FRED Reports

UPPER SUSITNA RIVER
SALMON ENHANCEMENT STUDY

by
Lowell Barrick, Bernard Kepshire
and
George Cunningham

Number 4

Alaska Department of Fish & Game
Division of Fisheries Rehabilitation,
Enhancement and Development

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1. FOREWORD

This study is the result of a $200,000 appropriation by the Alaska State Legislature. The study was implemented because of the impact that the proposed Susitna hydroelectric project could have on any future salmon enhancement projects in the upper reaches of the Susitna River; i.e., the river area upstream of Devil Canyon.

The details of this study are described in the work plan which is contained in the appendices. In general the study was to determine (1) if Devil Canyon (Plate 1-1) is a barrier to the upstream migration of salmon and if it is feasible to bypass salmon around this potential barrier, (2) the potential benefits of salmon production in the streams and lakes upstream of Devil Canyon, (3) the impact on resident fish from the introduction of salmon into their habitat and (4) what affect the construction of the Susitna hydroelectric dams may have on any future salmon enhancement projects.

The data for this report was collected by a team from the FRED Division of the Alaska Department of Fish and Game. Most of the field information was collected during the four month period from July 1982 through October 1982. Considerable material was researched from literature, especially the literature prepared for the Susitna hydroelectric project by Acres American Incorporated and the Alaska Department of Fish and Game Aquatic Habitat and Instream Flow Study Section. Independent field work was conducted in July, August, and September to verify questionable or missing data.

Plate 1-1. Devil Canyon oblique aerial view (from North Pacific Aerial Surveys, Inc.).

2. INTRODUCTION

The Susitna River (Figure 2-1) is nearly 300 miles long from its sources in the Alaska Mountain Range to its point of discharge into Cook Inlet. The total river drainage area encompasses about 19,400 square miles of which the upper basin above Gold Creek comprises approximately 6,160 square miles. The 150 mile stretch of the main-stem Susitna River, flowing from its mountain source through Devil Canyon to Portage Creek, contains about 30% of the entire drainage basin. The main stem and the major tributaries of the Susitna River originate in glaciers and carry a heavy load of glacial flour during the ice-free months. There are, however, many smaller tributaries and lakes which are perennially silt-free.

The proposed Susitna Hydroelectric Project has precipitated many studies on the Susitna River and its drainage basin. The studies completed through mid-1982 indicate that the two hydro dams will have various impacts on the aquatic environments of the Susitna River downstream of the dams; i.e. below Devil Canyon. However, as the general belief is that the Devil Canyon area constitutes a partial or total barrier to the upstream migration of adult salmon, very little of the fisheries data collected is pertinent to the spawning and rearing of salmon upstream of Devil Canyon.

To eliminate the question of a possible "Devil Canyon salmon block" the Alaska State Legislature appropriated $200,000 to the Alaska Department of Fish and Game (ADF&G) to study the feasibility of passing salmon through Devil Canyon and to determine the potential for salmon enhancement in the river drainage basin above Devil Canyon. The work plan, contained in Appendix 10.3, describes the full study commissioned by the Legislature.

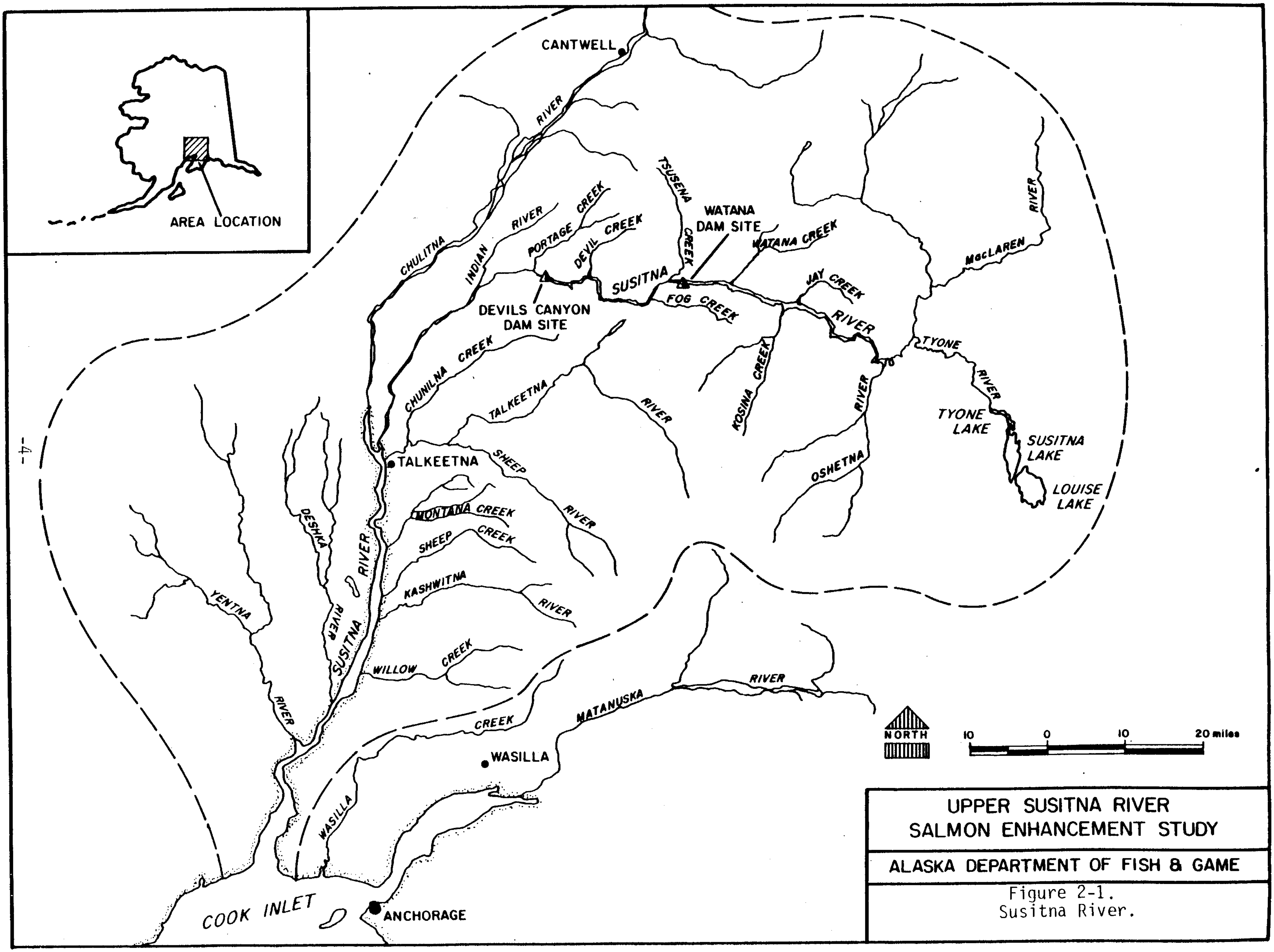

Figure 2-1.
Susitna River.

3. STATEMENT OF OBJECTIVES

The reasons for conducting this study are outlined in the foreword (Section 1) and are further detailed in the project work plan (Appendix 10.3).

The objective of this study is to find answers to the questions posed in the foreword and to prepare a report of the findings, including recommendations, for submittal to the Alaska State Legislature in 1983.

4. STUDY METHODS

4.1 Biological Studies

The salmon production potential of upper Susitna River lakes and streams was determined for sockeye, chinook, coho and chum salmon. Because of the limited time allocated to this study, the study methods (both biological and engineering) were primarily literature reviews of pertinent information. The literature reviews were, however, supplemented by three field trips plus extensive conversations with appropriate ADF&G staff and consultants from the private sector.

Any consideration of salmon production in the upper Susitna River watershed must address potential barriers to salmon migration in the main stem of the Susitna River. The rapids at Devil Canyon and Devil Creek areas constitute potential barriers to both juveniles migrating downstream and returning adults. This barrier question was addressed via literature review and conversations with ADF&G staff. The results are in section 5.1.1 and form the basis for assumptions 1 and 2 used for determining the production potential for each salmon species in this methods section.

Methods for determining the production potential for juvenile and adult salmon are now discussed relative to each species.

4.1.1 Sockeye Salmon

The watershed with the potential for the greatest sockeye salmon production is the Tyone River drainage. Two attempts, unsuccessful due to bad weather, were made by ADF&G biologists in September and October 1982, to obtain limnological data from the three major lakes, viz. Lake Louise, Susitna Lake, and Tyone Lake. These data were intended for use in a limnological model, developed by ADF&G limnology staff, that would predict the numbers and individual sizes of sockeye smolts produced by each lake. Without these data, the juvenile sockeye salmon production potentials at these and other Susitna River lakes were assessed by literature review, field trips, and conversations with knowledgeable ADF&G staff.

Conversations with Mr. Ken Roberson[1/] (August 30, 1982), and Dr. Jeff Koenings[2/] (August 30 and November 11, 1982), indicate that the production of Lake Louise is perhaps similar to that of Summit Lake and should exceed that of the very turbid, glacial Tustumena Lake (Kenai Peninsula, Alaska). Summit Lake, near Paxson, Alaska, is a high altitude (3,210 ft), clear lake which is typical of the majority of the lake water in the upper Susitna River basin. Upper Susitna River lakes useable by salmon range in elevation from 2,110 ft (Fog Lake) to 3,595 ft (Roosevelt Lake). Summit Lake is only 60 miles northeast of the Tyone River lakes and 60 miles east of the Susitna River main stem at Denali. This location puts Summit Lake in a climatic zone similar to that of the upper Susitna River basin

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1/ ADF&G Fishery Biologist III, Glennallen.

2/ ADF&G Principal Limnologist, Soldotna.

(Table 4-1). The biological productivity of lakes within a similar geographic and climatic zone should be similar if limnological factors are similar for each lake.

Prior to using the production of Summit Lake as a model for productivity of all lakes in the upper Susitna River basin, the production of the former was compared to that of other lakes in Alaska, British Columbia and the eastern USSR. Summit Lake has produced 0.8 lb of sockeye smolts/acre/yr or 47 smolts/acre/yr based on analysis of data in Roberson and Holder (1982) and a conversation with Mr. Ken Roberson (September 2, 1982). All smolts were age I and had a mean weight of .017 lb. Tenmile Lake, much smaller than Summit Lake and located near Summit Lake has an average production of 0.4 lb of sockeye smolts/acre/yr or 36 smolts/acre/yr based on analysis of data in Roberson et al. (1980).

Production and smolt weight data for other lakes (Table 4-2) when compared with Summit Lake show that Summit Lake's production is low and that the mean weight of age I smolts is in the mid-range of weights for other lakes. Note that the known annual production of Summit Lake may actually be less than the potential sustainable smolt production (Dr. Jeff Koenings, pers. comm., August 30, 1982).

Table 4-1. Climatology of the upper Susitna River basin and Summit Lake area.

Climate parameter		Geographical area: upper Susitna River basin 1/	
	Summit Lake 2/	Tyone River	Denali
General climate	arctic continental 3/	arctic continental	arctic continental
Mean maximal air temperature (°F)	37.3	50.3	51.3
Mean minimal air temperature (°F)	16.6	-12.6	-5.5
Mean air temperature (°F)	27.2	25.2	25.1
Mean annual precipitation (in.)	11.7	11.5	7.79
Ice present (months)	October-June	October-June	October-June
Frequent monthly wind direction	NE,E,SW	NE,E,SW	N,S,SW

1/ Calculated from 1980-81-82 data of R&M Consultants Inc., P.O. Box 6087, Anchorage, Alaska 99502. (Carol Larson, pers. comm., December 3, 1982).

2/ From VanWhye and Peck (1968).

3/ Cold, dry winters and warm, moderately moist summers.

As mentioned previously, the production of Lake Louise, which is typical of the majority of lake water in the upper Susitna River basin, should exceed that of Tustumena Lake. The production of Summit Lake would also be expected to and in fact does exceed that of Tustumena Lake. The latter's mean production is 0.24 lb of smolts/acre/yr or 40 smolts/acre/yr based on analysis of data provided by Dr. Jeff Koenings (pers. comm., November 12, 1982).

Table 4-2. Sockeye salmon smolt production and mean weights for lakes in Alaska, British Columbia and the eastern USSR.1/

	Pounds of smolts/acre/yr	Number of smolts/acre/yr	Mean weight of Age I smolts(lb/smolt)
Range of annual values	.08-79.00	13-2,024	-
Range of means of annual values	0.24-44.48	36-893	.004-.034

1/ From data listed in or based on analysis of data in Crone (1981), Foerster (1968), Goodlad et al. (1974), Dr. Jeff Koenings (pers. comm., November 12, 1982), Meacham (1981), Nelson (1981), Mr. Ken Roberson (pers. comm., August 30, 1982), Roberson and Holder (1982), and Roberson et al. (1977, 1978, 1980, 1981 and 1982).

With the production capability of Summit Lake already examined, assumptions used for determining the sockeye salmon production potentials of upper Susitna River lakes are now discussed.

Assumption 1.

- Upper Susitna River lakes that could produce salmon have no barriers to smolt emigration, including the Susitna River main stem rapids at Devil Canyon and Devil Creek.

Assumption 2.

- Upper Susitna River lakes that could produce salmon are accessible to adult salmon if they can pass through the Susitna River rapids at Devil Canyon and Devil Creek; and if they can negotiate streams, located between the Susitna River and the lakes, that have a maximal slope of .03 over a 0.5 mile distance, and have typical adult resting areas, e.g., pools, undercut stream banks, and sloughs.

Assumption 3.

- Each sockeye salmon spawning pair requires 72 ft^2 of area (Bell 1973).

- Most sockeye salmon will spawn in the lakes. The required spawning area is the lake bottom under 0.4% of the lake surface area. These spawning areas must consist of correct-sized gravel and upwelling intragravel water flow during the spawning and incubation period.

- Sockeye redds are not superimposed by other salmon species.

Assumption 4.

- The smolt production of upper Susitna River lakes is equal to that of Summit Lake, which is currently 0.8 lb/acre/yr or 47 smolts/acre/yr.

Assumption 5.

- The adult sockeye salmon production of upper Susitna River lakes is 31 lb of adults/acre/yr or 5 adults/acre/yr.

- The average size of a commmercially-harvested Susitna River sockeye salmon is 6.5 lb (Mr. Jim Browning[3/], pers. comm., November 19, 1982).

- A sockeye smolt to adult marine survival of 10% (Alaska Department of Fish and Game 1982b; Foerster 1968) is assumed.

4.1.2 Chinook Salmon

The chinook salmon production potential of upper Susitna River tributaries was determined using the following assumptions.

Assumption 1.

- Upper Susitna River tributaries that could produce salmon have no barriers to smolt emigration, including the Susitna River main stem rapids at Devil Canyon and Devil Creek.

3/ ADF&G Fishery Biologist II, Soldotna.

Assumption 2.

- Upper Susitna River tributaries that could produce salmon are accessible to adult salmon if they can pass through the Susitna River rapids at Devil Canyon and Devil Creek; and if they can negotiate streams or stream sections that have a maximal slope of .03 over a 0.5 mile distance, and have typical adult resting areas, e.g., pools, undercut stream banks, and sloughs.

Assumption 3.

- Each chinook salmon spawning pair requires 216 ft^2 of area (Bell 1973).

- One percent of the surface area of Susitna River tributary main stems has acceptable pools and riffles, gravel, and water for successful adult spawning and incubation. The number "one percent (1%)" was selected because of severely restricted water flows during the winter and early spring incubation period. Williams (1975) noted that many small tributaries of the upper Susitna River are dry during this period. Comparisions between monthly winter and summer water discharges for the upper Susitna River at Gold Creek station (Alaska Department of Fish and Game 1982a) indicate that winter water flows of tributaries may periodically be only 1% to 5% of summer flows.

- Most tributaries of Susitna River tributary main stems are unacceptable for incubation since most dry up during the winter as was noted for many small tributaries of the upper Susitna River by Williams (1975).

- Chinook redds are not superimposed by other salmon species.

Assumption 4.

- The smolt production of upper Susitna River tributary main stems is 0.18 lb of smolts/acre/yr or 81 smolts/acre/yr. This production was derived by averaging production values for four Alaskan streams which were obtained by estimating the number of smolts/stream/yr produced based on known adult escapements/3% marine smolt survival (Alaska Department of Fish and Game 1982b) and by estimating an approximate surface area for each tributary main stem, plus the Middle and West Forks of the Gulkana River. These production values are based on analysis of data for Crooked Creek, Kenai Peninsula (Waite 1979; Mr. Dave Waite 4/, pers. comm., October 11, 1982); Gulkana River, Gulkana (Albin 1977; Williams and Pottervil le 1981); Indian River and Portage Creek, Susitna River (Alaska Department of Fish and Game 1981a, 1981b and 1982a).

4/ ADF&G Fishery Biologist II, Soldotna.

- Most tributaries of Susitna River tributary main stems are considered unproductive because most dry up during the winter. The surface areas of most tributaries are unknown.

- For determining the number of smolts/acre/yr, an individual smolt size of .01 lb was used which is a reasonable size for Alaskan chinook smolts according to data in Engel (1968), Francisco and Dinneford (1977), Mr. Paul Kissner 5/ (pers. comm., October 26, 1982), Meehan and Siniff (1962), and Trasky (1974).

Assumption 5.

- The adult chinook salmon production of upper Susitna River tributaries is 40.6 lb of adults/acre/yr or 2 adults/acre/yr.
- The average size of a commercially-harvested Susitna River chinook salmon is 16.7 lb (Mr. Jim Browning, pers. comm., November 23, 1982b).

- A chinook smolt to adult marine survival of 3% (Alaska Department of Fish and Game 1982b) is assumed.

4.1.3 Coho Salmon

The coho salmon production potential of upper Susitna River tributaries was determined using the following assumptions.

Assumption 1.

- Upper Susitna River tributaries that could produce salmon have no barriers to smolt emigration, including the Susitna River main stem rapids at Devil Canyon and Devil Creek.

Assumption 2.

- Upper Susitna river tributaries that could produce salmon are accessible to adult salmon if they can pass through the Susitna River rapids at Devil Canyon and Devil Creek; and if they can negotiate streams or stream sections that have a maximal slope of .03 over a 0.5 mile distance, and have typical adult resting areas, e.g., pools, undercut stream banks, and sloughs.

5/ ADF&G Fishery Biologist III, Juneau.

Assumption 3.

- Each coho salmon spawning pair requires 126 ft^2 of area (Bell 1973).

- One percent of the surface area of Susitna River tributary main stems has acceptable pools and riffles, gravel, and water for successful adult spawning and incubation. The number "one percent (1%)" was selected because of severely restricted water flows during the winter and early spring incubation period. Williams (1975) noted that many small tributaries of the upper Susitna River are dry during this period. Comparisons between monthly winter and summer water discharges for the upper Susitna River at Gold Creek station (Alaska Department of Fish and Game 1982a) indicate that winter water flows of tributaries may periodically be only 1% to 5% of summer flows.

- Most tributaries of Susitna River tributary main stems are unacceptable for incubation since most dry up during the winter as was noted for many small tributaries of the upper Susitna River by Williams (1975).

- Coho redds are not superimposed by other salmon species.

Assumption 4.

- The smolt production of Upper Susitna River tributary main stems is 0.18 lb of smolts/acre/yr or 40 smolts/acre/yr. This production in weight of smolts was selected since it is conservative relative to coho smolt production in other more productive Pacific Northwestern streams (Table 4-3).

- Most tributaries of Susitna River tributary main stems are considered unproductive because most dry up during the winter. The surface areas of most tributaries are unknown.

- For determining the number of smolts/acre/yr, an individual smolt size of .02 lb was used, which is a reasonable size for stream produced Alaskan coho smolts according to data of Armstrong (1970), Crone and Bond (1976), Meehan and Siniff (1962), and Thedinga and Koski (1982).

Table 4-3. Coho salmon smolt production for streams in Alaska, British Columbia, Oregon and Washington.[1]

	Pounds of smolts/acre/yr	Number of smolts/acre/yr
Range of annual values	5-50	221-2,699

[1]/From data listed in or based on analysis of data in Chapman (1965), Crone (1981), Crone and Bond (1976), Hunter (1959), Mason (1976), Salo and Bayliff (1958), Thedinga and Koski (1982).

Assumption 5.

- The adult coho salmon production of upper Susitna River tributaries is 24.7 lb of adults/acre/yr or 4 adults/acre/yr.

- The average size of a commercially-harvested Susitna River coho salmon is 6.1 lb (Mr. Jim Browning, pers. comm., November 19, 1982).

- A coho smolt to adult marine survival of 10% (Alaska Department of Fish and Game 1982b) is assumed.

4.1.4 Chum Salmon

The chum salmon production potential of upper Susitna River tributaries was determined using the following assumptions.

Assumption 1.

- Upper Susitna River tributaries that could produce salmon have no barriers to fry emigration, including the Susitna River main stem rapids at Devil Canyon and Devil Creek.

Assumption 2.

- Upper Susitna River tributaries that could produce salmon are accessible to adult salmon if they can pass through the Susitna River rapids at Devil Canyon and Devil Creek; and if they can negotiate streams or stream sections that have a maximal slope of .03 over a 0.5 mile distance, and have typical adult resting areas, e.g., pools, undercut stream banks, and sloughs.

Assumption 3.

- Each chum salmon spawning pair requires 99 ft^2 of area (Bell 1973).

- One percent of the surface area of Susitna River tributary main stems has acceptable pools and riffles, gravel, and water for successful adult spawning and incubation. The number "one percent (1%)" was selected because of severely restricted water flows during the winter and early spring incubation period. Williams (1975) noted that many small tributaries of the upper Susitna River are dry during this period. Comparisons between monthly winter and summer water discharges for the upper Susitna River at Gold Creek station (Alaska Department of Fish and Game 1982a) indicate that winter water flows of tributaries may periodically be only 1% to 5% of summer flows.

- Most tributaries of Susitna River tributary main stems are unacceptable for incubation since most dry up during the winter as was noted for many small tributaries of the upper Susitna River by Williams (1975).

- Chum redds are not superimposed by other salmon species.

Assumption 4.

- The emigrant fry production of upper Susitna River tribuary main stems is 62 lb of fry/acre/yr or 121,000 fry/acre/yr. This production in weight of fry is based on an average fry weight of .0008 lb from data at the ADF&G Beaver Falls hatchery (Mr. Dan Rosenberg6/, pers. comm., July 9, 1980). This weight is reasonable for an emigrant fry with an average length of 1.46 inch which was derived from data for Talkeetna River (Friese 1975) and lower Susitna River chum fry (Kent Roth 7/, pers. comm., November 30, 1982).

- The number of fry/acre/yr is based on a female adult chum spawning area of 99 ft^2 (Bell 1973), an average fecundity of 2,200 eggs/female chum (Alaska Department of Fish and Game 1982b), 100% egg deposition/female, and a deposited egg to emigrant fry survival of 12.5% which is based on data in Crone and Bond (1976), Foerster (1968), and Hunter (1959).

Assumption 5.

- The adult chum salmon production of upper Susitna River tributaries is 9,329 lb of adults/acre/yr or 1,210 adults/acre/yr.

- The average size of a commercially-harvested Susitna River chum salmon is 7.7 lb (Mr. Jim Browning, pers. comm., November 19, 1982).

- An emigrant fry to adult marine survival of 1% (Alaska Department of Fish and Game 1982b) is assumed.

4.1.5 Field Surveys

Surveys of upper Susitna River tributaries and lakes were necessary for obtaining otherwise unavailable information for assessing salmon enhancement potential and enhancement techniques.

4.1.5.1 Fixed-wing aircraft overview

The purpose of this survey was to study the terrain and future survey sites within the entire upper Susitna River watershed.

The upper Susitna River main stem was overflown from lower Devil Canyon

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6/ ADF&G Fish Culturist IV, Klawock hatchery.

7/ ADF&G Fishery Biologist II, Anchorage.

upstream to Susitna Lodge on July 13, 1982. All tributary streams were seen, and all named and some unnamed streams were photographed.

4.1.5.2 Helicopter survey

The purpose of this two-day survey (August 4 and 5, 1982) was on-the-ground assessment of the salmon enhancement potential of most streams and lakes (Plate 4-1) in the upper Susitna River area that are inaccessible to road vehicles.

More than 25 named and unnamed streams and lakes were surveyed. We made the following observations concerning conditions at stream confluences (and various distances upstream) with the Susitna River and at lake outlets:

1) Water quality for adult and juvenile salmon. Water temperature, dissolved oxygen, conductivity, and pH were measured.

2) Water velocity.

3) Stream width, depth, pool-riffle ratio, and gravel availability at various distances upstream of stream confluences with the Susitna River and at lake outlets.

4) Any barriers to migration of adult and juvenile salmon.

5) Presence and location of any fish species that may prey on, and compete for food and space with salmon (or vice versa).

4.1.5.3 Road vehicle survey

This survey was undertaken during September 15,16, and 17, 1982. The periphery of the Susitna River drainage area was examined via truck (Plate 4-2) on the Glenn, Richardson, Denali and Parks Highways.

The survey was intended to:

1) Evaluate the adult spawning and juvenile rearing potentials in streams and lakes adjacent to the road system. This included assessement of lake and stream depth, width, water temperature, turbidity, gravel, pool-riffle areas, stream velocity, accessibility to salmon, and presence of fish and mammals.

2) Identify sites for stocking of juvenile salmon into streams and lakes.

3) Examine potential hatchery sites for producing juvenile salmon to stock into streams and lakes.

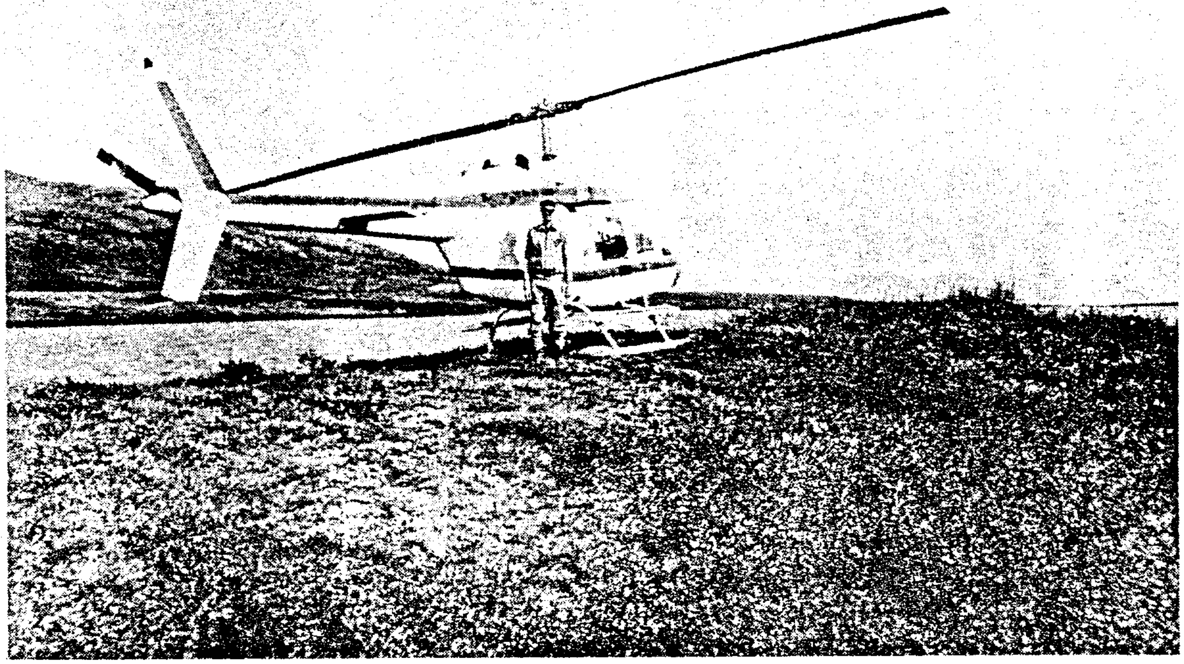

Plate 4-1. Helicopter at Butte Lake.

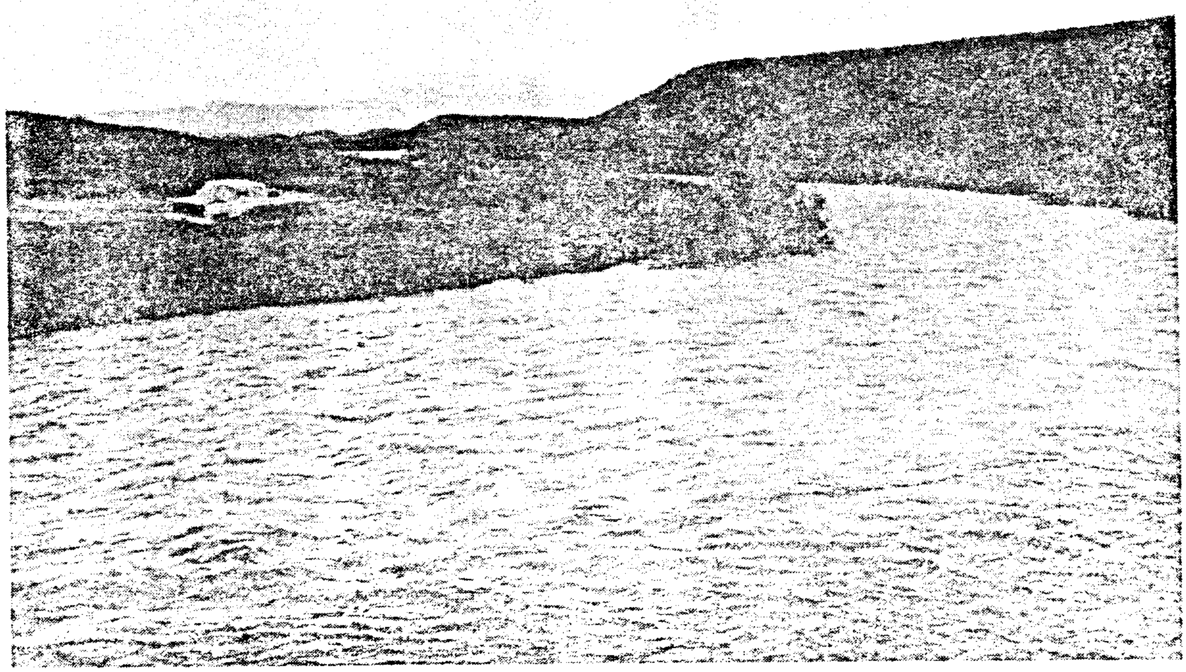

Plate 4-2. State vehicle at Clearwater Creek.

4.1.5.4 Tyone River system surveys

The large lakes within the Tyone River system, a tributary of the upper Susitna River, have the potential for producing a large number of sockeye salmon. To assist with the estimation of juvenile sockeye production in these lakes, a limnological survey was planned in late September, 1982. This and another attempted survey in October, 1982 were cancelled because of very hazardous weather.

4.1.6 Determination of Stream and Lake Surface Areas

Knowledge of stream and lake surface areas are essential for determining salmon production since production is definitely related to surface area (Burns 1971; Hayes and Anthony 1964; Youngs and Heimbuch 1982). Streams and lakes were selected for potential salmon production based on:

1) Knowledge of stream main stem lengths (Orth 1971), and stream widths in different sections of each stream from Alaska Department of Fish and Game (1981c), and 1982 helicopter and road vehicle surveys.

2) Aquatic habitat surveys which included water quality and quantity, pool-riffle relationships, accessibility to salmon, gravel availability, and presence of fish which prey on or compete with salmon (Alaska Department of Fish and Game 1981c, 1982a; Allin 1957; Andrews 1961; Mr. Christopher Estes 8/, Mr. Kent Roth, Mr. Joe Sautner9/, Mr. Dana Schmidt 10/, pers. comm., August 2, 1982; Mr. Fred Williams11/ pers. comm., October 7, 1982, August 10, 1982; Williams 1964, 1965, 1966, 1967, 1969, 1972; Williams and Potterville 1978). Additional aquatic habitat surveys were conducted during the 1982 fixed-wing aircraft , helicopter, and road vehicle surveys.

   Stream areas were calculated from stream length and width data or by planimeter using maps. Stream area was assumed equal to a rectangle for a short stream length when average widths were known and the widths were similar throughout the specific length of stream. Stream area was assumed equal to a trapezoid when stream widths were dissimilar throughout the stream length, e.g., when the area of an entire stream main stem was determined.

   All lake areas were obtained via planimeter on maps, except for Lake Louise, which was obtained from Mr. Stan Jones12/ (pers. comm., September 7, 1982).

4.1.7 Biological Impact of Introduced Salmon on Resident Fish

Predator-prey relationships and competition between salmon and resident fish were examined via literature research. Results of this research are found in Section 5.3.

8/ ADF&G Fishery Biologist III, Anchorage.

9/ ADF&G Fishery Biologist II, Anchorage.

10/ ADF&G Fishery Biologist III, Anchorage.

11/ ADF&G Fishery Biologist III, Glennallen.

12/ United States Geological Survey, Anchorage.

4.2 Engineering Studies

4.2.1 Feasibility Studies

The primary engineering concern of this study was to determine if it was feasible to bypass salmon through the velocity barriers in the confines of Devil Canyon and the general consensus was that "bypass methods" primarily meant fishways. In a feasibility study, preliminary sketch plans and preliminary cost estimates with conclusions and recommendations can usually be produced without incurring the expense of extended field work and the detailed investigations needed for the preparation of construction documents. In reviewing the abundant data available on the Susitna River and its drainage basin, the study team concluded that it could indeed determine the feasibility of bypassing salmon through the Devil Canyon area, by means of a fishway or fishways, without having to undertake time consuming and costly field investigations.

The study team did feel, however, that literature research alone was inappropriate because the "Susitna River data" did not contain river velocity information in the Devil Canyon area during the times of the salmon migrations. Then too, the biological information on the lakes and tributaries upstream of Devil Canyon was sketchy or missing entirely. For these reasons some field work was deemed necessary.

Following is a brief description of the engineering studies performed by the study team.

July 13: Overflew the entire upper Susitna River drainage basin with a biologist and engineering personnel (Figure 4-1). The purpose of the overflight was to acquaint the study team with the terrain, the size of the study area and to identify any features in the area that may require on-site inspection.

Aug. 4 & Aug. 5: These two days were spent in on-site investigations by the study teams. By means of helicopter transportation, the engineers inspected the canyon walls and stream banks in Devil Canyon (Plate 4-3) and in the vicinity of Devil Creek. Observations were made from as low as 20 ft, and where conditions permitted, landings were made to permit on ground inspection. The engineers were successful in measuring the surface velocities through Devil Canyon by dropping marker buoys from the helicopter and timing their transit through predetermined distances (Table 4-4). The measuring of these velocities was fortunate as it was on August 5 that the Susitna Hydro Aquatic Studies Group made their first sighting of adult chinook salmon upstream of Devil Canyon. The passage of upstream migrant salmon through Devil Canyon during the period of measured velocities and a known river level greatly assisted in establishing fishway parameters. While the engineers were observing the hydraulic conditions in Devil Canyon, a second helicopter transported the study team's biologists to selected lakes and streams in the upper drainage basin. Details of the biologists' investigations are found in Section 4.1.

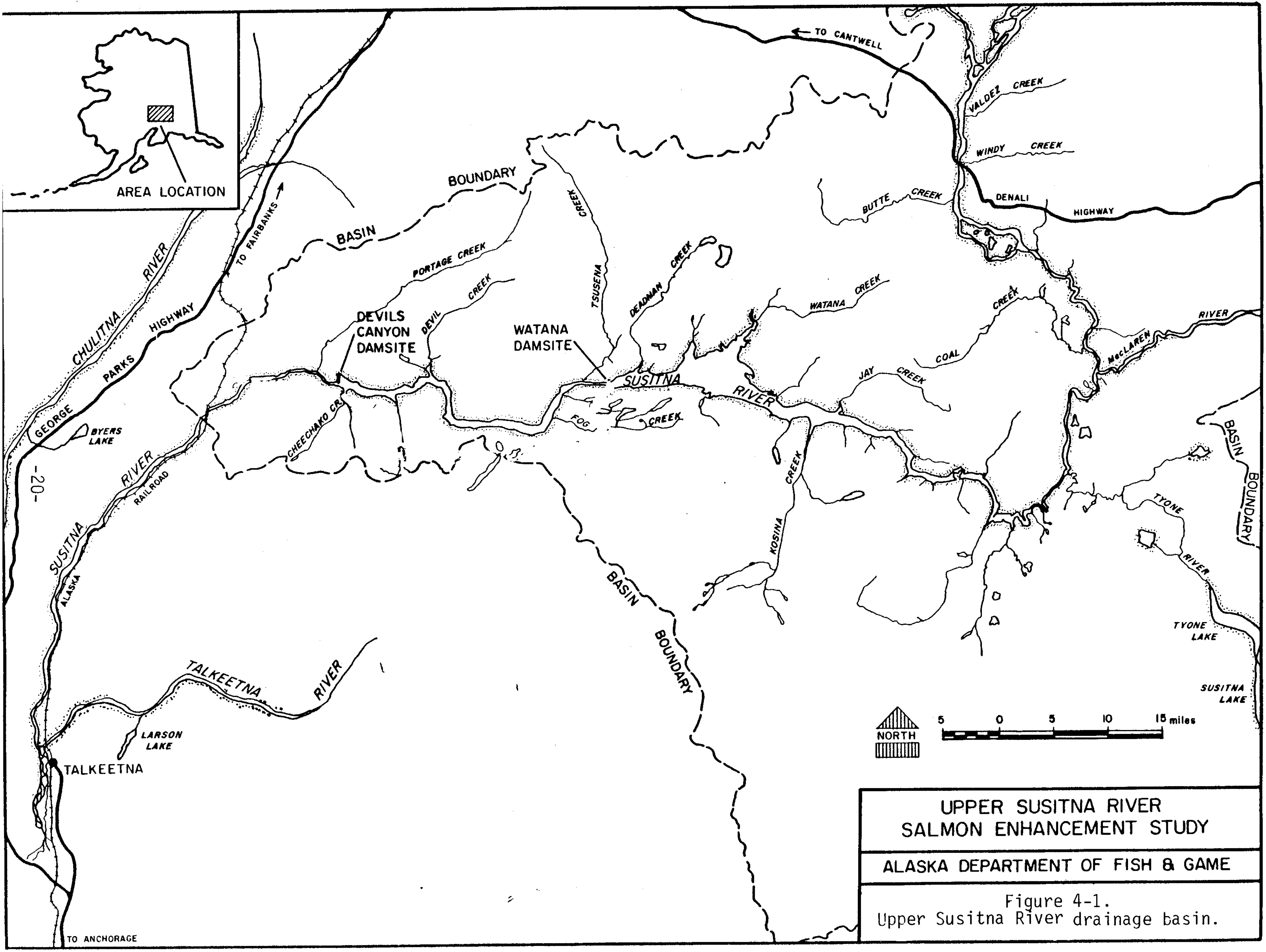

Figure 4-1.
Upper Susitna River drainage basin.

