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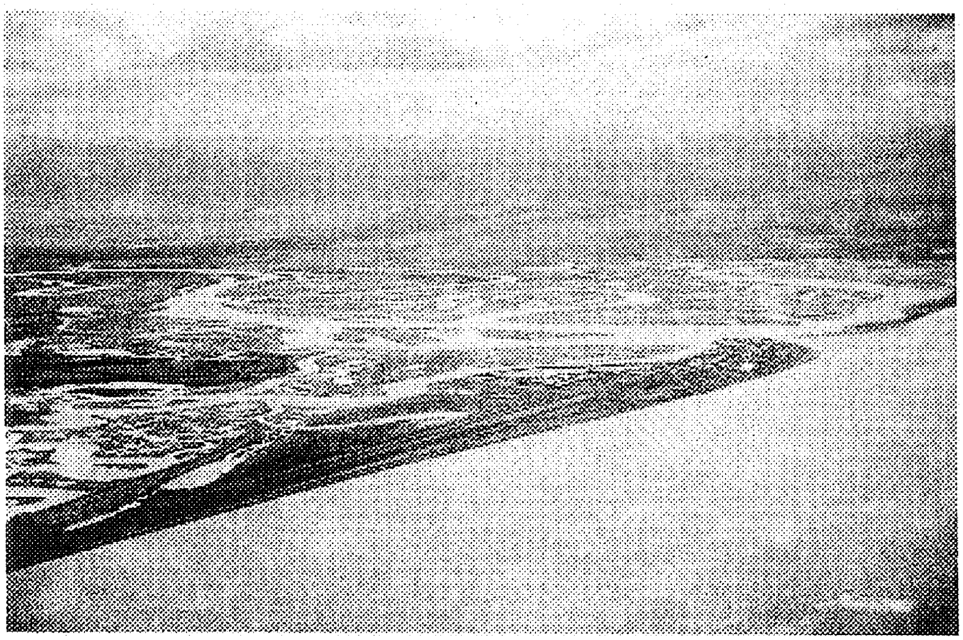
Unalakleet National Wild River, Alaska: Resource Values and Instream Flow Assessment

Joe Klein, Mike Scott and Bunny B. G. Sterin



Cover Photo
Aerial view of the mouth of the Unalakleet River entering Norton Sound.

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Mission Statement
The Bureau of Land Management sustains the health, diversity and productivity of the public lands for the use and enjoyment of present and future generations.

Unalakleet National Wild River, Alaska: Resource Values and Instream Flow Assessment

by

Joe Klein, Mike Scott and Bunny B. G. Sterin

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Executive Summary

In 1993, the BLM began an instream flow water resources monitoring project on the Unalakleet River. The goal was to identify the amount of water necessary to preserve and protect the natural values of the Unalakleet Wild River and its immediate corridor , and to recommend a legal mechanism through which recommended streamflow regimes can be recognized and protected.

The Unalakleet River is located in the northwestern portion of Alaska and drains into Norton Sound. It was designated a National Wild River by Congress on December 2, 1980. The outstandingly remarkable characteristics of the Unalakleet River include fish, wildlife and scenic values (1972, USDI).

Four species of salmon inhabit the Unalakleet River: chinook, coho, chum, and pink. Protection of these fisheries requires discharges sufficient to provide certain depths and velocities for various salmon life stages during different times of the year. The life stages and time periods are:

- passage: late May through late September
- spawning: June through early October
- incubation: mid-May through mid-July
- rearing: year-round

The methodology selected for this study in the "wild" portion of the Unalakleet River was the U.S. Fish and Wildlife Services' Instream Flow Incremental Methodology and associated Physical Habitat Simulation model (PHABSIM). PHABSIM was used to quantify spawning flows for salmon indigenous to the river.

PHABSIM models predict depths and velocities at differing flows. These models incorporate habitat suitability curves with a hydraulic model to calculate a weighted usable area. Habitat suitability curves were based on curves from the Susitna Hydro Aquatic Studies and modified by the fisheries biologist familar with salmon stocks in the Unalakleet River. The results from PHABSIM were incorporated with the simulated flow record to provide a habitat time series analysis for instream flow recommendations.

The project team recommends that a State of Alaska *Application for Reservation of Water* be submitted to the Alaska Department of Natural Resources, Division of Mining, Land and Water, Water Resources Section, specifying the stream flow amounts recommended in this report and summarized as:

One hundred percent of the stream flow is recommended during the critical winter months, November through April, to protect salmon overwintering habitat and incubation. A base flow is recommended during May, with a 48-hour channel maintenance flow to preserve the natural channel development and to flush sediments from spawning substrates. For June, July, and August, flow recommendations are based on the median spawning habitat values for chinook salmon. September and October flow recommendations are based on median spawning habitat values for coho salmon. It is assumed that reserving instream flows associated with the median spawning habitat values will maintain the salmon fishery at historic production levels and protect those values for which the river was designated as "wild."

