to 7.71 percent) for the 1983 through 1985 brood releases while S stock survival ranged from 6.10 percent to 7.50 percent and averaged 6.80 percent for the 1973 brood year (A. Appleby, WDF, pers. commun.).

Adult time of return ranges from August through January (Table 34). Spawning occurs from late October through January and fry emerge from January through April. Yearling fish are reared until release the following April through June. Some fish are released as fingerlings in the first June after hatching. Fecundity of Type-S and Type-N coho from 1977 through 1986 averaged 2,759 (n=8,526) and 2,496 (n=5,007) eggs per female, respectively.

Table 33. Plants of S and N stock coho in the Kalama Subbasin.

Brood Year	Unfed Fry		Fingerlings		Smolts	
	S	N	S	N	S	N
1975					1,012,508	886,082
1976			365,700		1,255,188	
1977					1,005,941	217,200
1978	329,346	88,641			1,522,246	1,413,200
1979	1,920,680				318,800	1,423,000
1980	611,213	1,100,000		469,000	290,400	549,000
1981		724,758	406,000			536,800
1982					209,000	453,000
1983				350,400	328,400	1,035,879
1984				219,940	528,500	957,500
1985			259,300	78,800		950,300

Saltwater age composition of hatchery coho in 1977 through 1986 was based on hatchery rack returns and length frequencies. For Type-S fish, 25.4 percent of hatchery returns were 1-ocean jacks and 74.6 percent were 2-ocean adults (n=52,652). Male-to-female sex ratio of adults was 1.2-to-1. For the Type-N stock, 22 percent of hatchery returns were 1-ocean jacks and 78 percent were 2-ocean adults (n=31,404). Male-to-female sex ratio of adults was 2.01-to-1. Length frequency profiles at the hatcheries were not available. Recoveries of marked production Type-N stock indicated only 0.2 percent were found at 3-ocean age.

Table 34. Freshwater life history of Kalama Subbasin coho. The developmental stage timing represents basinwide averages; local conditions may cause some variability.

Developmental Stages	Time of year	Peak occurrence
Adult immigration	September-January	October-November
Adult holding	September-January	October-November
Spawning	October-February	October-November
Egg/alevin incubation	October-March	November-March
Emergence	January-April	February-March
Rearing	Jan-May (17 mos.)	Feb-May (16 mos.)
Juvenile emigration	April-June	April-May

Run size of hatchery fish was estimated with the observations of Devore (1987) on the Cowlitz River where 78 percent of the fish returned to the hatchery rack and 91 percent of the total were hatchery origin. Since an average of 6,776 fish returned to the racks, total run size was estimated at 8,687 fish of which 7,905 fish would be hatchery origin. Hatchery rack returns for 1981 through 1986 averaged 405 and 1,886 Type-S coho jacks and adults, respectively. Type-N returns averaged 841 and 3,644 jacks and adults, respectively for 1981 through 1986 (Table 35).

Table 35. Hatchery rack returns of coho to the Kalama Subbasin.

Year	Type-S Jacks	Type-S Adults	Type-N Jacks	Type-N Adults
1981	493	2,260	1,047	4,323
1982	843	767	1,410	5,640
1983	117	1,147	1,161	2,745
1984	597	185	635	1,480
1985	191	1,341	631	713
1986	187	5,616	163	6,961

Harvest

Subbasin harvest of coho averaged 441 jacks and 650 adults for 1977 through 1986. For 1981 through 1986, sport harvest rate averaged 12.5 percent within the subbasin.

The System Planning Model estimated 75.3 percent of total production was harvested in the ocean and Columbia River.

In the Kalama River, management goals are hatchery oriented with the realization that some returns will use natural habitat. Due to the low harvest rate within the subbasin, most harvest is intended to occur in the ocean and Columbia River.

Management procedures within the subbasin consists of regulation through Washington Department of Fisheries sport harvest restrictions. The daily limit is six salmon of 12-inch minimum size of which two may exceed 24 inches. The area downstream of the Kalama Falls Hatchery is open the entire year, although from September 1 to October 31 the area between the Lower Kalama Hatchery pump house intake downstream to the natural gas pipeline crossing at Mahaffey's Campground is open to fly-fishing only. All other waters in September and October are limited to bait or lures with one single-pointed hook measuring no more than 0.5 inch from point to shank. When the Washington Department of Fisheries temporary rack is installed just below Modrow Bridge, that portion of the river 200 feet above the rack to 1,500 feet below the rack is closed to salmon angling. Above Kalama Falls Hatchery, from Summers Creek upstream to Road 6420, the area is open from the last Saturday in May through November 30 to fly-fishing only. From Summers Creek downstream to the Kalama Falls Hatchery, the area is open from the last Saturday in

May through November 30. Enforcement activities consist of Washington Department of Fisheries and Washington Department of Wildlife personnel checking anglers for compliance with harvest restrictions.