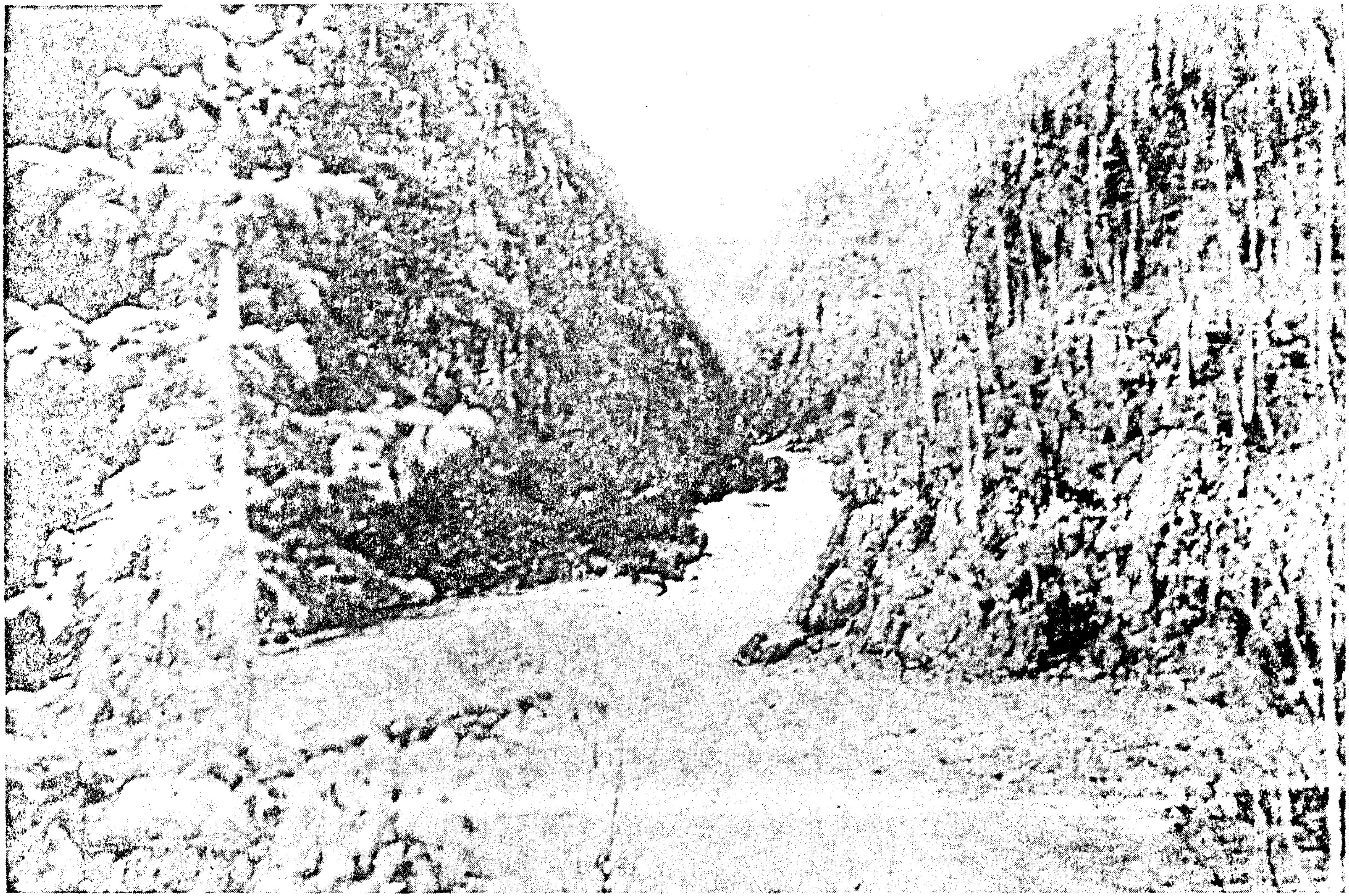

Plate 4-3. Devil Canyon looking downstream from proposed dam site (from Alaska Power Authority).

Table 4-4. Devil Canyon velocity measurements.

R & M Consultants (1982)
4/13/81 & 4/14/81

Station number	Distance between stations (ft)	Velocity (ft/sec)
2		
	1400	
3		
	200	3.0
4		
	140	
5		
	180	
6		
	200	6.0
7		
	200	
8		
	155	
9		
	325	8.6
10		
	200	4.5
11		
	200	
12		
	400	6.4
13		

ADF&G
8/5/82

Station number	Distance between stations (ft)	Velocity (ft/sec)
2		
	1400	14.1
3		
	520	13.6
6		
	880	13.3
10		
	800	13.3
13		

Aug. 31: This was a similar site investigation trip as that described for August 4 & 5 except that on this trip Mr. Milo C. Bell, a noted fisheries engineer, accompanied the study team. Again, close attention was made of the hydraulic conditions within Devil Canyon and the canyon area immediately downstream of Devil Creek. A report on Mr. Bell's observations and recommendations is contained in the appendix 10.4.

Sept. 15 - Sept. 17: This ground inspection trip was to evaluate the potential rearing areas in the upper Susitna River drainage basin and to locate hatchery sites for use in conjunction with a juvenile stocking program. The study team drove the periphery of the drainage area via the Glenn, Richardson, Denali and Parks highways (Figure 4-2). The emphasis of this investigation was the evaluation of adult spawning and juvenile rearing streams that are accessible to the road system. Stream crossings of the Denali highway made it possible to take water temperatures and observe stream bed conditions in many locations. This information was not only useful in projecting probable production capacities but identified several initial stocking points for juvenile salmon should a salmon enhancement program in the upper Susitna River drainage basin be implemented.

4.2.2 Design Studies

Although the feasibility studies described in Section 4.2.1 are sufficient to support the findings and recommendations in this report, it should be pointed out that further detailed studies would be needed to design any of the facilities recommended. In particular the following studies/investigations would have to be completed before commencing with the design of a fishway(s) in Devil Canyon. The following studies are both biological and engineering in nature:

1) A thorough topographic survey of the blockage area(s). This survey should include, if possible, the contours of the river bottom.

2) A hydrological study of the blockage area(s) during the months of the upstream salmon migrations. This study should determine the river levels during all periods of migration and should determine the stream velocities at both banks and the location of points of turbulence and upwelling.

3) A geotechnical investigation to include both surface examinations and sub-surface exploratory drilling.

4) Additional studies regarding construction requirements and site access.

5) Sonic tagging studies of upstream migrants to determine, if possible, their migration route(s) within the blockage area(s).

6) Hydraulic model studies. This is a desireable but not a mandatory study. Due to the certain high cost of any fishway(s) constructed in Devil Canyon the cost of a model study could certainly be justified.

7) Refined cost estimate. Based on the detailed information obtained in studies (1) through (6) a refined cost estimate could influence a decision on whether or not a proposed project should proceed.

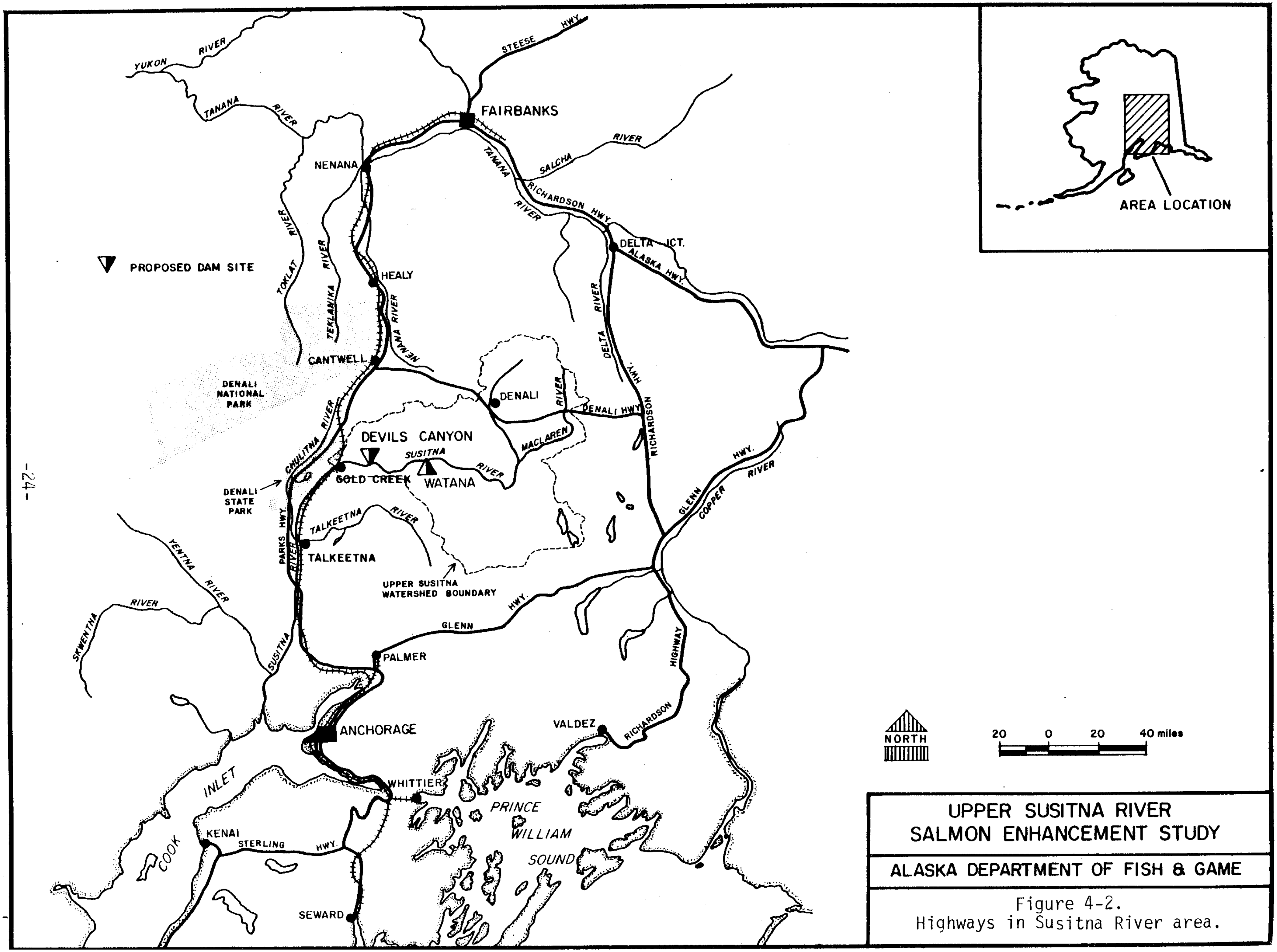

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Figure 4-2.
Highways in Susitna River area.

5. RESULTS AND DISCUSSION

5.1 Salmon Enhancement Potential (S.E.P.)

5.1.1 S.E.P. Without Hydroelectric Dams

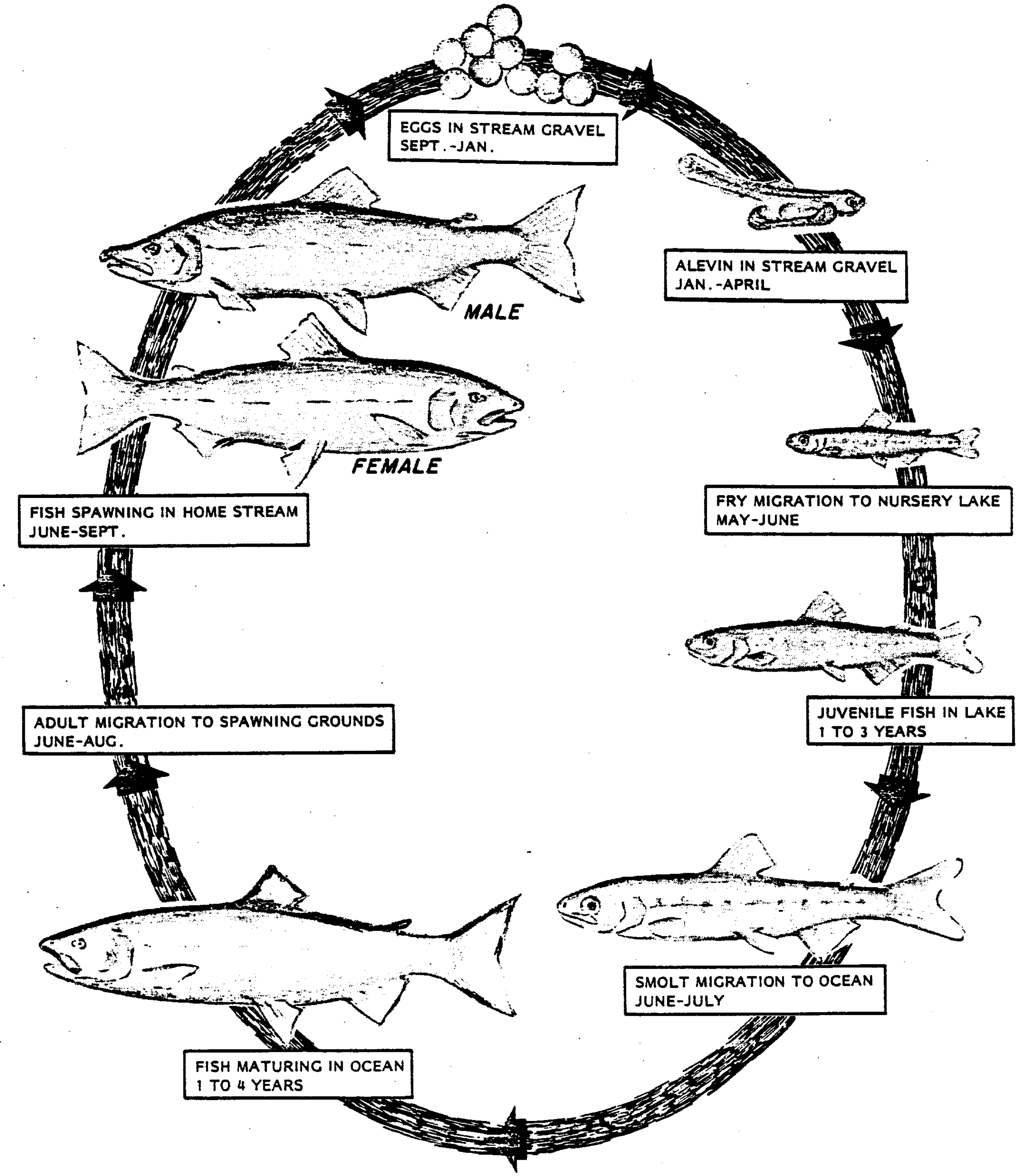
The upper Susitna River watershed is suitable for the rearing of salmon. The problem is that the watershed is not accessible to salmon. However, adult salmon could be introduced into the watershed via fishways or juvenile salmon could be introduced into the watershed by means of hatchery stocking. A fishway enhancement program and a hatchery enhancement program are described in sections 5.2.3 and 5.2.4.

Juvenile salmon production in the upper Susitna River watershed with resultant adult production is now considered for each salmon species.

5.1.1.1 Sockeye Salmon

The life cycle of sockeye salmon is depicted in Figure 5-1.

Selected lakes in the upper Susitna River basin will produce approximately 1,600,000 sockeye smolts (Table 5-1). These smolts will produce approximately 160,000 adults (Table 5-1). Of the 31 lakes considered for producing sockeye salmon, the three largest lakes, viz. Lake Louise, Susitna Lake, and Tyone Lake (Plate 5-1), produce 120,000 adults or 75% of the total.



(McNeil and Bailey 1975)

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Figure 5-1.
Life cycle of sockeye salmon.

Table 5-1. The potential production of sockeye salmon in upper Susitna River lakes.

Lake	Lake surface area (acres)	Smolts (number)	Adults (number)
Lake Louise	14,720	699,200	69,920
Susitna Lake	9,000	427,880	42,788
Tyone Lake	1,600	76,000	7,600
Little Lake Louise	1,020	48,639	4,864
Lake 2505[1/], Tyone River system	919	43,168	4,317
Beaver Lake	896	42,560	4,256
Dog Lake	750	35,690	3,569
Butte Lake	704	33,440	3,344
Moore Lake	640	30,400	3,040
Sandy Lake	403	19,152	1,915
Clarence Lake	378	17,940	1,794
Lake Creek lakes	346	16,416	1,642
Mud Lake	326	15,504	1,550
Fog Lake, nearest Fog Creek	314	14,900	1,490
Lily Lake	256	12,160	1,216
Snodgrass Lake	250	11,856	1,186
Osar Creek lakes	230	10,944	1,094
Grayling Lake	205	9,729	973
Black Lake	204	9,728	973
Lake 3285[1/], Kosina Creek system	128	6,080	608
Lake 2460[1/], Tyone River system	128	6,080	608
Tabert Lake	122	5,776	578
Roosevelt Lake	57	2,736	274
Glaser Lake	32	1,520	152
Total:	33,628	1,597,498	159,751

1/ Elevation in feet.

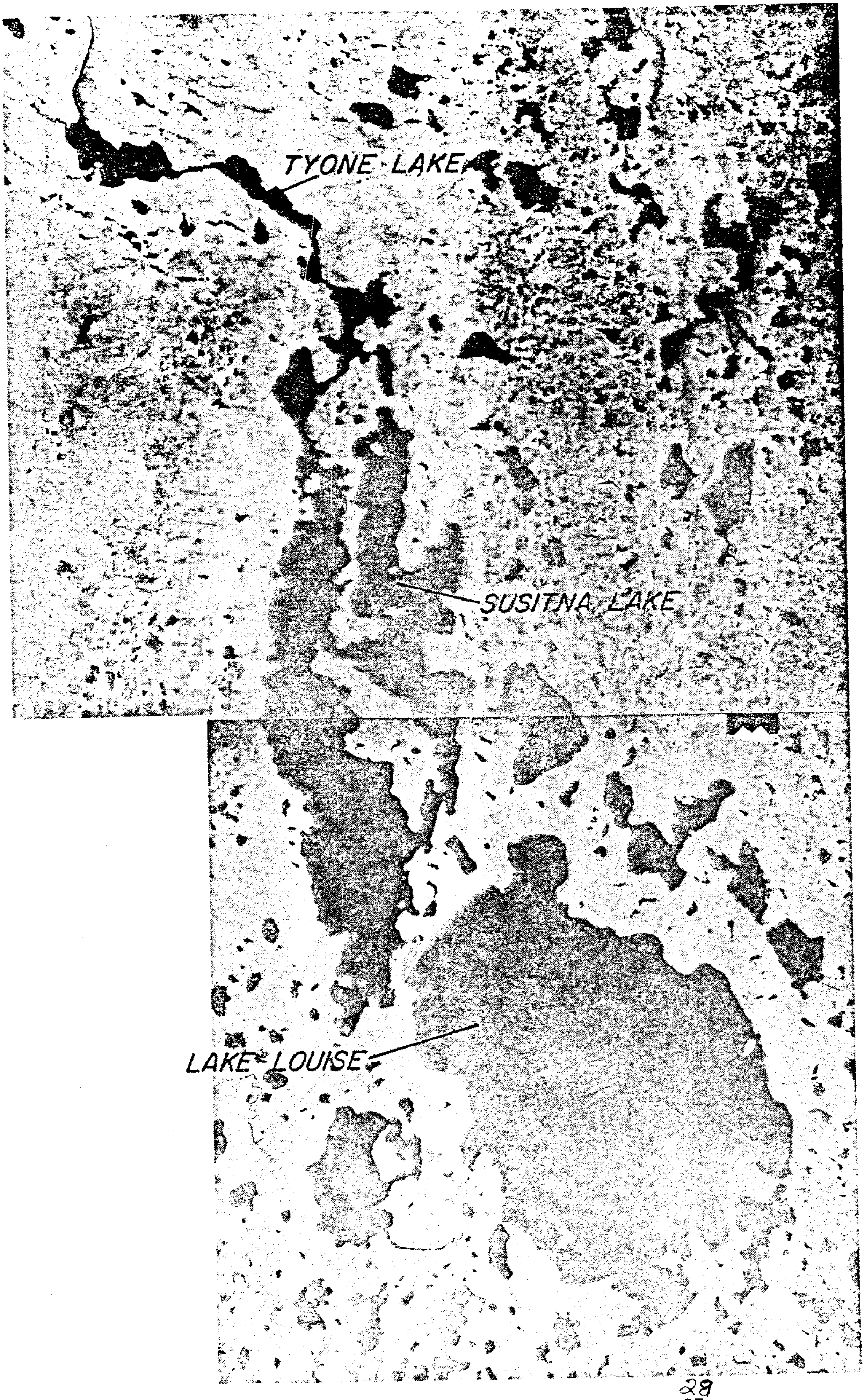


Plate 5-1. The Tyone River system lakes.

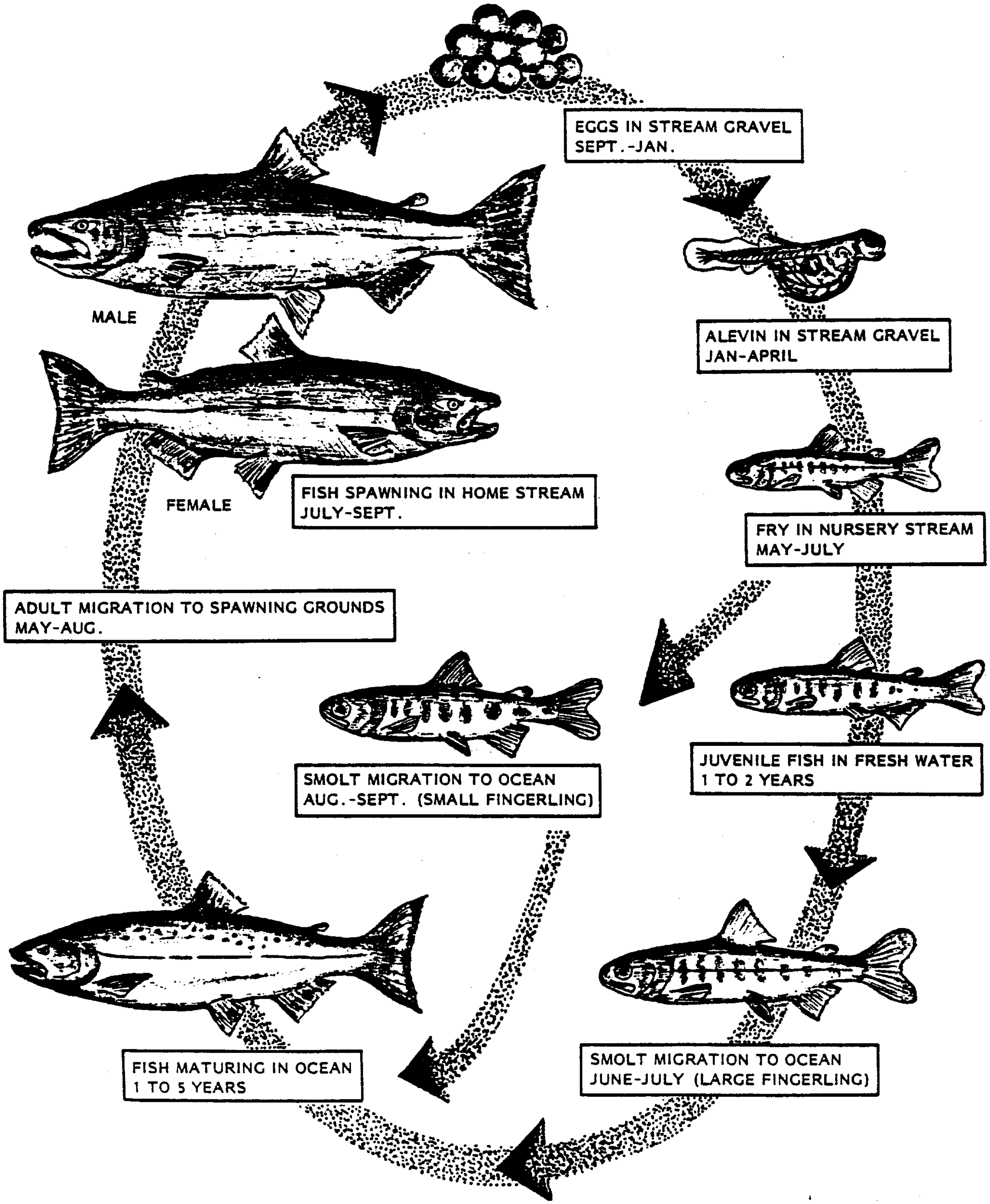
5.1.1.2 Chinook Salmon

The life cycle of chinook salmon is depicted in Figure 5-2.

Selected streams in the upper Susitna River basin will produce approximately 100,000 chinook smolts (Table 5-2). These smolts will produce approximately 3,000 adults (Table 5-2). Of the 21 streams considered for producing chinook salmon, the following eight streams produce 2,880 adults or 95% of the total: Tyone River, Oshetna River, Kosina Creek, Clearwater Creek, Watana Creek, Butte Creek, Fog Creek, and Coal Creek (Plates 5-2 through 5-9). Two streams, Tyone River and Oshetna River, together produce 1,618 adults or 53% of the total.

Table 5-2. The potential production of chinook salmon in upper Susitna River tributaries.

Tributary	Tributary surface area (acres)	Smolts (number)	Adults (number)
Tyone River	382.50	30,972	929
Oshetna River	283.37	22,945	688
Kosina Creek	179.30	14,518	436
Clearwater Creek	171.27	13,868	416
Watana Creek	74.20	6,009	180
Butte Creek	38.74	3,137	94
Fog Creek	35.46	2,871	86
Coal Creek	22.73	1,840	55
Valdez Creek	16.17	1,310	39
Windy Creek	15.76	1,275	38
Tsusena Creek	6.94	562	17
Jay Creek	6.19	501	15
Goose Creek	2.73	221	7
Waterfall Creek	2.56	207	6
Sandy Creek	2.46	199	6
Raft Creek	2.30	186	6
Lake Creek	2.00	162	5
Snodgrass Lake creek	1.70	138	4
Deadman Creek	1.60	129	4
Boulder Creek	1.08	187	3
Devil Creek	.26	21	2
	1,249.32	101,158	3,036



(From McNeil and Bailey 1975)

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Figure 5-2.
Life cycle of chinook salmon.

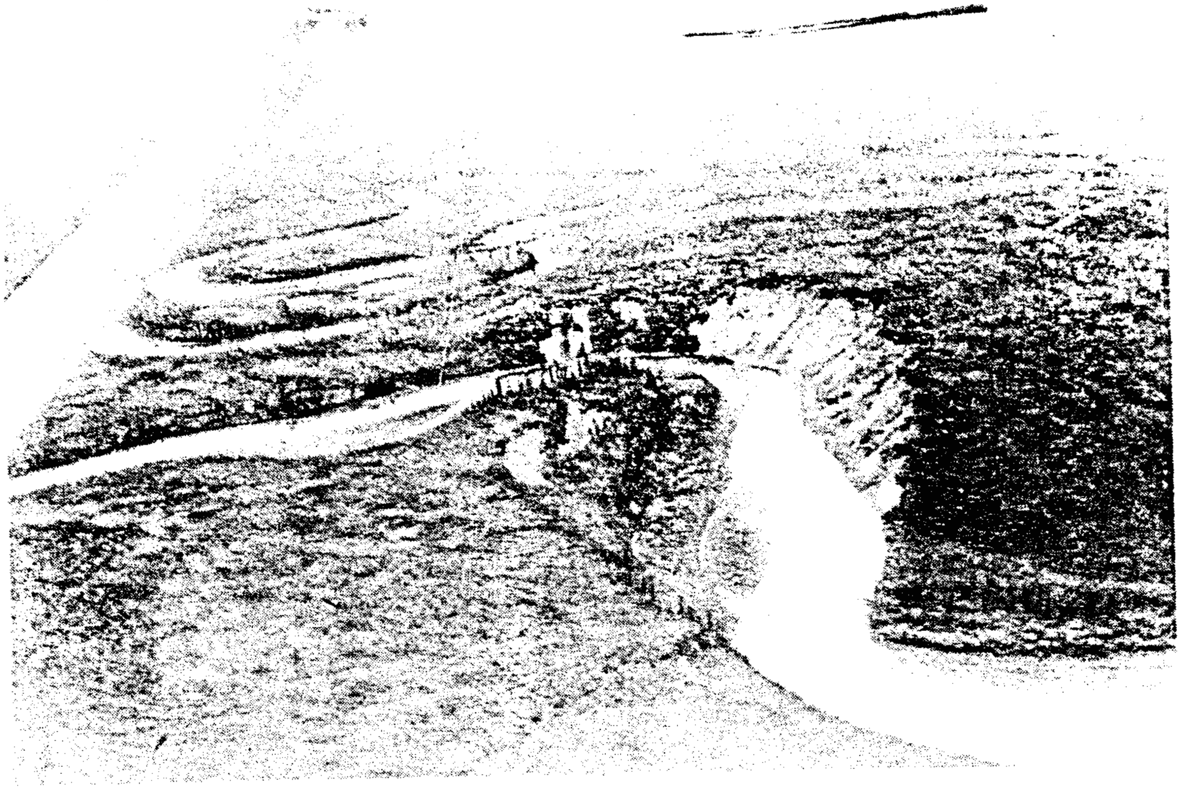


Plate 5-2. The Tyone River just upstream from its confluence with the Susitna River.

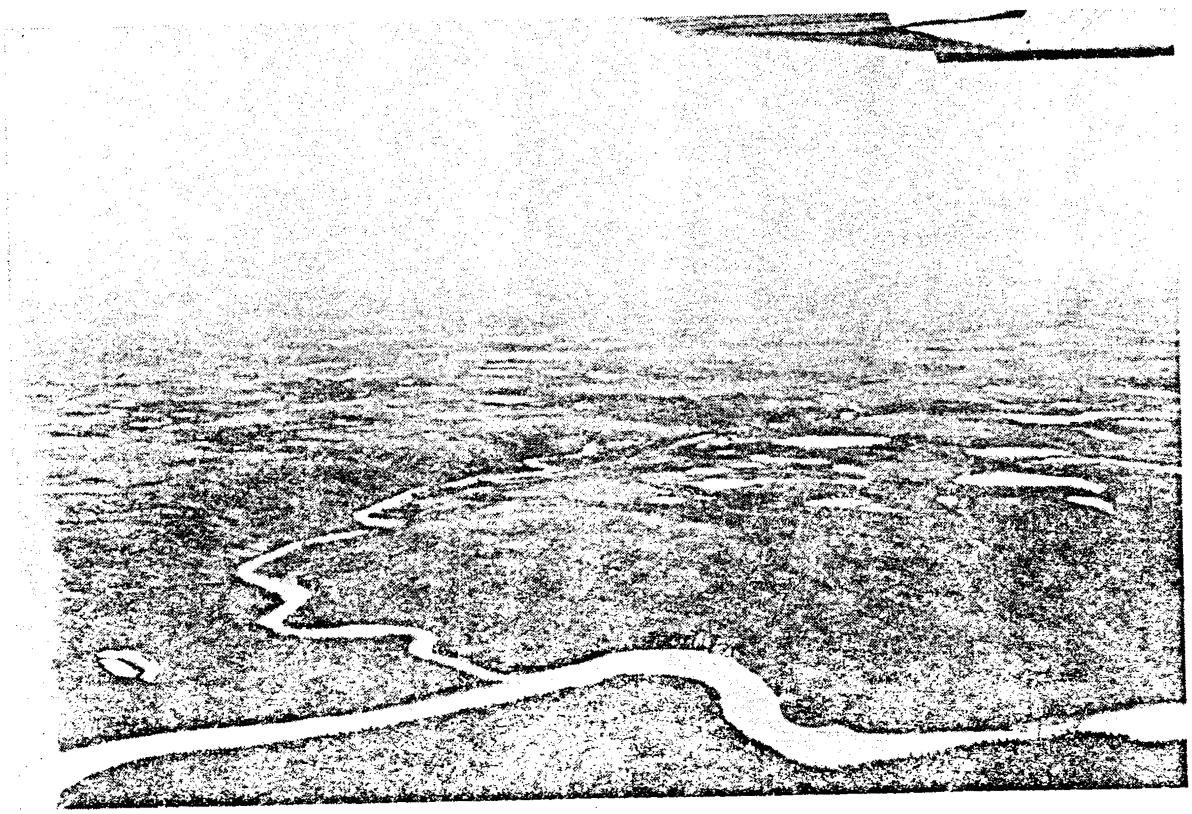


Plate 5-3. The Oshetna River at its confluence with the Susitna River.

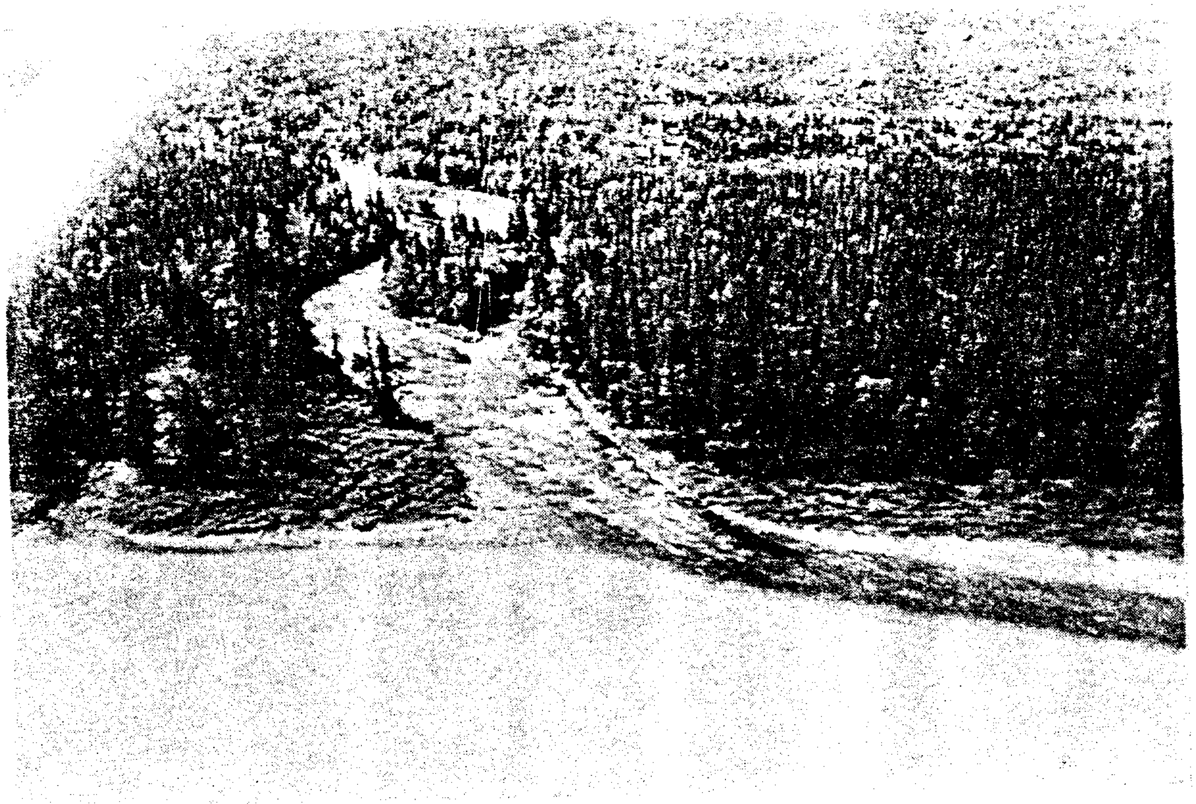


Plate 5-4. Kosina Creek at its confluence with the Susitna River.

Plate 5-5. Clearwater Creek just upstream from its confluence with the Susitna River.

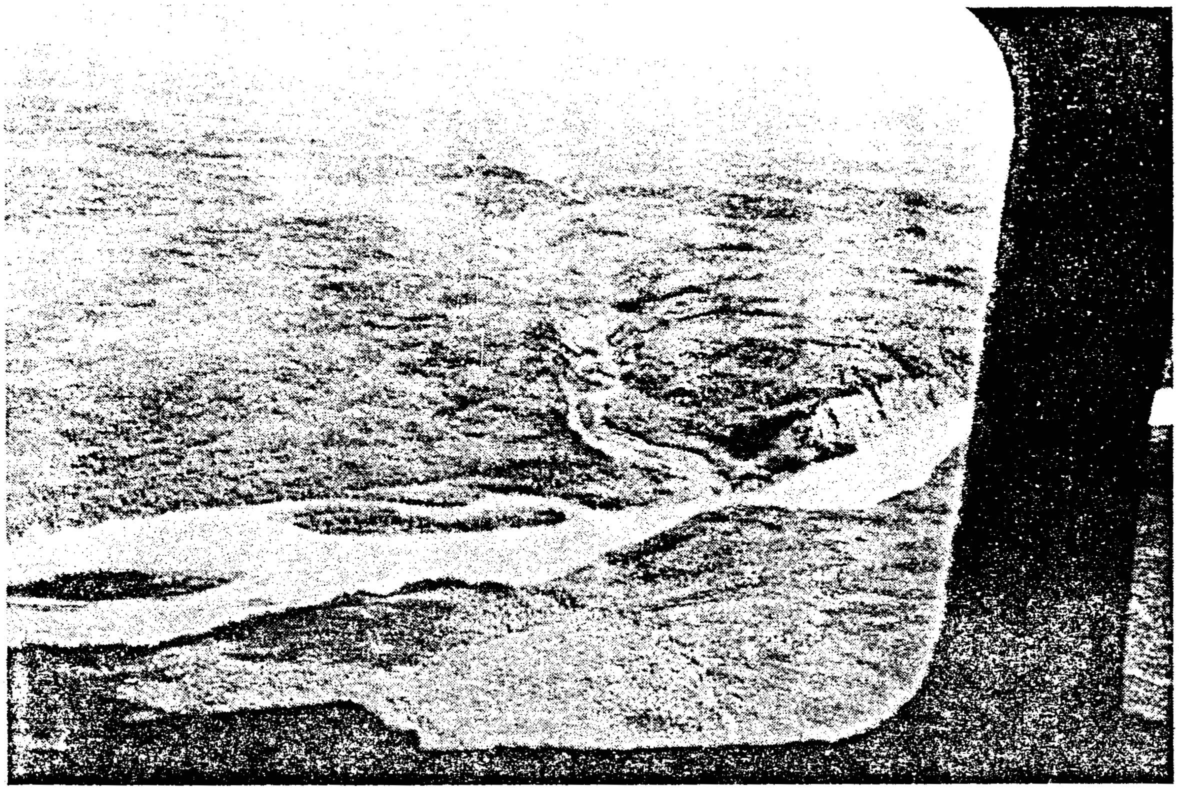


Plate 5-6. Watana Creek at its confluence with the Susitna River.