Chapter I - Introduction

The Alaska National Interest Lands Conservation Act of December 2, 1980 (ANILCA, P.L. 96-487), established the upper portion of the Unalakleet River and certain tributaries, as a component of the National Wild and Scenic Rivers System to be administered by the Secretary of the Interior through the Bureau of Land Management (BLM). Approximately 81 miles of the Unalakleet River were designated as "wild" pursuant to the Wild and Scenic Rivers Act (WSRA)(USDI 1983). The WSRA declared it a policy of the United States that "selected rivers of the nation which, with their immediate environments, possess outstandingly remarkable scenic, recreational, geologic, fish and wildlife, historic, cultural, or other similar values, shall be protected in free-flowing condition, and that they and their immediate environments shall be protected for the benefit and enjoyment of present and future generations." In addition, the WSRA states:

> Designation of any stream or portion thereof as a national wild, scenic, or recreational river area shall not be construed as a reservation of the waters of such streams for purposes other than those specified in this Act, or in quantities greater than necessary to accomplish these purposes.

It is the current policy of BLM (BLM Manual Section 7250) to assert water rights for designated wild, scenic, or recreational rivers under BLM management responsibility. Flow determinations, related to the minimum amount of water necessary to fulfill the primary purpose of the reservation, must be made on a case-by-case basis. The above policies and directives provide the impetus for a water rights assessment in the "wild" portion of the Unalakleet River.

Study Objectives

The major objectives of the study were to:

1. Describe existing salmonid spawning habitat conditions of the Unalakleet River.

2. Determine spawning habitat-flow relationships for each salmon species in the wild portion of the Unalakleet River.

3. Assess the change in available salmon spawning habitat with time and channel maintenance requirements to determine a flow regime that will protect those values for which the river was designated as "wild."

Description of the Study Area

Setting

The Unalakleet River is located in the northwestern portion of Alaska (Figure 1). The headwaters originate in the Kaltag Mountains, a section of the Nulato Hills, approximately 105 miles inland, and flow in a southwesterly direction into Norton Sound. The designated "wild" portion of the river ranges from its headwaters to the confluence with the Chiroskey River. The village of Unalakleet, with a population of approximately 800, is located at the mouth of the Unalakleet River where it flows into Norton Sound (USDI 1994).

The Unalakleet River and its tributaries drain an area of approximately 2,100 square miles. Major tributaries include the North, South, Chiroskey, North Fork Unalakleet, and Old Woman rivers, and Tenmile Creek. The Unalakleet River drops 2,000 feet in elevation over its length (Figure 2).