Specific Considerations

Coho in the Kalama Subbasin are managed as a hatchery stock and relatively few hatchery fish are needed for hatchery escapement. However, natural spawning by some of the large numbers of hatchery fish may offset underescapement of natural fish. The estimated habitat carrying capacity was 53,758 smolts. An average of 302,800 fingerlings were planted annually with most going into tributaries above Kalama Falls Hatchery.

Both the Type-S and Type-N stocks exist in the subbasin. Smolt-to-adult survival (catch plus escapement) of N stock coho averaged 4.67 percent for 1983 through 1985 broods while smolt-to-adult survival of the S stock averaged 6.80 percent. Due to the ineffective harvest rate within the subbasin, most subbasin coho are intended for ocean and Columbia River harvest.

Critical Data Gaps

Spawning survey data is needed to determine spawning escapement. Origin of spawners also needs to be ascertained to estimate hatchery run size.

Objectives

Stock: Kalama Type "S" Coho

Utilization Objective: 750 for sport harvest and support out-of-basin harvest. The utilization component has priority for this stock within the Kalama River.

Biological Objective: Maintain biological characteristics of the existing population.

This is an increased subbasin harvest of 250 fish. With existing harvest rates this would require an increase of 2,000 fish to the subbasin, bringing the total to 10,687 fish for both stocks.

Stock: Kalama Type "N" Coho

Utilization Objective: 500 for sport harvest and support out-of-basin harvest. The utilization component has priority for this stock within the Kalama River.

Biological Objective: Maintain biological characteristics of the existing population.

Because no increase is sought for this stock, no alternative strategies are presented. Existing subbasin returns were estimated at 2,937 Type-S and 5,750 Type-N fish, a total of 8,687 fish.

Alternative Strategies

Strategies for coho in this report have specific themes. Means to meeting the objectives are first attempted using natural methods followed by less natural techniques and finally, hatchery production. Actions identified under each strategy are closely related to the theme. Strategy 1 has a natural production theme seeking to improve the productivity of the existing natural stock. Strategy 2 is a "benign" supplementation strategy, emphasizing actions to develop a single supplemented run with yet higher productivity. Strategy 3 employs all the actions to improve stock productivity, but also includes any opportunities to increase stock size by providing passage into inaccessible habitat or releasing fry into such areas to make use of additional natural rearing potential. Strategy 4 relies on a traditional hatchery program to meet objectives. Only those actions necessary for the success of a hatchery program would be included in Strategy 4.

Modeling results for each strategy are presented in Table 36 as fish produced at "maximum sustainable yield" (MSY). The sustainable yield of a fish population refers to that portion of the population that exceeds the number of fish required to spawn and maintain the population over time. Sustainable yield can be "maximized," termed MSY, for each stock at a specific harvest level. The MSY is estimated using a formula (Beverton-Holt function) that analyzes a broad range of harvest rates. Subbasin planners have used MSY as a tool to standardize results so that decision makers can compare stocks and strategies.

In MSY management, managers set a spawning escapement level and the remaining fish (yield) could theoretically be harvested. In practice, a portion of the yield may be reserved as a buffer or to aid rebuilding. Thus, managers may raise the escapement level to meet a biological objective at the expense of a higher utilization objective.

The amount of buffer appropriate for each stock is a management question not addressed in the subbasin plans. For this reason, the utilization objective, which usually refers to harvest, may not be directly comparable to the MSY shown in Table 36. At a minimum, a strategy should produce an estimated MSY equal to or greater than the utilization objective. A MSY substantially larger than the subbasin utilization objective may be needed to meet subbasin biological objectives.

Estimated costs of the alternative strategies below are summarized in Table 37.

STRATEGY 1: Natural Production. This strategy seeks to achieve the objectives by eliminating sources of direct mortality to natural fish, answering management questions, and reducing risks of genetic modification of natural stocks.

This strategy provides for prudent stewardship of existing habitat and water quality in the historic distribution range through various existing laws and agreements. Streams in the subbasin need to be inventoried for summer temperature profiles; those exceeding temperature sensitivity criteria should be classified as such through the Department of Natural Resources so future impacts will be minimized. Riparian zones should be managed to provide a continuous recruitment of large organic debris into the subbasin system. Fishways should be maintained.

Hypothesis: Existing habitat, if properly managed, should optimize natural smolt production.

Assumptions: This strategy assumes relative egg-to-smolt survival could be increased by 10 percent.

Numeric Fish Increases: The System Planning Model indicated an additional 28 coho would return to the subbasin at current harvest rates. Total production would increase by 218 fish at MSY.

ACTIONS: 1

1. Maintain at least current level of stream habitat quality and quantity. Seek improved water quality via reduction of sedimentation and temperatures.