Plate 5-7. Butte Creek at the outlet of Butte Lake.

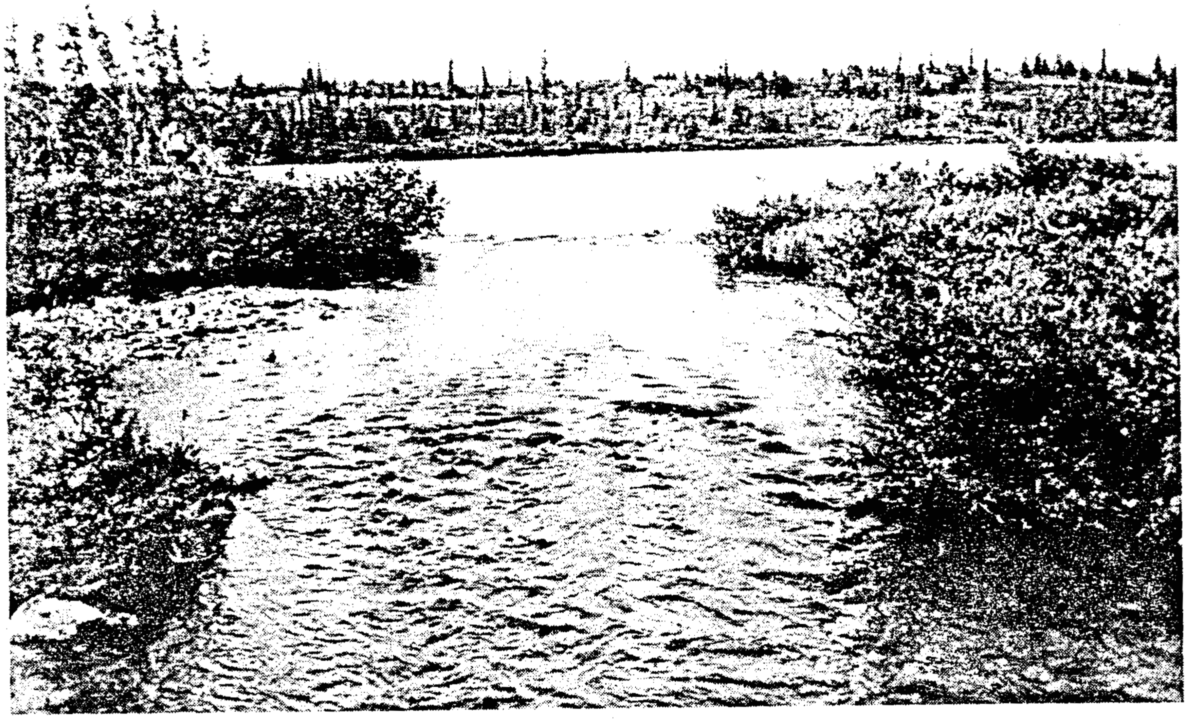


Plate 5-8. Fog Creek at the outlet of Fog Lake.

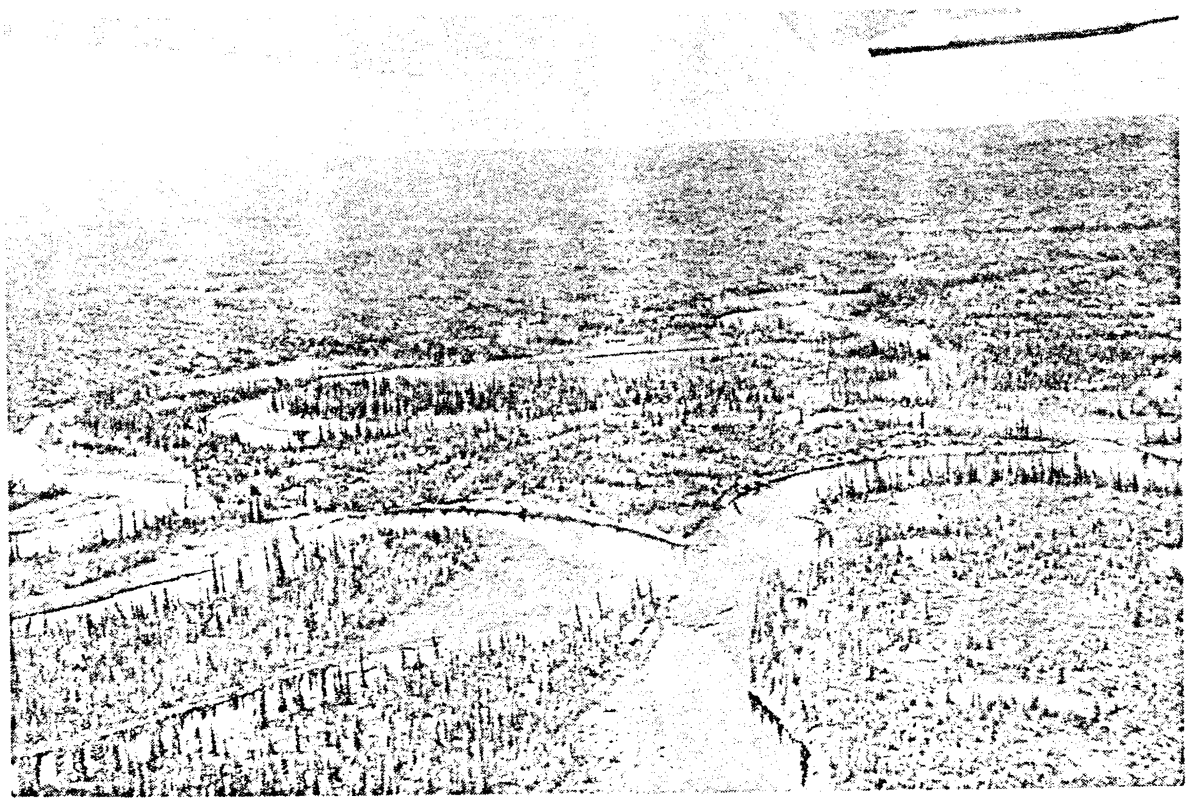


Plate 5-9. Coal Creek.

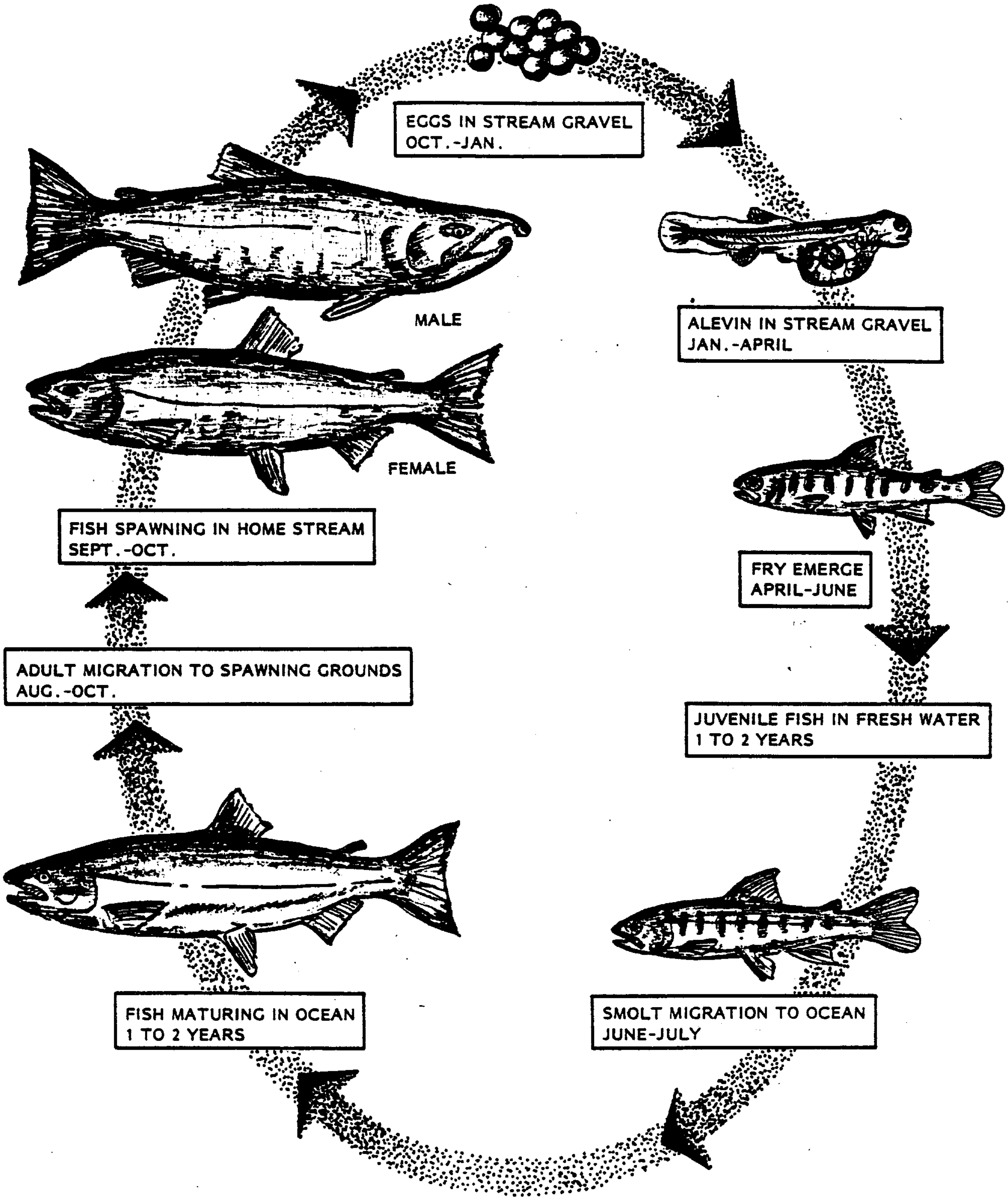
5.1.1.3 Coho Salmon

The life cycle of coho salmon is depicted in Figure 5-3.

In addition to chinook salmon, selected streams in the upper Susitna River basin will produce approximately 51,000 coho smolts (Table 5-3). These smolts will produce approximately 5,100 adults (Table 5-3). Of the 21 streams considered for producing coho salmon, the same eight streams listed for chinook salmon produce 4,800 coho adults or 94% of the total. The Tyone and Oshetna Rivers together produce 2,700 coho adults or 53% of the total.

Table 5-3. The potential production of coho salmon in upper Susitna River tributaries.

	Tributary surface area (acres)	Smolts (number)	Adults (number)
Tyone River	382.50	15,486	1,549
Oshetna River	283.37	11,473	1,147
Kosina Creek	179.30	7,259	726
Clearwater Creek	171.27	6,934	693
Watana Creek	74.20	3,004	300
Butte Creek	38.74	1,568	157
Fog Creek	35.45	1,435	144
Coal Creek	22.73	920	92
Valdez Creek	16.17	655	66
Windy Creek	15.76	638	64
Tsusena Creek	6.94	281	28
Jay Creek	6.19	250	25
Goose Creek	2.73	111	11
Waterfall Creek	2.56	104	10
Sandy Creek	2.46	100	10
Raft Creek	2.30	93	9
Lake Creek	2.00	81	8
Snodgrass Lake creek	1.70	69	7
Deadman Creek	1.60	64	6
Boulder Creek	1.08	44	4
Devil Creek	.27	11	2
Total:	1,249.34	50,580	5,058



(From McNeil and Bailey 1975)

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Figure 5-3.
Life cycle of coho salmon.

5.1.1.4 Chum Salmon

The life cycle of chum salmon is depicted in Figure 5-4.

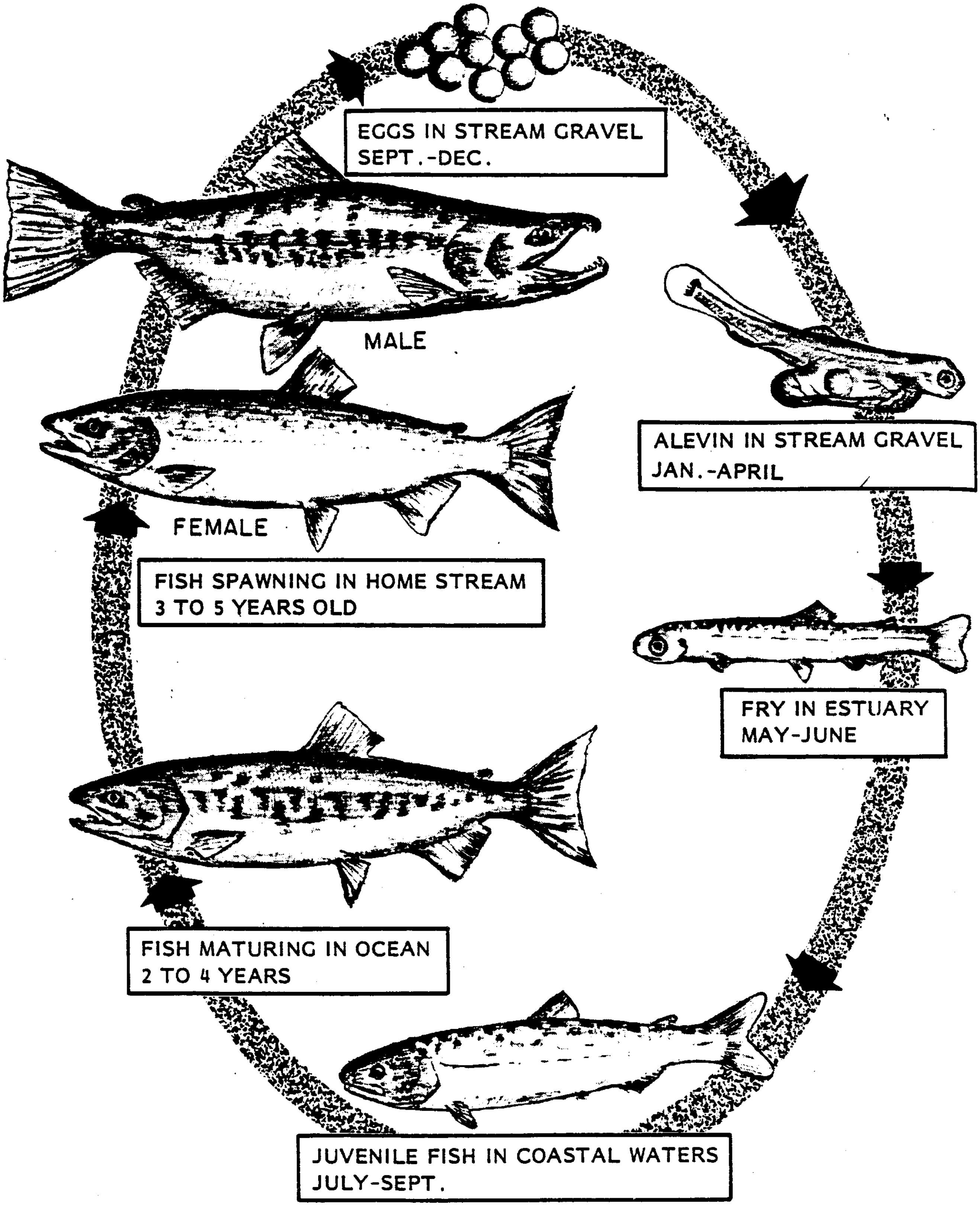
In addition to chinook and coho salmon, selected streams in the upper Susitna River basin will produce approximately 970,000 emergent chum fry (Table 5-4). These fry will produce approximately 9,700 adults (Table 5-4). Of the 18 streams considered for producing chum salmon, the same eight streams listed for chinook salmon produce 9,105 chum adults or 95% of the total. The Tyone and Oshetna Rivers together produce 5,440 chum adults or 57% of the total.

Table 5-4. The potential production of chum salmon in upper Susitna River tributaries.

	Tributary surface area (acres)	Fry (number)	Adults (number)
Tyone River	3.04	368,300	3,683
Oshetna River	1.45	175,700	1,757
Clearwater Creek	1.38	166,800	1,668
Watana Creek	.59	71,500	715
Kosina Creek	.43	52,250	523
Butte Creek	.31	37,400	374
Fog Creek	.27	33,000	330
Coal Creek	.18	22,000	220
Windy Creek	.13	15,400	154
Valdez Creek	.07	8,000	80
Tsusena Creek	.05	6,623	66
Jay Creek	.05	6,050	61
Waterfall Creek	.02	2,475	25
Goose Creek	.02	2,475	25
Raft Creek	.02	1,925	19
Snodgrass Lake creek	.01	1,650	17
Deadman Creek	.01	1,449	15
Boulder Creek	.01	825	8
Total:	8.04	973,822	9,740

In summation, the upper Susitna River watershed can produce sockeye, chinook, coho and chum salmon if emigration/immigration of juveniles/adults is provided. The potential for sockeye salmon far outweighs that for the other salmon species due primarily to the large lakes in the Tyone River system.

The salmon production potentials are conservative since the biological and limnological data base for streams and lakes is too inadequate to accurately predict the carrying capacity for juvenile salmon. However, certain assumptions may actually be too liberal, e.g., a high percentage of salmon smolts may not survive the rapids in Devil Canyon and Devil Creek areas though 100% survival was assumed.



(From McNeil and Bailey 1975)

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Figure 5-4.
Life cycle of chum salmon.

5.1.1.5 Potential Barriers to Juvenile Salmon Emigration and Adult Immigration

Potential barriers to salmon migration in the Susitna River are located in the upper river at the Devil Canyon and Devil Creek areas. These barriers are rapids and supersaturated gases. Rapids can dash emigrant juveniles against rocks and may delay juvenile emigration by temporarily trapping them in eddies. Juvenile salmon are known to survive movement through rough water including waterfalls. Coho salmon smolts survived numerous high falls at Seldovia River, Kenai Peninsula (Dudiak et al. 1979). This stream drops 265 ft in elevation in a 2 mile-long section and is totally impassable to adult salmon. Pink salmon fry survived the Paint River falls, Alaska Peninsula, which plunge into salt water and can drop more than 40 ft depending on the tide stage. Chinook salmon adults and eggs were found in the upper Susitna River between the Devil Canyon rapids and the Devil Creek rapids for the first time ever in 1982 by ADF&G staff. It is the professional judgement of the ADF&G Susitna Hydro Aquatic Studies Team that juvenile chinook salmon are produced in this area of the upper Susitna River (Mr. Tom Trent 13/, pers. comm., December 3, 1982). Therefore, some juvenile chinook salmon do survive their emigration through the Devil Canyon rapids.

Some juvenile salmon may suffer delayed emigration or mortality during their passage through the rapids. However, experiences noted in the previous paragraph indicate that the mortalities should be negligible.

Adult salmon immigration is definitely partially or even totally blocked by the rapids during high water periods during the summer. Water flow rates may exceed 50,000 cfs through the rapids; 29-year annual mean flows are 28,040, 23,680 and 21,514 cfs for June, July and August, respectively (Alaska Department of Fish and Game 1982a). If fishways are installed, these rapids would no longer be a barrier. The adult chinook salmon observed upstream of the Devil Canyon rapids probably migrated through these rapids during July 1982, during which daily water flows were as low as 14,500 cfs (Mr. George Cunningham 14/, pers. comm., November 12, 1982).

Total dissolved gas concentrations exceeding 110% have been measured in the upper Susitna River rapids though concentrations fluctuate throughout the area (Schmidt 1981). Gas concentrations exceeding 110% can cause mortality of juvenile and adult salmon (Bouck et al. 1976; Dawley and Ebel 1975; Ebel 1969; Ebel et al. 1971; Nebeker et al. 1976, 1979; Rucker 1975; Rucker and Kangas 1974; U.S. Environmental Protection Agency 1976; Westgard 1964). Juvenile salmon emigrating through the rapids during May and June could encounter total dissolved gas concentrations exceeding 101% over a 40 mile distance with concentrations exceeding 110% over an 18 mile distance. Water velocity measurements taken in Devil Canyon during the summer of 1982 (Table 4-4) along with extrapolations

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13/ ADF&G Aquatic Studies Coordinator, Susitna Hydro Aquatic Studies Team, Anchorage.

14/ ADF&G Civil Engineer I, Anchorage

on velocity vs. width of the Susitna River at the low flow rate of 17,400 cfs (Gold Creek station) indicate a range of 2 to 9 mph over the 18 mile distance. Assuming a conservative 2 mph water flow rate and further that juvenile salmon will travel downstream at this rate, the 18 mile distance would be covered in 9 hours. Juvenile salmon are therefore totally safe over this distance since at even 115-116% saturation the onset of mortality takes more than 240 hours at 8-10° C for fry (Rucker and Kangas 1974) and more than 268 hours for smolts to reach 20% mortality (Bouck et al. 1976). Even if juvenile salmon took twice as long to travel the 18 mile distance, i.e., 18 hours, due to delays, they should not be affected by dissolved gases.

Adult salmon are present at the rapids during the summer season (Alaska Department of Fish and Game 1981a). Adult salmon could encounter the same dissolved gas concentrations as the juveniles. Average swimming speeds of sockeye, chinook, coho and chum salmon adults from the mouth of the Susitna River to the Devil Canyon dam site (152 miles) range from 0.16 to 0.23 mph or 3.8 to 5.6 miles/day based on data in Alaska Department of Fish and Game (1981a). Gas concentrations may exceed 110% over an 18 mile distance, and may exceed 115% over a 4 mile distance. These 4 and 18 mile sections of the Susitna River would include the two fishways proposed for passing adult salmon through the rapids. Salmon passage through the 1.5 miles of fishways, if they are constructed, should take from 8 to 12 hours depending on the species (Mr. Lowell Barrick 15/ pers. comm., November 11, 1982).

Using the lowest average swimming speed of 0.16 mph (chinook salmon), a salmon could negotiate the 4 and 18 mile distances in 29 and 91 hours, respectively. Adults should be safe for the 29 hours at 115%, and 117 hours at 110% saturation since the exposure times necessary for 20% mortality at these saturations exceed 122 and 268 hours, respectively (Bouck et al. 1976).

In summation, the rapids at Devil Canyon and Devil Creek may delay or inflict some mortality on emigrating juvenile salmon, and will prevent migration of adult salmon during high water velocities. Total dissolved gas supersaturation will probably not adversely affect juvenile or adult salmon.

15/ ADF&G, Department Engineer, Juneau.

5.1.2 S.E.P. With Hydroelectric Dams

Fifty years of observing salmon migrating past the numerous dams that have been built on the Columbia and the Snake Rivers have proven conclusively that all large dams create serious obstacles to the migration of salmon. The obstacles are many and varied and affect both the upstream migrants and the downstream migrants (Figure 5-5). Attempts to overcome the obstacles created by the dams have met with limited success. Although it has been shown that special features at a dam, e.g. fishways, fish locks, bypass by trucking, etc. can be built to pass fish around the barrier, these features are very costly to construct and maintain, and their successfulness is questionable. The proposed 645 ft high concrete arch dam at Devil Canyon and the 885 ft high earth fill dam at Watana Creek (Plate 5-10) are much greater in height than are any of the Columbia River or Snake River dams, for which salmon bypass features have been constructed, and therefore they undoubtedly present similiar problems, as do the Columbia/Snake River dams, but at a greatly magnified scale. Following is a partial list of the known problems that the Columbia River and Snake River dams cause to migrating salmon in those systems. (Remember that the Columbia River and Snake River dams are in the 50 ft to 150 ft height range with reservoirs of comparable depths).

1) Changed water temperatures above and below the dams.

2) Change in the seasonal flow pattern of the river.

3) Change in water quality; i.e. low oxygen content below the dam, high nitrogen content and gas supersaturation.

4) Change in food supply and disruption of the ecological balance.

5) Siltation of the reservoir.

6) Fishway problems

   a) Fishways rising to heights of nearly 900 ft have never been constructed before. Although fishway construction is theoretically possible, the cost would certainly be exceedingly high.

   b) Fishways built on acceptable slopes of 10:1 could require up to 2 miles of fishways for dams 900 ft high.

   c) Devil Canyon - very difficult to construct a fishway on the face of a concrete arch dam. Construction in the canyon walls would be very expensive.

   d) Watana - similiar construction problems as at Devil Canyon. It is doubtful that a fishway would be permitted on an earthen structure. Construction in canyon walls would be very expensive.

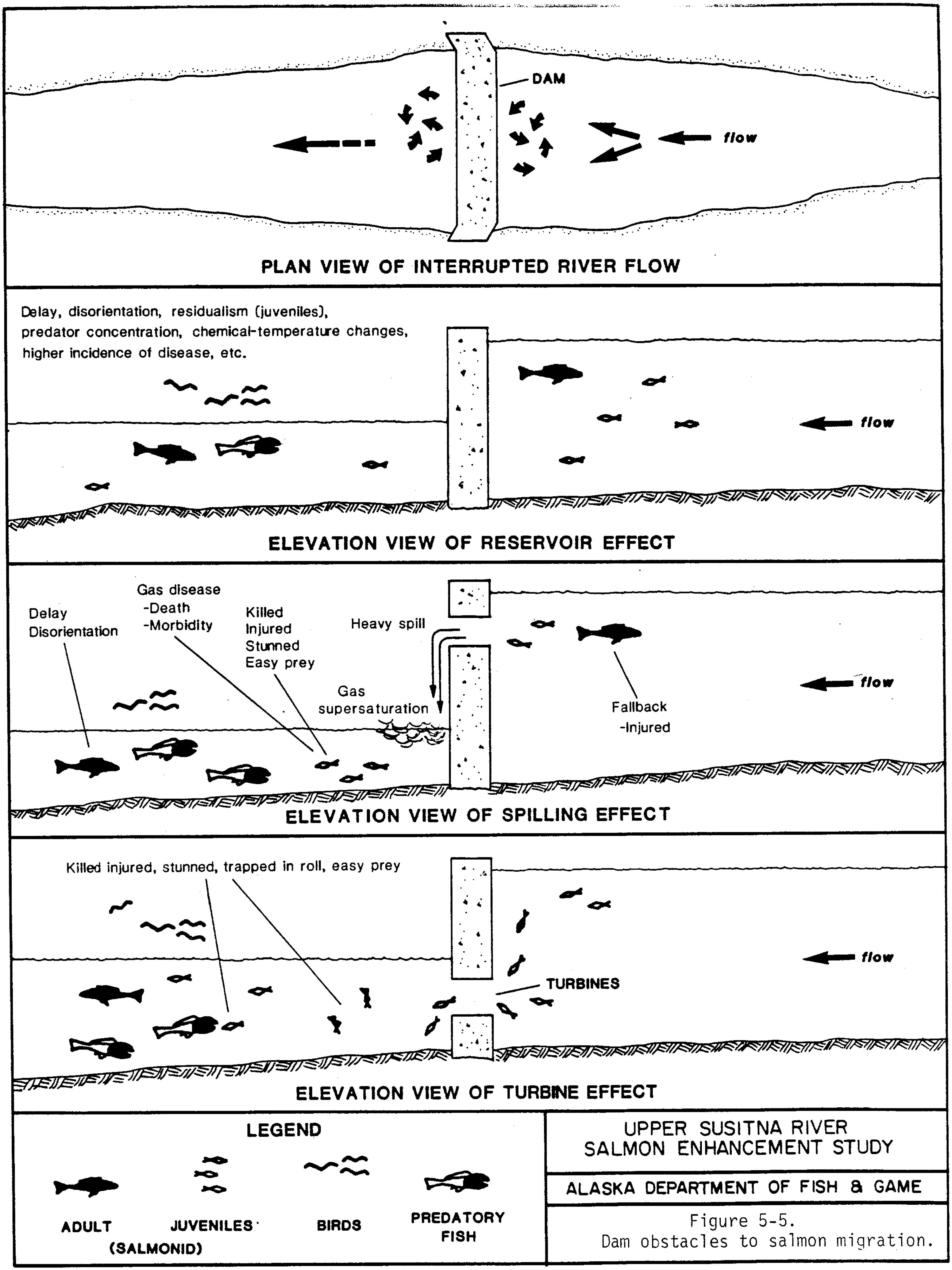
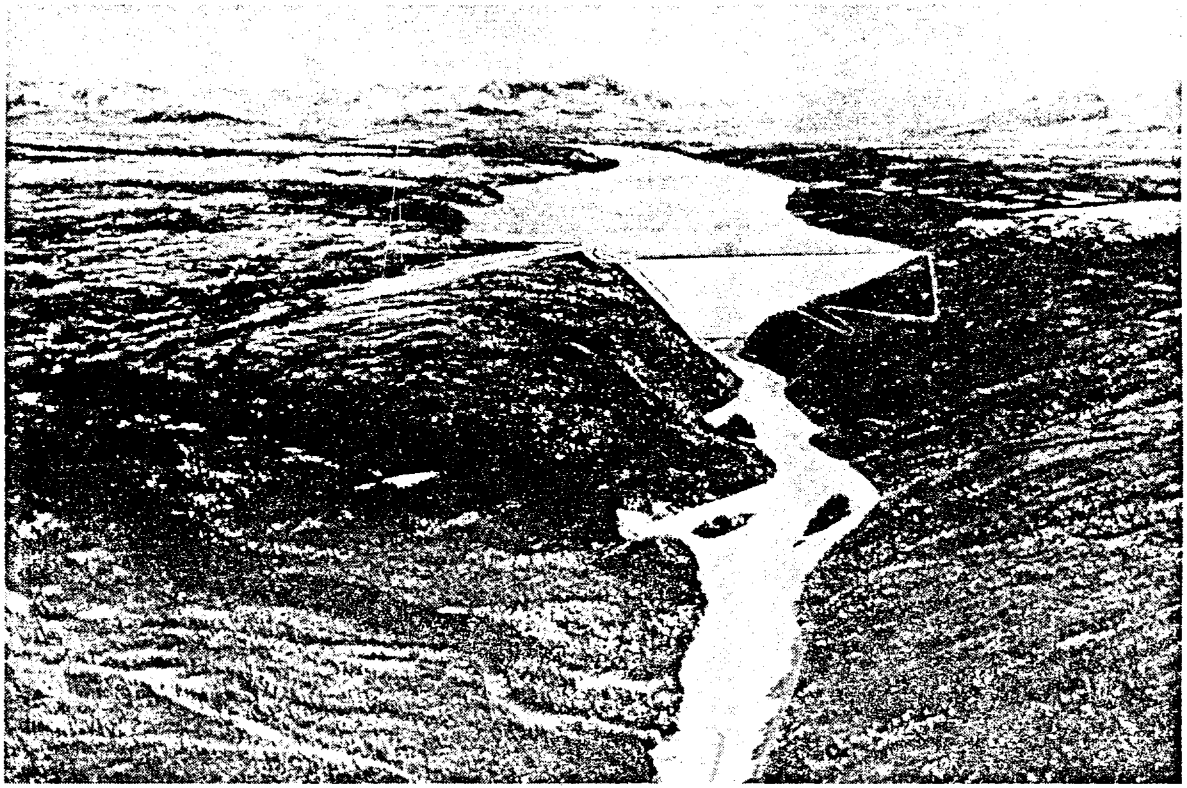
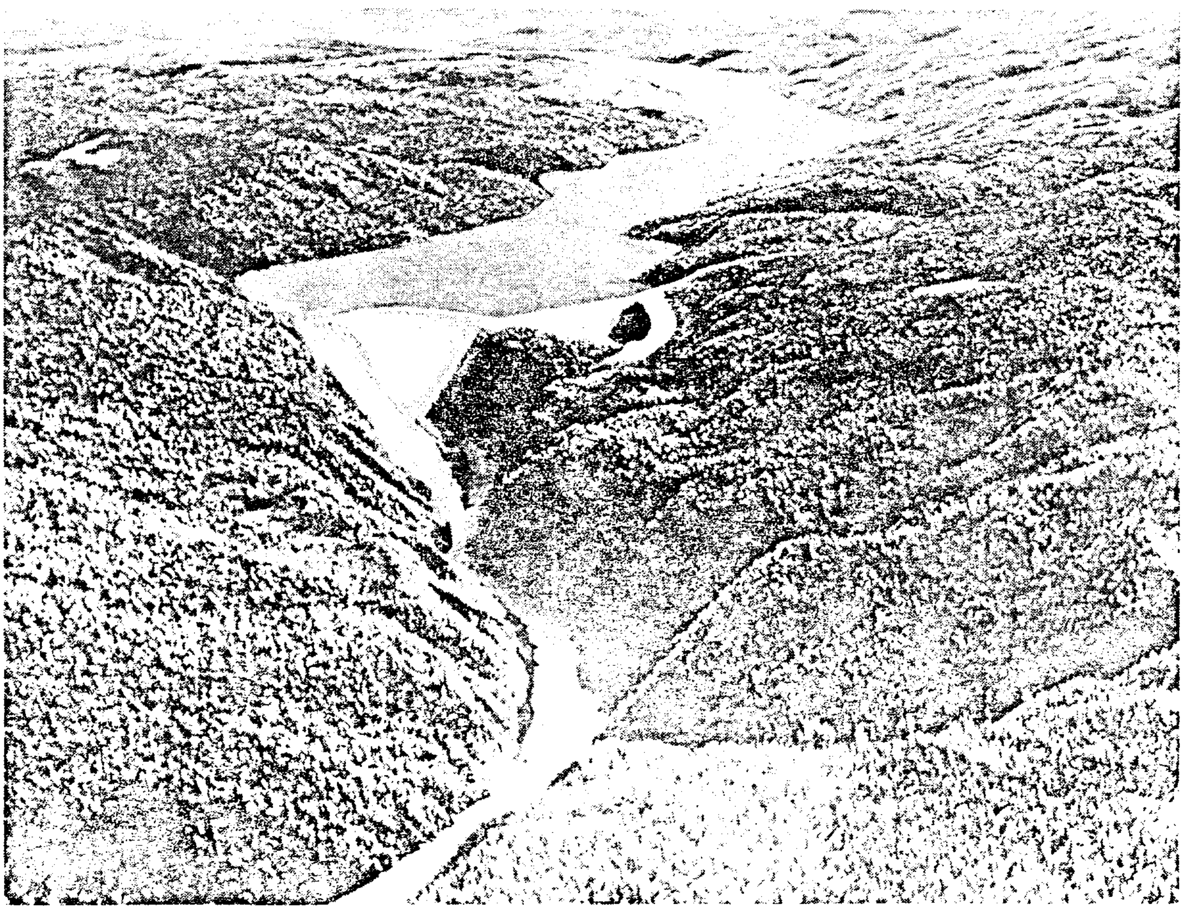


Figure 5-5.
Dam obstacles to salmon migration.



Watana Creek dam



Devil Creek dam
Plate 5-10. Proposed Susitna River dams (from Alaska Power Authority).

e) Fluctuating reservoir level will make the design of the fishways' water intake complex and costly.

f) Fish passage delays due to confusion in locating the fishway entrance in the tailrace discharge.

7) Reservoirs

Most of the studied reference material indicated that reservoirs create an unnatural condition that is neither lake or stream. The slack water of the deep reservoirs cause confusion in both the adult and juvenile migrants (Bell 1973). Studies show that the confusion causes lengthy delays which are deterimental to the physiology of the adult spawners (may cause adults to die before spawning) and which apparently cause some juveniles to become lost and stop their migration to the sea. The 74 miles of resevoir, with depths in excess of 800 ft, created by the Devil Canyon and Watana dams is certain to create serious migration problems for both adults and juveniles.

8) Downstream migration of juveniles

a) In reiterating the problems in item 7, the reservoir obstacle appears to be more detrimental to the juvenile salmon than to the adults. The juveniles are not strong swimmers and without a downstream current to guide them they often become lost and fail to continue their seaward migration.

b) Mortalities of juveniles over dam spillways or through turbine blades are very high (Figure 5-6).

c) Trapping facilities to capture juveniles at dams are only marginally successful and their maintenance and operating costs are high.

d) Migration delays in reservoirs contribute to extensive predation by fish populations in the reservoirs.

9) Reservoir flooding of the productive spawning areas in the lower reaches of the tributary streams reduces spawning potential.

5.1.3 Conclusion

It is the study team's conclusion that the problems and the costs associated with conducting a salmon enhancement program in the upper Susitna River, with the two proposed dams in place, far outweigh the benefits to be received from such a program. For this reason the team recommends against implementing any salmon enhancement program above Devil Canyon if the proposed Susitna dams are constructed. A salmon enhancement program is feasible, however, if the Susitna River dams are not constructed.