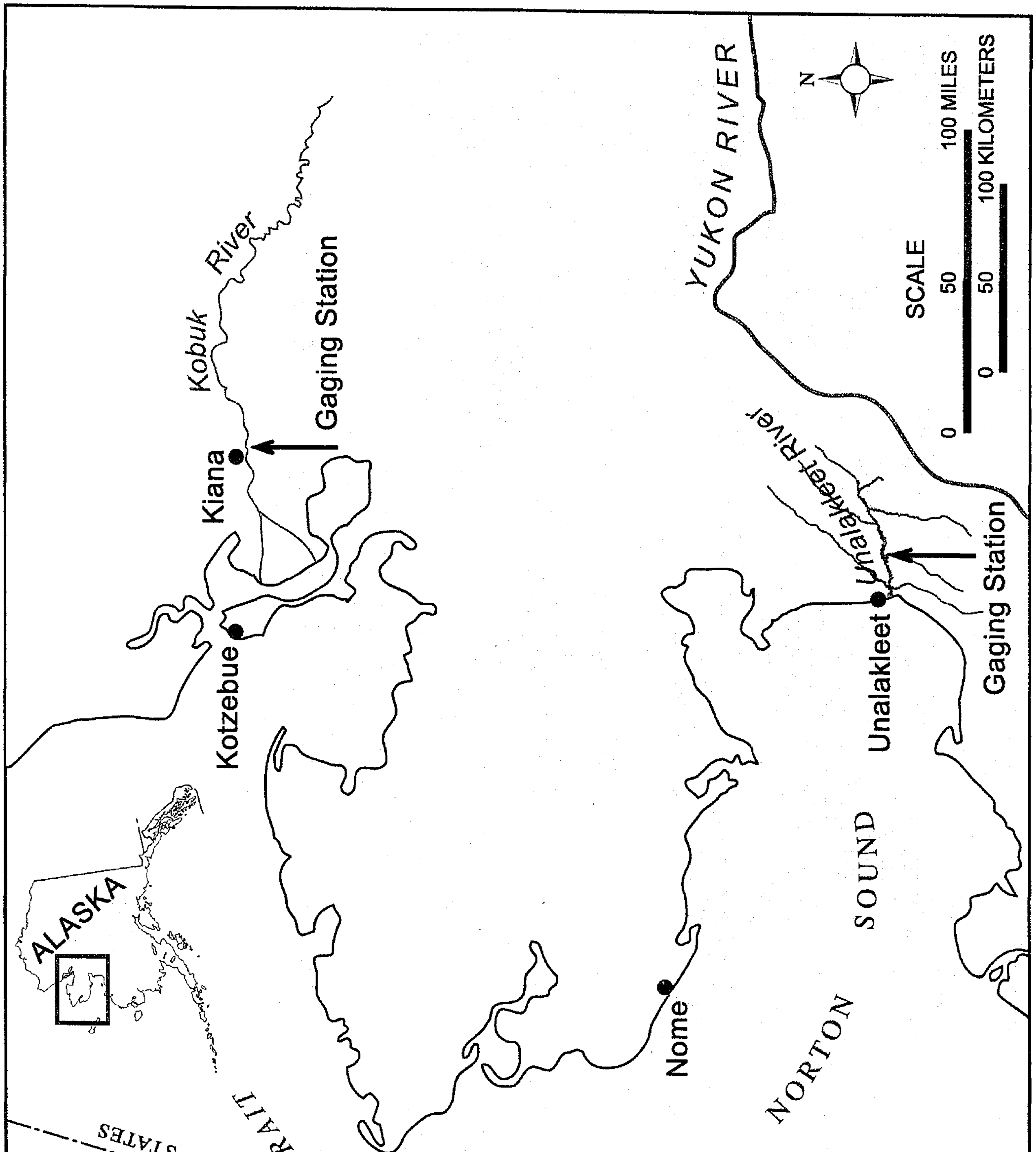


Figure 1. Regional map of the Unalakleet River, Alaska, Unalakleet gaging station and the USGS Kobuk River gaging station near Kiana.