STRATEGY 2: Supplementation. This strategy seeks to achieve the objectives by supplementing natural production with an appropriate existing hatchery stock or natural stock. Any actions identified in Strategy 1 necessary for the success of the supplementation program are also required.

Hypothesis: Maximizing production potential from hatchery stream plants might have other benefits within the hatcheries such as additional room and costs reductions. Increasing hatchery production with a new facility would increase adult returns.

Assumptions: Action 2 was not modeled in the System Planning Model, but it would ensure carrying capacity is fully utilized. This strategy assumes increased smolt production would result in commensurate adult returns.

Numeric Fish Increases: The System Planning Model indicated 2,119 additional fish would return to the subbasin at current harvest rates. Total production would increase by 8,511 fish at MSY. This strategy would meet objectives.

ACTIONS: 1, 2, 4

1. -

2. Conduct research to determine optimum fingerling planting densities to optimize production. Bilby and Bisson (1987) suggested that excessive coho fingerling plants resulted in a decline in net coho production. Fraser (1969) indicated that high density coho plants resulted in decreased biomass of steelhead and coho. Seed the subbasin with fingerlings as needed and conduct annual spawning surveys to determine fingerling needs.

4. Construct a hatchery facility to produce 350,000 smolts.

STRATEGY 3: Supplementation and Habitat Base Increase. This strategy seeks to achieve the objectives by all the measures to increase productivity contained in Strategies 1 and 2, but also increases stock size by providing passage into inaccessible areas or release of fry into such areas.

Hypothesis: By making new habitat available, additional smolts would be produced.

Assumptions: It is assumed fish would fully utilize newly accessed waters. The falls on Elk Creek would be difficult to ladder due to access. Production increases would amount to about 1,770 smolts on Hatchery Creek, 3,287 smolts on Summers Creek, 6,575 smolts on Elk Creek, and 4,763 smolts on Wildhorse Creek -- a total of 16,395 smolts.

Numeric Fish Increases: The System Planning Model indicated subbasin returns would increase by 2,311 fish (192 more than Strategy 3) at current harvest rates. Total production would increase 8,948 fish at MSY. This strategy would meet objectives.

ACTIONS: 1-4

1. -
2. -

3. Expand historic distribution through laddering of falls. Streams that could be laddered or fry planted include Hatchery Creek (4 miles), Summers Creek (3 miles) and Elk Creek (4 miles) and Wildhorse Creek (2.9 miles). Wildhorse Creek has occasionally received coho fry plants.

4. -

STRATEGY 4: Hatchery Production. This strategy seeks to achieve the objectives solely through traditional hatchery production. Only those actions necessary for maintenance of the hatchery program are included.

Hypothesis: By producing additional smolts, number of adults would also increase.

Assumptions: This strategy assumes increased smolt production results in commensurate adults. Strategy 4 also assumes that suitable water quality and quantity, facility space, and such can be located.

Numeric Fish Increases: The System Planning Model indicated 2,103 additional fish would return to the subbasin at current harvest rates. Total production would increase by 8,273 fish at MSY. This strategy would meet objectives.

ACTIONS: 4 (see above)

Recommended Strategy

The recommended strategy for Kalama coho is Strategy 4, hatchery enhancement of 350,000 smolts. Kalama coho are a hatchery stock with high out-of-basin harvest rates, making management for natural fish difficult. Also, there is relatively little natural habitat available in the subbasin and little genetic concern of adding additional hatchery fish. Hatchery enhancement appears to be the only way to provide the large number of smolts needed to meet objectives. The SMART analysis (Appendix B) also supports Strategy 4.

Table 36. System Planning Model results for early-run coho in the Kalama Subbasin. Baseline value is for pre-mainstem implementation, all other values are post-implementation.

Utilization Objective:
500 sport harvest of Type N stock and 750 sport harvest of Type S stock.

Biological Objective:
Maintain unique biological characteristics, run timing and distribution of Type-S and Type-N coho returning to the Kalama River.

Strategy[1]	Maximum[2] Sustainable Yield (MSY)	Total[3] Spawning Return	Total[4] Return to Subbasin	Out of[5] Subbasin Harvest	Contribution[6] To Council's Goal (Index)
Baseline	175 -N	7,711	8,743	26,666	0(1.00)
All Nat	89 -N	7,958	8,932	27,244	766(1.02)
1	88 -N	7,815	8,771	26,753	115(1.00)
2	109 -N	9,674	10,858	33,117	8,566(1.24)
3	111 -N	9,863	11,069	33,763	9,423(1.27)
4*	108 -N	9,655	10,836	33,051	8,477(1.24)

*Recommended strategy.

[1]Strategy descriptions:

For comparison, an "all natural" strategy was modeled. It represents only the natural production (non-hatchery) components of the proposed strategies plus current management (which may include hatchery production). The all natural strategy may be equivalent to one of the alternative strategies below.