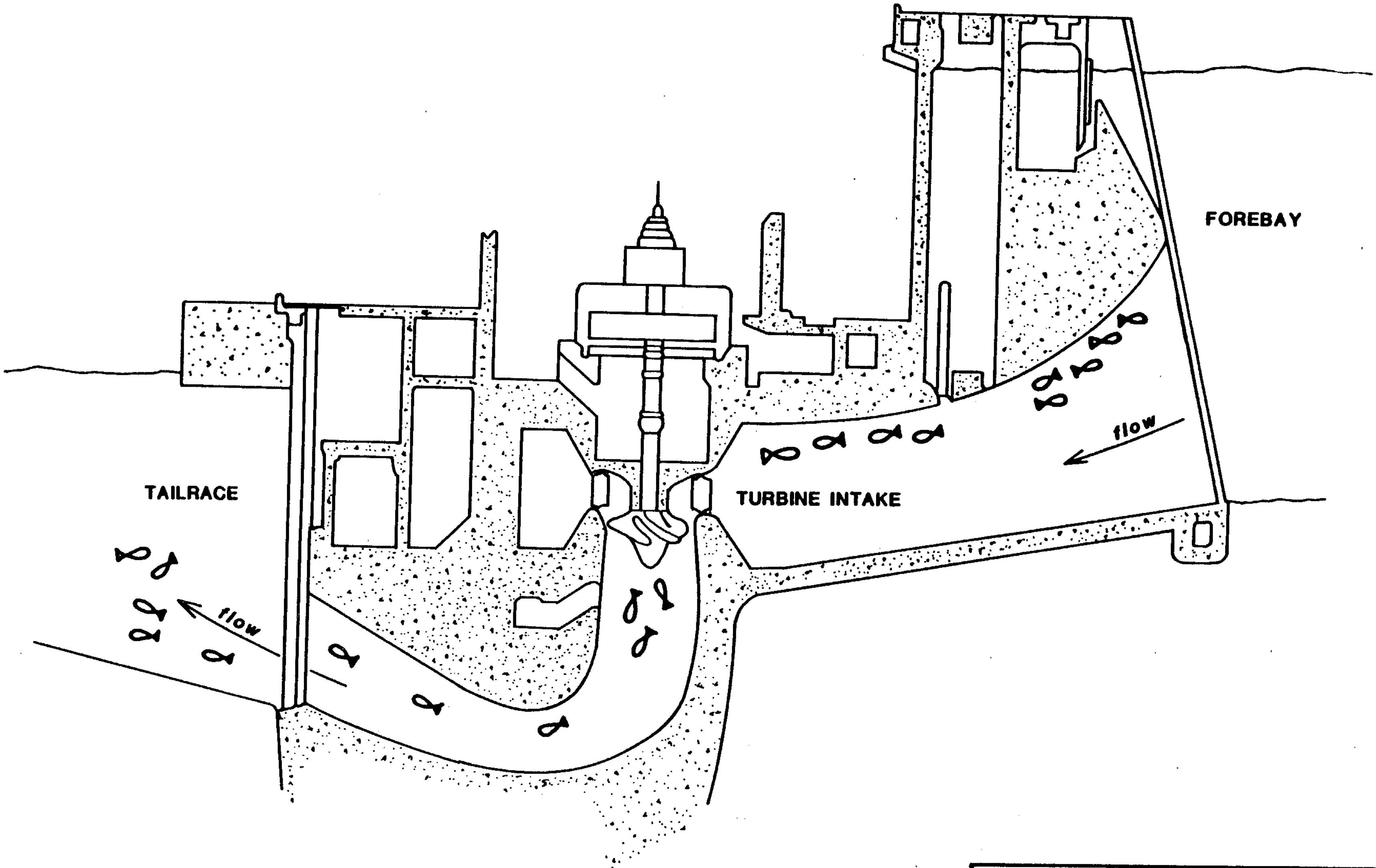


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Figure 5-6.
Salmon migration through a dam turbine.

An idea to divert the water from Lake Louise into the Copper River watershed has been discussed for several years. The theory behind this idea is that Copper River salmon would then make use of the Lake Louise watershed for spawning and the subsequent rearing of juveniles. While this water diversion project may have merit, it opens up a whole new series of questions concerning biological impact, socio-economic factors, cost, benefits and etc. The study team felt that the "Lake Louise diversion proposal" was outside the scope of this study so no investigations were conducted.

A trout or grayling enhancement project could possibly succeed in the upper Susitna basin even if the dams were constructed. The trout/grayling enhancement would be a "put-take" operation wherein hatchery produced trout/grayling juveniles would be released into suitable rearing waters in the upper Susitna River drainage area for natural rearing and subsequent sport fish harvest. The cost of such a "put-take" operation would vary according to the facilities used. If existing hatchery operations could be adjusted to support this operation, capital costs would be minimized and the project might be economically feasible. If a new hatchery had to be constructed specifically for this project, then the project may not prove to be feasible. Like the "Lake Louise diversion proposal" mentioned in the preceeding paragraph, the study team felt that a "trout/grayling enhancement proposal" was outside the scope of this study and investigations of this type were not conducted.

5.2 Enhancement Techniques (E.T.)

This section discusses various salmon enhancement techniques that may be feasible for use in the upper reaches of the Susitna River if the proposed hydropower dams are not constructed. The alternatives discussed consider the more familiar methods of passing adult salmon through fishways of the pool and weir type, the vertical slot baffle, submerged orifice weirs and the Denil design. In addition to fishways, other solutions such as low head dams and brail systems are considered. Put and take methods such as eyed egg and juvenile plants, which require the support of hatcheries, are also discussed.

Because of the limited access (primarily river boat and helicopter) into Devil Canyon, many different construction materials and construction techniques were considered. Even so, it was quickly determined that any construction conducted at Devil Canyon could only be done at considerable cost. An aerial reconnaissance of the terrain between Gold Creek (adjacent to the Alaska Railroad) and Devil Canyon revealed the presence of a trail that was constructed by the Bureau of Reclamation in the late 1950's in association with Devil Canyon dam investigations. Some reduction in construction costs might be realized through the reduction in helicopter support, if use of the trail is made available to a contractor.

5.2.1 Low Head Dams

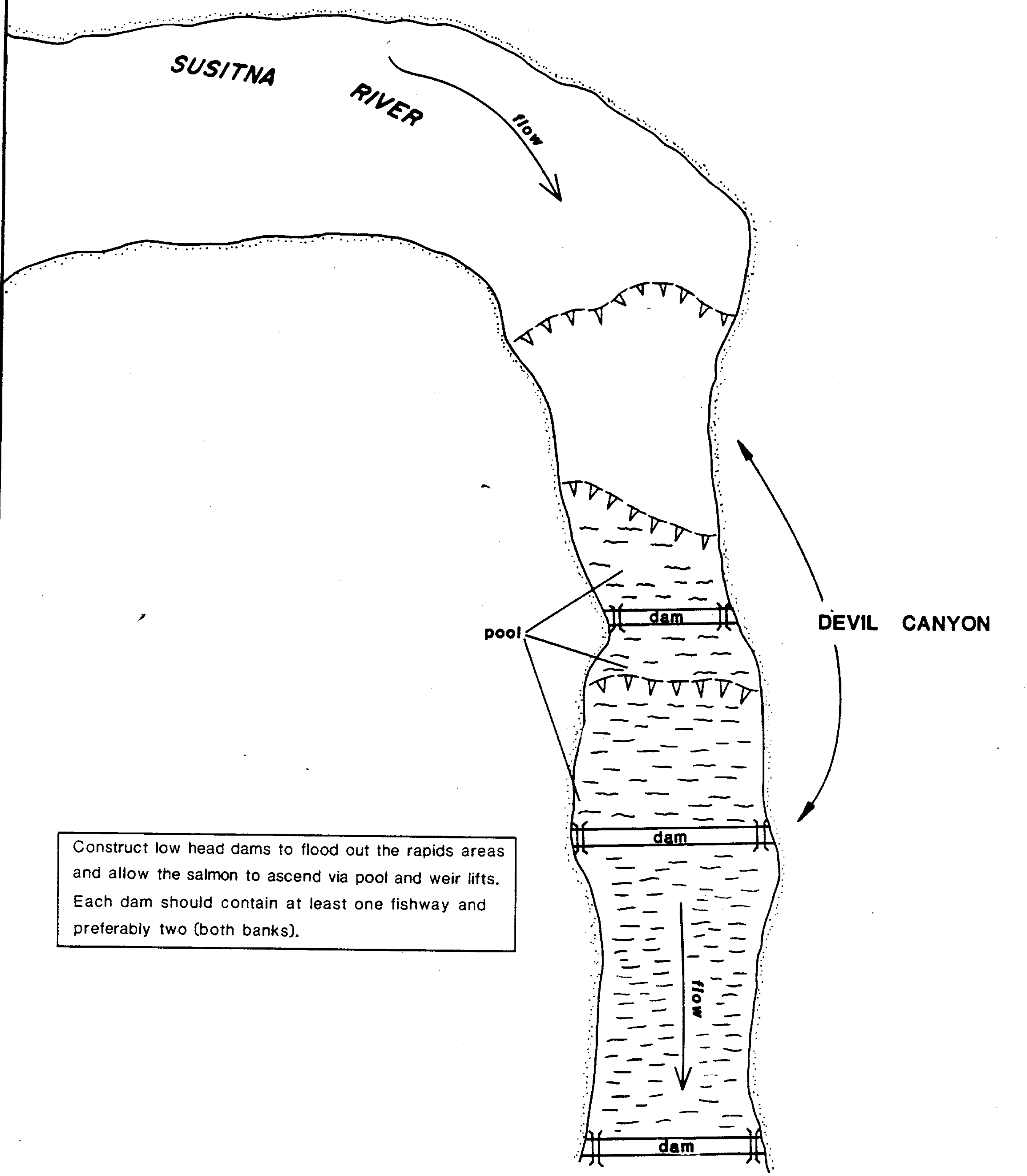
An alternative to the installation of conventional fishways could be the construction of several low head dams, 5 to 15 ft high, at the down stream (chute) end of identified velocity barriers (Figure 5-7). The purpose of the dams would be to drown out the velocity barriers and create quiet water resting pools upstream of the dams. The dams would eliminate the long (500 - 1500 ft) stretches of fast water (velocity barriers) but would create their own 5 ft to 15 ft high vertical barriers. To overcome the vertical barriers conventional fishways would be installed over both ends of each dam. Because of the extreme difficulty of working in the confines of the canyon and because of the high cost of constructing dams capable of withstanding the flood water forces of the Susitna River, this alternative was rejected.

5.2.2 Mechanical/Helicopter Brail Systems

ADF&G experimented with brail systems at two sites in Alaska during the 1970's (Plate 5-11). At Anan Creek in southeastern Alaska where a 10 ft drop over a 100 ft reach often created a velocity barrier to large numbers of pink salmon, a mechanical brail system consisting of a cable tramway, engine driven hoists and dip nets was used to lift pink salmon over the barrier. Although the system used did work, the fish mortality rates were high and its operation required the use of large numbers of personnel.

At Russian River, on the Kenai Peninsula, where a 30 ft drop over a 300 ft reach often created a velocity barrier to large numbers of sockeye salmon, a hybrid type of the Anan Creek brail system was tried. In this system the sockeye were brailled at the base of the obstruction and then airlifted over the obstruction in fire buckets slung beneath a helicopter. The Russian River system was more successful than the Anan Creek system in terms of reduced fish mortality and a reduction in the numbers of people involved. However, because of the large numbers of sockeye to be transported, the expense of the helicopters and the dangers of flying in the confines of a narrow canyon, this transportation experiment was quickly discarded.

Although both brail systems were marginally successful, the experience gained showed that neither system was practical for the long term solution of moving large numbers of salmon past a barrier, especially if that barrier is in the confines of a canyon such as Devil Canyon. A brail system is not recommended for use in Devil Canyon.



Construct low head dams to flood out the rapids areas and allow the salmon to ascend via pool and weir lifts. Each dam should contain at least one fishway and preferably two (both banks).

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Figure 5-7.
Low head dams.

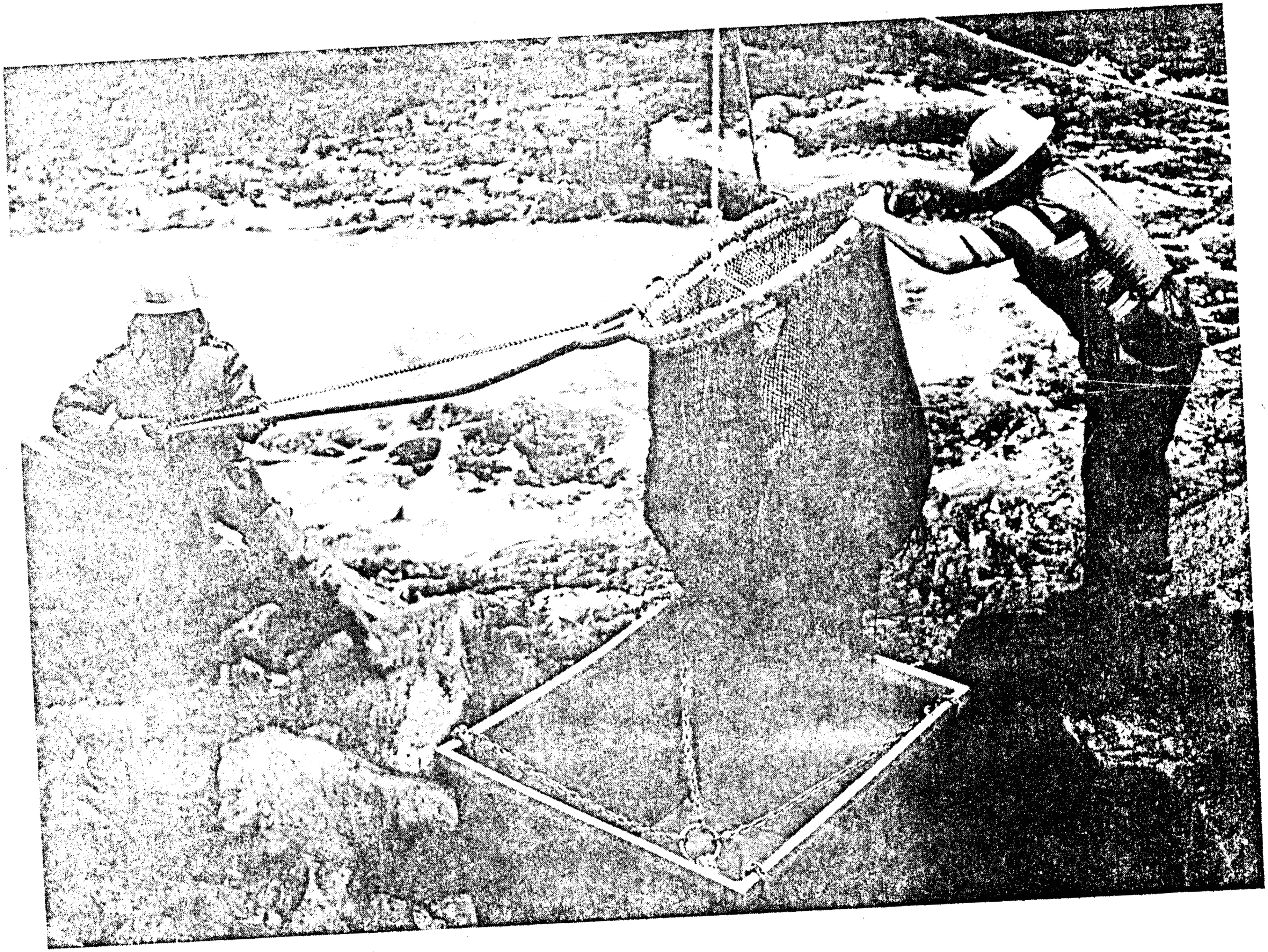


Plate 5-11. Brailling salmon at Anan Creek.

5.2.3. Fishways

5.2.3.1. General Information and Discussion

Fishway, fish ladder, and fishpass are all terms used to describe methods of passing fish upstream at dams and natural obstructions. In this study the term fishway is used. There is a difference in concept between designing a fishway at a natural obstruction and in designing a fishway at a dam. Briefly, the difference is that the natural obstruction to migration is in most cases a part of the natural environment of the fish affected by it. The population of migrating fish has presumably become adjusted to some extent to this environment. However, if the obstruction each year takes its toll by reason of direct mortality, or physical impairment as a result of delay or damage, any facilities installed which will reduce this mortality or impairment will be beneficial. The design criterion then becomes one of constructing the most efficient fishway at the lowest cost to provide the greatest benefit. With a fishway at a dam, however, the primary aim is usually the ultimate one of providing for no delay and no physical impairment of the fish, since any such delay or impairment is not part of the natural environment. As the Devil Canyon velocity barrier is a natural obstruction, the evaluation of fishways in this chapter will be made with the goal of selecting a design that will provide the greatest benefit for the least cost.

5.2.3.2 ADF&G Criteria for Fishways Under Twenty Feet in Height

In designing fishways in Alaska, the Department of Fish and Game considers the following three items to be essential features of a fishway:

1) The entrance must be located such that it is easily found and readily entered by the fish.

2) The fish must be able to swim through the fishway without undue effort.

3) The fishway design must be such that entrance and passage through the facility are accomplished with a minimum of delay and injury to the fish.

The following guidelines should be used as a check to ensure that the three essential elements of a fishway are incorporated into each design:

1) Velocities in salmon fishways should not exceed 8 fps.

2) The fishway must discharge enough water to attract fish to the entrance. Discharge velocity will vary in relation to the stream flow, but discharge velocities should be in the 3 to 8 fps range.

3) Fishway designs should not permit rapid changes in flow patterns.

Energy derived from increases in head must be dissipated quickly and without changing the general flow pattern features.

4) The fishway should provide ample physical and visual clearance for the fish. The smallest submerged opening must not be less than ten inches wide and water depths must allow complete coverage of any fish traversing the fishway. In some fishways, it may be advantageous to have openings in the bottom of weir baffles to allow passage of fish through rather than over the weir.

5) The fishway should provide adequate resting areas if it is long. Locations of resting pools will vary with the species of fish and the type of fishway used.

6) Location of the entrance is extremely important. It should be at the furthest upstream point of the fish migration. If this is physically impossible, then some type of fish guidance fence into the entrance may be required. Entrance discharge should be nearly parallel with the stream flow and should discharge into a non-turbulent pool if possible.

7) The fishway exit should be into a protected area away from the barrier overflow to prevent fish from being swept back over the barrier.

8) Designs must consider fluctuations in water levels and should minimize the use of mechanical controls in regulating flow through the structure. This is especially important at a site such as Devil Canyon where access, for maintenance and operations purposes, is very limited.

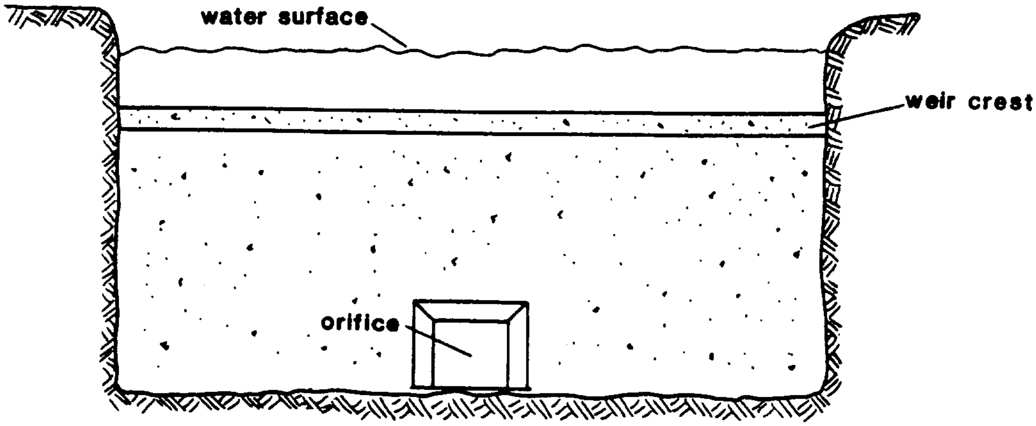
9) Consideration must be given to the intended location of the fishway so that adequate maintenance can be provided.

10) The maintenance effort will be minimized if due design consideration is given to problems of debris at the exit, ice accumulations, destructive forces caused by flood water, and sediment in and through the fishway.

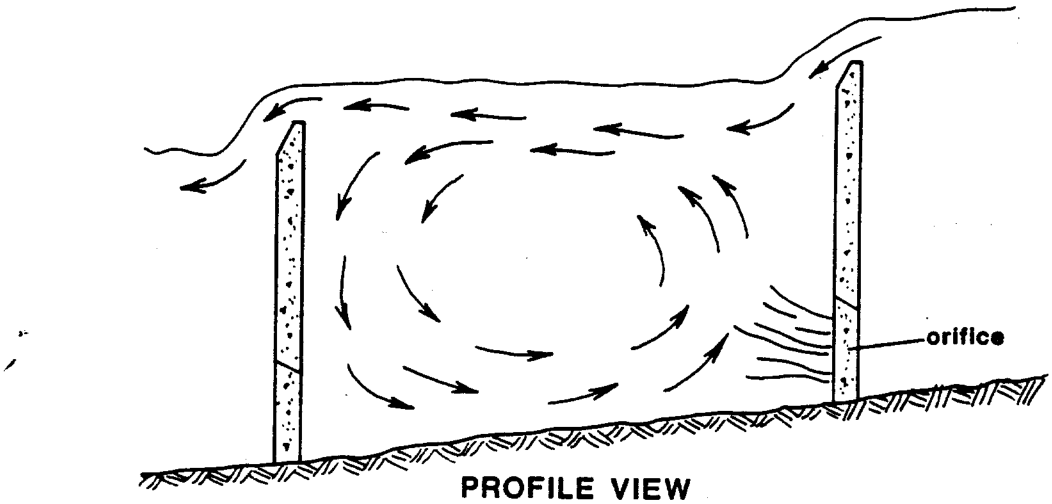
5.2.3.3 Weir and Orifice Fishway

See Figure 5-8 for an example of a weir/orifice type fishway. This type of fishway is one of the oldest and probably most common designs in use. Initially, just a series of weirs was installed, but later refinements led to the installation of orifices within the weir. Under certain conditions, a weir/orifice type fishway will provide a cost efficient method of transporting fish over a barrier. However, this type of design has some serious operating deficiencies that preclude its use at a remote site like Devil Canyon.

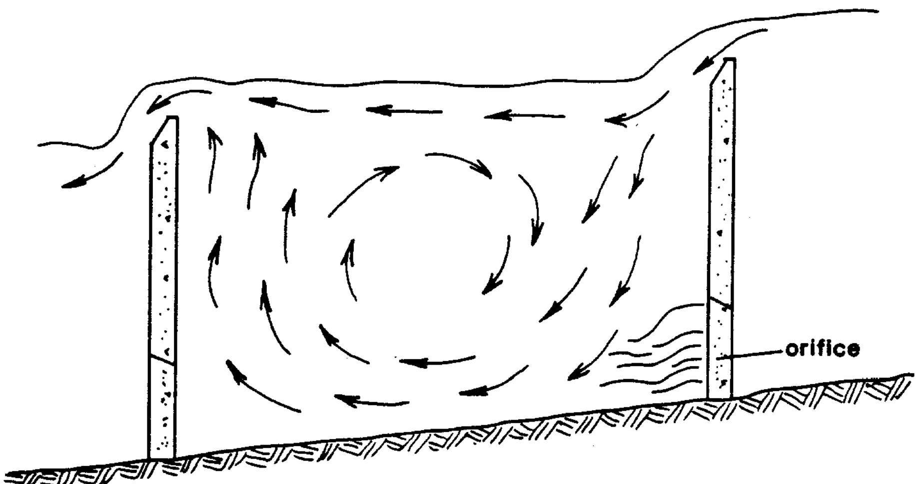
The two most serious deficiencies concern variable stream flows and transportation of sediment. A weir operates efficiently only within a



END VIEW



PROFILE VIEW
STREAMING OR SHOOTING FLOW (below critical flow)



PROFILE VIEW
PLUNGING FLOW (above critical flow)

(Adapted from Bell 1973)

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Figure 5-8.
Weir and orifice fishway.

very narrow range of flows. The flow in the fishway is controlled by the upstream weir and it can operate efficiently only when river levels are within the range producing the desired flows over the upper weir. If the stream flow is not within the narrow operating range of the weir, the fishway will be either starved or drowned. In some cases (mostly at inhabited sites such as man-made dams), it is practical to provide for regulation of the fishway flow over a wider range of stream levels by means of adjustable weir crests or gates, but due to the remoteness of Devil Canyon, this solution is not feasible. Also, the weir/orifice type design is readily clogged by stream debris and sediment. During high flow conditions, the Susitna River carries a considerable load of sand/silt which would lodge in the weir pools and destroy the velocity-reducing characteristics of the design. Maintenance considerations alone preclude the selection of this design for use at Devil Canyon.

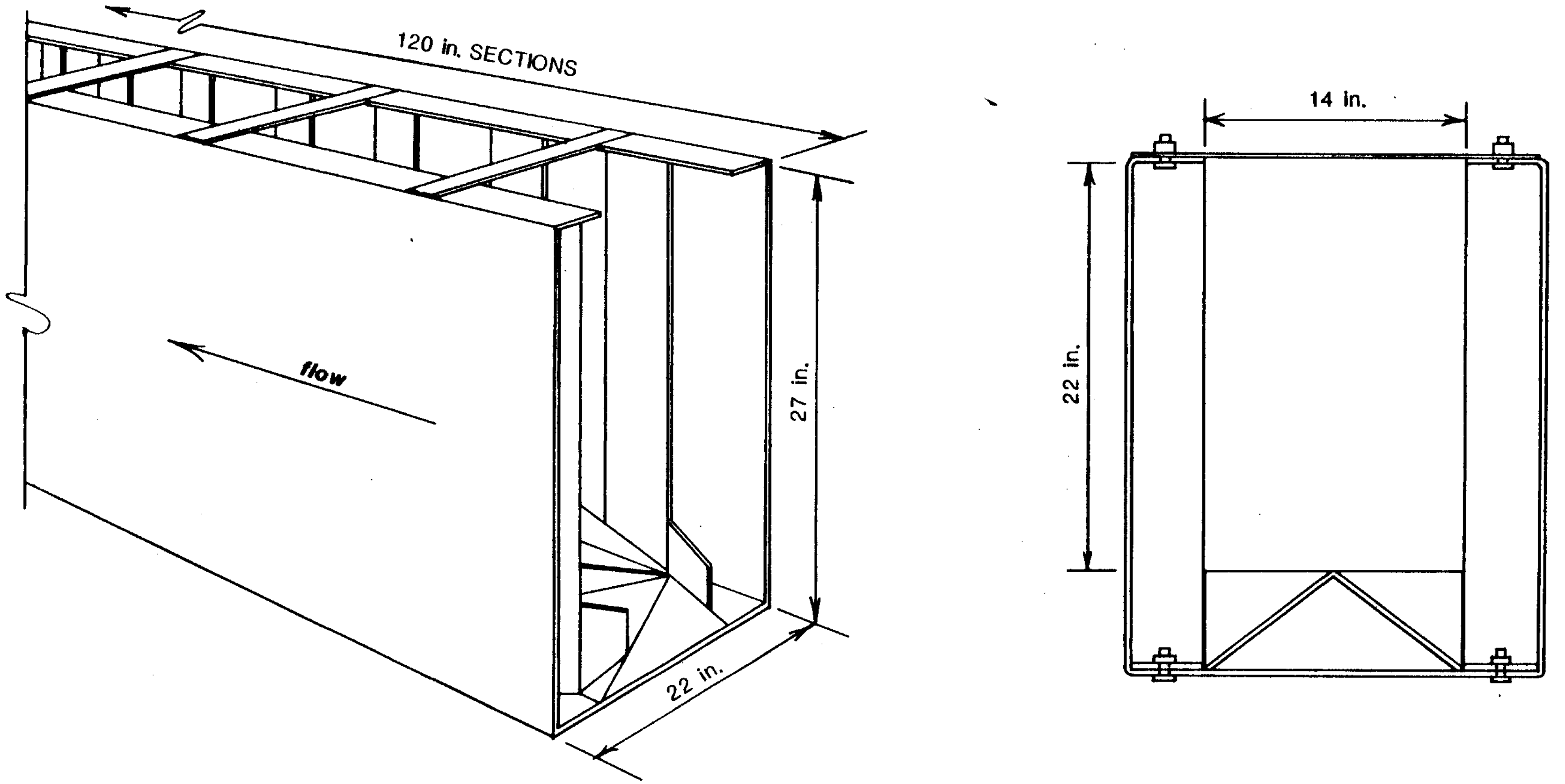
5.2.3.4 Denil and Alaskan Steeppass Designs

The Denil design was developed about the turn of the century and was probably designed to overcome the problems that were inherent in the weir/orifice design. The Denil design does operate through a wider range of stream levels than the weir type without serious impairment of its efficiency; however, sediment transportation still poses a problem in the Denil design. In the case of the Denil design, sediment clogging is not the problem as much as is sediment abrasion. The movement of silt, sand, gravel, and large stones through the thin baffle members of the fishway causes serious maintenance problems in fishways of this design.

The Alaskan steeppass is an aluminum section modification of the Denil design. The Alaskan Steeppass was adapted from the Denil design for the Alaska Department of Fish and Game by Chief Engineer G. L. Ziemer, P.E. The initial adaptation and testing was done in the late 1950's and early 1960's. The major innovation of the Alaskan Steeppass is in the use of aluminum panels in the construction of fishways. The relatively light aluminum sections (complete with energy-dissipating baffles) are prefabricated in ten foot lengths and then transported (by boat, air, or hand-carried) to the obstruction site where they are bolted together and installed. Several Alaskan Steeppass fishways are in use throughout the state. The Alaskan Steeppass works well in streams where there is little fluctuation in the level of flow. However, practical applications have shown that the Alaskan Steeppass would not be suitable in Devil Canyon where there are extreme fluctuations in the water level. See Figure 5-9 for details of the Alaskan Steeppass.

5.2.3.5 Vertical Slot Baffle

Figure 5-10 depicts a typical vertical slot baffle which was developed to overcome the deficiency of the weir/orifice and Denil-type designs in operating under a wide range of stream flows without the use of attendants or automatic controls to adjust for the fluctuations in water levels.



DATA

GENERAL CHARACTERISTICS:

(Basic Models: A and C)

Model A:	Model C:
slopes: 20% to 35%	slopes: 20% to 35%
velocities: 2.5 to 3.5 fps	velocities: 4.1 to 4.5 fps
flows (Q): 3.5 to 4.0 cfs	flows (Q): 4.5 to 5.7 cfs
@ flow depth of one foot	@ flow depth of one foot

General Use:

For fish obstructions (falls) up to twenty feet in height

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Figure 5-9.
Alaskan steeppass.

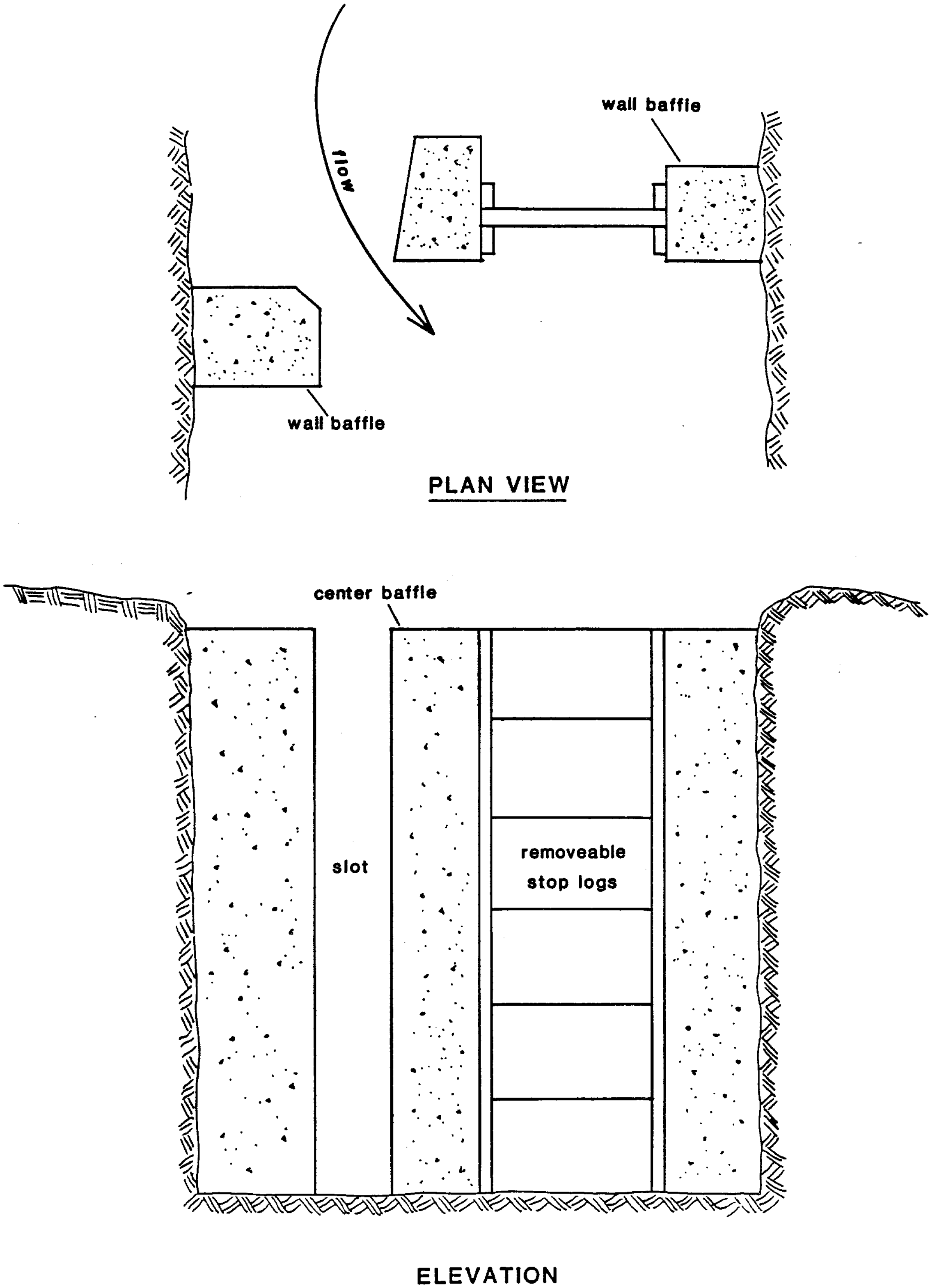

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Figure 5-10.
Vertical slot baffle.

It wasn't determined just when or where the first vertical slot fishway was used. However, there is considerable information dating back to the 1940's that describes the use of vertical slot baffles used in fishways at Hell's Gate and at Farewell Canyon in British Columbia as well as sites in the lower 48 states. From all of the information read, the vertical slot design works well at sites with highly variable stream flows. Clay's Design of Fishways and Other Fish Facilities states that the vertical slot fishways at Hell's Gate have operated successfully over periods during which the range in water levels has been as much as 45 ft. Furthermore, the vertical slot is probably the most efficient design in transporting sediment through the fishway. Both of these later characteristics of the vertical slot make it a promising design for use at Devil Canyon.

In reviewing all of the enhancement techniques discussed in sections 5.2.1 through 5.2.3, the study team came to the conclusion that only the vertical slot fishway would be efficient in passing salmon through the Devil Canyon area (Table 5-5 and Figure 5-11). In the case of the barriers at Anan Creek (Plate 5-12) and at Russian River, the permanent solution was the installation of vertical slot baffles in 8 ft diameter tunnels circumventing the velocity barriers. The Anan Creek fishway (110 lineal ft of tunnel plus 35 lineal ft of open trench) was constructed in 1977 at a cost (contractor payment only - not total project costs) of $212,000. The Russian River fishway (280 lineal ft of tunnel plus 50 lineal ft of open trench) was constructed in 1978/79 at a cost (contractor payment only - not total project cost) of $727,000. Both fishways are functioning well and it is believed that fishways of similar design would be suitable for use at Devil Canyon.

5.2.3.6 Fishway Construction Costs

From field observations made in July and August, 1982 and from a review of Susitna River hydraulic data, the study team concluded that there are a series of 4 to 6 velocity barriers in the Devil Canyon area. These velocity barriers essentially prevent the upstream migration of salmon when the river discharge exceeds 15,000 cfs. The 4 to 6 velocity barriers identified are basically located in two stretches of the river. The first series of barriers occurs in the river from near the site of the proposed Devil Canyon dam (approx. river mile 152) and extends downstream about 4,000 ft. The second series of barriers starts at a point which is about 1,000 ft below the mouth of Devil Creek (about river mile 162) and extends downstream nearly 4,000 ft. A series of short tunnel fishways could theoretically be constructed around each individual velocity barrier, which would entail the construction of 4 to 6 relatively short tunnel fishways. Because of construction considerations and factors concerning the potential for migration delay with the salmon searching for entrances to several tunnels, the study team recommends that two major tunnel fishways be constructed instead of several shorter fishways. Figure 5-12 shows the alignment and profile for a 4,200 ft long tunnel fishway at Devil Canyon (lower fishway) and Figure 5-13 shows the alignment and profile for a 3,900 ft long tunnel fishway at Devil Creek (upper fishway).

Table 5-5. Comparison of fishway designs.

Type of fishway	Guidelines for essential elements of fishway design (pg 74 and 75) 1	2	3	4	5	6	7	8	9	10	Remarks
Weir/Orifice fishway	G,C	F	F	E,C	E,C	E,C	E,C	U	F	F,C	Unacceptable due to the highly fluctuating stream flow conditions and high maintenance operational characteristics
Alaskan steeppass Denil	E,C	F	E	F	G,C	E,C	E,C	U	F	F,C	Unacceptable for the same reasons given for the weir/orifice design
Vertical slot baffle	E,C	E	E	E	E,C	E,C	E,C	E	E	G,C	Acceptable: This design meets all the requirements needed to pass salmon.
Low head dams	F,C	F	F	F	N/A	F,C	F	F,C	U	F,C	Unacceptable because of construction difficulties and anticipated high maintenance costs.
Mechanical or helicopter brail	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Unacceptable: The mechanical brail is unacceptable due to high operational costs and excessive fish mortalities. The helicopter system is unacceptable for moving large numbers of salmon due to the high operating costs.