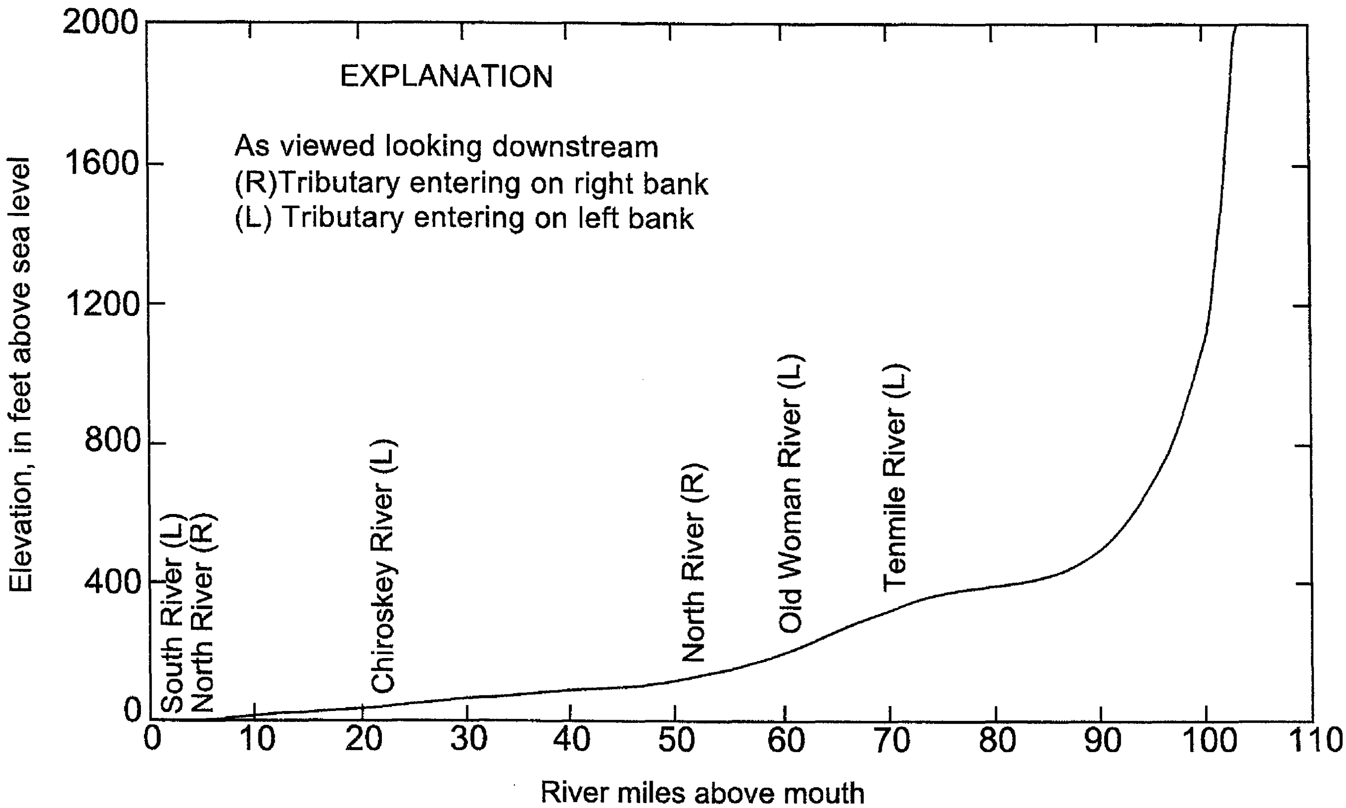


Figure 2. Profile of Unalakleet River and location of tributary junctions.

Channel sinuosity ranges from 1.15 in the headwaters to 2.3 in the lower basin. The basin is within the Continental climatic zone. Winter temperatures average from -5° to -12° F. Average summer temperatures range from 42° to 61° F. Extreme high and low temperatures recorded in the basin are 87° and -52° F, respectively. Prevailing winds are generally easterly (Unalakleet means "place where the east wind blows") averaging 10 mph and during fall storms can reach speeds in excess of 50 mph. Average annual precipitation is 14.2 inches, including 37 inches of snowfall.

The Unalakleet River follows the Kaltag fault. The river basin is underlain by sedimentary bedrock consisting of graywacke, shale, sandstone and igneous materials (Cass 1959).

Biotic Resources

Four species of salmon and several other species of fish are indigenous to the Unalakleet River (Photo 1). Pink *(Oncorhynchus gorbuscha)* and chum *(O. keta)* salmon are the most abundant of the four anadromous species. Coho *(O. kisutch)* and chinook *(O. tshawytscha)* salmon, while less abundant, are also significant fish resources and contribute to the local fisheries. Two resident species, Arctic grayling *(Thymallus arcticus)* and Dolly Varden *(Salvelinus malma)*, are found throughout the drainage. The abundance and quality of these species were major reasons why a portion of the river was included in the Wild River System.

Fish resources are important to the basin ecosystem, making significant contributions to the food sup-

Photo 1. Several species of salmon and other species of fish indigenous to the Unalakleet River.

ply of other vertebrate and invertebrates. A large population of black bear *(Ursus americanis)* and brown bear *(U. horribilis)* feed on spawning salmon. Avian species, including loons *(Gavra sp.)*, belted kingfishers *(Megaceryle alcyon)*, common merganser *(Mergus merganser)*, gulls *(Larus sp.)*, and several species of raptors, feed on fish species. After spawning, decomposing salmon carcasses provide nutrients to the system. These nutrients directly or indirectly benefit other vertebrates and invertebrates in the stream and estuary.

Fisheries Resources

The fish resources of the Unalakleet River support commercial, subsistence, and sport fisheries. The Unalakleet River supports the largest fishing effort within the Alaska Department of Fish and Game's (ADF&G) Norton Sound Management District. Commercial fishing is a major source of income to local residents of the community of Unalakleet. The commercial fishery usually begins between June 8 and June 20, and ends by September 7. A summary of the commercial salmon catch in the Unalakleet subdistrict is shown in Table 1 (ADF&G 1993).

Subsistence is an important and significant use of the fish resources in remote Alaska villages. Although available to Native and non-Native households, Native households are more likely to practice a subsistence lifestyle as an expression of their lives and culture in this area. They are also more likely to prefer food coming from a wider variety of wild resources than non-Native households. Fish often accounts for more than half of a community's total harvest (Georgette and Loon 1993).

Sportfishing has become popular on the river (Photo 2) with participants including local residents and non-local fishermen. A major sport fishing lodge and,,to a lesser extent, local guides, cater to sport fishermen from around the world. Visiting anglers provide a source of income to the local economy. Anglers fish mostly for chinook and coho salmon, but other species such as Arctic grayling and Dolly Varden are also popular.

Salmon Life History

Four species of salmon inhabit the Unalakleet River: chinook, coho, chum, and pink. The following section summarizes their life history.

Chinook salmon enter the system in late May. Peak escapement occurs about the last week of June. Chinook tend to mill in the system much longer than other salmon species prior to spawning. Spawning is complete by mid-August (Table 2). Chinook use suitable spawning habitats throughout the study area, but are likely to spawn more extensively in the lower reaches of the study area. Morrow (1980) reports incubation periods from seven to 12 weeks, depending on water temperature. Alevins

Table 1. Commercial and subsistence salmon catches by species, Unalakleet Subdistrict.[1]

Year[2]	Chinook	Coho	Pink	Chum	Total
1982	4,681	68,380	162,901	49,214	285,090
1983	8,890	42,986	40,006	113,621	205,549
1984	8,454	54,579	17,418	46,665	127,123
1985	14,018	17,665	56	27,079	58,842
1986	4,494	20,580	—	30,239	55,466
1987	3,246	15,097	97	17,525	36,106
1988	2,218	24,232	23,730	25,363	75,700
1989	4,402	36,025	—	20,825	61,474
1990	5,998	52,015	—	23,659	82,230
1991	4,534	52,033	—	39,609	96,323
1992	3,409	84,449	6,284	52,547	146,918
10-year Average	5,511	36,075	19,288	37,939	98,935

[1] Alaska Department of Fish and Game 1993.