1. Aggressive Habitat Protection.
2. Strategy 1 plus 350,000 smolts.
3. Strategy 2 plus laddering of several barrier falls.
4. Baseline plus 350,000 smolts.

[2]MSY is the number of fish in excess to those required to spawn and maintain the population size (see text). These yields should equal or exceed the utilization objective. C = the model projections where the sustainable yield is maximized for the natural and hatchery components combined and the natural spawning component exceeds 500 fish. N = the model projection where sustainable yield is maximized for the naturally spawning component and is shown when the combined MSY rate results in a natural spawning escapement of less than 500 fish.

[3]Total return to subbasin minus MSY minus pre-spawning mortality equals total spawning return.

[4]Total return to the mouth of the subbasin.

[5]Includes ocean, estuary, and mainstem Columbia harvest.

[6]The increase in the total return to the mouth of the Columbia plus prior ocean harvest (as defined by the Northwest Power Council's Fish and Wildlife Program), from the baseline scenario. The index () is the strategy's total production divided by the baseline's total production.

Table 37. Estimated costs of alternative strategies for Kalama early-run coho. Cost estimates represent new or additional costs to the 1987 Columbia River Basin Fish and Wildlife Program; they do not represent projects funded under other programs, such as the Lower Snake River Compensation Plan or a public utility district settlement agreement. (For itemized costs, see Appendix C.)

	Proposed Strategies			
	1	2	3	4*
Hatchery Costs				
Capital[1]	0	575,000	575,000	575,000
O&M/yr[2]	0	62,500	62,500	62,500
Other Costs				
Capital[3]	0	25,000	525,000	0
O&M/yr[4]	30,000	40,000	50,000	0
Total Costs				
Capital	0	600,000	1,100,000	575,000
O&M/yr	30,000	102,500	112,500	62,500

* Recommended strategy.

[1] Estimated capital costs of constructing a new, modern fish hatchery. In some subbasins, costs may be reduced by expanding existing facilities. For consistency, estimate is based on $23/pound of fish produced. Note that actual costs can vary greatly, especially depending on whether surface or well water is used and, if the latter, the number and depth of the wells.

[2] Estimated operation and maintenance costs per year directly associated with new hatchery production. Estimates are based on $2.50/pound of fish produced. For consistency, O&M costs are based on 50 years.

[3] Capital costs of projects (other than direct hatchery costs) proposed under a particular strategy, such as enhancing habitat, screening diversions, removing passage barriers, and installing net pens (see text for specific actions).

[4] Estimated operation and maintenance costs per year of projects other than those directly associated with new hatchery production. For consistency, O&M costs are based on 50 years.

PART V. SUMMARY AND IMPLEMENTATION

Objectives and Recommended Strategies.

Winter Steelhead

Provide a subbasin sport harvest of 1,000 hatchery fish. The System Planning Model indicated that recent "wild release" regulations will increase subbasin returns of natural fish by 459 fish. Planners recommend Strategy 3, constructing a rearing pond in the lower Kalama River and increasing smolt production by 40,000 fish.

Summer Steelhead

Provide a subbasin sport harvest of 3,100 hatchery fish. The System Planning Model indicated that recent "wild release" regulations will increase subbasin returns of natural fish by 59 fish. No strategy has been recommended for Kalama summer steelhead; objectives are being met and current production is five to 10 times greater than historic production.

Sea-Run Cutthroat

Objectives are to increase returns to the subbasin from 757 to 1,200 fish. Planners recommend Strategy 1, a combination of aggressive habitat protection where at least current level of stream habitat quality and quantity are maintained, water quality improvements are sought for reduction of sedimentation and temperature, and an improved rack installed at Kalama Falls Hatchery to monitor run strength.

Fall Chinook

Objectives are to provide a subbasin sport harvest of 1,340 fish while supporting out-of-basin harvest. Planners recommend Strategy 2, a combination of 1) aggressive habitat protection where at least current level of stream habitat quality and quantity are maintained, water quality improvements are sought for reduction of sedimentation and temperature; 2) improving hatchery smolt quality; and 3) increasing hatchery production by 3,850,000 smolts.

Spring Chinook

Objectives are to provide a subbasin sport harvest of 2,000 fish while providing some out-of-basin harvest. Planners recommend Strategy 5, improving survival of adults being held at Kalama Falls Hatchery via modifications to the fish ladder and adult holding facilities. The excess adults could then be passed upstream to utilize existing habitat which goes unused in most years.

Coho

Objectives are to provide a subbasin sport harvest of 500 Type-N and 750 Type-S coho while supporting out-of-basin harvest. Planners recommend Strategy 4, increasing hatchery production by 350,000 smolts.

Implementation

In the summer of 1990, the Columbia Basin Fish and Wildlife Authority submitted to the Northwest Power Planning Council the Integrated System Plan for salmon and steelhead in the Columbia Basin, which includes all 31 subbasin plans. The system plan attempts to integrate this subbasin plan with the 30 others in the Columbia River Basin, prioritizing fish enhancement projects and critical uncertainties that need to be addressed.