Legend: U - Unsatisfactory, F - Fair, G - Good, E - Excellent,
C - Can be designed in, N/A - Not Applicable

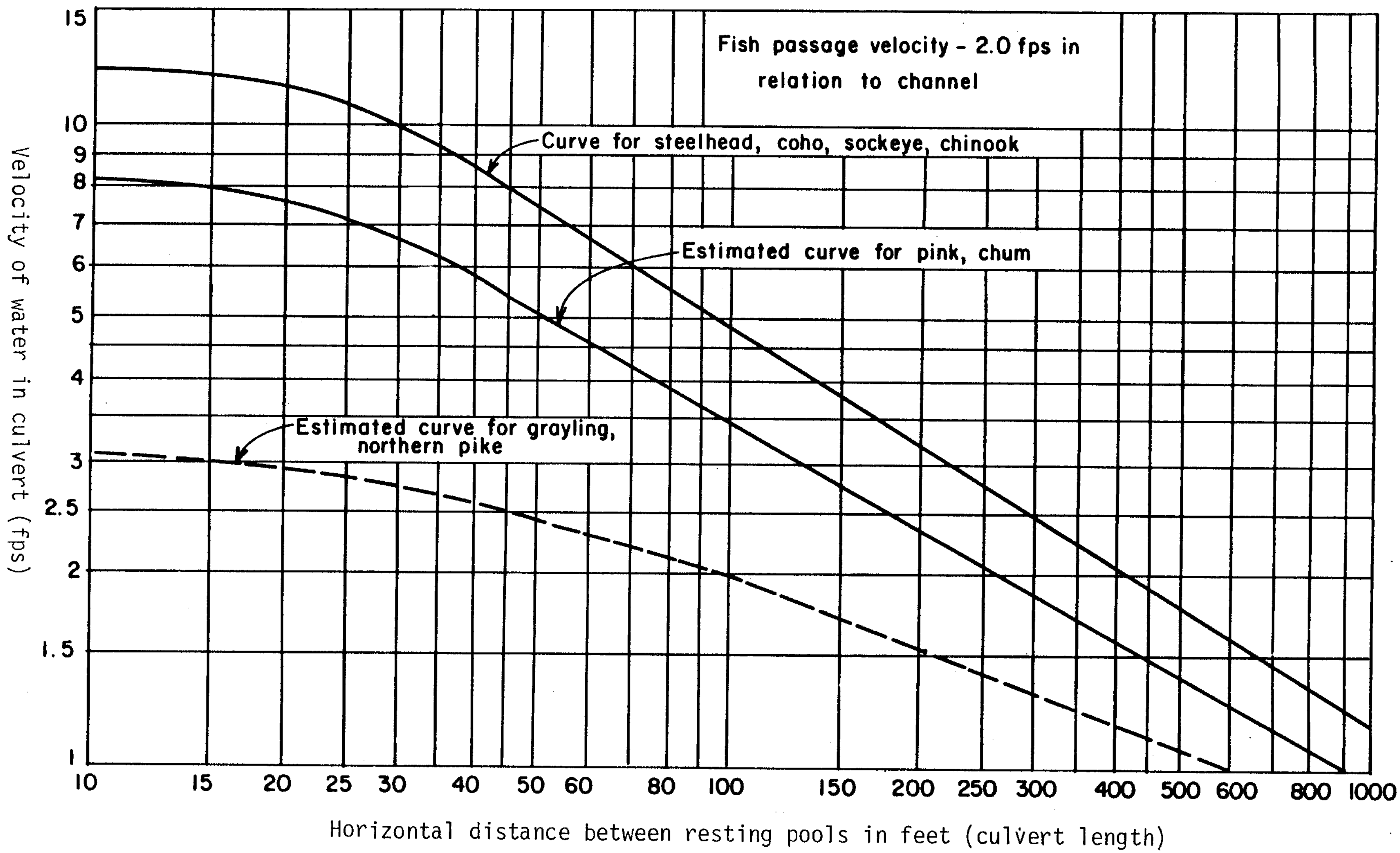

Figure 5-11. Swimming speeds of fish relative to horizontal distance between resting pools.

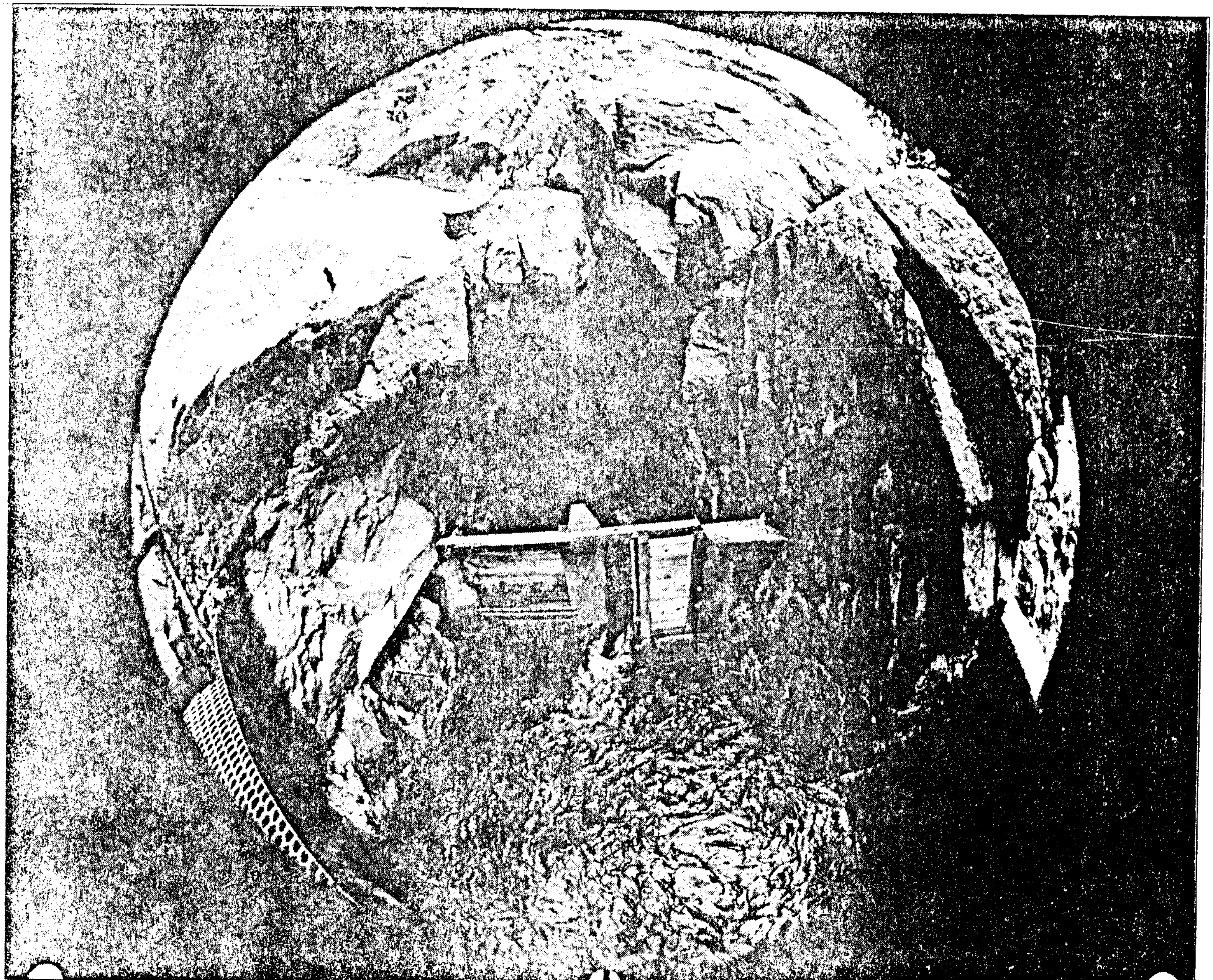

Plate 5-12. Anan Creek fishway-vertical slot baffle in tunnel.

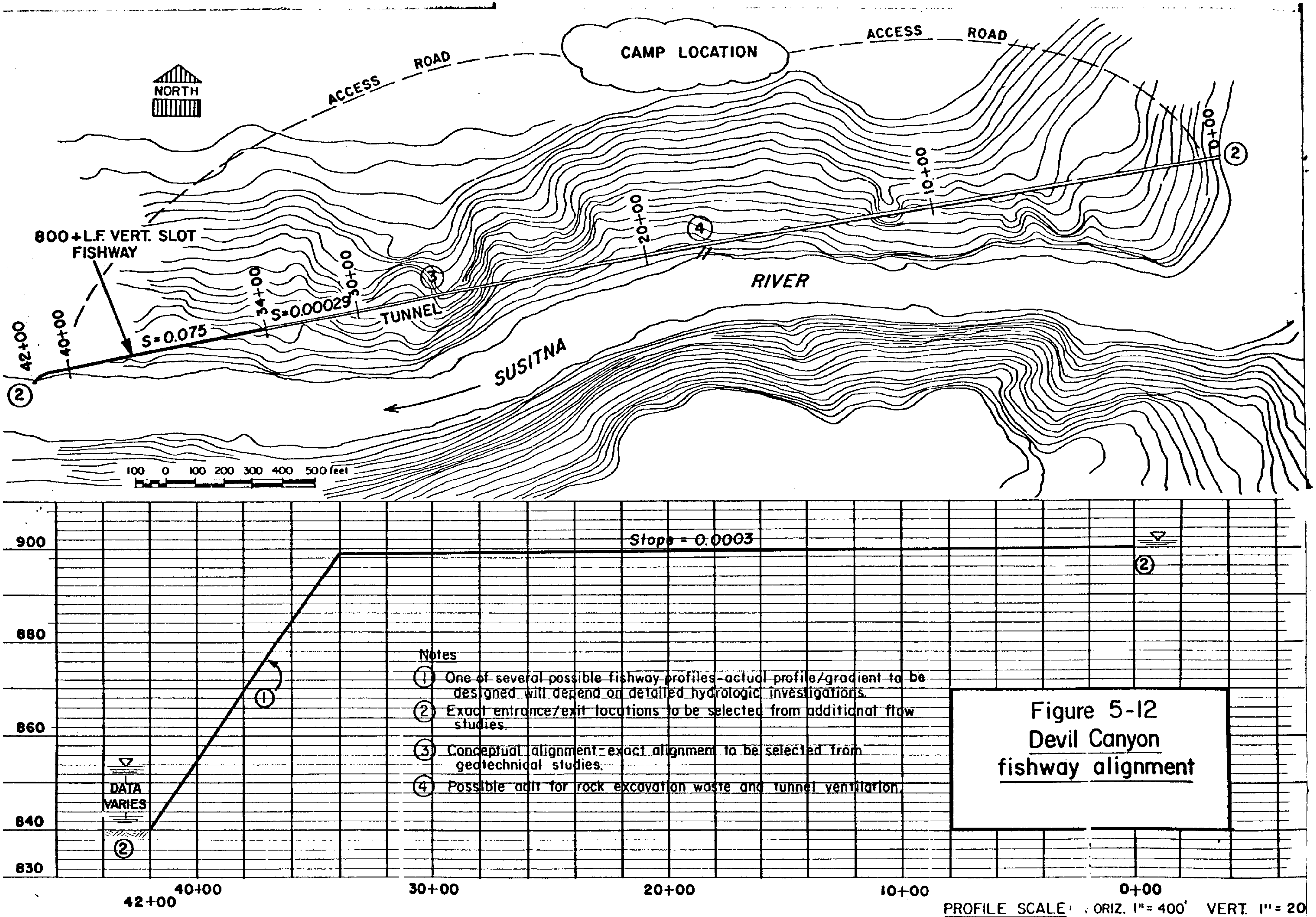

Figure 5-12
Devil Canyon fishway alignment

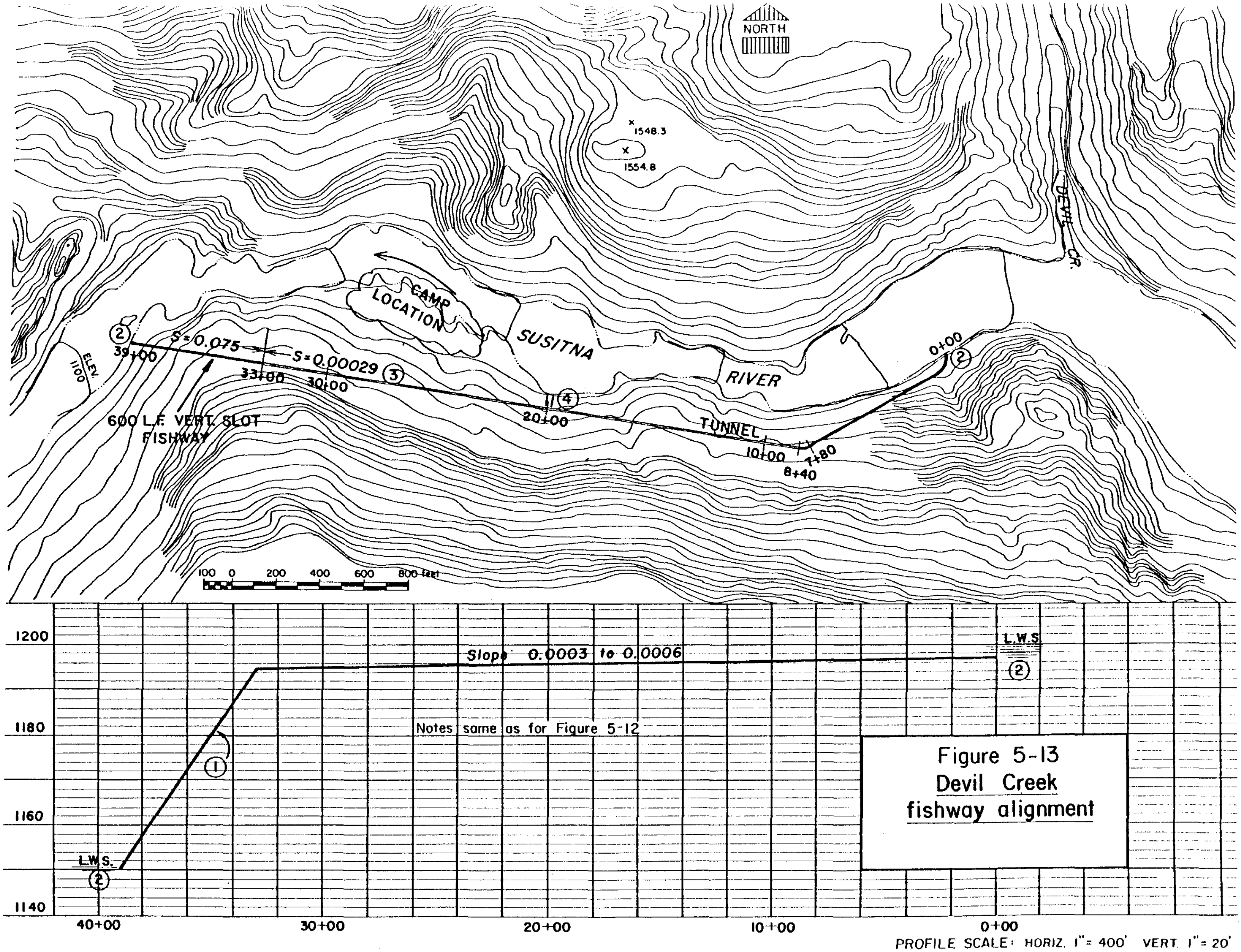

Figure 5-13
Devil Creek
fishway alignment

Fishway installation assumptions:

1) Assumptions for Lower Fishway (Devil Canyon)

   a) Locate 22-man camp on north side of river near mid point of tunnel.

   b) Paths constructed from top of bluff to portals.

   c) Compressor and alternator located at each portal.

   d) Raft constructed to transport heavy equipment and tools to downstream portal. Raft used as temporary work platform.

   e) Rock wasted in river.

   f) Landing strip used as a marshalling area and for cement batch plant.

   g) Work from both portals towards the center (work 2 faces simultaneously): Two 10 hr. shifts per face on 15 ft diameter tunnel (Figure 5-14). Assume 5 ft advance per shift = 20 ft per day.

   h) Contract period: Mobilization through construction through demobilization = 12 months. Tunnel excavation, October through April = 7 months.

2) Assumptions for upper fishway (Devil Creek)

   The upper fishway will be constructed under a scenario similar to that for the lower fishway. The major difference being that the construction camp for the upper fishway would be located on the river bank near the center of the tunnel alignment. It is expected that the contractor would construct an adit into the tunnel, near its center, and excavate from the center both ways. By tunneling from the center both ways some consolidation of equipment, with corresponding cost savings, can be achieved.

3) Adult capture facilities

   Because of the velocity barriers, few salmon migrate upstream of Devil Canyon to spawn. With the construction of the fishways, the salmon will be physically able to proceed upstream but because of the limited (virtually nonexistent) brood stock upstream of Devil Canyon the study team feels that the upper Susitna River drainage basin must be "stocked" with the desired salmon species. The recommended "stocking program" would consist of taking sockeye eggs at the Gulkana River and chinook, coho and chum eggs from the Susitna River. The eggs would be incubated to fry/fingerling size in existing facilities near Paxson and in Anchorage. The fry/fingerling would then be transported to select release sites in the upper Susitna River drainage basin. This operation would continue for 5 or 6 years until the adults returned in numbers sufficient to propagate the species naturally, at which time the stocking program would be discontinued.

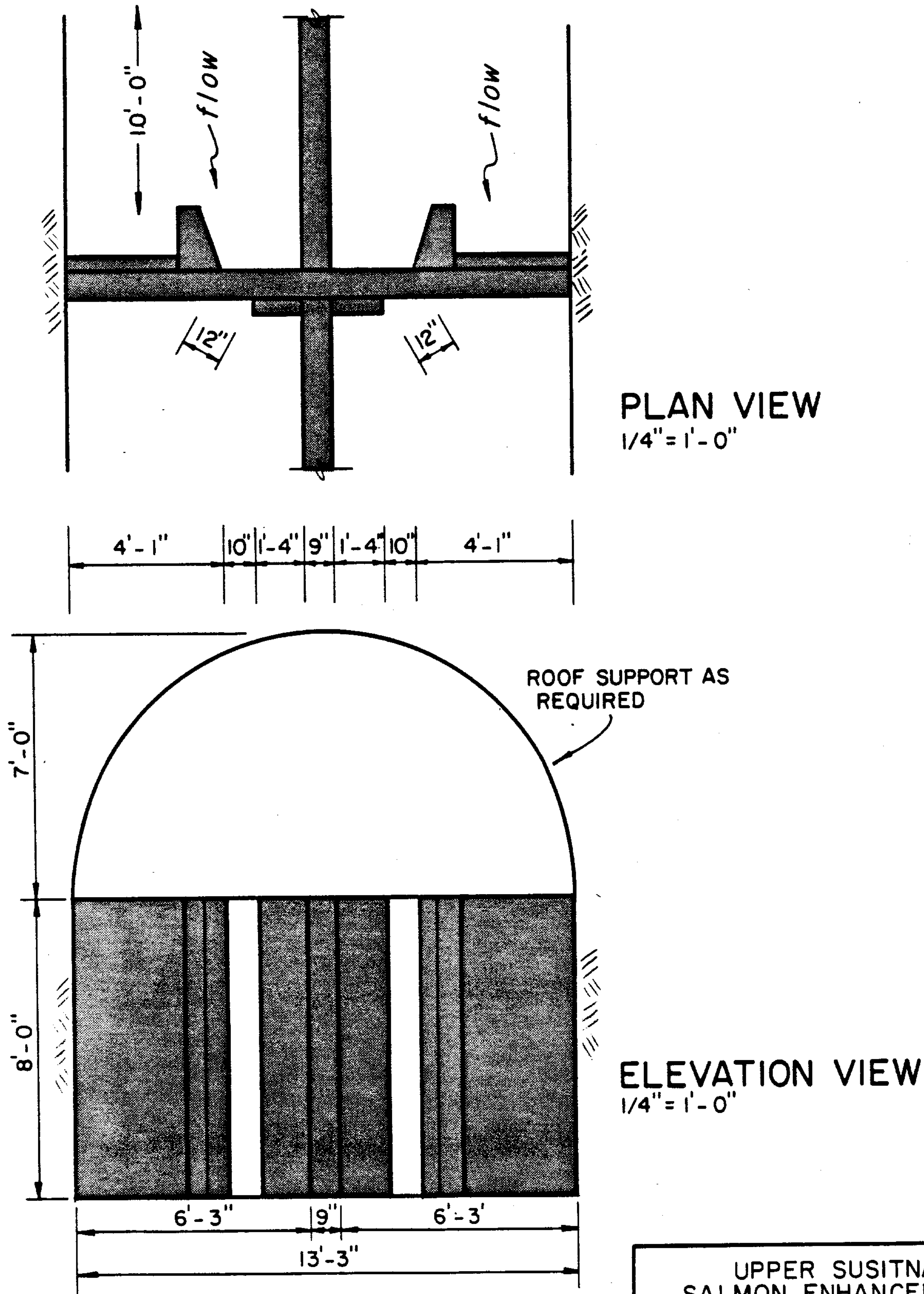

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Figure 5-14.
Typical tunnel/baffle section.

By adjustments in its existing hatchery program, the FRED Division could basically accommodate a stocking program for the upper Susitna River for the 5 to 6 year period specified. The only significant addition required to the existing facilities would be the construction of a summer weir camp at Gold Creek and adult capture weirs at Indian River and at Portage Creek. These facilities would be needed to obtain the Susitna River chinook, coho and chum eggs necessary for the juvenile stocking program. Cost estimates for the construction of the Devil Canyon fishway, the Devil Creek fishway, the Indian River and Portage Creek weirs and the fry/fingerling stocking operations are shown in Tables 5-6, 5-7, 5-8 and 5-9, respectively.

Table 5-6.
Devil Canyon fishway C.I.P costs.

CLASS OF WORK OR MATERIAL	QUANTITY	UNIT	MATERIALS/LABOR UNIT	MATERIALS/LABOR EXTENSION
A. Mobilization				
1. Equip. Rental				
LHD: 3 @ $10,800/mo = $32,400/mo	10	Mo	$32,400	$324,000
Compressors: 3 @ 2800 = 8,400/mo	10	Mo	8,400	84,000
Generators: 4 @ 1100 = 4,400/mo	12	Mo	4,400	52,800
Air Leg + 3" Drill: 6 @ 425 = 2,550/mo	10	Mo	2,550	25,500
Vent. Blower: 2 @ 250 = 500/mo	10	Mo	500	5,000
3" Diameter Pump: 2 @ 850 = 1700/mo	10	Mo	1,700	17,000
3" Sub. Pump: 2 @ 425 = 850/mo	12	Mo	850	10,200
4" Cent. Pump: 2 @ 1050 = 2100/mo	12	Mo	2,100	25,200
Suc./Pres. Hose: Misc. Lengths	12	Mo	1,000	12,000
3 Drum Diesel Powered Hoist	12	Mo	2,600	31,200
Loader with 4-way Bucket	12	Mo	3,000	36,000
Hoist Bucket	12	Mo	800	9,600
Portable Gravel Plant	6	Mo	12,000	72,000
16 C.F. Cement Mixer	6	Mo	1,350	8,100
Sub-Total Item A1				712,600
2. Misc. Equip. Rent:	1	LS	150,000	150,000
Sub-Total Item A2				150,000
3. 22 Man Construction Camp				
a. Purchase 9 - 8' x 20' Units 6 sleepers/ 1 office/ 1 kitchen/ 1 laundry-wet unit	1	LS	110,000	110,000
b. Setup & Outfit	1	LS	55,000	55,000
Sub-Total Item A3				165,000

Table 5-6 cont.

CLASS OF WORK OR MATERIAL	QUANTITY	UNIT	MATERIALS/LABOR UNIT	MATERIALS/LABOR EXTENSION	
Mobilization (cont.)					
4. Transportation					
FRT: RR Transport/Demurrage	1	LS	188,000	188,000	
Bell 212 (trans): Mat'l. & Equip.	450	HR	1,500	675,000	
Bell 212 (Stdby): 20-4 hr days	80	HR	1,500	120,000	
Bell 206B: Bi-Weekly Supply	104	HR	500	52,000	
Sub-Total Item A4				1,035,000	
5. Camp Setup					
a. Labor: 7 men (10 hr/day) 60 days	4200	M-HR	30	126,000	
b. Camp Cost: $70/man/day	420	M-DY	70	29,400	
Sub-Total Item A5				155,400	
Total Mobilization: Item A				2,218,000	= $2,218,000
B. Demobilization					
Bell 212 (trans.): Mat'l. & Equip.	200	HR	1,500	300,000	
Bell 212 (stdby.): 10-4 hr days	40	HR	1,500	60,000	
Bell 206B: Pers. & Supply	25	HR	500	12,500	
Labor: 6 men (10 hr/day) 30 days	1800	HR	20	36,000	
Camp Cost: $70/man/day	180	DY	70	12,600	
FRT: RR Transport/Demurrage	1	LS	40,000	40,000	
Total Demobilization: Item B				461,100	= $461,100

Table 5-6 cont.

CLASS OF WORK OR MATERIAL	QUANTITY	UNIT	MATERIALS/LABOR UNIT	MATERIALS/LABOR EXTENSION	
C. Materials					
1. Blasting Material					
a. Powder	2,800	Cases	100	280,000	
b. Caps	220	Boxes	75	16,500	
c. Detonation Cord	75	Rolls	75	5,625	
2. Tunnel Liner	288,000	Lbs	0.65	187,200	
3. Cement	2,400	Bags	5.50	13,200	
4. Rebar	36,000	Lbs	0.50	18,000	
5. Misc. Weir Materials	1	LS	132,000	132,000	
6. Rock Bolts & Fasteners	1	LS	10,000	10,000	
7. Misc. Timbers/Steel/Concrete	1	LS	166,000	166,000	
8. Diesel Fuel/Gas	73,000	Gal	1.50	109,500	
Total Materials: Item C --				938,025	= $938,025
D. Mat'l. Installation cost (labor)					
1. Tunnel: 15'H x 14'W x 4200' L	4200	LF	375	1,575,000	
2. Vertical Slot Weirs	80	EA	7,100	568,000	
3. Tunnel Liner	1,200	LF	250	300,000	
4. Concrete Division Wall	800	LF	1,000	800,000	
5. Entrance & Exit Structures	2	EA	72,000	144,000	
6. Repair Suspension Bridge	1	LS	30,000	30,000	
7. Camp: Board & Room at $70/man/day	6,600	M-DY	70	462,000	
Total Labor: Item D --				3,879,000	= $3,879,000

Table 5-6 cont.

CLASS OF WORK OR MATERIAL	QUANTITY	UNIT	MATERIALS/LABOR UNIT	MATERIALS/LABOR EXTENSION	
E. Construction Overhead & Profit					
Construction Cont.: 10% (A-D)	SAY			750,000	
Contractor Overhead: 25% (A-D)	SAY			1,874,000	
Contractor Profit: 15% (A-D)	SAY			1,124,000	
Total O & P: Item E				3,784,000	= $3,784,000
F. Total Construction Costs: Items A-E				11,244,125	= $11,244,125
G. Consultant Design Services					
a. Engr. surveys: Topo. & Hydraulic	1	LS	200,000	200,000	
b. Geotechnical Investigations (In conjunction with upper fishway)	1	LS	500,000	500,000	
c. Construction Documents (5% of F when designed in conjunction with upper fishway)	1	LS	562,000	562,000	
Total CDS: Item G				1,262,000	= $1,262,000
H. DOTPF Administrative Costs					
a. Design/construction control: 15% F	SAY			1,687,000	
b. Contingency: 5% F	SAY			562,000	
Total DOTPF: Item H				2,249,000	= $2,249,000
I. Total Project Cost: Items F+G+H					= $14,755,125 ; SAY =$14,750,000

Table 5-7.
Devil Creek fishway C.I.P costs.

CLASS OF WORK OR MATERIAL	QUANTITY	UNIT	MATERIALS/LABOR UNIT	MATERIALS/LABOR EXTENSION
. Mobilization				
1. Equipment Rental				
LHD: 2 @ $10,800/mo = 21,600/mo	14	Mo	$21,600	$302,400
Compressors: 2@ 2800 = 5600/mo	14	Mo	5,600	78,400
Air Leg + 3" Drill: 4 @ 425 = 1700/mo	14	Mo	1,700	23,800
Ventilation Blower:	14	Mo	350	4,900
3" diameter Pump:	12	Mo	850	10,200
3" sub. Pump:	12	Mo	425	5,100
4" cent. Pump:	12	Mo	1,050	12,600
Suc./pres. hose: Misc. Lengths	12	Mo	1,000	12,000
Loader with 4 way Bucket	14	Mo	3,000	42,000
Portable Gravel Plant	6	Mo	12,000	72,000
16 C.F. Cement Mixer	6	Mo	1,350	8,100
Generators: 4 @ 1100 = 4400/mo	14	Mo	4,400	61,600
Sub-Total Item A1				633,100
2. Misc. Equip. Rent:	1	LS	150,000	150,000
Sub-Total Item A2				150,000
3. 22 Man Construction Camp				
a. Purchase 9- 8'x 20' Units 6 sleepers/ 1 office/ 1 kitchen/ 1 laundry-wet unit	1	LS	110,000	110,000
b. Setup and Outfit	1	LS	55,000	55,000
Sub-Total Item A3				165,000

Table 5-7 cont.

CLASS OF WORK OR MATERIAL	QUANTITY	UNIT	MATERIALS/LABOR UNIT	MATERIALS/LABOR EXTENSION	
Mobilization (cont.)					
4. Transportation					
FRT: RR Transport/Demurrage	1	LS	188,000	188,000	
Bell 212 (Trans): Mat'l. & Equip.	600	HR	1,500	900,000	
Bell 212 (Stdby): 15-4HR Days	80	HR	1,500	120,000	
Bell 206B: Bi-weekly Supply	200	HR	500	100,000	
Sub-Total Item A4 ----------				1,308,000	
5. Camp Setup					
a. Labor: 7 men (10hr/day) 60 days	4200	M-HR	30	126,000	
b. Camp Cost: $70/man/day	420	M-DY	70	29,400	
Sub-Total Item A5 ----------				155,400	
Total Mobilization Item A ----------				2,411,500	= $2,411,500
Demobilization					
Bell 212 (trans.): Mat'l. & Equip.	250	HR	1,500	375,000	
Bell 212 (stdby.): 15-4 hr Days	60	HR	1,500	90,000	
Bell 206B: Pers. & Supply	40	HR	500	20,000	
Labor: 6 men (10 hr/day) 30 days	1800	HR	20	36,000	
Camp cost: $70/man/day	180	DY	70	12,600	
FRT: RR Transport/Demurrage	1	LS	40,000	40,000	
Total Demobilization Item B ----------				573,600	= $573,600

Table 5-7 cont.

CLASS OF WORK OR MATERIAL	QUANTITY	UNIT	MATERIALS/LABOR UNIT	MATERIALS/LABOR EXTENSION	
Materials					
1. Blasting Material					
a. Powder	2,800	Cases	100	280,000	
b. Caps	220	Boxes	75	16,500	
c. Detonation Cord	140	Rolls	75	10,500	
2. Tunnel Liner	288,000	Lbs	0.65	187,200	
3. Cement	2,400	Bags	5.50	13,200	
4. Rebar	36,000	Lbs	0.50	18,000	
5. Misc. Weir Materials	1	LS	132,000	132,000	
6. Rock Bolts & Fasteners	1	LS	10,000	10,000	
7. Misc. Timbers/Steel/Concrete	1	LS	166,000	166,000	
8. Diesel Fuel/Gas	60,000	Gal	1.50	90,000	
Total Materials: Item C --				923,400	= $923,400
Mat'l. Installation cost (labor)					
1. Tunnel: 15'H x 14'W x 3900' L	3,900	LF	438	1,708,200	
2. Vertical Slot Weirs	60	EA	8,300	498,000	
3. Tunnel Liner	1,200	LF	292	350,400	
4. Concrete Division Wall	600	LF	1,170	702,000	
5. Entrance & Exit Structures	2	EA	84,200	168,400	
6. Camp: Board & Room at $70/man/day	7,700	M-DY	70	539,000	
Total Labor: Item D --				3,966,000	= $3,966,000

CLASS OF WORK OR MATERIAL	QUANTITY	UNIT	MATERIALS/LABOR UNIT	MATERIALS/LABOR EXTENSION		
						Table 5-7 cont.
. Construction Overhead & Profit						
Construction Cont.: 10% (A-D)	SAY			787,000		
Contractor Overhead: 25% (A-D)	SAY			1,969,000		
Contractor Profit: 15% (A-D)	SAY			1,181,000		
Total O & P: Item E				3,937,000	= $3,937,000	
. Total Construction Costs: Items A-E				11,811,500	= $11,811,500	
. Consultant Design Services						
a. Engr. surveys: Topo & Hydraulic	1	LS	200,000	200,000		
b. Geotechnical Investigations (In conjunction with lower fishway)	1	LS	500,000	500,000		
c. Construction Documents (5% of F when designed in conjunction (with lower fishway)	1	LS	590,000	590,000		
Total CDS: Item G				1,290,000	= $1,290,000	
I. DOTPF Administrative Costs						
a. Design/Construction Control: 15% F	SAY			1,772,000		
b. Contingency: 5% F	SAY			591,000		
Total DOTPF: Item H				2,363,000	= $2,363,000	
. Total Project Cost: Items F+G+H					= $15,464,500 ;	SAY=$15,465,000

Table 5-8.
Indian River and Portage Creek weirs C.I.P. costs.

CLASS OF WORK OR MATERIAL	QUANTITY	UNIT	MATERIALS/LABOR UNIT	MATERIALS/LABOR EXTENSION	
A. Contract Items (ADF&G Design)					
1. Mobilization/Demobilization	1	LS	$40,000	$ 40,000	
2. Indian River Weir	1	LS	150,000	150,000	
3. Portage Creek Weir	1	LS	225,000	225,000	
4. ADF&G Camp: Setup/Water/Sewer	1	LS	15,000	15,000	
5. Profit/Overhead/Ins. @ 25% (1-4)	1	LS	105,000	105,000	
Total Item A -----				535,000	= $535,000
B. DOTPF PJT Admin: 15% (A) -----					= $ 80,000
C. ADF&G Equip. Purchase					
1. 12' x 20' Hansen Weatherports	5	EA	3,600	18,000	
2. 16' Ø Redwood Tanks	4	EA	3,500	14,000	
3. 12' Ø Redwood Tanks	4	EA	3,000	12,000	
4. 4" Diesel Pumps	2	EA	5,000	10,000	
5. 10 kw Deisel Generator	1	EA	15,000	15,000	
6. Misc. Piping & Fittings	1	LS	6,000	6,000	
7. Jet Boats & Fittings	2	EA	20,000	40,000	
Total Item C -----				115,000	= $115,000
Total Project Cost: Items A+B+C -----					= $730,000; SAY = $700,000

Table 5-9. Fry/fingerling transport and stocking operational costs.

A) Sockeye (Initially from Gulkana River at Paxson):

1) Truck operations

a) Juveniles trucked from Paxson to Lake Louise.
b) 4 trips.
c) Rental truck from Anchorage for 5 days.

Cost:	Truck @ 5 day x 8 hr/day x $70/hr	=	$2,800
	Truck mileage = 1100 mile x $2.10/mile	=	2,310
	Driver P.D. = 5 day x $70/day	=	350
			$5,460

2) Helicopter charter

a) Dead Head = 4 hrs x $650/hr	=	$2,600
b) Planting = 14 hr x $650/hr		9,100
c) Pilot P.D. = 2 day x $70/day		140
		$11,840

B) Chinook, coho, chum (initially from Anchorage)

1) Truck operations

a) Juveniles trucked from Anchorage to Lake Louise and the Denali Highway.
b) 4 trips.
c) Rental truck from Anchorage for 5 days.

Cost:	Truck @ 5 days x 8 hr/day x $70/hr	=	$2,800
	Truck mileage = 2,300 mile x $2.10/mile	=	4,830
	Driver P.D. = 5 day x $70/day	=	350
			7,980

2) Helicopter charter
Included with 1b.

3. Total planting cost/season

A1 + A2 + B1 = $5,460 + $11,840 + $7,980 ---------------- = $25,280; SAY=25,000/season

5.2.4 Hatcheries

This section describes a hatchery operation for a salmon enhancement program in the upper drainage basin of the Susitna River. The cost estimates developed will be combined, in Section 6, with the value of the expected salmon returns to develop a benefit vs. cost (B/C) ratio for both a fishway and a hatchery salmon enhancement program.

5.2.4.1 General Information and Discussion

Fish hatcheries are a useful tool in man's attempt to artificially propagate fish. Fish hatcheries have been in use in the United States for more than one hundred years since the first hatchery was built in Orland, Maine in 1871. The FRED Division of the Alaska Department of Fish and Game has constructed many hatcheries in Alaska since 1975 and considerable information on the cost and operations of hatcheries is available.

Because it is assumed that most Alaskans, and especially the readers of this report, are familiar with the purpose and operations of a hatchery, no detailed description of a hatchery operation will be provided here. Suffice it to say that hatcheries have several functions, some of which are:

1) Mitigation of fish losses caused by the construction of barriers (dams) to natural spawning areas.

2) Maintaining and/or increasing fish stocks overexploited by fishing.

3) Mitigation of fish losses due to pollution and/or alteration of the natural environment.

4) Stocking of rehabilitated habitat areas where fish populations have been depleted by unfavorable conditions, both natural and man-caused.

5) Introduction of species more suitable to an altered environment, i.e. introducing warm water fish into warm water reservoirs.

6) Enhancement in areas where natural production is not realized.

It is function number (6) that is of concern to this study since salmon production in the upper Susitna River area could be achieved by the introduction of adult spawners to the area via fishways or by the alternate method of introducing fry/fingerlings into the area by means of hatchery operations. In the latter case, the study team envisions a simplified hatchery program in which maximal emphasis is placed on the natural rearing of fry/fingerlings, thus reducing hatchery costs associated with the rearing and feeding of juveniles.