[2] 1982-1985 represents combined commercial and subsistence catches; 1986-1992 represents commercial catch.

spend an additional two to three weeks in the redd; emergence is believed to occur a few weeks after the yolk sac is absorbed. The freshwater rearing period for Unalakleet River chinook fry and juveniles is two years, while three to four years are spent maturing in the ocean before returning to spawn (Charles Lean personal communication, ADF&G, Nome, Alaska).

Coho salmon return to the Unalakleet River much later than other salmon species (Photo 3). Coho initially enter the river in late July and peak escapement typically occurs between August 25 and September 7 (Table 2). Coho salmon have been observed spawning throughout the study area. However, unlike other Pacific salmon, coho have been documented to use the upper portions of drainage basins to spawn (Scott and Crossman 1973).

Coho egg development usually takes from six to seven weeks, but much longer periods have been reported (Morrow 1980). Sac fry spend another two to four weeks

Photo 2. Sportfishing opportunities on the Unalakleet River.

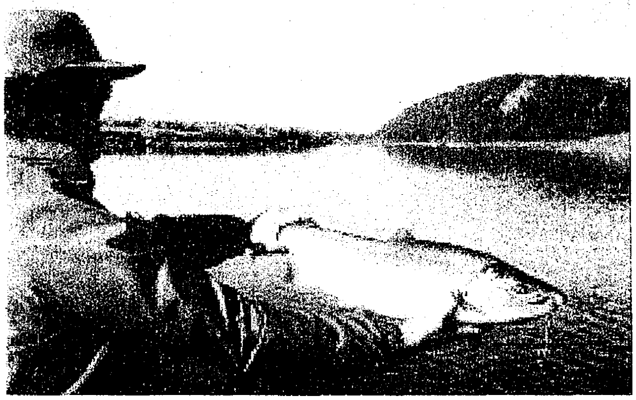


Photo 3. Coho salmon found on the Unalakleet River.

in the redd, absorbing their egg sac before emerging as free swimming fry. Emergence occurs between mid-March and mid-May. During their fresh water residence, coho utilize a variety of habitats depending on their age and time of season. Most Unalakleet River fry spend three years in the system before migrating to the ocean, and one year in the ocean before returning to the river as adults (Charles Lean, personal communication, ADF&G, Nome, Alaska).

Adult chum salmon enter the system in early June. Peak escapement usually occurs between July 21 and July 31. Spawning continues until early September. Chum salmon have been observed spawning over a wide range of water velocities. Vincent-Lang et al. (1984b) suggests that surface velocities may be less important than the presence of upwelling groundwater.

Chum salmon eggs are estimated to hatch from March to mid-May. Fry emergence occurs two to four weeks after hatching. Fry migrate to the estuaries shortly after emerging from their redds. Chum salmon spend three to four years in the ocean before returning to their spawning grounds.

Pink salmon are the most abundant of the anadromous salmonids in the Unalakleet River drainage. They return to the system to spawn in late June through late July. Peak escapement occurs about mid-July (Charles Lean personal communication, ADF&G, Nome, Alaska). Spawning occurs throughout the study area. During even years of high abundance, pink salmon have been observed utilizing marginal spawning habitat. Dvinin (1952) observed pink salmon spawning in shallow water depths of 0.32 feet (<0.1 meter) under crowded conditions.

As with all salmon, pink salmon egg development and hatching is controlled by temperature. Egg development ranges from eight to 16 weeks, and hatching usually occurs between February and March. After hatching, the sac fry remain in the intergravel spaces of the redd for several more weeks. The sac fry emergence occurs from late March through mid-May. After emerging, pink fry spend about two weeks in the stream before migrating to the estuaries. The life span of the pink salmon is the shortest of the Pacific salmon. They spend 14 to 16 months maturing in the ocean prior to returning to their natal stream to spawn and die.