From here, the Northwest Power Planning Council will begin its own public review process, which will eventually lead to amending its Columbia River Basin Fish and Wildlife Program. The actual implementation schedule of specific projects or measures proposed in the system plan will materialize as the council's adoption process unfolds.

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APPENDIX A
NORTHWEST POWER PLANNING COUNCIL
SYSTEM POLICIES

In Section 204 of the 1987 Columbia River Basin Fish and Wildlife Program, the Northwest Power Planning Council describes seven policies to guide the systemwide effort in doubling the salmon and steelhead runs. Pursuant to the council's plan, the basin's fisheries agencies and Indian tribes have used these policies, and others of their own, to guide the system planning process. The seven policies are paraphrased below.

1) The area above Bonneville Dam is accorded priority.

Efforts to increase salmon and steelhead runs above Bonneville Dam will take precedence over those in subbasins below Bonneville Dam. In the past, most of the mitigation for fish losses has taken the form of hatcheries in the lower Columbia Basin. According to the council's fish and wildlife program, however, the vast majority of salmon and steelhead losses have occurred in the upper Columbia and Snake river areas. System planners turned their attention first to the 22 major subbasins above Bonneville Dam, and then to the nine below.

2) Genetic risks must be assessed.

Because of the importance of maintaining genetic diversity among the various salmon and steelhead populations in the Columbia River Basin, each project or strategy designed to increase fish numbers must be evaluated for its risks to genetic diversity. Over millions of years, each fish run has evolved a set of characteristics that makes it the best suited run for that particular stream, the key to surviving and reproducing year after year. System planners were to exercise caution in their selection of production strategies so that the genetic integrity of existing fish populations is not jeopardized.

3) Mainstem survival must be improved expeditiously.

Ensuring safe passage through the reservoirs and past the dams on the Columbia and Snake River mainstems is crucial to the success of many efforts that will increase fish numbers, particularly the upriver runs. Juvenile fish mortality in the reservoirs and at the dams is a major cause of salmon and steelhead losses. According to estimates, an average of 15 percent to 30 percent of downstream migrants perish at each dam, while 5 percent to 10 percent of the adult fish traveling upstream perish. Projects to rebuild runs in the tributaries have and will represent major expenditures by the region's ratepayers -- expenditures and long-term projects that should be protected in the mainstem.

4) Increased production will result from a mix of methods.

To rebuild the basin's salmon and steelhead runs, fisheries managers are to use a mixture of wild, natural and hatchery production. Because many questions still exist as to whether wild and natural stocks can coexist with significant numbers of hatchery fish, no one method of production will be solely responsible for increasing fish numbers. System planners were to take extra precaution when considering outplanting hatchery fish into natural areas that still produce wild fish. The council is relying on the fish and wildlife agencies and tribes to balance artificial production with wild and natural production.

5) Harvest management must support rebuilding.

Like improved mainstem passage, effective harvest management is critical to the success of rebuilding efforts. A variety of fisheries management entities from Alaska to California manage harvest of the Columbia Basin's salmon and steelhead runs. The council is calling on those entities to regulate harvest, especially in mixed-stock fisheries, in ways that support the basin's efforts to double its runs.

6) System integration will be necessary to assure consistency.

The Northwest Power Planning Council intends to evaluate efforts to protect and rebuild Columbia River Basin salmon and steelhead from a systemwide perspective. Doubling the runs will require improvements in mainstem passage, fish production and harvest management -- three extremely interdependent components. System planners from all parts of the basin are to coordinate their efforts so, for example, activities in the lower Columbia are consistent with and complement the activities 800 miles upstream in Idaho's Salmon River. The fisheries management organizations and their plans vary from subbasin to subbasin, but the council is calling upon the agencies and tribes to help resolve conflicts that arise.

7) Adaptive management should guide action and improve knowledge.

System planners were to design projects so that information can be collected to improve future management decisions. By designing projects that test quantitative hypotheses and lend themselves to monitoring and evaluation, managers can learn from their efforts. This learning by doing is called "adaptive management." Using such an approach, managers can move ahead with plans to rebuild the Columbia Basin's salmon and steelhead runs, despite many unanswered questions about how best to accomplish their goal. With time, the useful information revealed by these "experiments" can guide future projects.

APPENDIX B
SMART ANALYSIS

To help select the preferred strategies for each subbasin, planners used a decision-making tool known as Simple Multi-Attribute Rating Technique (SMART). SMART examined each proposed strategy according to the following five criteria. In all cases, SMART assumed that all of the Columbia River mainstem passage improvements would be implemented on schedule.