For a hatchery program, eggs are collected from appropriate brood stocks and incubated. Depending on the type of program desired, eyed eggs, fry/fingerlings, or smolts are stocked. A recommended program for a 16 million egg incubation facility follows.

5.2.4.2 Brood Stocks

Indian River and Portage Creek are potential sources of chinook, coho and chum salmon eggs. Reasons for considering these streams as donor sources are:

1) The homing response of returning adults is enhanced if stocks are used from the natal watershed. Indian River and Portage Creek are tributary streams of the Susitna River and are located at Susitna River miles 138.6 and 148.9, respectively.

2) Salmon for the upper Susitna River watershed should originate from broodstocks which are accustomed to migrating long distances in rivers. Indian River and Portage Creek salmon stocks migrate approximately 140 and 150 miles upstream in the Susitna River and are essentially the nearest stocks to the Devil Canyon rapids. Devil Canyon, the first impassable rapids to adult migration, is only a couple of miles upstream of the mouth of Portage Creek.

3) Stock sources must contain an adequate number of brood fish. The number of adult salmon annually required to provide eggs for the hatchery program each year is:

Chinook Salmon	-	225
Coho Salmon	-	320
Chum Salmon	-	320

Based on aerial and foot surveys, Indian River and Portage Creek should provide these fish.

4) The stock sources must be accessible. Adult capture and holding facilities can be installed at Indian River and Portage Creek, which are accessible by boat, helicopter, and fixed-wing aircraft. Talkeetna is located approximately 44 and 54 Susitna River miles downstream of Indian River and Portage Creek, respectively. Also, Talkeetna is the recommended site for a new hatchery if a hatchery-supported salmon enhancement program is implemented in the upper Susitna River drainage basin.

The Gulkana River, a tributary of the Copper River, is an potential source of sockeye salmon eggs. Pros and cons are as follows:

1) Sockeye salmon for the upper Susitna River watershed should originate from stocks which are accustomed to migrating long distances in rivers. Upper Gulkana River sockeye adults migrate more then 270 river miles from the mouth of Copper River to their spawning grounds. By comparison, the Susitna River salmon are blocked at river mile 152 (Devil Canyon).

2) Adequate numbers of sockeye brood are essential. The number of sockeye adults needed to provide eggs for hatchery propagation each year is 7,667. The upper Gulkana River, upstream of its confluence with Mud Creek near Paxson, supports annual escapements probably exceeding 15,000 sockeye adults(Mr. Ken Roberson, pers. comm., December 28, 1982). The Gulkana hatchery, located near Paxson at a spring flowing into the upper Gulkana River, is expanding its sockeye adult production and in 1982 had a record escapement of 8,000 sockeyes.

3) Sockeye stock sources must be accessible. An adult capture and holding area is already installed at the Gulkana hatchery. Increased adult production at this hatchery should provide adequate brood stock for the upper Susitna River in the future. Adequate water and space now exist for incubating many more eggs than are presently being incubated and the Gulkana hatchery is readily accessible by road.

Additional sockeye adults are available in the upper Gulkana River adjacent to the hatchery. This river section like the Gulkana hatchery is adjacent to the Richardson Highway.

There is one potential problem with the Gulkana River sockeye stock. This stock, like other sockeye stocks, has the viral disease, infectious hematopoietic necrosis (IHN), which causes severe mortality of juvenile salmon. IHN has caused severe mortality at state hatcheries. The strain of IHN virus found in the Gulkana River stock has caused mortality of Cook Inlet sockeye fry in tests conducted by ADF&G's fish pathology laboratory (Dr. Roger Grischkowsky 16/ pers. comm., December 29, 1982). The potential implication of a transplant of Gulkana River sockeye salmon into the Susitna River is clear--a virulent strain of IHN virus could adversely affect Cook Inlet sockeyes. There is perhaps some good news. Water hardening of sockeye salmon eggs in an iodophor solution may kill IHN viruses inside as well as outside of the eggs. If this procedure proves viable, IHN virusfree juvenile sockeye salmon could be produced at hatcheries, such as Gulkana hatchery, which have an IHN virus-free water source. Further research may prove or disprove the viability of this procedure.

There is one other potential sockeye salmon stock, the Stephan Lake stock, that has advantages and disadvantages relative to the Gulkana River stock. Stephan Lake is located 3 miles south of the upper Susitna River between its confluence with Devil Creek and Fog Creek. This lake drains into the Talkeetna River. Advantages of this stock are:

1) The homing response of returning adults will exceed that of the Gulkana River stock since the former now migrate up the Susitna River approximately 97 miles.

16/ ADF&G Principal Pathologist, Anchorage.

2) The Stephan Lake stock does migrate a considerable distance, approximately 154 river miles, which, however, is a much shorter migration than the 270 miles the Gulkana River salmon travel.

Disadvantages of this stock are:

1) Inadequate number of brood fish. Cursory surveys indicate an annual run of 115 to 1,142 adults. These numbers are perhaps only 10% of the actual run, so 1,150 to 11,420 adults may annually spawn in the lake. (Mr. Ken Tarbox 17/ pers. comm., December 28, 1982). Approximately 7,667 sockeye adults are required annually for hatchery propagation, so the Stephan Lake stock would have to be increased, if this is possible, through hatchery propagation before enough adults would be available as brood for the upper Susitna River watershed. If the Stephan Lake stock is not increased, less juvenile sockeyes than planned would be planted in the upper Susitna River and the run would take many more years to reach a maximum.

2) Stephan Lake is not as easily accessible as the Gulkana River. The only access to the lake is by fixed-wing aircraft or helicopter. Access from Talkeetna is not possible by boat.

3) The IHN disease history for the Stephan Lake stock is unknown. This stock may or may not be a viable candidate for transplanting into the upper Susitna River watershed.

17/ ADF&G Fishery Biologist III, Soldotna.

5.2.4.3. Juvenile Salmon Stocking

Juvenile salmon could be introduced into the upper Susitna River watershed as eyed eggs, fry/fingerlings or smolts. The advantages and disadvantages of each life stage are now discussed, with a resultant recommendation.

5.2.4.4 Eyed Egg Planting

With the eyed egg program, eggs are taken from brood fish at egg take facilities. Eggs are taken to an incubation facility and incubated until eyed. These eyed eggs are then transported to and planted in selected gravel in streams where incubation is naturally completed. A modern salmon egg planting device is shown in Figure 5-15. In the spring, the fry emerge from the gravel, spread throughout the streams, and after one or more years migrate to sea as smolts if chinook, coho or sockeye salmon. Chum fry migrate to sea within several months after emerging from the gravel.

Advantages of planting eyed eggs:

1) Hatchery capital and operational expenses would be minimized when compared to a hatchery fry/fingerling or smolt program.

2) The homing response of adults resulting from eyed eggs should exceed the homing response of adults resulting from fry or smolt releases as the eyed egg progeny will spend additional months incubating in the Susitna River watershed.

Disadvantages of planting eyed eggs:

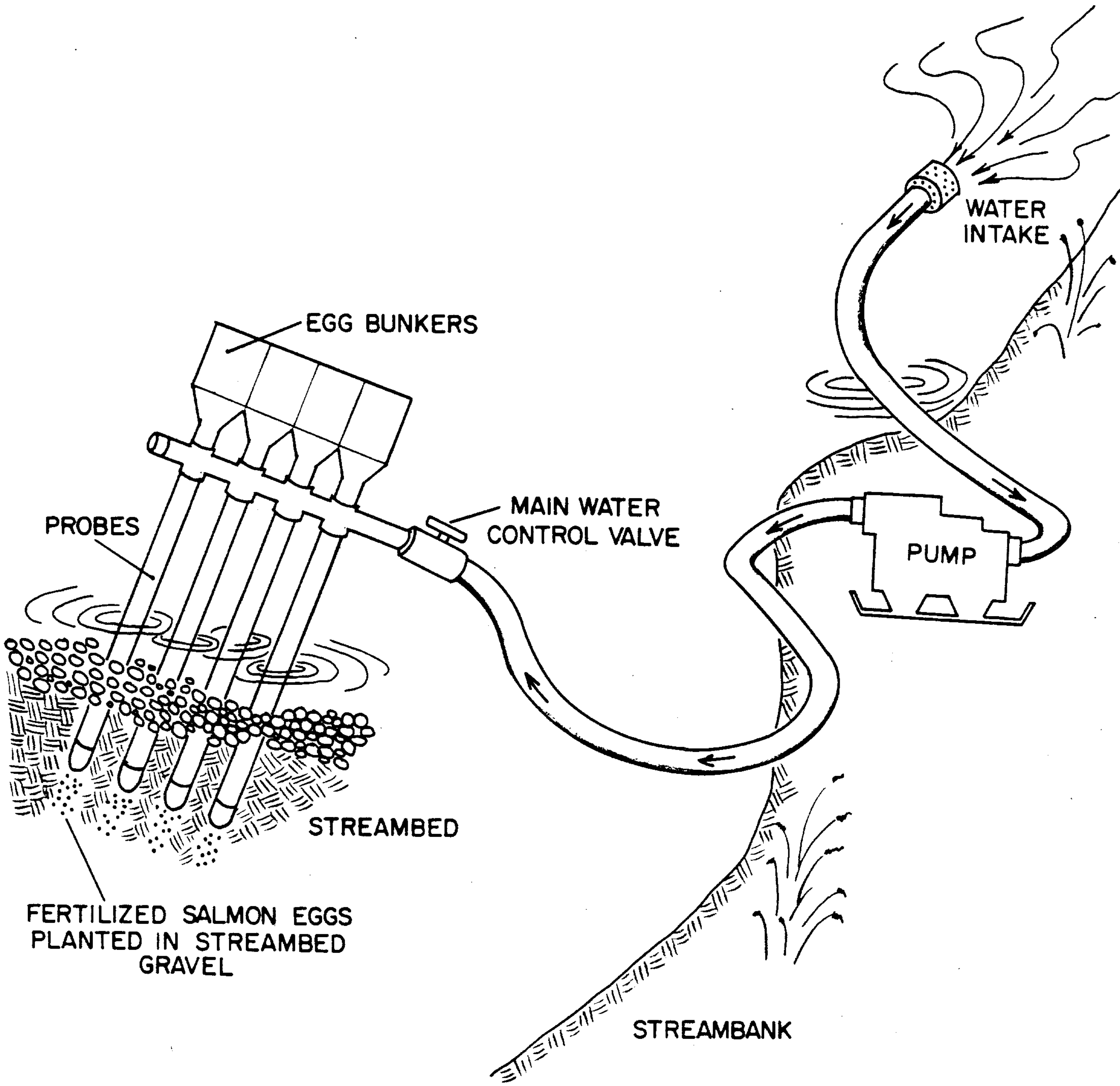
1) Survival to adulthood will be less for eyed eggs than for older life stages.

2) The upper Susitna watershed freezes up early in the fall due to the high latitude and elevation. Some eggs will not be eyed before ice covers the streams. This factor combined with hazardous flying conditions during the fall, precludes successful planting of a certain percentage of the eggs.

3) Costs of transporting and planting eyed eggs may not be less than the costs of planting fry/fingerlings or smolts. Many more eggs than later life stages must be planted to attain the same number of adults. Also, more manpower is required to plant eyed eggs than to release fry/fingerlings and smolts.

5.2.4.5 Smolt Stocking

Production of smolts for stocking involves egg incubation and long term rearing. Smolts can be transported in the same manner as fry/fingerlings



A salmon egg planting device (SEPD)
(From Jones et al. 1977).

UPPER SUSITNA RIVER
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Figure 5-15.
SEPD.

with releases into streams or lake outlets in the upper Susitna River basin. Smolts would immediately migrate to sea.

Advantages of stocking smolts:

1) Survival to adulthoood will exceed that for eyed eggs and for fry/fingerlings.

2) Unlike eyed eggs, smolts can be stocked after the ice has left the streams and lakes in May and June.

Disadvantages of stocking smolts:

1) The hatchery for smolts will be more expensive than for eggs and fry/fingerlings due to the long term rearing needed for the smolts. Unlike fry/fingerlings, smolts will require one or more years of rearing depending on the temperature of the rearing water.

2) Sockeye salmon may not attain smolthood under hatchery conditions due to IHN disease.

5.2.4.6 Fry/Fingerling Stocking

Production of fry/fingerlings for stocking involves egg incubation and some rearing of resultant fry to the fed fry stage (25% weight gain from emergent fry weight) or the fingerling stage (100% weight gain from emergent fry weight). After rearing at the hatchery, juvenile salmon would then be transported via truck/trailer, fixed-wing aircraft or helicopter and stocked in streams and lakes in the upper Susitna River basin. After one or more years, the chinook, coho and sockeye juveniles would migrate to sea as smolts. Chum fry/fingerlings would migrate to sea within a few months after stocking.

Advantages of stocking fry/fingerlings:

1) The homing response of adults resulting from stocking fry/fingerlings should exceed that for smolts since the former remain in fresh water much longer than smolts.

2) Survival to adulthood will exceed that for eyed eggs.

3) Unlike eyed eggs, fry/fingerlings can be stocked after the ice has left the streams and lakes in May and June.

4) The hatchery capital and operational costs are cheaper for fry/fingerlings than for smolts.

Disadvantages of stocking fry/fingerlings:

1) Survival to adulthood will be less than for smolts.

2) The artificial rearing requires a more expensive hatchery than for eyed eggs.

All things considered, a fry/fingerling stocking operation is recommended over that of eyed egg plants or smolt plants if a hatchery enhancement program is implemented. Fry/fingerling survival will exceed that for eyed eggs and the homing response should exceed that for smolts. Fry/fingerlings, unlike smolts, will have the ability to spread throughout a lake or stream, or perhaps move from stream to stream, adapting to the natural environment, and thereby guaranteeing a good homing response.

5.2.4.7 Hatchery Construction Costs

To implement a fry/fingerling stocking program, such as discussed in section 5.2.4.6, a hatchery would have to be built to support that program. The study team identified a potential site for the hatchery on state-owned property at the airport in Talkeetna (Figure 5-16). A hatchery site plan is depicted in Figure 5-17. The site selected was chosen for the following reasons:

1) Availability of land, water, electricity and other utilities.

2) Ease of access by air, vehicle and railroad.

3) Central location relative to brood sources and juvenile stocking sites.

4) Relatively easy construction conditions to moderate cost.

5) Seasonal hatchery support from local labor source.

6) Rural environment with support of hospital, schools, commercial facilities etc.

A suitable hatchery layout is shown in Figure 5-18 and would consist of the following major features:

1) Sixteen (16) million egg incubation capacity. This facility would be staffed by 2 full time employees with summer supplemental help of from 4 to 6 seasonal helpers. The facility would incubate 1 million chinook, 1 million coho, 1 million chum and 13 million sockeye salmon eggs to the fry/fingerling stage for transplanting to the upper Susitna River drainage basin for release and natural rearing.

2) Two adult capture weirs, one at Indian River and one at Portage Creek. These two sites would be manned during the summer months by a 12-14 person crew operating from a common camp at Gold Creek. The chinook, coho, and chum eggs used for the hatchery operation would be collected at these weirs, while the sockeye eggs would initially come from the Gulkana River facility at Paxson. Once a strong sockeye run is established upstream

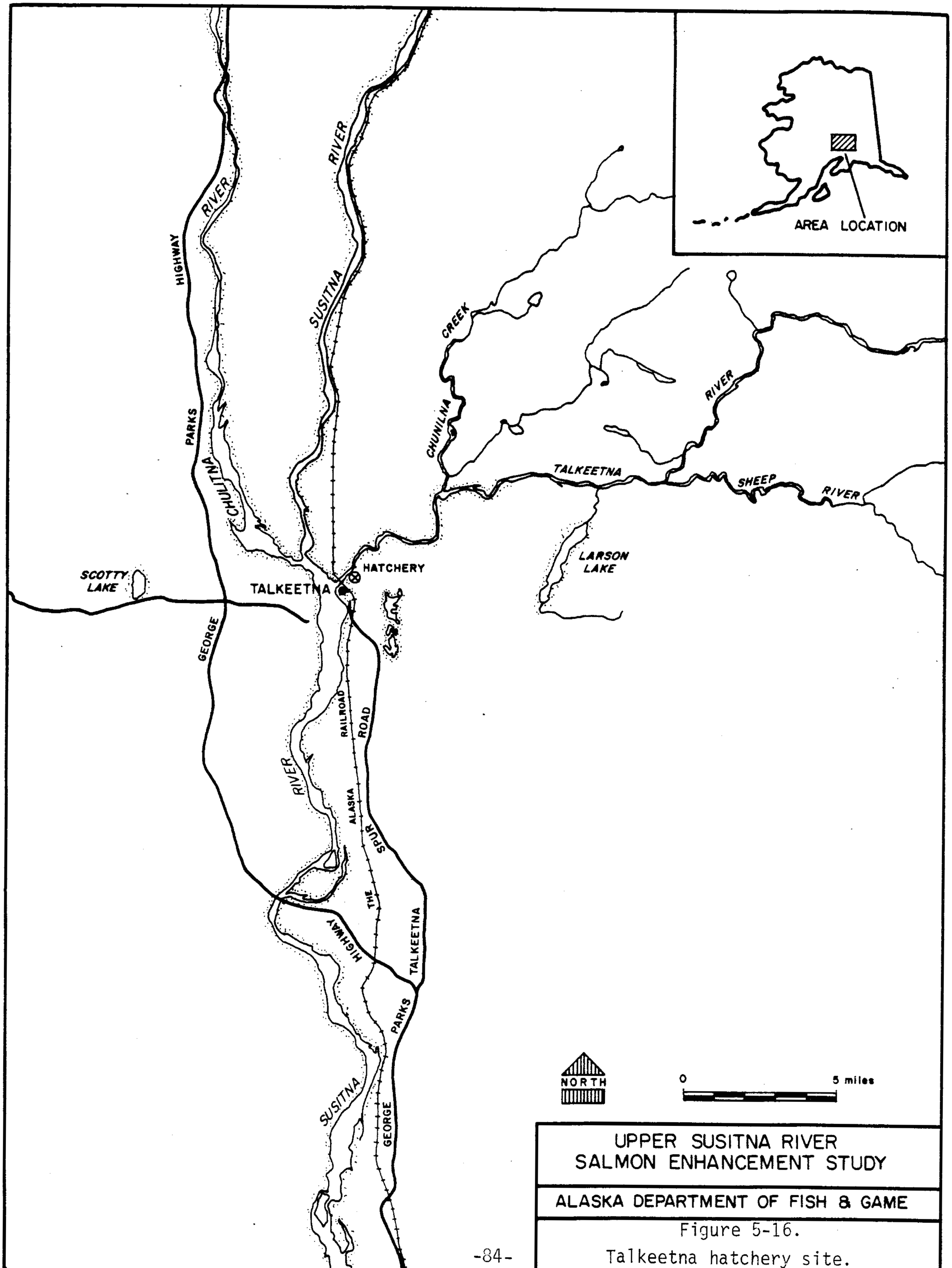

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Figure 5-16.
Talkeetna hatchery site.

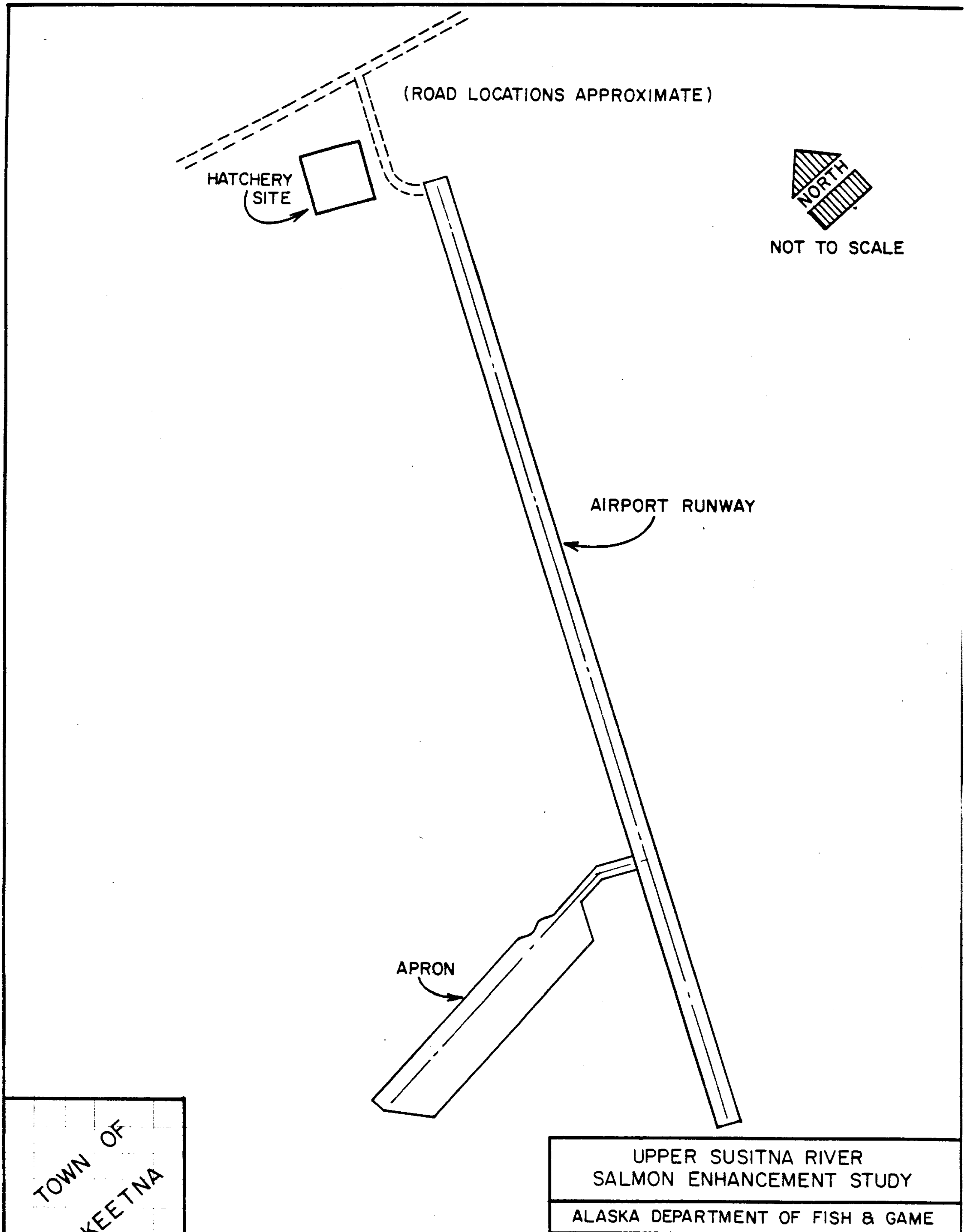

Figure 5-17.
Talkeetna hatchery site plan.

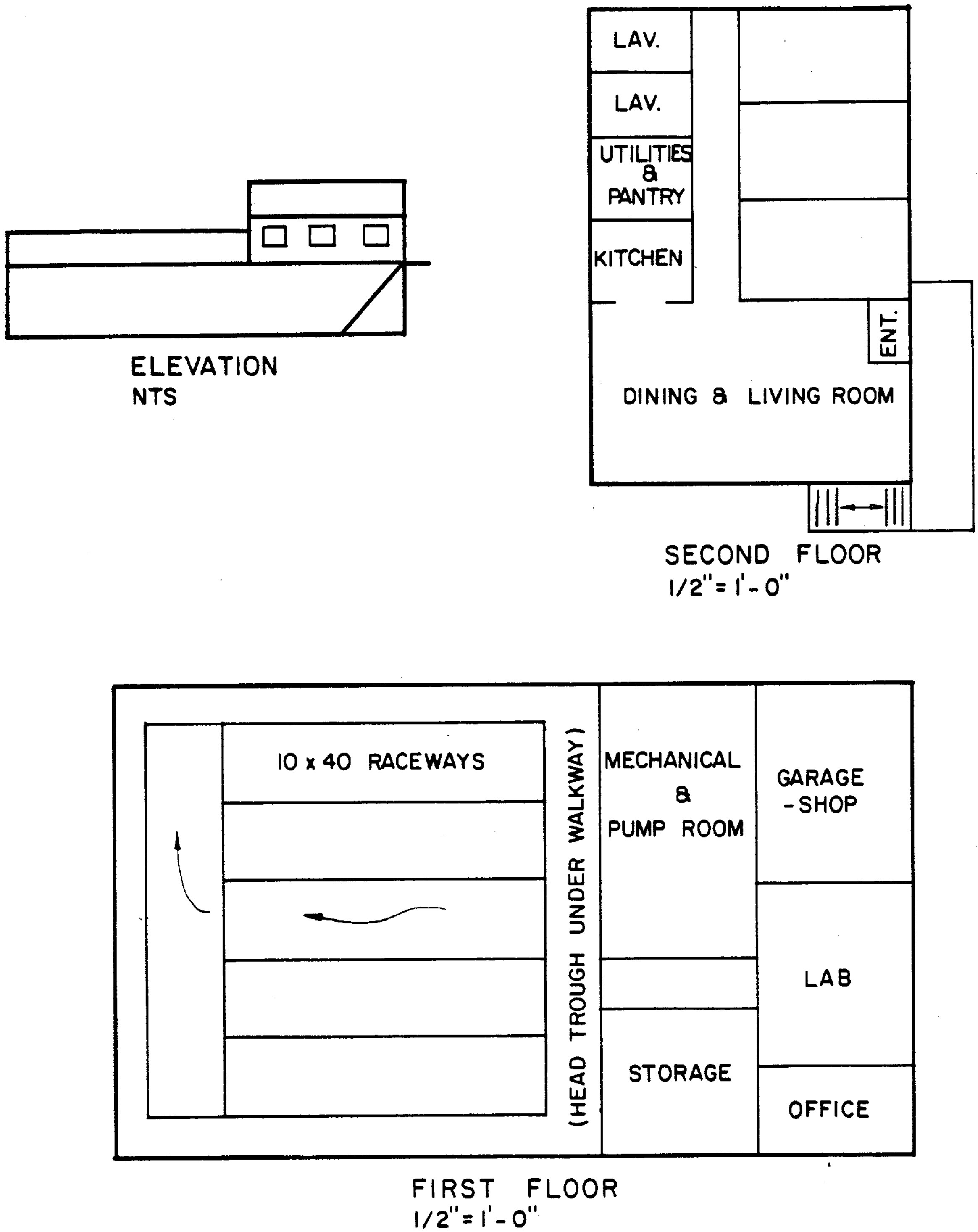

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Figure 5-18.
Talkeetna hatchery layout.

of Gold Creek, sockeyes will be blocked by the Devil Canyon velocity barrier and most will subsequently stray into the largest nearby tributaries, viz. Indian River and Portage Creek. The sockeye eggs would then be collected at the same weirs used for the chinook, coho and chum eggs.

3) Fry/fingerling planting operation. Initial stocking of the enhancement area would be from fry/fingerlings taken from the Anchorage and the Gulkana River facilities. As the Talkeetna hatchery becomes operational, the incubation and planting operations would be transferred to Talkeetna until the entire enhancement program was carried out from Talkeetna. The planting operation would consist of truck transport to Lake Louise and helicopter transport from Lake Louise to pre-selected release points in that area. These operations would be conducted by rented truck, chartered helicopter and support of the hatchery's seasonal crew.

Cost estimates for the hatchery features just described, viz. (1) hatchery C.I.P costs, (2) weir C.I.P costs and (3) operational costs for the fry/fingerlings planting operation are listed in Tables 5-10, 5-8, and 5-9, respectively.

Table 5-10.
Talkeetna Hatchery C.I.P costs.

CLASS OF WORK OR MATERIAL	QUANTITY	UNIT	MATERIALS/LABOR UNIT	MATERIALS/LABOR EXTENSION	
1. Mobilization/Demobilization	1	LS	110,000	110,000	= $110,000
2. Site Work					
Survey/layout - clearing/grubbing	2	AC	4,000	8,000	
Fill	1200	CY	11	13,200	
Spreading, Grading, Compaction	2000	SY	6	12,000	
Water Supply: 100' wells	10	EA	10,000	100,000	
30' screens	10	EA	4,200	42,000	
testing	600	HR	150	90,000	
sub-pumps	10	EA	7,000	70,000	
Manifold Building & Piping	1	LS	60,500	60,500	
Sanitary Sewer	1	LS	15,000	15,000	
Incb. Bldg. Water Drain Ditch	2,500	LF	100	250,000	
Sub-Total: Item 2				660,700	= $660,700
3. Hatchery Building	4800	SF	75	360,000	= $360,000
4. Living Quarters and Support Bldg.	2400	SF	85	204,000	= $204,000
5. Hatchery Bldg. Process Piping	1	LS	60,000	60,000	
Incubation Supply & Drain	1	LS	36,000	36,000	
Inc. Support System & Grating	1	LS	35,000	35,000	
Sub-Total: Item 5				131,000	= $131,000
6. Electrical	1	LS	150,000	150,000	= $150,000
7. Equipment					
Incubators	100	TRAY	200	20,000	
150 kw Emergency Generator	1	LS	75,000	75,000	
4 W.D. 3/4T Pickup	1	LS	20,000	20,000	
Fish Transport Tanks	4	EA	2,500	10,000	
Office Equip., Tools, misc. items	1	LS	25,000	25,000	
Sub-Total: Item 7				150,000	= $150,000

Table 5-10 cont.

CLASS OF WORK OR MATERIAL	QUANTITY	UNIT	MATERIALS/LABOR UNIT	MATERIALS/LABOR EXTENSION	
8. Hatchery Manager Residence	1	LS	120,000	120,000	= $120,000
9. Construction Cont.: 10% (Items 1-8)	SAY			188,000	= $188,000
10. Contractors Overhead & Profit					
a. Overhead @ 20% (Items 1-9)	SAY			415,000	
b. Profit @ 10% (Items 1-9)	SAY			207,000	
Sub-Total Item 10				622,000	= $622,000
11. Consultant Design 8% of Items 1-9	SAY			166,000	= $166,000
12. DOTPF Administration					
Design/Const. Control: 15% (Item 1-9)	SAY			311,000	
Contingency: 10% (Items 1-9)	SAY			207,000	
Total DOTPF: Item 12				518,000	= $518,000
13. Total Project Cost: Items 1-12					=$3,379,700 SAY = $3,400,000

5.3 Biological Impact of Introduced Salmon on Resident Fish

Resident fishes of the upper Susitna River drainage are listed in Table 5-11.

Table 5-11. Resident fishes of the upper Susitna River drainage.1/

Arctic grayling
Lake trout
Dolly Varden char
Humpback whitefish
Round whitefish
Burbot
Longnose sucker
Slimy sculpin
Arctic lamprey

1/ From Alaska Department of Fish and Game (1981g and 1982a).

Adult and juvenile salmon will affect and be affected by resident fish. Adult sockeye salmon that spawn in lakes may affect the eggs of lake trout. The spawning dates of potential sockeye stocks for the upper Susitna River, namely lower Susitna River (Barrett 1974) or Gulkana River fish do overlap with those of Alaskan lake trout, namely late August and September (Morrow 1980; VanWhye and Peck 1968).

The spawning depths of sockeye salmon and lake trout overlap with the lake trout having the greater range of 1 to more than 300 ft deep (Carlander 1969; Scott and Crossman 1973).

Unlike sockeye salmon, lake trout do not dig redds and generally spawn in areas that lack upwelling water flow. For example, lake trout frequently spawn on boulders and rubble and also on gravel, silt, mud, clay and marl lake bottom (Carlander 1969; Scott and Crossman 1973). Though little interaction between sockeyes and lake trout adults is expected, sockeye adults could dig up the eggs of lake trout that spawn on lake gravel with upwelling water flow. In very rare instances, lake trout spawn in streams (Scott and Crossman 1973) in which case sockeye and other salmon species could dig up trout eggs. Uncovered trout eggs could then be eaten by the resident burbot, longnose sucker, round whitefish, and even lake trout (Scott and Crossman 1973; Morrow 1980).

Adult salmon may affect the eggs of Dolly Varden char. The spawning dates of potential chum, coho, and sockeye stocks for the upper Susitna River do overlap with those of Alaskan Dolly Varden, namely late August and September (Morrow 1980). These salmon species could spawn on previously-constructed Dolly Varden redds. Since these salmon generally dig deeper redds than those of Dolly Varden (Blackett 1968; Morrow 1980), Dolly Varden eggs would be dislodged and could be eaten by resident burbot, longnose sucker, and round whitefish (Morrow 1980; Scott and Crossman

1973). The opposite situation could occur when late spawning Dolly Varden might dislodge salmon eggs during their own redd digging activities.

Juvenile salmon will, depending on individual size, compete for the same food items as resident fish and also prey upon resident fish. Sockeye fry and fingerlings compete for food (zooplankton) most frequently with threespine stickleback and even whitefish and char (Foerster 1968). Sockeye competition with other resident fish is unknown.

Chinook and coho salmon will probably compete with resident fish for food and space. Of all the resident fish species, arctic grayling will be primarily affected by these salmon. Chinook and coho salmon frequently reside in the slower-moving areas of streams, i.e., sloughs, undercut streambanks, back eddies, and pools (Morrow 1980; Albin 1977; Scott and Crossman 1973). Grayling also reside in pools and defend territories as do coho salmon (Morrow 1980; Alaska Department of Fish and Game 1982a; Warren 1971). Unlike coho and chinook salmon, grayling will sometimes inhabit riffle areas of streams (Albin 1977). Salmon and grayling eat primarily insects. Coho salmon, probably the major salmon competitor for space, will probably be the major competitor for food with grayling since both of these fish feed on insects primarily at the surface of the water or at mid-depth (Morrow 1980; Scott and Crossman 1973). Chinook salmon will also compete for food and will eat insects at any depth in the stream. Competition between salmon and other resident fish species will probably be for food more than for space. Unlike coho and chinook salmon, burbot and Dolly Varden inhabit the stream bottom and whitefish reside in riffles (Albin 1977; Morrow 1980). Some competition for food will occur, since most juvenile resident fish species eat insects.

Chum salmon compete less for food and space than the other salmon. Shortly after emerging from the gravel, the chum fry begin swimming downstream to salt water. The fry do feed on zooplankton and small insects while in freshwater but are so small in size and reside for such a short time in freshwater that they are not serious competitors for food with the resident fish. Chum fry will also inhabit the main stem of the Susitna River during spring and early summer and therefore will not compete for space with resident fish, which will at this time of year reside in tributaries (Alaska Department of Fish and Game 1981f; Riis and Friese 1978).

The salmon that will prey on resident fish are coho and chinook salmon. Sockeye and chum salmon primarily eat zooplankton and some insects. Fingerling coho and chinook salmon primarily eat insects, but, if given the opportunity will consume resident fish eggs that drift downstream during or after spawning. Juvenile chinook salmon do not appear to consume fish but coho smolts definitely do (Morrow 1980). Coho smolts are significant predators of juvenile sockeye salmon (Morrow 1980) and do prey on stickleback (Parr 1972). Evidence for predation by coho smolts on other resident fish was not found, but surely coho smolts will consume the fry of resident fish if given the opportunity.

Predator-prey relationships are a "two-way street" and introduced salmon will be eaten by resident fish. Grayling will on occasion consume sockeye salmon eggs and fry (Williams 1969). The lake whitefish, closely related to the humpback whitefish, consume sockeye fry (VanWhye and Peck 1968) and the round whitefish, which consumes lake trout and whitefish eggs (Morrow 1980; Scott and Crossman 1973), will probably consume salmon eggs if given the opportunity. Other known predators of sockeye fry are lake trout (VanWhye and Peck 1968), burbot (Roberson, Bird and Fridgen 1978), and Dolly Varden (Hartman and Burgner 1972). Dolly Varden consume sockeye from egg through smolt life stages (Meacham and Clark 1979; Foerster 1968) and are known predators of coho salmon (Crone 1981 and Parr 1972), and chum fry (Hunter 1959). Longnose suckers are known to eat salmonid eggs, given the opportunity (Morrow 1980).

In summation, salmon will impact the resident fish. Competition for food and space, and predator-prey relationships will be complex with salmon affecting other salmon species as well as resident fish, and resident fish affecting other resident fish as well as salmon.

Introduced salmon may actually benefit certain resident fish species by acting as "buffer prey", a term mentioned in Hartman and Burgner (1972). For example, salmon are preyed on by Dolly Varden and lake trout which frequently prey on stickleback and whitefish, respectively. The extent of predation on these latter two prey species would therefore be reduced, which could allow their numbers to increase. By salmon acting as "buffer prey", any reduction in resident fish due to competition or predation by salmon may be balanced.

6. ECONOMIC ANALYSIS

6.1 Vertical Slot Fishway Enhancement Program

The purpose of constructing a fishway at a velocity barrier such as occurs in Devil Canyon is to make available additional spawning and rearing areas in the stream above the barrier. Earlier sections gave consideration to such physical factors as:

1) Accessiblity of the barrier: The method of accessibility (plane, boat, road) of personnel to the site for construction, maintenance, and operating purposes.

2) Stream hydrology: Maximum, mean, and minimum discharges.

3) Terrain topography: Stream gradient.

4) Foundation material: Geotechnical investigations for determining the type of construction needed.

5) Characteristics of barrier: Height and length of the barrier. Vertical barrier, velocity barrier, or combination of both.

6) Spawning area: The area available for the spawning and rearing of chinook, coho, chum and sockeye salmon.

This section will consider the fiscal factors that determine if the tunnel-vertical slot fishway described in Section 5.2.3.5 is economically practical.

6.1.1 Benefit/Cost Ratio

There are several financial methods for determining the acceptable cost of a project. This study will use the benefit/cost (B/C) method because it is a procedure that is familiar to most people.

The reader should be aware that B/C ratio analysis is not an exact science and that limitations exist in this method of fiscal evaluation. In this study the writers have used estimated figures for project costs, maintenance costs, project life, fish yields, and the interest rate of financing.

The variable factors listed in the previous paragraph were estimated with the best information available, but still they are only estimates. If actual costs are less than estimated costs, the B/C ratio will be increased, and, of course, if the benefits are less than estimated the B/C ratio will be reduced. Variables that are not included in this cost evaluation are the unknowns of nature such as unusually cold weather, extreme flow conditions during floods and drought, and the influence of future fishing regulations, all of which can affect the anticipated salmon harvest.