Table 2. Salmon species periodicity chart for Unalakleet River.[1]

Chinook	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Passage[2]					X	XXXX	XXXX					
Spawning						XX	XXXX	XX				
Incubation[3]	XXXX	XXXX	XXXX	XXXX	XX	XX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX
Rearing	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX

Chum	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Passage						XXX	XXXX	X				
Spawning							XXX	XXXX	X			
Incubation	XXXX	XXXX	XXXX	XXXX			XXX	XXXX	XXXX	XXXX	XXXX	XXXX
Rearing				XX	XXX							

Pink	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Passage						X	XXX					
Spawning							XX	X				
Incubation	XXXX	XXXX	XXXX	XXXX	X		XX	XXXX	XXXX	XXXX	XXXX	XXXX
Rearing					XXXX	XXX						

Coho	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Passage							X	XXX	XXXX			
Spawning								X	XXXX	X		
Incubation	XXXX	XXXX	XXXX	XXXX	XX			X	XXXX	XXXX	XXXX	XXXX
Rearing	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX

[1]Based on professional judgement by ADF&G and BLM fisheries biologist.

[2]Passage life phase is immigration.

[3]Incubation life phase is from egg deposition to emergence.

Chapter 2 - Methods

The U.S. Fish and Wildlife Service's Instream Flow Incremental Methodology (IFIM) and associated Physical Habitat Simulation Model (PHABSIM) was used as the methodology for the instream flow analysis. The methodology has wide application in the United States and is considered the most scientific and legally defensible method by the U.S. Department of the Interior addressing most instream flow problems (Wesche and Rechard 1980). PHABSIM is designed to quantify potential physical habitat available for each species and life stage of interest. Major components of the design methodology, as modified by the BLM study team, are:

1) Identification of the study area, study sites, and transect selection.
2) Identification of target resource(s).
3) Selection of suitability criteria.
4) Identification of field methods.
5) Hydrologic modeling procedures.
6) PHABSIM calibration and simulation.
7) Habitat times series modeling procedures.
8) Identification of flow recommendations.

Reach Selection

The geographical extent of the study area was limited to the mainstem of the river included in the "wild" portion of the Unalakleet River (Figure 3). The study area begins at the Chiroskey River and continues up to Tenmile Creek. Based on slope, accretion, and channel characteristics, the study area was divided into four segments. Aerial photos and USGS topographic maps were used to assist in delineation of segment boundaries.

Segments were consecutively numbered 1 through 4 (Figure 4). All segments were accessible by boat, except segment 4. The first segment boundary was added upstream from the confluence with the Chiroskey River because the slope and sinuosity change was greater than 25 percent. The second and third segment boundaries were placed at the confluences with the North Fork Unalakleet and Old Woman rivers, respectively, based on accretion of flows greater than 10 percent compared to the mainstem of the Unalakleet River.

Segment 1 is characterized as a meandering, alluvial channel with copious gravel bar development (Photo 4). It was 21.5 river miles beginning at the "wild" river boundary near the Chiroskey River confluence (river mile (RM) 25). The average stream gradient is 1.4 feet per mile with a drainage basin of 1,032 square miles. Three study sites were selected in segment 1: sites 1001, 1002, and 1003.

The river braids through segment 2. Beginning at RM 46, segment 2 was 8.1 river miles with an average stream gradient of 6.3 feet per mile. Study sites 2001 and 2002 were selected in segment 2.

Segment 3 begins at the confluence of the North Fork River (RM 54) and continues to Old Woman River (RM 63) for a total of 8.8 river miles. The stream gradient averages 7.8 feet per mile. It drains an area of 611 square miles. Difficult access and time limitations precluded selecting more than one study site (site 3001) for segment 3.

Segment 4 is similar to a headwater stream. Beginning at Old Woman River (RM 63), segment 4 was 13.2 river miles ending at the confluence of Tenmile Creek. The stream gradient averages 14.3 feet per mile and drains an area of 292 square miles. Two study sites were selected in segment 4.