1) Extent the subbasin objectives were met

2) Change in maximum sustainable yield

3) Impact on genetics

4) Technological and biological feasibility

5) Public support

Once SMART assigned a rating for each criteria, it multiplied each rating by a specific weight applied to each criteria to get the "utility" value (see following tables). Because the criteria were given equal weights, utility values were proportional to ratings. The confidence in assigning the ratings was taken into consideration by adjusting the weighted values, (multiplying the utility value by the confidence level) to get the "discount utility." SMART then totaled the utility values and discount utility values for all five criteria, obtaining a "total value" and a "discount value" for each strategy.

System planners used these utility and discount values to determine which strategy for a particular fish stock rated highest across all five criteria. If more than one of the proposed strategies shared the same or similar discount value, system planners considered other factors, such as cost, in the selection process. Some special cases arose where the planners' preferred strategy did not correspond with the SMART results. In those cases, the planners provide the rationale for their selection.

Subbasin: Kalama Stock: Winter steelhead Strategy: 1

Criteria	Rating	Confidence	Weight	Utility	Discount Utility
1 EXT OBJ	8	0.6	20	160	96
2 CHG MSY	5	0.6	20	100	60
3 GEN IMP	7	0.6	20	140	84
4 TECH FEAS	8	0.6	20	160	96
5 PUB SUPT	7	0.6	20	140	84
TOTAL VALUE				700	
DISCOUNT VALUE					420
CONFIDENCE VALUE					0.60

Subbasin: Kalama Stock: Winter steelhead Strategy: 2

Criteria	Rating	Confidence	Weight	Utility	Discount Utility
1 EXT OBJ	4	0.6	20	80	48
2 CHG MSY	3	0.6	20	60	36
3 GEN IMP	7	0.6	20	140	84
4 TECH FEAS	7	0.6	20	140	84
5 PUB SUPT	7	0.6	20	140	84
TOTAL VALUE				560	
DISCOUNT VALUE					336
CONFIDENCE VALUE					0.60

Subbasin: Kalama Stock: Winter steelhead Strategy: 3

Criteria	Rating	Confidence	Weight	Utility	Discount Utility
1 EXT OBJ	8	0.9	20	160	144
2 CHG MSY	6	0.6	20	120	72
3 GEN IMP	7	0.9	20	140	126
4 TECH FEAS	8	0.9	20	160	144
5 PUB SUPT	8	0.6	20	160	96
TOTAL VALUE				740	
DISCOUNT VALUE					582
CONFIDENCE VALUE					0.79

Subbasin: Kalama   Stock: Fall Chinook   Strategy: 1

Criteria	Rating	Confidence	Weight	Utility	Discount Utility
1 EXT OBJ	3	0.6	20	60	36
2 CHG MSY	3	0.6	20	60	36
3 GEN IMP	2	0.9	20	40	36
4 TECH FEAS	5	0.6	20	100	60
5 PUB SUPT	6	0.6	20	120	72
TOTAL VALUE				380	
DISCOUNT VALUE					240
CONFIDENCE VALUE					0.63

Subbasin: Kalama   Stock: Fall chinook   Strategy: 2

Criteria	Rating	Confidence	Weight	Utility	Discount Utility
1 EXT OBJ	6	0.6	20	120	72
2 CHG MSY	6	0.6	20	120	72
3 GEN IMP	3	0.9	20	60	54
4 TECH FEAS	8	0.6	20	160	96
5 PUB SUPT	7	0.6	20	140	84
TOTAL VALUE				600	
DISCOUNT VALUE					378
CONFIDENCE VALUE					0.63

Subbasin: Kalama   Stock: Fall Chinook   Strategy: 3

Criteria	Rating	Confidence	Weight	Utility	Discount Utility
1 EXT OBJ	5	0.6	20	100	60
2 CHG MSY	6	0.6	20	120	72
3 GEN IMP	3	0.9	20	60	54
4 TECH FEAS	8	0.6	20	160	96
5 PUB SUPT	6	0.6	20	120	72
TOTAL VALUE				420	
DISCOUNT VALUE					258
CONFIDENCE VALUE					0.61

Subbasin: Kalama   Stock: Fall Chinook   Strategy: 4

Criteria	Rating	Confidence	Weight	Utility	Discount Utility
1 EXT OBJ	5	0.6	20	100	60
2 CHG MSY	6	0.6	20	120	72
3 GEN IMP	3	0.9	20	60	54
4 TECH FEAS	9	0.9	20	180	162
5 PUB SUPT	6	0.9	20	120	108
TOTAL VALUE				580	
DISCOUNT VALUE					456
CONFIDENCE VALUE					0.79

Subbasin: Kalama Stock: Spring Chinook Strategy: 1

Criteria	Rating	Confidence	Weight	Utility	Discount Utility
1 EXT OBJ	3	0.6	20	60	36
2 CHG MSY	3	0.6	20	60	36
3 GEN IMP	2	0.9	20	40	36
4 TECH FEAS	5	0.6	20	100	60
5 PUB SUPT	6	0.6	20	120	72
TOTAL VALUE				380	
DISCOUNT VALUE					240
CONFIDENCE VALUE					0.63