6.1.2 Economic Factors, Assumptions, and Calculations

A) Susitna River salmon

1) Average weight of salmon in Cook Inlet

a) Chinook - sport 18/ = 20.5 lb
commercial 19/ = 16.7 lb

b) Coho - sport and commercial 19/ = 6.1 lb

c) Sockeye - commercial 19/ = 6.5 lb

d) Chum - commercial 19/ = 7.7 lb

2) 1982 average value to fishermen in Cook Inlet

a) Chinook - sport 20/ = $120.00/fish
commercial 21/ = $25.00/fish

b) Coho - sport 20/ = $38.00/fish
commercial 20/ = $5.50/fish

c) Sockeye - commercial 20/ = $7.30/fish

d) Chum - commercial 20/ = $4.90/fish

B) Potential return to system

1)	Chinook	-	3,000 fish
2)	Coho	-	5,100 fish
3)	Sockeye	-	160,000 fish
4)	Chum	-	9,700 fish
	Total	=	177,800 fish

18/ From Mr. Kevin Delaney, pers, comm., November 22, 1982, ADF&G Fishery Biologist III, Anchorage.

19/ From Mr. Jim Browning, pers. comm., November 19, 1982.

20/ From Mr. Jeff Hartman, pers. comm., November 18, 1982, ADF&G Fish Culturist IV, Anchorage.

21/ From Development Planning and Research Associates, Inc. (1982).

C) Potential harvest in the upper Susitna River due to fishway installation (See biocriteria, Table 6-1)

1) Chinook = 800 fish

2) Coho = 660 fish

3) Sockeye = 53,300 fish

4) Chum = 2,600 fish

Total = 57,360 fish

D) Value of harvest

1) 1982 value of salmon

a) Chinook - 780 sport + 20 commercial= $94,000

b) Coho - 290 sport + 370 commercial= $13,000

c) Sockeye - 53,300 commercial= $390,000

d) Chum - 2,600 commercial= $13,000

Total = $510,000

Table 6-1. Biocriteria 1/ for determining the harvestable surplus of salmon adults with the fishway enhancement program at Devil Canyon and Devil Creek areas.

	Chinook salmon	Coho salmon	Sockeye salmon	Chum salmon
Smolt to adult survival	3%	10%	10%	1%
Egg to smolt survival	1.4%	1%	1%	12.5%
Fecundity (no. eggs/female)	6,500	2,300	3,000	2,200
Egg retention	0%	0%	0%	0%
Male: female	1:1	1:1	1:1	1:1
Recruitment: spawner	1.4	1.2	1.5	1.4
Brood survival in fresh water	$\geq$ 90%	$\geq$ 90%	$\geq$ 90%	$\geq$ 90%

1/ From data listed in Alaska Department of Fish and Game (1982b), Crone and Bond (1976), Drucker (1972), Foerster (1968) and Hunter (1959).

2) Assume the salmon harvest (all species) will occur as follows:

1st - 4th year-------0%	=	0 fish
5th year------------50%	=	28,700 fish
6th year------------60%	=	34,400 fish
7th year------------70%	=	40,200 fish
8th year------------80%	=	45,900 fish
9th year------------90%	=	51,600 fish
10th-40th year-----100%	=	57,400 fish

3) Future annual value of harvest

1st-4th-year 1982 - 1986	=	$0
5th year -----------1987	=	$ 255,000
6th year -----------1988	=	$ 306,000
7th year -----------1989	=	$ 357,000
8th year -----------1990	=	$ 408,000
9th year -----------1991	=	$ 459,000
10th-40th year 1992-2022	=	$ 510,000

E) Assumptions concerning fishway costs

1) Fishways (Devil Canyon and Devil Creek)

a) Tunnel life of 40 years - initial tunnels cost $30,215,000

b) Replace vertical slot baffles at year 20 - $2,000,000

c) Yearly opening/closing costs of fishway - $5,000

d) Significant maintenance: Year 10 - $25,000 year 30 - $25,000

2) Two weirs/camp facility

a) Camp/weirs used for 5 years - initial weir cost $700,000

b. Weir operations for 5 years at $25,000/year

3) Stocking operational costs - $25,000/year

4) Donor stock losses

The use of donor adult salmon for hatchery-production of fingerlings for 5 years is a cost item. Once the adults are removed from their native watersheds, no wild progeny are produced from these adults for future harvests. Of course, the donor adult salmon will produce more progeny via hatchery production than if left in their native streams. These benefits are shown on page 95.

In the calculation of donor stock losses, average values to fishermen in Cook Inlet are used as in A)2) on page 94. This assumes that all donor stocks, even sockeyes, come from the Susitna River drainage. This assumption gives a slightly higher value for sockeyes since Copper River (Gulkana River) sockeyes are valued at less ($6.57/fish) 22/ than the Cook Inlet sockeyes. Donor stock costs are a follows:

a) Chinook	- 81 sport + 2 commercial	= $ 9,770/year	x 5 years	= $ 48,850
b) Coho	- 21 sport + 27 commercial	= $ 947/year	x 5 years	= $ 4,735
c) Sockeye	- 3,835 commercial	= $28,000/year	x 5 years	= $140,000
d) Chum	- 120 commercial	= $ 558/year	x 5 years	= $ 2,940
	Totals	= $39,305/year		= $196,525/5 years

5) Cost of capital: i*

*Assumptions/explanation

a) Nominal rate = 13%.

b) Real rate = 3%.

c) Future benefits & costs have been adjusted to 1982 (base economic year) with a real (discount) rate of 3%.

d) The real interest rate is equivalent to the real interest paid on current AA corporate bonds of the same maturity as the minimum life of the permanent fishway structures.

e) Real interest rate: the interest (i) used in calculating present value. In the case of a single future amount coming in n years the present worth factor (PWF) is: $(1+i)^{-n}$.

22/ From Mr. Richard Randall, pers. comm., June 2, 1983, ADF&G Fishery Biologist III.

f) Present worth value: the amount which a person would be willing to pay today to obtain the right to a certain amount or series of amounts in the future as estimated through use of a discount rate.

The benefit of the fishway enhancement program is calculated in Table 6-2 and the cost is calculated in Table 6-3.

Table 6-2 Fishway enhancement benefit calculations for all salmon species.

Year	Benefit	x	PWF 3%	=	PW Benefit 1982
0-1982	0		1.000		0
1	0		.971		0
2	0		.943		0
3	0		.915		0
4	0		.888		0
5-1987	255,000		.863		220,100
6	306,000		.837		256,100
7	357,600		.813		290,200
8	408,400		.789		321,900
9	459,200		.766		351,600
10-1992	510,000		.744		379,400
11	510,000		.722		368,200
12	510,000		.701		357,500
13	510,000		.681		347,300
14	510,000		.661		337,100
15-1997	510,000		.642		327,400
16	510,000		.623		317,700
17	510,000		.605		308,600
18	510,000		.587		299,400
19	510,000		.570		290,700
20-2002	510,000		.554		282,500
21	510,000		.538		274,400
22	510,000		.522		266,600
23	510,000		.507		258,600
24	510,000		.492		250,900
25-2007	510,000		.478		243,800
26	510,000		.464		236,600
27	510,000		.450		229,500
28	510,000		.437		222,900
29	510,000		.424		216,200
30-2012	510,000		.412		210,100
31	510,000		.400		204,000
32	510,000		.388		197,900
33	510,000		.377		192,300
34	510,000		.366		186,700
35-2017	510,000		.355		181,000
36	510,000		.345		176,200
37	510,000		.335		170,900
38	510,000		.325		165,800
39	510,000		.317		161,700
40-2022	510,000		.307		156,600

Total benefit at 1982 value = $9,257,800

Table 6-3. Fishway enhancement combined cost calculations.

Year	Cost	x	PWF 3%	=	PW Cost 1982
0-1982	$30,954,305		1.000		$30,954,305
1	94,305		.971		91,570
2	94,305		.943		88,930
3	94,305		.915		86,290
4	94,305		.888		83,745
5-1987	55,000		.863		47,465
6	5,000		.837		4,185
7	5,000		.813		4,065
8	5,000		.789		3,945
9	5,000		.766		3,830
10-1992	25,000		.744		18,600
11	5,000		.722		3,610
12	5,000		.701		3,505
13	5,000		.681		3,405
14	5,000		.661		3,305
15-1997	5,000		.642		3,210
16	5,000		.623		3,115
17	5,000		.605		3,025
18	5,000		.587		2,935
19	5,000		.570		2,850
20-2002	2,000,000		.554		1,108,000
21	5,000		.538		2,690
22	5,000		.522		2,610
23	5,000		.507		2,535
24	5,000		.492		2,460
25-2007	5,000		.478		2,390
26	5,000		.464		2,320
27	5,000		.450		2,250
28	5,000		.437		2,185
29	5,000		.424		2,120
30-2012	25,000		.412		10,300
31	5,000		.400		2,000
32	5,000		.388		1,940
33	5,000		.377		1,885
34	5,000		.366		1,830
35-2017	5,000		.355		1,775
36	5,000		.345		1,725
37	5,000		.335		1,675
38	5,000		.325		1,625
39	5,000		.317		1,585
40-2022	5,000		.307		1,535

Total cost at 1982 value = $32,573,325

Benefit/Cost ratio:

$$\frac{B}{C} = \frac{\$\ 9,257,800}{\$\ 32,573,325} = 0.28:1$$

B = Total benefit from Table 6-2

C = Total cost from Table 6-3

6.1.3 Sensitivity Analysis

The sensitivity of the benefit/cost calculations shown depends on the uncertainty of:

1) Estimated construction costs
2) Estimated maintenance costs
3) Salmon survival rates (egg to fry to adult)
4) Estimated future salmon catches
5) Estimated value of salmon catches
6) The cost of capital (i)

The following explanation of figures used (both expenses & benefits) is numbered to correspond with the six indeterminates listed above.

1) The estimated construction costs are based on ADF&G's experience in constructing similar type fishways at Anan Creek and at Russian River and therefore the estimates are thought to be reliable.

2) The maintenance and operations costs are based on ADF&G experience gained from similar fishways at Anan Creek and at Russian River. However, the reader can readily observe from Table 6-3 that the maintenance and operations costs are insignificant when compared to the initial C.I.P. costs. The maintenance and operations costs could be trebled or deleted altogether and not significantly alter the B/C ratio. Figure 6-1 shows a cash flow comparison of benefits vs. costs.

3) The survival rates are based on standards accepted by and used by the Fisheries Rehabilitation and Enhancement Division of the Alaska Department of Fish and Game. These values are the standards used in the State of Alaska.

4) The estimated future salmon catches are based upon the survival rates described in sensitivity analysis number 3. The survival rates and catch estimates are available from Dr. Bernard Kepshire23/

23/ ADF&G Principal Fish Culturist, Juneau.

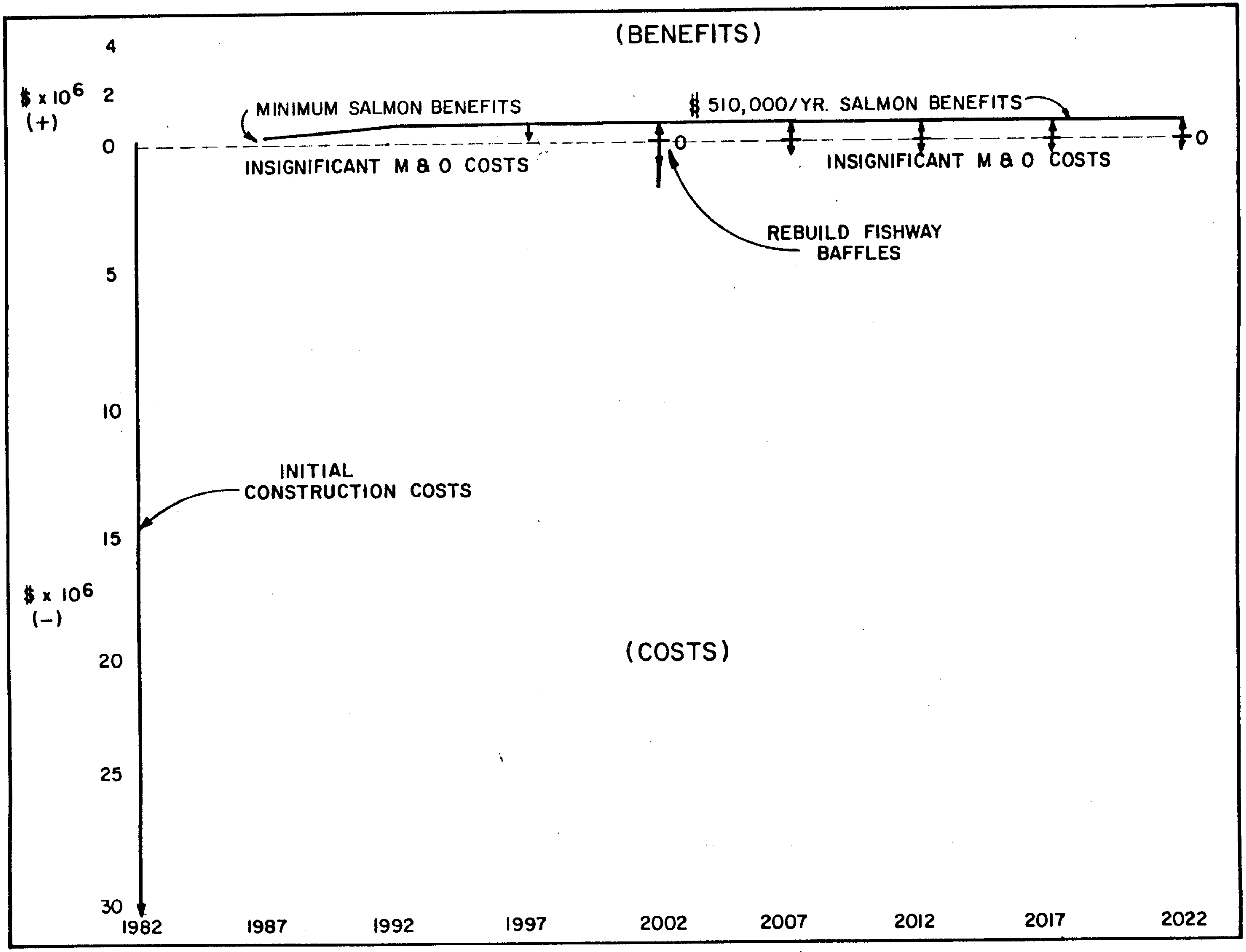

Figure 6-1. Fishway enhancement (B/C) cash flow.

5) The 1982 Cook Inlet salmon catch and prices are as recorded by the Commercial Fisheries and Sport Fish Divisions. To avoid the uncertainties of future inflation all benefits and costs have been computed based on 1982 prices.

6) The three percent cost of capital was obtained from Mr. Jeff Hartman [20]/. In the way of a comparison, the fishway B/C ratio was computed on the basis of a real interest rate of 10%. In the i=10% calculations, the B/C ratio computed to be 0.1:1. The 0.1:1 B/C ratio indicates an even more economically unsatisfactory project.

6.2 Hatchery Enhancement Program

This section develops the economic analysis for constructing and operating a hatchery enhancement program such as discussed in section 5.2.4. In the case of the upper Susitna River drainage basin where miles of spawning streams and acres of lake rearing go barren because there are no spawners, a hatchery-induced enhancement program may be desirable. With the existing natural rearing areas available, the "hatchery facility" would be limited to an "incubation facility" wherein hatchery fry would receive limited rearing, just enough to start them feeding and to await optimum release conditions. The resultant fry/fingerlings would then be transported to the upper Susitna River drainage basin for release and natural rearing.

The hatchery/incubation facility needed for the enhancement program described would consist of the following major features.

1) An incubation facility constructed in the Talkeetna area. 1982 C.I.P. cost of $3,400,000 with annual operating costs of $250,000 per year.

2) An egg take camp at Gold Creek with adult capture weirs at Indian River and Portage Creek. C.I.P. cost of $700,000 plus $25,000 per year operational costs.

3) Fry/fingerling planting operations. Initially the planting operations will be from Paxson/Anchorage to the upper Susitna River but will eventually operate between Talkeetna and the upper Susitna River drainage (Lake Louise area). The fry/fingerling planting operational costs are expected to be approximately $25,000 per year.

6.2.1 Benefit/Cost Ratio

The same type of B/C analysis as used for the vertical slot fishway tunnel (Section 6.1) is used for the hatchery enhancement analysis.

6.2.2 Economic Factors, Assumptions, and Calculations

A) Susitna River salmon

1) Average weight of salmon in Cook Inlet

a)	Chinook	- sport [18]	= 20.5 lb
		commercial [19]	= 16.7 lb
b)	Coho	- sport and commercial [19]	= 6.1 lb
c)	Sockeye	- commercial [19]	= 6.5 lb
d)	Chum	- commercial [19]	= 7.7 lb

2) 1982 average price paid to fishermen in Cook Inlet

a) Chinook - sport 20/ = $120.00/fish
commercial 20/ = $25.00/fish

b) Coho - sport 20/ = $38.00/fish
commercial 20/ = $5.50/fish

c) Sockeye - commercial 20/ = $7.30/fish

d) Chum - commercial 20/ = $4.90/fish

B) Potential return to system

1) Chinook = 3,000 fish

2) Coho = 5,100 fish

3) Sockeye = 160,000 fish

4) Chum = 9,700 fish

Total = 177,800 fish

C) Potential harvest in the upper Susitna River.
(See biocriteria, Table 6-4)

1) Chinook = 2,800 fish

2) Coho = 4,740 fish

3) Sockeye = 152,000 fish

4) Chum = 9,260 fish

Total = 168,800 fish

D) Value of harvest

1) 1982 value of salmon

a) Chinook - 2,730 sport + 70 commercial = $329,000

b) Coho - 2,100 sport + 2,640 commercial = $94,000

c) Sockeye - 152,000 commercial = $1,110,000

d) Chum - 9,260 commercial = $45,000

Total = $1,578,000

2) Assume the salmon harvest (all species) will occur as follows:

1st - 4th year-----------0% = 0 fish

5th year----------------50% = 84,400 fish

6th year----------------60% = 101,280 fish

7th year----------------70% = 118,160 fish

8th year----------------80% = 135,040 fish

9th year----------------90% = 151,920 fish

10th - 40th year-------100% = 168,800 fish

3) Future annual value of harvest

1st-4th year-----1982 - 1986 = $ 0

5th year--------------- 1987 = $ 789,000

6th year--------------- 1988 = $ 946,800

7th year--------------- 1989 = $ 1,104,600

8th year--------------- 1990 = $ 1,262,400

9th year--------------- 1991 = $ 1,420,200

10th - 40th year-1992 - 2002 = $ 1,578,000

Table 6-4. Biocriteria 1/ for determining the harvestable surplus of salmon adults with the hatchery enhancement program at Devil Canyon and Devil Creek areas.

	Chinook Salmon	Coho Salmon	Sockeye Salmon	Chum Salmon
Smolt to adult survival	3%	10%	10%	0.7%
Egg to smolt survival	15%	15%	15%	85.5%
Fecundity (no. eggs/female)	6,500	2,300	3,000	2,200
Egg retention	0%	0%	0%	0%
Male: female	1:1	1:1	1:1	1:1
Recruitment: spawner	20.5	17.3	22.5	20.6
Brood survival in freshwater	≥ 90%	≥ 90%	≥ 90%	≥ 90%

1/ Based on or from data listed in Alaska Department of Fish and Game (1982b), Crone and Bond (1976), Drucker (1972), Foerster (1968), and Hunter (1959).

E) Assumptions concerning hatchery costs

1) Hatchery life of 40 years - initial hatchery cost $3,400,000.

2) Hatchery reconstruction at year 20 - $2,000,000.

3) Hatchery operation costs - $250,000/year.

4) Donor stock losses
The use of donor adult salmon for hatchery-production of fingerlings for 5 years is a cost item. Once the adults are removed from their native watersheds, no wild progeny are produced from these adults for future harvests. Of course, the donor adult salmon will produce more progeny via hatchery production than if left in their native streams. These benefits are shown on page 105.

In the calculation of donor stock losses, average values to fishermen in Cook Inlet are used as in A)2) on page 105. This assumes that all donor stocks, even sockeyes, come from the Susitna River drainage. This assumption gives a slightly higher value for sockeyes since Copper River (Gulkana River) sockeyes are valued at less ($6.57/fish) 22/ than the Cook Inlet sockeyes. Donor stock costs are as follows:

a) Chinook - 81 sport +	2 commercial	= $ 9,770/year	x 5 years	= $ 48,850
b) Coho - 21 sport +	27 commercial	= $ 947/year	x 5 years	= $ 4,735
c) Sockeye -	3,835 commercial	= $28,000/year	x 5 years	= $140,000
d) Chum -	120 commerical	= $ 558/year	x 5 years	= $ 2,940
	Totals	= $39,305/year		= 196,525/5 years

5) 2 weirs/camp - initial weir cost $700,000.

6) Replace weirs/camp at 20 years - $700,000.

7) Weir operating costs - $25,000/year.

8) Planting operating costs - $25,000/year.

9) Cost of capital: i*

*Assumptions/explantion

a) Nominal rate = 13%.

b) Real rate = 3%.

c) Future benefits & costs have been adjusted to 1982 (base economic year) with a real (discount) rate of 3%.

d) The real interest rate is equivalent to the real interest paid on current AA corporate bonds of the same maturity as the minimum life of the permanent hatchery structures.

e) Real interest rate: the interest (i) used in calculating present value. In the case of a single future amount coming in n years the present worth factor (PWF) is: $(1+i)^{-n}$.

f) Present worth value: the amount which a person would be willing to pay today to obtain the right to a certain amount or series of amounts in the future as estimated through use of a discount rate.

The benefit of the hatchery enhancement program is calculated in Table 6-5 and the cost is calculated in Table 6-6.

Table 6-5. Hatchery enhancement benefit calculations for all salmon species.

Year	Benefit	x	PWF 3%	=	PW Benefit 1982
0-1982	$0		1.000		$0
1	0		.971		0
2	0		.943		0
3	0		.915		0
4	0		.888		0
5-1987	789,000		.863		680,900
6	946,000		.837		791,800
7	1,104,600		.813		898,000
8	1,262,400		.789		996,000
9	1,420,200		.766		1,087,900
10-1992	1,578,000		.744		1,174,000
11	1,578,000		.722		1,139,300
12	1,578,000		.701		1,106,200
13	1,578,000		.681		1,074,700
14	1,578,000		.661		1,043,100
15-1997	1,578,000		.642		1,013,100
16	1,578,000		.623		983,100
17	1,578,000		.605		954,700
18	1,578,000		.587		926,300
19	1,578,000		.570		899,500
20-2002	1,578,000		.554		874,200
21	1,578,000		.538		849,000
22	1,578,000		.522		823,700
23	1,578,000		.507		800,100
24	1,578,000		.492		776,400
25-2007	1,578,000		.478		754,300
26	1,578,000		.464		732,200
27	1,578,000		.450		710,100
28	1,578,000		.437		689,600
29	1,578,000		.424		669,100
30-2012	1,578,000		.412		650,100
31	1,578,000		.400		631,200
32	1,578,000		.388		612,300
33	1,578,000		.377		594,900
34	1,578,000		.366		577,500
35-2017	1,578,000		.355		560,200
36	1,578,000		.345		544,400
37	1,578,000		.335		528,600
38	1,578,000		.325		512,900
39	1,578,000		.317		500,200
40-2022	1,578,000		.307		484,400

Total benefit at 1982 value = $28,644,000

Table 6-6. Hatchery enhancement combined cost calculations.

Year	Cost	x	PWF 3%	=	PW Cost 1982
0-1982	$4,139,305		1.000		$4,139,305
1	339,305		.971		329,465
2	339,305		.943		319,965
3	339,305		.915		310,465
4	339,305		.888		301,300
5-1987	300,000		.863		258,900
6	300,000		.837		251,100
7	300,000		.813		243,900
8	300,000		.789		236,700
9	300,000		.766		229,800
10-1992	300,000		.744		223,200
11	300,000		.722		216,600
12	300,000		.701		210,300
13	300,000		.681		204,300
14	300,000		.661		198,300
15-1997	300,000		.642		192,600
16	300,000		.623		186,900
17	300,000		.605		181,500
18	300,000		.587		176,100
19	300,000		.570		171,000
20-2002	3,000,000		.554		1,662,000
21	300,000		.538		161,400
22	300,000		.522		156,600
23	300,000		.507		152,100
24	300,000		.492		147,600
25-2007	300,000		.478		143,400
26	300,000		.464		139,200
27	300,000		.450		135,000
28	300,000		.437		131,100
29	300,000		.424		127,200
30-2012	300,000		.412		123,600
31	300,000		.400		120,000
32	300,000		.388		116,400
33	300,000		.377		113,100
34	300,000		.366		109,800
35-2017	300,000		.355		106,500
36	300,000		.345		103,500
37	300,000		.335		100,500
38	300,000		.325		97,500
39	300,000		.317		95,100
40-2022	300,000		.307		92,100

Total cost at 1982 value = $12,715,400

Benefit/Cost ratio:

$$\frac{B}{C} = \frac{\$28,644,000}{\$12,715,400} = 2.25:1$$

B = Total benefit from Table 6-5

C = Total cost from Table 6-6

6.2.3 Sensitivity Analysis

The sensitivity of the benefit/cost calculations shown depends on the uncertainty of:

1) Estimated construction costs

2) Estimated operations costs

3) Salmon survival rates (egg to fry to adult)

4) Estimated future salmon catches

5) Estimated value of salmon catches

6) The cost of capital (i)

The following explanation of figures used (both expenses & benefits) is numbered to correspond with the six indeterminates listed above.

1) The estimated construction costs are based on ADF&G's experience in constructing numerous hatcheries and hatchery support facilities over the past several years. These estimates are considered to be reliable.

2) The maintenance and operations costs are based on FRED's experience gained from operating numerous hatcheries during the past several years. These estimates are considered to be reliable. Figure 6-2 shows a cash flow comparison of benefits vs. costs.

3) The survival rates are based on standards accepted by and used by the Fisheries Rehabilitation and Enhancement Division of the Alaska Department of Fish & Game. These values are the standards used in the State of Alaska.

4) The estimated future salmon catches are based on the survival rates described in sensitivity analysis number 3. The survival rates and catch estimates are available from Dr. Bernard Kepshire[23/].

5) The 1982 Cook Inlet salmon catch and prices are as recorded by the Commercial Fisheries and the Sport Fish Divisions. To avoid the uncertainties of future inflation all benefits and costs have been computed based on 1982 prices.

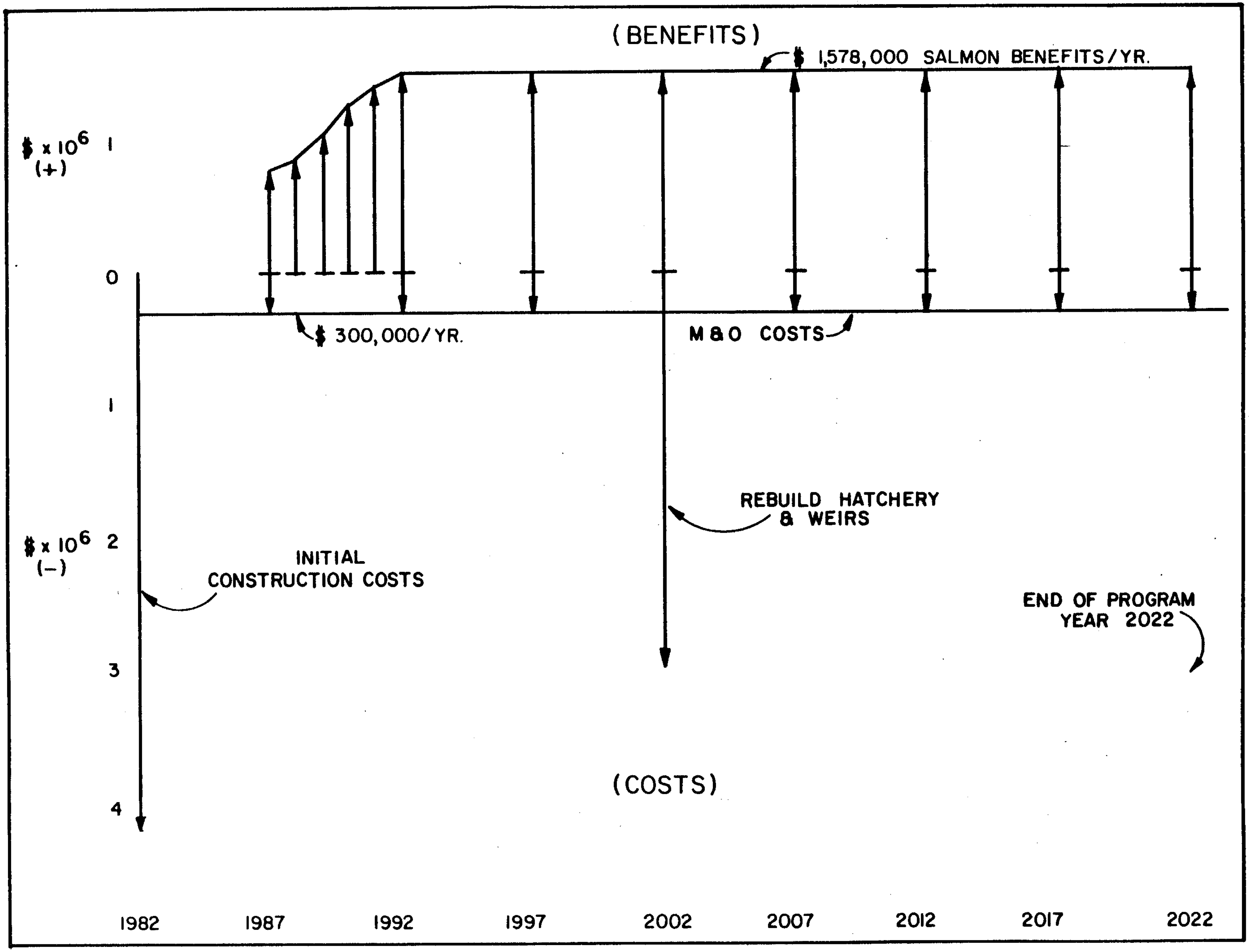

Figure 6-2. Hatchery enhancement (B/C) cash flow.

6) The three percent cost of capital was obtained from Jeff Hartman[20]. In the way of comparison the hatchery B/C ratio was computed on the basis of a real interest rate of 10%. In the i=10% calculations the B/C ratio computed to be 1.23:1. Even at the higher interest rate, with the reduced B/C ratio, the hatchery salmon enhancement project appears to be viable.

7. RECOMMENDATIONS

7.1 Salmon Enhancement Without Hydroelectric Dams

The findings in section 5.2.3 indicate that salmon enhancement of the upper Susitna River is technically feasible via the use of vertical slot fishways to pass adult salmon to unused spawning grounds. However, the economic analysis of the vertical slot fishway program, as discussed in section 6.1, indicates that such a project is not economically sound. The exceedingly high construction costs, when compared to the relatively low benefits, produce a B/C ratio of only 0.28 to 1. Because of the low B/C ratio, the study team cannot recommend the construction of fishways as a method for salmon enhancement.

The findings in section 5.2.4 indicate that salmon enhancement of the upper Susitna River is technically feasible via a fry/fingerling stocking program conducted from a hatchery located in the Talkeetna area. The economic analysis of the hatchery program, as discussed in section 6.2, indicates that such a project is also economically sound. The resultant B/C ratio of 2.25 to 1 compares favorably with many of the hatchery operations now being conducted in Alaska. The study team recommends that if a salmon enhancement project is to be conducted in the upper Susitna River drainage basin, then the project should be a hatchery stocking program of the nature described in section 5.2.4. This recommendation is valid based on the information available at this time. However, it would be prudent to field verify some of the assumptions made prior to entering into a 40 year multi-million dollar enhancement project.

The hatchery program produces more harvestable salmon than the fishway program (Table 7-1). This occurs because a hatchery allows for a much greater egg-to-released-juvenile survival and therefore a lower broodstock requirement than the fishway program, which depends solely on natural production (compare Table 6-4 with Table 6-1). The hatchery program produces a harvestable potential of 95% of the run compared to the fishway program potential of 32%. The high harvest potential of the hatchery program provides a challenge for fisheries managers in Cook Inlet. This report does not intend to tell fisheries managers how to manage for this high harvest or even for the low fishway program harvest. A hypothetical harvest strategy that fisheries managers might consider is a terminal harvest zone in the Susitna River between the railroad bridge (near Gold Creek gauging station) and Devil Canyon for fishwheels and perhaps gill nets. Hatchery-produced salmon could perhaps be separated from wild salmon on the basis of run timing or other stock separation techniques, with subsequent harvest either in Cook Inlet or the Susitna River harvest zone or both. The main point in this discussion is that prior to implementing any salmon enhancement program in the upper Susitna River, fisheries managers must provide harvest strategy expertise. The exploitation rate that can be realized without disrupting the balance of the mixed stock fisheries in Cook Inlet must be more precisely known.

Table 7-1. The annual harvestable salmon available with hatchery and fishway enhancement programs after year 10.

Salmon species	Salmon enhancement program	Harvestable salmon: Number	Percent of run	Value at 1982 prices
Sockeye	hatchery	152,000	95	$1,110,000
	fishway	53,300	33	390,000
Chinook	hatchery	2,800	93	329,000
	fishway	800	27	94,000
Coho	hatchery	4,740	93	94,000
	fishway	660	13	13,000
Chum	hatchery	9,260	96	45,000
	fishway	2,600	27	13,000
Total combined species	hatchery	168,800	95	$1,578,000
	fishway	57,360	32	$ 510,000

The economic benefit/cost ratios presented herein are based solely on exploitation of single stocks and do not take into account what the exploitation of these stocks should or must be in the context of mixed stocks. For example, if after careful and imaginitive review by fisheries managers, it turns out that the hatchery program produces a run that can be exploited only at 60% rather than 95%, then the benefit/cost for the hatchery program would be 1.42:1. However, it is extremely unlikely that a viable use couldn't be found for those fish in excess of the 60% harvest in Cook Inlet and the 5% needed as hatchery brood stock.

7.2 Salmon Enhancement With Hydroelectric Dams

Fifty years of monitoring salmon migrations in the Columbia and the Snake Rivers of Washington, Oregon and Idaho have shown that adult salmon will ascend fishways bypassing hydroelectric dams. In bypassing dams such as Bonneville (65 ft high), The Dalles (88 ft), John Day (132 ft), McNary (100 ft), Ice Harbor (100 ft), Lower Monumental (93 ft), Little Goose (100 ft), Lower Granite (82 ft) and others, some salmon ascend over 800 feet in a river stretch of about 500 miles. The same observations show, however, that the mortalities to the migrating salmon, both the adult and the juvenile downstream migrants, is significant as dicussed in section 5.1.2. The numerous statistics quoted for the mortality of the migrants are quite varied but the bottom line consensus is that the present Columbia River salmon run is significantly less than it was in the "pre-dam" days and the data indicates that the dams have been a major factor in the decline of the salmon runs.

Although the proposed Susitna dams may not be directly comparable to the dams on the Columbia River, it is the study team's belief that the construction of the Devil Canyon and the Watana dams will essentially eliminate any salmon enhancement potential in the Upper Susitna River drainage basin. The problems, and associated costs, of passing salmon, both upstream and downstream, over a height of 1,500 ft in a run of only 26 miles will far outweigh the limited benefits that could be achieved from any salmon enhancement program. As mentioned in section 5.1.2 the study team feels that if the Susitna dams are constructed then thought should be given to a trout/grayling enhancement project in lieu of a salmon enhancement project.

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Typing--------------------------------------Tanya Zahn and Cindy Smith

B. Acknowledgement:

In addition to the staff contributors, many individuals representing state, federal and private organizations contributed valuable information in the writing of this report. In particular the authors wish to thank Tom Trent and the staff of the Susitna Hydro Aquatic Studies Group, Milo Bell and John Hutchins of ABK&J, Jeff Weltzin and Eric Meyers of the Northern Alaska Environmental Center, Acres American Incorporated and R&M consulting Engineers. Bob Burkett, Chief of Technology and Development for FRED Division, appointed the study team, outlined the work plan, and set the schedule for this study.

10. APPENDICES

Letter from Commissioner Ronald O. Skoog to the Honorable Vic Fisher

465-4100

March 31, 1982

The Honorable Vic Fischer
State Senate
Pouch V, State Capitol
Juneau, Alaska 99811

Dear Senator:

The following information is provided by the department in response to your inquiry concerning that portion of CS SSSB 608(Res) providing $200,000 for the assessment of the fisheries' potential of the Susitna River. This initial funding would provide for the development of a baseline feasibility analysis only for the area above Devils Canyon to answer in a preliminary manner, the following questions:

1. Is it technically feasible to pass adult anadromous fish upstream and the resultant fry/smolts safely downstream through Devils Canyon if no hydro electric development occurs on the Susitna River? And if feasible, what would be the preliminary cost estimates for various fish passage designs to accomplish this?

2. What is the potential for the up-river habitat (above Devils Canyon) to support anadromous fish populations? If fish passage becomes possible on a regular basis, what would be the biological impacts to the up-river resident fish species and habitat by such access to anadromous species above Devils Canyon?

3. What specific areas of study should a comprehensive plan address should it be determined that such a project be implemented by the Legislature?

If you have any questions regarding this matter please do not hesitate to contact this office.

Sincerely,

Ronald O. Skoog
Commissioner

ROS/LSB/as

cc: Ron Lehr
Keith Specking

bcc: Tom Trent
Christopher Estes
Mary Jablonski

10.2

Letter from Mr. Jeff Weltzin to Commissioner Ronald O. Skoog

Northern Alaska Environmental Center

218 DRIVEWAY
FAIRBANKS, ALASKA 99701
(907) 452-5021

June 4, 1982

Commissioner Ronald O. Skoog
Alaska Department of Fish and Game
P.O. Box 3-2000
Juneau, Alaska 99802

Dear Commissioner Skoog,

As you know, my organization has worked with others to support a $200,000 appropriation through the Legislature to study the potential of upper Susitna River salmon enhancement. I wish to thank you and your staff for the helpful background information describing how ADF&G would approach this study.