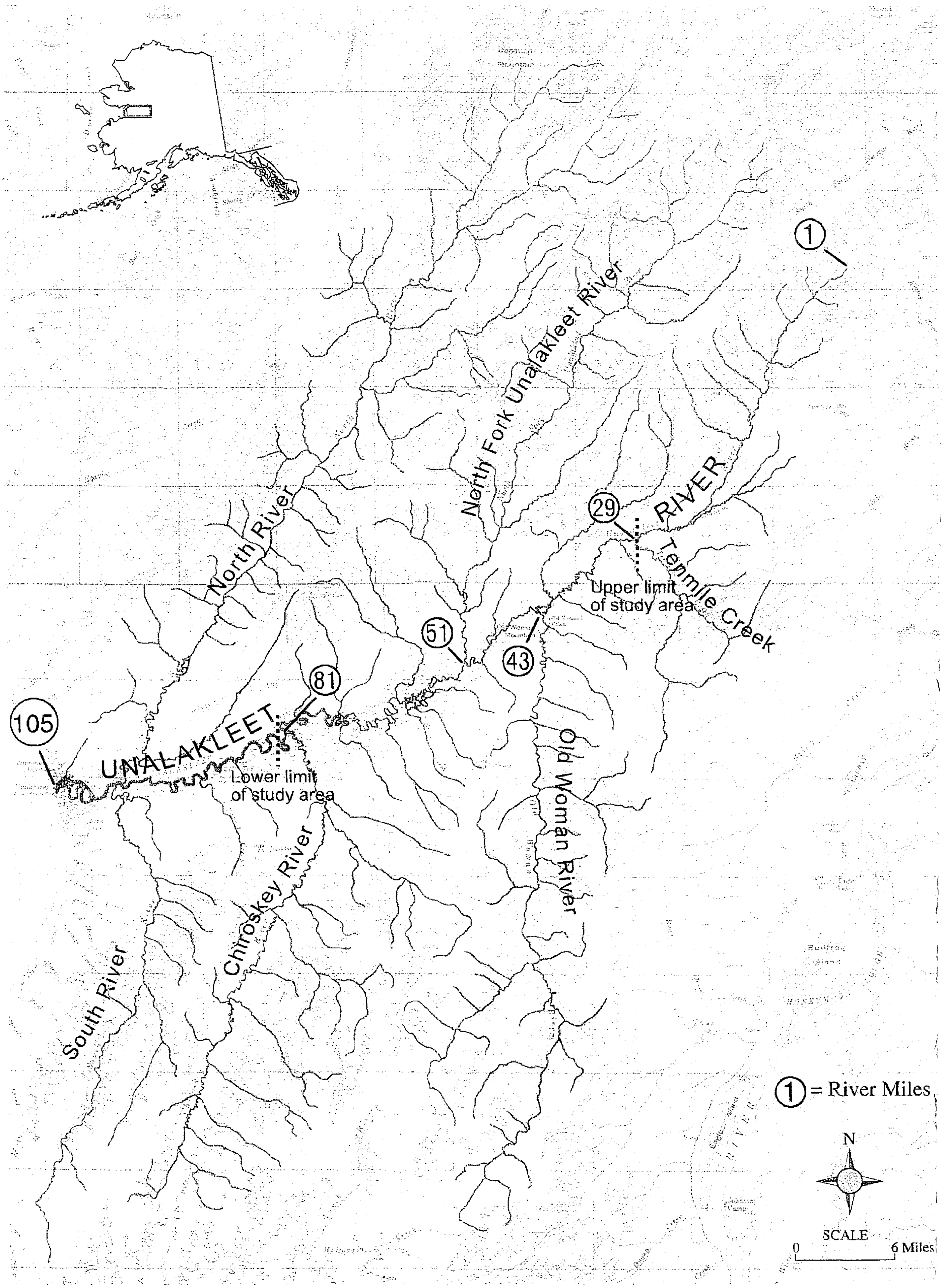


Figure 3. Study area for the Unalakleet River instream flow assessment.