Subbasin: Kalama Stock: Spring chinook Strategy: 2

Criteria	Rating	Confidence	Weight	Utility	Discount Utility
1 EXT OBJ	5	0.9	20	100	90
2 CHG MSY	5	0.6	20	100	60
3 GEN IMP	2	0.9	20	40	36
4 TECH FEAS	6	0.6	20	120	72
5 PUB SUPT	6	0.6	20	120	72
TOTAL VALUE				480	
DISCOUNT VALUE					330
CONFIDENCE VALUE					0.69

Subbasin: Kalama Stock: Spring Chinook Strategy: 3

Criteria	Rating	Confidence	Weight	Utility	Discount Utility
1 EXT OBJ	5	0.9	20	100	90
2 CHG MSY	6	0.9	20	120	108
3 GEN IMP	2	0.9	20	40	36
4 TECH FEAS	6	0.9	20	120	108
5 PUB SUPT	6	0.6	20	120	72
TOTAL VALUE				500	
DISCOUNT VALUE					414
CONFIDENCE VALUE					0.83

Subbasin: Kalama   Stock: Spring Chinook   Strategy: 4

Criteria	Rating	Confidence	Weight	Utility	Discount Utility
1 EXT OBJ	5	0.9	20	100	90
2 CHG MSY	5	0.6	20	100	60
3 GEN IMP	2	0.9	20	40	36
4 TECH FEAS	7	0.6	20	140	84
5 PUB SUPT	5	0.9	20	100	90
TOTAL VALUE				480	
DISCOUNT VALUE					360
CONFIDENCE VALUE					0.75

Subbasin: Kalama   Stock: Spring Chinook   Strategy: 5

Criteria	Rating	Confidence	Weight	Utility	Discount Utility
1 EXT OBJ	5	0.9	20	100	90
2 CHG MSY	5	0.6	20	100	60
3 GEN IMP	2	0.9	20	40	36
4 TECH FEAS	7	0.6	20	140	84
5 PUB SUPT	7	0.9	20	140	126
TOTAL VALUE				520	
DISCOUNT VALUE					396
CONFIDENCE VALUE					0.76

Subbasin: Kalama Stock: Coho Strategy: 1

Criteria	Rating	Confidence	Weight	Utility	Discount Utility
1 EXT OBJ	5	0.6	20	100	60
2 CHG MSY	3	0.6	20	60	36
3 GEN IMP	3	0.9	20	60	54
4 TECH FEAS	5	0.6	20	100	60
5 PUB SUPT	5	0.6	20	100	60
TOTAL VALUE				420	
DISCOUNT VALUE					270
CONFIDENCE VALUE					0.64

Subbasin: Kalama Stock: Coho Strategy: 2

Criteria	Rating	Confidence	Weight	Utility	Discount Utility
1 EXT OBJ	6	0.6	20	120	72
2 CHG MSY	6	0.6	20	120	72
3 GEN IMP	3	0.9	20	60	54
4 TECH FEAS	7	0.6	20	140	84
5 PUB SUPT	5	0.6	20	100	60
TOTAL VALUE				540	
DISCOUNT VALUE					342
CONFIDENCE VALUE					0.63

Subbasin: Kalama Stock: Coho Strategy: 3

Criteria	Rating	Confidence	Weight	Utility	Discount Utility
1 EXT OBJ	6	0.6	20	120	72
2 CHG MSY	6	0.6	20	120	72
3 GEN IMP	3	0.9	20	60	54
4 TECH FEAS	7	0.6	20	140	84
5 PUB SUPT	4	0.3	20	80	24
TOTAL VALUE				520	
DISCOUNT VALUE					306
CONFIDENCE VALUE					0.59

Subbasin: Kalama Stock: Coho Strategy: 4

Criteria	Rating	Confidence	Weight	Utility	Discount Utility
1 EXT OBJ	6	0.6	20	120	72
2 CHG MSY	6	0.6	20	120	72
3 GEN IMP	3	0.9	20	60	54
4 TECH FEAS	8	0.6	20	160	96
5 PUB SUPT	6	0.6	20	120	72
TOTAL VALUE				580	
DISCOUNT VALUE					366
CONFIDENCE VALUE					0.63

APPENDIX C
SUMMARY OF COST ESTIMATES

The cost estimates provided in the following summary tables represent new or additional costs necessary to implement the alternative strategies. Although many strategies involve projects already planned or being implemented under the Columbia River Basin Fish and Wildlife Program or other programs, such as the Lower Snake River Compensation Plan, the associated costs and hatchery production do not appear in the following tables.