We based our decision to pursue this funding for the ADF&G on your letter of March 20, 1981 which stated that the present arrangement between your agency and the APA would not include any assessment of upper Susitna River salmon enhancement potential. More specifically, our motivations in supporting this funding are outlined in the following questions that hopefully this study will answer:

1. Can the Devils Canyon hydraulic barriers to the migration of the five species of salmon (chinook, coho, chum, sockeye and pink) be altered or bypassed to permit the passage of these species to both tributaries and connecting lakes above Devils Canyon in absence of the proposed Susitna hydro project?

2. If fish passage through Devils Canyon is feasible, what would the potential benefit of salmon production from the tributaries and lakes upstream of Devils Canyon be to the sport, commercial and subsistence fishermen?

3. What would the biological impacts be to other species presently residing in the upper Susitna?

4. If the Susitna dams are built, how would this effect the potential of upper Susitna River salmon enhancement?

It is our hope that this baseline study can be integrated into the ADF&G's Susitna hydro investigations to obtain the maximum understanding of the feasibility of providing access to and from the habitat of the upper Susitna. We believe that this knowledge is absolutely essential to determining whether the instream flows of the upper Susitna are best suited for fishery enhancement or hydro development or both.

In conclusion, the results of the first phase of the Susitna studies show that if the proposed Susitna dams have benefits, they are over a fifty year or longer period. It is our belief that the benefits of the potential salmon enhancement of the upper Susitna should also be examined in the same context. Just as the Railbelt will experience increased demand for electricity over the long term, the Railbelt could equally experience increased demand for Susitna salmon. Both potential developments of the Susitna must be understood to allow Alaskans the ability to make an informed decision on what are the best uses of the Susitna River.

In anticipation that the Governor will not veto this appropriation, I would be pleased to meet with you to discuss this appropriation in more detail if you so desire. I would also appreciate being informed on how you intend to implement this study and its progress as it evolves.

Sincerely,

Jeff Weltzin

Appendix 10.3. Upper Susitna River salmon enhancement study work plan (1982-1983)

I. STATEMENT OF THE PROBLEM

In the upper reaches of the Susitna River, in the vicinity of Devil Canyon, it is reported that a series of rapids and/or waterfalls create a barrier or series of barriers that prevent or seriously limit the passage of migatory fish (anadromous salmon) to spawning areas upstream of the barrier(s). As of mid-1982 the exact nature of the reported barrier(s) was not known by the Department of Fish and Game. The problems to be identified are described in a letter of March 31, 1982 from Fish and Game Commissioner Ron Skoog to Senator Vic Fischer and are listed as follows:

1) Determine the nature, location and the extent of any fish barrier(s) located on the Susitna River upstream of Devil Canyon.

2) Determine the nature and extent of salmon spawning habitat located upstream of Devil Canyon.

3) Determine methods of introducing salmon upstream of Devil Canyon. Methods could include fishpass facilities, stocking of hatchery produced fish, eyed egg plants and other methods.

4) Develop cost figures, suitable for budgetary purposes, for implementing any of the methods, of item 3, that are determined to be practical.

5) Determine the biological impact on resident fish species inhabiting the area upstream of Devil Canyon that could be expected from the introduction of salmon into this area.

6) Determine any specfic areas of study that need to be conducted if Salmon are to be artificially introduced into the Susitna River above Devil Canyon.

In addition to the questions posed by Commissioner Skoog the Northern Alaska Environmental Center, in its letter of June 4, 1982 asked the following additional question. "If the Susitna dams are built, how would this effect the potential of the upper Susitna River Salmon Enhancement?"

This study will try to answer the questions posed by Commissioner Skoog and by the Northern Alaska Environmental Center.

II. HOW BARRIER STUDY WILL BE ACCOMPLISHED

Two individuals have been assigned to this study full time during fiscal year 1983 and two additional individuals will be assigned to the study part time during the five month period 7/1/82 through 12/1/82. During this five month period a draft report of the study, suitable for submission to the legislature, will be prepared. Following the legislature's review the study report will be refined as needed. Because the draft report is needed by December 1 there will not be time to make detailed field investigations of the site during all seasons of the year. Therefore, heavy emphasis will be placed on literature research of data that has been collected by others. Following is a list of sources known to posses information that should be relevant to this study:

1) Alaska Department of Fish and Game

   a. The Susitna Hydro Aquatic Studies Group - Tom Trent

   b. Habitat Division - Carl Yanagawa

   c. Sport Fish Division

   d. Commercial Fish Division

   e. FRED Division

2) The Alaska Power Authority

3) The U.S. Fish and Wildlife Service

4) The U.S. Geological Survey

5) Acres American - Susitna Hydro Feasibility Study

6) U.S. Army Corp. of Engineers

7) R & M Consultants

8) North Pacific Aerial Surveys Inc.

In addition to the literature research site investigation work will be necessary but because of the short time frame available in which to prepare the draft report detailed site investigations will not be made. Instead, the site investigation will be limited to site/terrain familiarization, verification of questionable data found in literature, observing the extent of salmon migration in Devil Canyon (if any occurs) and obtaining site specific measurement such as stream velocity. The following site investigation trips are planned:

1) July 12-16: Fixed wing aircraft over flight. The purpose of this trip will be to familiarize the investigators with the extent of the study area, terrain conditions, watershed, areas of potential blockage and etc.

2) August 2-6: Rotor-wing aircraft inspection. This flight will permit on ground site investigation of questionable features and allow observation of the pink salmon migration

which reached its peak, near Devil Canyon, on August 8 in 1981.

3) August 30 - September 3: Rotor-wing aircraft inspection. This flight will permit additional ground observations and will permit observation of the coho migration which extends into September in the vicinity of Devil Canyon.

4) It is expected that three site investigation trips will be adequate. However, additional flights or ground trips (if possible) will be conducted if necessary.

III. PROJECT SCOPE

This study will attempt to find answers to the questions posed in section I. The study will be conducted by means of personnel interviews, literature search and on-site investigations as described in section II. The draft report will be completed by December 1, 1982 with follow up research and report elaboration performed after comments to the draft report have been received.

IV. MILESTONES (Critical Dates)

1) July 1982

Initiate literature search and conduct over flight of the Upper Susitna River study area.

2) August - September 1982

Complete field investigations, literature search and initiate the draft report.

3) October - November 1982

Collect additional data found missing in first draft and modify draft as appropriate.

4) December 1, 1982

Barrier study report published.

5) December 1982 - January 1983

Barrier study report reviewed by legislature.

6) February - June 1983

Barrier study report completed per comments submitted by the legislature. Recommendations made.

V. STUDY BUDGET

1)	Salaries (#100) 2 full time/2 part time	=	159,800
2)	TVL & PD (#200)	=	20,000
3)	Publication Costs (#300)	=	10,400
4)	Administrative/Office Supplies	=	500
	Subtotal	=	190,700
	5% Cont. (additional charter flts/ drafting)	=	9,300
	Total Study Cost	=	200,000

Registered
Professional
Engineer

MILO C. BELL
Consulting Engineer
BOX 23
MUKILTEO, WASHINGTON 98275

December 30, 1982

Lowell S. Barrick, P.E.
Alaska Department of Fish and Game
FRED Division
P.O. Box 3-2000
Juneau, Alaska 99802

Dear Lowell:

Drawings covering the proposed fishways for the Susitna canyons are being sent under ~~separate~~ this cover. They show possible configurations for fishways to pass fish through the canyons.

Those of us who have been in the Susitna area recognize the paucity of information available to us to aid in making a decision on structures, and we should remind ourselves that the winter survey by R & M, and the chopper surveys made by you and George Cunningham, which included velocity measurements by flow, form the basis at this time for judgement as to whether fish can be passed through the canyons.

The river flows for the year 1982 apparently were at record low, arounds 14,000 cfs, during the fish passage time. The normal range during the period is from 24,000 to 28,000, or approximately double the flow the fish faced in their successful movement through this canyon in 1982.

Obviously, before a final decision could be reached it would be necessary to conduct at least one year's examination of river levels in the canyon areas. Measurement of major drops which are known to exist in the canyon areas must be made before a final figure can be placed on the cost of providing fishways around such obstructions. It must be assumed that the barriers in these canyons are velocity barriers created by river energy, or the destruction of such energy associated with bank and bed roughness, which becomes more apparent at the lower flows. It is also reported that there was a standing wave of great height created below the lower canyon at higher flows which was not shown either by the winter surveys of R & M or by the pictures taken by you and George Cunningham during your helicopter survey, or at the time when I surveyed the canyon.

This is the first time (in 1982) that it has been reported that any numbers of anadromous fish have been found above the lower canyon. With this assumption, it must also be assumed that flows probably above 16,000 cfs may create sufficient drops at various control points in the canyon as to prevent successful passage bacause of the increased velocities.

There may be two approaches to the development of a fishway system for these canyons: 1. passage from the lowest barrier to and above the canyon by a single fishway, or 2. passage around obstruction points by properly located fishways. There are problems associated with both approaches. If a single fishway system is to be created it must be assumed that fish now approach the canyon on one bank and that the entrance to this fishway would be at the farthest point of upstream migration on that bank. If this is not true, then an obstruction must be built on the bank on which there is no entrance to create a head drop, which would not allow fish passage and would require the fish to move to the bank where the fishway entrance is. If the entrance position is not properly located and the fish could bypass any point of potential obstruction, the length of time that the fish have before they must spawn would not allow them to search too long for an entrance downstream from the point in which they were collecting. This means, of course, that a very careful field examination would be necessary to insure that an entrance would be placed at the most precise location possible for the farthest point of upstream travel on that bank chosen for a single fishway passage.

If a multifishway development were to be proposed, that is, a fishway at each point at which fish have difficulty passing because of increased velocities, it would mean that the fish would be free to enter the river above such a short fishway, perhaps diverting to either bank in order to pass. A longer passage time would be required, for example, for fish to move from the left to right bank and back again if the fishways were on two banks. Again, time might not permit such delays in the canyon.

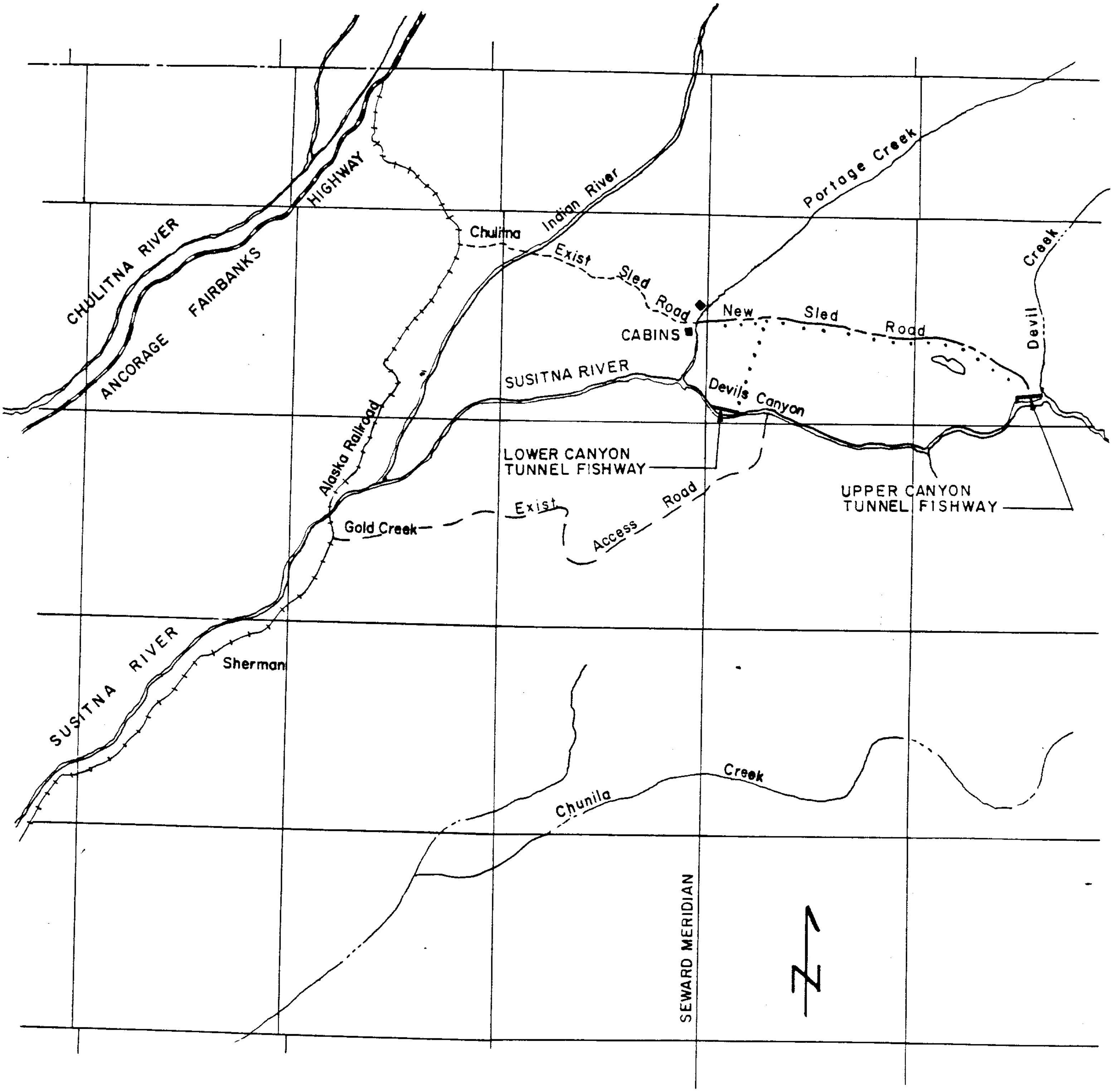
If a single fish passage facility were to be provided, it probably would be best then to provide entrances into this facility at those points that were shown to be barriers to fish, provided that the fish were able to pass the next lower obstruction. Thus there would be insurance that if the fish did pass the next lower obstruction they would find an entrance and would continue through the fishway system into the canyon area above the fishways.

The costs for these two approaches are provided as an appendix or separate document. Only one is included here

Previous tests have indicated that supersaturated nitrogen is now occurring in the canyon area. The effect of this has not been measured and it may affect passageway or the life span of the fish. It must be borne in mind that for each foot that the fish remain below the surface, the supersaturation level in reduced by approximately 3%.

Sincerely yours,

Milo



SUSITNA RIVER TUNNEL FISHWAYS

LOCATION MAP

SCALE 3 2 1 0 6 Miles

ANDERSEN
BJORNSTAD
KANE
JACOBS, INC.
CONSULTING ENGINEERS

Milo C. Bell, Inc.
Box 23
Mukilteo, WA 98275

LOWER SUSITNA RIVER CANYON FISHWAY

Cost Estimate Assumptions

1. Construction equipment would be brought to Gold Creek by rail car and off loaded.

2. An existing unimproved dirt road would be used to transport construction equipment, materials, and construction camp to the foot bridge midway in Devils Canyon.

3. Drilling machines, mining machines, tools, supplies, and mining equipment will be swung across the river using a skyline and a several drum donkey.

4. A trail would be constructed along the north ridge and down to the lower portal. Machinery and supplies could be lowered down the step slopes.

5. Mine tailing would be wasted into the river.

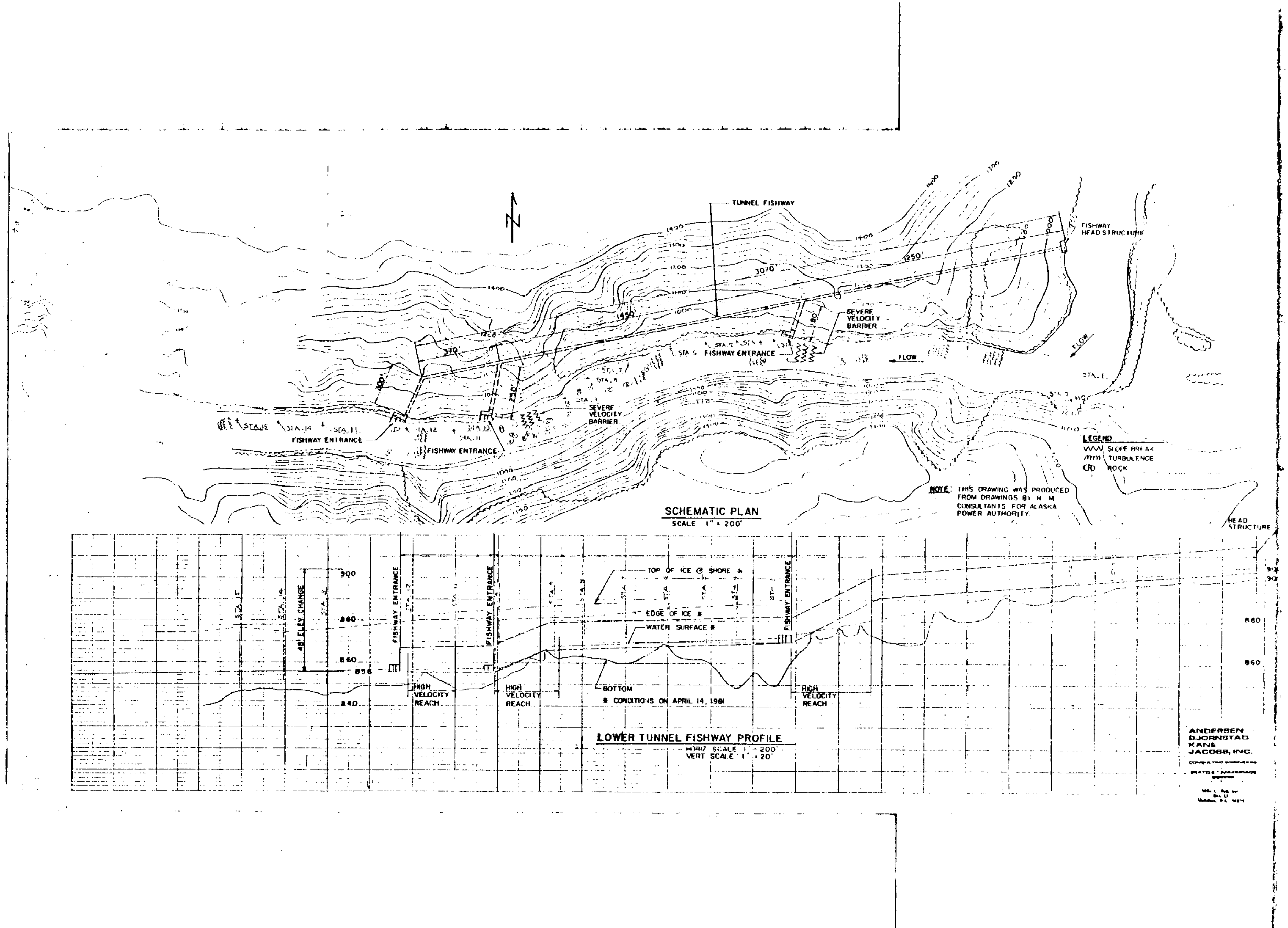
6. The existing landing strip would be used for air lifting materials and supplies.

7. The tunneling operation would anticipate working two tunnel faces concurrently and two shifts each day.

8. We assume a minimum construction camp size of 45 people during production.

Superintendant	1
Assistant	1
Foreman	4
Miners	16
Riggers	3
Iron Workers	2
Carpenters	5
Laborers	5
Camp	4
Helicopter	2
Equipment operators	2
TOTAL	45

9. Equipment and supplies are as listed in the quantity estimate.



TUNNEL FISHWAY
FISHWAY HEAD STRUCTURE
3070'
1250'
370'
300'
230'
80'
SEVERE VELOCITY BARRIER
FISHWAY ENTRANCE
FLOW
SEVERE VELOCITY BARRIER
FISHWAY ENTRANCE
FISHWAY ENTRANCE
LEGEND
SLOPE BREAK
TURBULENCE
ROCK
NOTE: THIS DRAWING WAS PRODUCED FROM DRAWINGS BY R. M CONSULTANTS FOR ALASKA POWER AUTHORITY.
SCHEMATIC PLAN
SCALE 1" = 200'
HEAD STRUCTURE
TOP OF ICE @ SHORE *
EDGE OF ICE *
WATER SURFACE *
48' ELEV CHANGE
FISHWAY ENTRANCE
FISHWAY ENTRANCE
FISHWAY ENTRANCE
HIGH VELOCITY REACH
HIGH VELOCITY REACH
HIGH VELOCITY REACH
BOTTOM
* CONDITIONS ON APRIL 14, 1981
LOWER TUNNEL FISHWAY PROFILE
HORIZ SCALE 1" = 200'
VERT SCALE 1" = 20'
ANDERSEN BJORNSTAD KANE JACOBS, INC.

10.4 cont.

ANDERSEN • BJORNSTAD • KANE • JACOBS, INC. CONSULTING ENGINEERS SEATTLE, WA. ANCHORAGE, AK.	PROJECT Lower Susitna Canyon Fishway Feasibility Study Cost Estimate JOB NO.	DATE 22 Dec. 82 BY J.R.H. SHT. NO. 1

COST ESTIMATE

CLASS OF WORK AND MATERIAL	QUANTITY	UNIT	MATERIAL UNIT	MATERIAL TOTAL	LABOR UNIT	LABOR TOTAL	TOTAL COST UNIT	TOTAL COST TOTAL
Sheet 2 & 3 Brought Forward								
Sheet 2				1,675,000				
Sheet 3				2,083,000		4,790,000		
Labor Tax 20%						958,000		
Subtotal				9,506,000				
Contractors Overhead & Profit 10%				951,000				
Subtotal				10,457,000				
Project Contingency 10%				1,046,000				
Subtotal				11,503,000				
Site Investigations				500,000				
Site Survey				200,000				
Design				700,000				
Construction Supervision				1,200,000				
TOTAL PROJECT COST				14,103,000				

ANDERSEN • BJORNSTAD • KANE • JACOBS, INC. CONSULTING ENGINEERS SEATTLE, WA. ANCHORAGE, AK.	PROJECT Lower Susitna Canyon Fishway Feasibility JOB NO. Cost Estimate	DATE 22 Dec. 82 BY J.R.H.
	COST ESTIMATE	SHT. NO. 2

CLASS OF WORK AND MATERIAL	QUANTITY	UNIT	MATERIAL		LABOR		TOTAL COST	
			UNIT	TOTAL	UNIT	TOTAL	UNIT	TOTAL
1. Mobilization & Demobilization								
Access Trail	50	STA	500	25,000				
Ship Equipment from Seattle								
3 Compressors								
5 Drillers								
3 Muckers								
2 Mixers								
Tractors, Trucks, Generators								
Skyline Rigging & Equipment								
Concrete								
Concrete Reinforcement								
Lumber								
	700,000	LBS	0.12	84,000				
Helicopter, 5000 lb. lifts	100	ea	2500	250,000				
2500 lb. lifts	800	ea	1000	800,000				
Construction Camp								
~~Set-Up and Operation~~	~~360~~	~~Day~~	~~1000~~	~~360,000~~				
Camp Rental	12	Mo.	3000	36,000				
2. Staging								
Site Clearing	10	AC	1000	10,000				
Sky Lines & Rigging (Purchase)		LS		10,000				
Safety; nets, equip., etc.		LS		100,000				
				1,675,000				

ANDERSEN • BJORNSTAD • KANE • JACOBS, INC. CONSULTING ENGINEERS SEATTLE, WA. ANCHORAGE, AK.	PROJECT / JOB NO. Lower Susitna Canyon Fishway Feasibility Study- Cost Estimate	DATE 24 Nov. 82 BY
	COST ESTIMATE	SHT. NO. 3

CLASS OF WORK AND MATERIAL	QUANTITY	UNIT	MATERIAL UNIT	MATERIAL TOTAL	LABOR UNIT	LABOR TOTAL	TOTAL COST UNIT	TOTAL COST TOTAL
3. Equipment Rental:								
3 Compressors	12	mo	600	7,200				
5 Drills	"	"	400	4,800				
2 Muckers	"	"	6000	72,000				
2 Mixers	"	"	1000	12,000				
1 Skyline	"	"	20000	240,000				
2 Tractors	"	"	6000	72,000				
2 Trucks	"	"	.000	24,000				
4 Generators	"	"	00	24,000				
2 Camp Generators	"	"	000	24,000				
Small Tools			1000	12,000				
4. Materials								
Rock Bolts	4200	EA	40	168,000				
	3000		40	120,000				
Cast-In-Place Concrete								
4 Portals @ 100 c.y.	EA 400	CY	1000	400,000				
Special Care & Handling	400	CY	1000	400,000				
Timber	2	MBF	1500	3,000				
Structural Steel	50,000	LBS	4000	200,000				
Wire Mesh	10,000	SF	2	20,000				
Grates	1,600	SF	50	80,000				
Other		LS		200,000				
5. Labor								
Supervision 6 @	12	MO			6000	432,000		
Tradesman 31m. @ 6 mo.	44,640	HRS			60	2,678,000		
Camp Labor 4m @ 12 mo	14,000	HRS			50	700,000		
Operators 4m @ 12 mo	14,000	HRS			70	980,000		
				2,083,000		4,790,000		

UPPER SUSITNA RIVER CANYON FISHWAY

Cost Estimate Assumptions

1. Construction equipment would be brought to Chulitna by Rail car and off loaded.

2. An existing sled road would be used to cabins at Portage Creek. From their A sled road would be constructed to near Devil Creek.

3. Drilling machines, mining machines, tools, supplies, and mining equipment would be transported by cat train to Devil Creek which is near the fishway's up-stream portal.

4. Helecopter & Snow Cat would be used to supply the camp through the construction year.

5. The fishway would be constructed in the north bank and would utilize additional shafts for fish entrances and tunnel tailings.

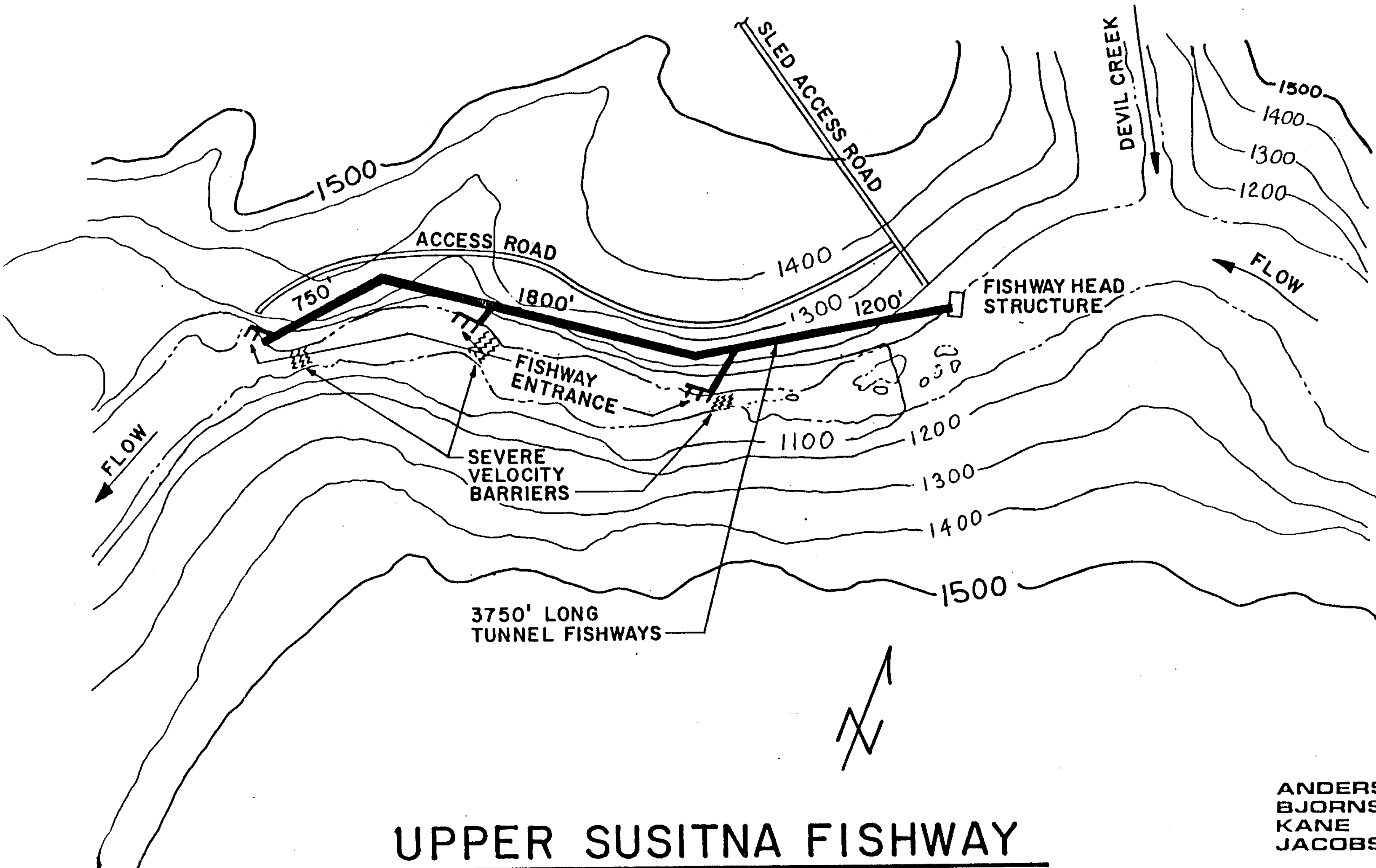
6. Tunneling operations would anticipate working two faces concurrently and two shifts each day.

7. An Access Trail will be constructed along the north bank so as to hoist equipment to the portals.

8. We assume a minimum construction camp size of 45 people during construction.

Superintendant	1
Assistant	1
Foremen	4
Miners	16
Riggers	3
Iron Workers	2
Carpenters	5
Laborers	5
Camp	4
Helicopter	2
Equipment Operators	2
	45

9. Equipment and supplies are as listed in the quantity estimate.



10.4 cont.

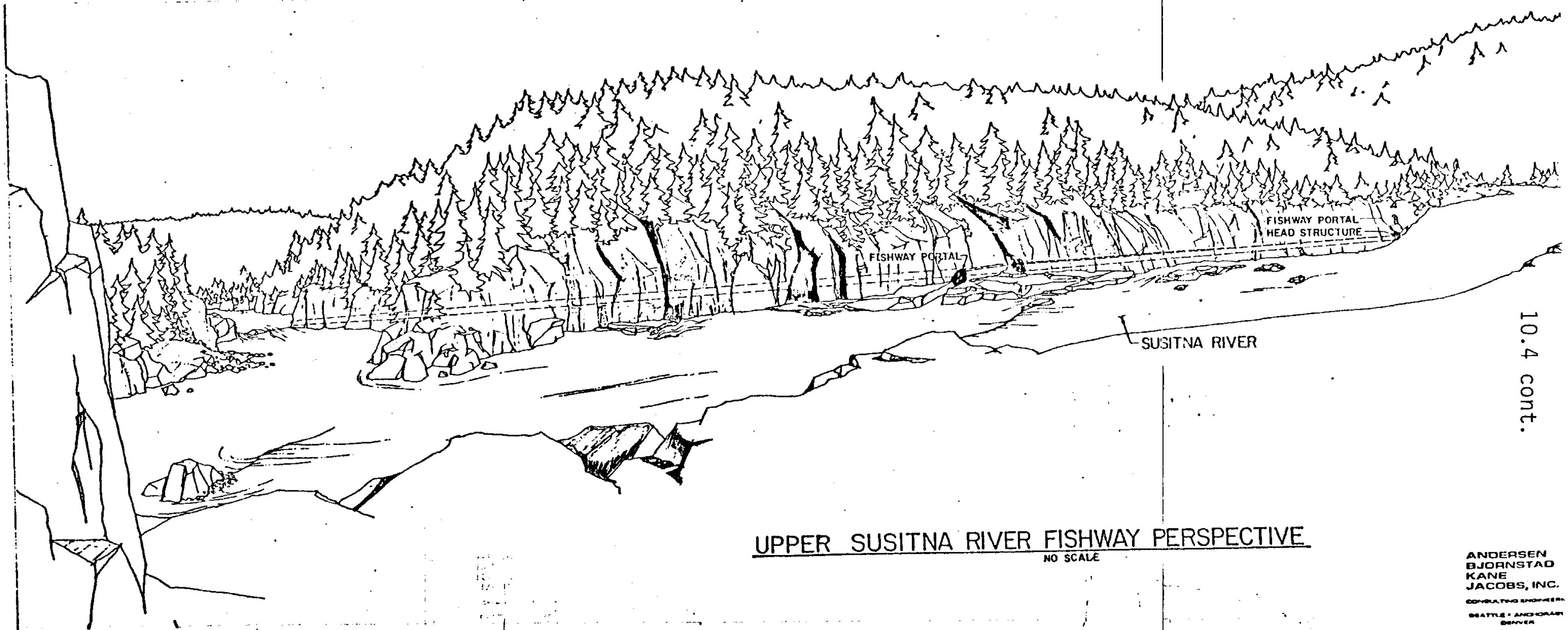
UPPER SUSITNA FISHWAY

SCHEMATIC PLAN

SCALE 1"= 600'

ANDERSEN
BJORNSTAD
KANE
JACOBS, INC.
CONSULTING ENGINEERS

Milo C. Bell, Inc.
Box 23



UPPER SUSITNA RIVER FISHWAY PERSPECTIVE

NO SCALE

ANDERSEN
BJORNSTAD
KANE
JACOBS, INC.
CONSULTING ENGINEERS
SEATTLE • ANCHORAGE
DENVER

ANDERSEN • BJORNSTAD • KANE • JACOBS, INC.
CONSULTING ENGINEERS
SEATTLE, WA. ANCHORAGE, AK.

PROJECT Upper Susitna Canyon Fishway Feasibility Study Cost Estimate
JOB NO.

DATE 22 Dec. 82
BY J.R.H.
SHT. NO. 1

COST ESTIMATE

CLASS OF WORK AND MATERIAL	QUANTITY	UNIT	MATERIAL		LABOR		TOTAL COST	
			UNIT	TOTAL	UNIT	TOTAL	UNIT	TOTAL
Sheet 2 & 3 Brought Forward								
SHT 2				2,424,000				
SHT 3				2,037,000		4,824,000		
Labor Tax 20%						965,000		
Subtotal				10,250,000				
Contractors Overhead & Profit 10%				1,025,000				
Subtotal				11,275,000				
Project Contingency 10%				1,128,000				
Subtotal				12,403,000				
Site Investigations				450,000				
Site Survey				350,000				
Design				750,000				
Construction Supervision				1,300,000				
TOTAL PROJECT COST				15,253,000				

ANDERSEN • BJORNSTAD • KANE • JACOBS, INC.
CONSULTING ENGINEERS
SEATTLE, WA ANCHORAGE, AK.

PROJECT Upper Susitna Canyon Fishway Feasibility
JOB NO. Study Cost Estimate

DATE ~~22 Dec. 82~~
BY J.R.H.
SHT. NO. 2

COST ESTIMATE

CLASS OF WORK AND MATERIAL	QUANTITY	UNIT	MATERIAL UNIT	MATERIAL TOTAL	LABOR UNIT	LABOR TOTAL	TOTAL COST UNIT	TOTAL COST TOTAL
1. Mobilization & Demobilization								
. 15 Miles Cat Train Road				50,000				
. 3 Compressors								
. 5 Drillers								
. 3 Muckers								
. 2 Mixers								
. Tractors, Generators								
. Hoisting Equipment								
. Concrete								
. Concrete Reinforcement								
. Lumber								
. Construction Camp								
Approx.	800,000	LBS	0.30	240,000				
Helicopter Lifts								
2500 lb Lifts	1,200	EA	1000	1,200,000				
Construction Camp								
Set-up & Operation	360	DAY	1000	360,000				
Camp Rental	14	MO	3000	42,000				
2. Staging								
Site Clearing	10	AC	1000	10,000				
Hoisting Equipment, Purchase			L.S.	10,000				
Explosives	4,200	LB	80	336,000				
Rock Bolts	3,800	EA	20	76,000				
Safety: Nets, Equip, Etc.			L.S.	100,000				
				2,422,000				

ANDERSEN • BJORNSTAD • KANE • JACOBS, INC.
CONSULTING ENGINEERS
SEATTLE, WA ANCHORAGE, AK.

PROJECT Upper Susitna Canyon Fishway Feasibility
JOB NO. Study Cost Estimate

DATE 22 Dec 82
BY J.R.H.
SHT. NO. 3

COST ESTIMATE

CLASS OF WORK AND MATERIAL	QUANTITY	UNIT	MATERIAL UNIT	MATERIAL TOTAL	LABOR UNIT	LABOR TOTAL	TOTAL COST UNIT	TOTAL COST TOTAL
3. Equipment Rental								
3 Compressors	14	MO	600	8,000				
5 Drills			400	6,000				
2 Muckers			6000	84,000				
2 Mixers			1000	14,000				
Hoisting Equip			5000	70,000				
2 Tractors			6000	84,000				
2 Snow Cats			4000	56,000				
4 Generators			2000	28,000				
2 Camp Generators			2000	28,000				
Small Tools			1000	14,000				
4. Materials								
Rock Bolts	4000	EA	40	160,000				
Explosives	4000	LBS	40	160,000				
Cast-In-Place-Concrete								
4 Portals	400	CY	1000	400,000				
Special Care & Handling	400	CY	1000	400,000				
Timber	3	MBF	1500	5,000				
Structural Steel	55,000	LB	4	220,000				
Wire Mesh	10,000	SF	2	20,000				
Gates	1,600	SF	50	80,000				
Other	LS			200,000				
5. Labor								
Supervision 6 @	15	MO			6000	540,000		
Tradesmen 31 @ 65 MO	48,360	HRS			60	2,902,000		
Camp Labor 4 M @ 12 MO	11,520	HRS			50	576,000		
Operators 4 M @ 12 MO	11,520	HRS			70	806,000		
				2,037,000		4,824,000		