In many cases, the following costs are no more than approximations based on familiarity with general costs of similar projects constructed elsewhere. Although the costs are very general, they can be used to evaluate relative, rather than absolute, costs of alternative strategies within a subbasin.

Particular actions are frequently included in strategies for more than one species or race of anadromous fish. In these cases, the same costs appear in several tables, but would only be incurred once, to the benefit of some, if not all, of the species and races of salmon and steelhead in the subbasin.

Subbasin planners used standardized costs for actions "universal" to the Columbia River system, such as costs for installing instream structures, improving riparian areas, and screening water diversions (see the Preliminary System Analysis Report, March 1989). For other actions, including the removal of instream barriers, subbasin planners developed their own cost estimates in consultation with resident experts.

Planners also standardized costs for all new hatchery production basinwide. To account for the variability in fish stocking sizes, estimates were based upon the cost per pound of fish produced. For consistency, estimated capital costs of constructing a new, modern fish hatchery were based on $23 per pound of fish produced. Estimated operation and maintenance costs per year were based on $2.50 per pound of fish produced.

All actions have a life expectancy, a period of time in which benefits are realized. Because of the variation in life expectancy among actions, total costs were standardized to a 50-year period. Some actions had life expectancies of 50 years or greater and thus costs were added as shown. Other actions (such as instream habitat enhancements) are expected to be long term, but may only have life expectancies of 25 years. Thus the action would have to be repeated (and its cost doubled) to meet the 50-year standard. Still other actions (such as a study or a short-term supplementation program) may have life expectancies of 10 years after which no further action would be taken. In this case, operation and maintenance costs were amortized over 50 years to develop the total O&M per year estimate. Capital costs, being up-front, one-time expenditures, were added directly.

Subbasin planners have estimated all direct costs of alternative strategies except for the purchase of water rights. No cost estimates have been or will be made for actions that involve purchasing water. Indirect costs, such as changes in water flows or changes in hydroelectric system operations, are not addressed.

ESTIMATED COSTS FOR ALTERNATIVE STRATEGIES

Subbasin: Kalama River
Stock: Winter Steelhead

Action	Cost Categories*	Proposed Strategies 1	2	3**
Habitat Enhancement	Capital:			
	O&M/yr:			
	Life:			
Screening	Capital:			
	O&M/yr:			
	Life:			
Barrier Removal	Capital:			
	O&M/yr:			
	Life:			
Acclimation Pond	Capital:		250,000	250,000
	O&M/yr:		5,000[a]	5,000[a]
	Life:		50	50
Hatchery Production	Capital:	184,000		184,000
	O&M/yr:	20,000		20,000
	Life:	50		50
TOTAL COSTS	Capital:	184,000	250,000	434,000
	O&M/yr:	20,000	5,000	25,000
	Years:	50	50	50
Water Acquisition		N	N	N
Fish to Stock	Number/yr:	40,000		40,000
	Size:	S, 5/lb.		S, 5/lb.
	Years:	50		50

* Life expectancy of the project is defined in years. Water acquisition is defined as either Y = yes, the strategy includes water acquisition; N = no, water acquisition is not part of the strategy. The size of fish to stock is defined as E = eggs; F = fry; J = juvenile, fingerling, parr, subsmolt; S = smolt; A = adult.

** Recommended strategy.

[a] O&M is strictly for acclimation pond; fish food and labor are presently paid by Washington Department of Wildlife.

ESTIMATED COSTS FOR ALTERNATIVE STRATEGIES

Subbasin: Kalama River
Stock: Fall Chinook

Action	Cost Categories*	Proposed Strategies 1	2**	3	4
Habitat Enhancement	Capital:	0	0	0	
	O&M/yr:	30,000	30,000	30,000	
	Life:	50	50	50	
Screening	Capital:				
	O&M/yr:				
	Life:				
Smolt Quality Study	Capital:		0	0	0
	O&M/yr:		30,000	30,000	30,000
	Life:		5	5	5
Adult Holding Facility	Capital:			1,000,000	1,000,000
	O&M/yr:			30,000	30,000
	Life:			25	25
Hatchery Production	Capital:		885,500	885,500	
	O&M/yr:		96,250	96,250	
	Life:		50	50	
TOTAL COSTS	Capital:	0	885,500	2,885,500	2,000,000
	O&M/yr:	30,000	129,250	159,250	33,000
	Years:	50	50	50	50
Water Acquisition		N	N	N	N
Fish to Stock	Number/yr:		3,850,000	3,850,000	
	Size:		J, 100/lb.	J, 100/lb.	
	Years:		50	50	

* Life expectancy of the project is defined in years. Water acquisition is defined as either Y = yes, the strategy includes water acquisition; N = no, water acquisition is not part of the strategy. The size of fish to stock is defined as E = eggs; F = fry; J = juvenile, fingerling, parr, subsmolt; S = smolt; A = adult.

** Recommended strategy.