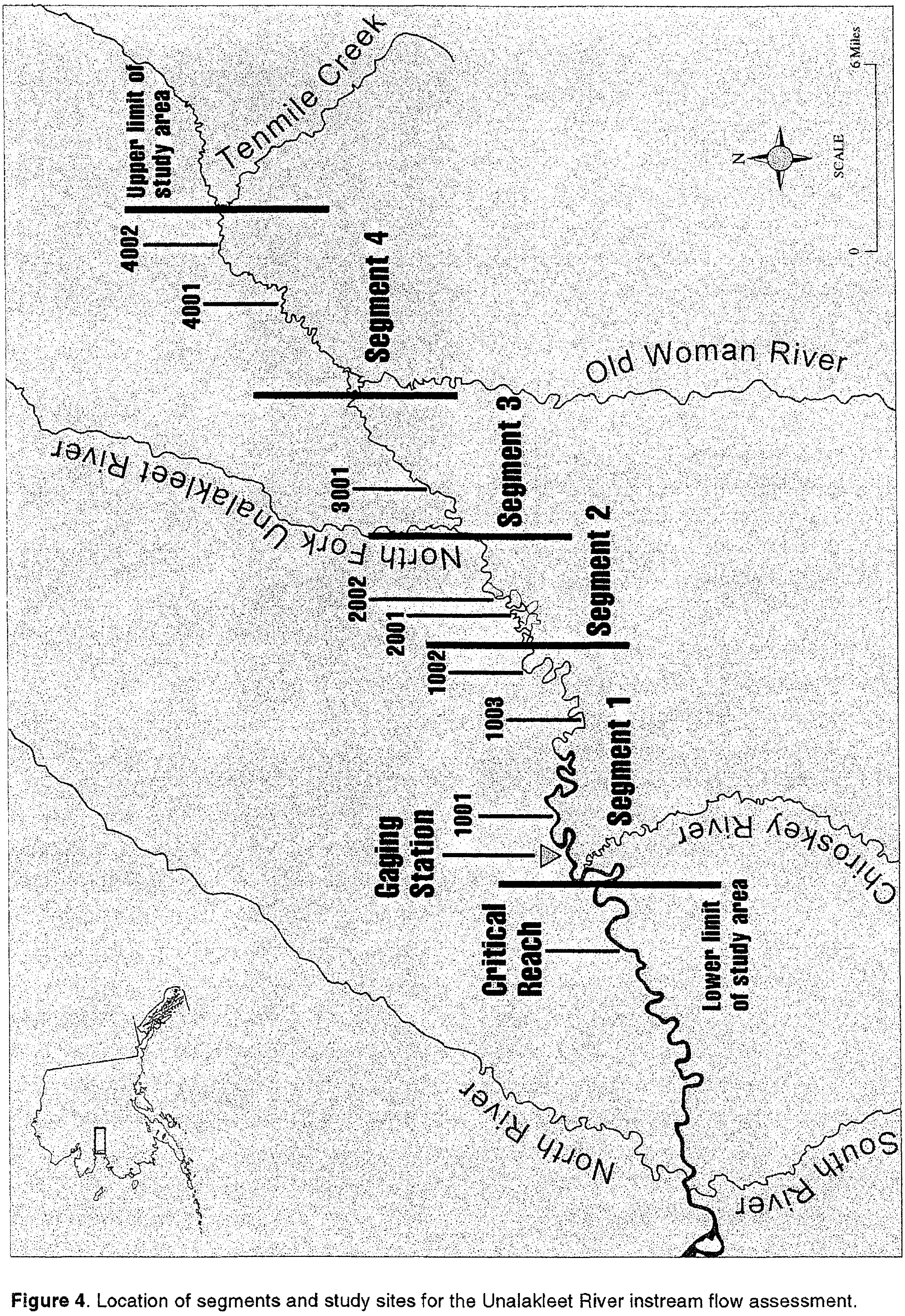


Figure 4. Location of segments and study sites for the Unalakleet River instream flow assessment.

Three calibration discharges were measured at six of the eight sites. Sites 4001 and 4002 were visited once and, consequently, only one discharge and water surface elevation (WSE) was collected. Temporary staff gages were installed at each study site during discharge measurements to monitor reach specific stage/discharge relationships. If the flow was unsteady during discharge measurements, WSE could be adjusted accordingly.

Study Site Selection

Thirty-seven known salmon spawning areas were mapped in segments 1 through 3 during fish studies conducted by BLM in 1990 and 1991. Study sites were randomly selected in segments 1, 2, and 3 from the known spawning areas occurring in each segment. No spawning areas had been previously mapped in segment 4. Study sites in segment 4 were arbitrarily selected after a helicopter reconnaissance of the reach (Figure 4).

Three transects were used to describe each study site. The downstream transect was placed at a hydraulic control to accommodate hydraulic modeling constraints imposed by PHABSIM. The other two transects were selected at representative upstream control points to simplify simulation of the stream channel. The head pin location at the downstream transects was recorded using Global Position Satellite system to facilitate relocation of study sites.

A critical reach site selection was necessary to evaluate salmon access into the "wild" portion of the river. Reservation of instream flows would be meaningless if the reserved flows did not ensure salmon passage into the "wild" portion of the river. Twenty-five river miles were evaluated, from the mouth of the Unalakleet River to the start of the "wild" boundary at the confluence of Chiroskey River. Four potential critical passage reaches were identified after reconnaissance of the reach and interviews with local residents, but only one reach was selected, due to time and budget constraints.

Photo 4. Meandering alluvial channel with well developed gravel bars are common on the Unalakleet River.

Target Species and Life History Stage

All life history phases of the four species of salmon, Arctic grayling and Dolly Varden were evaluated as target species because of their importance in the designation of the Unalakleet River to the National Wild and Scenic Rivers System, and because of their social and economic significance to the region.

In the final evaluation, the spawning life history stage of chinook and coho salmon were selected for this assessment. Time and money constraints were primary considerations in limiting this assessment to a single life history stage and to the two species. Chinook and coho salmon were chosen because their spawning life history included more of the open water period and they are the preferred salmon species.

Arctic grayling and Dolly Varden were not selected because more complete life history studies were unavailable. It was assumed that providing instream flows sufficient for any of the larger salmonid species would provide adequate protection for other species. Local biologists were also more familiar with life histories of the salmon in the drainage.

Suitability Criteria

PHABSIM uses habitat suitability criteria (HSC) to formulate suitability-discharge relationships. HSCs are mathematical representations of the response species/life stage or other attributes to stream flow dependent variables (e.g., velocity, depth, substrate, and cover) used by the model. HSCs interpret physical characteristics of the stream into indices of habitat quality. The accuracy and reliability of the output is dependent upon appropriate suitability criteria. An index is scaled between 0 and 1, with 0 denoting no utilization and 1 denoting optimum habitat utilization.

The Instream Flow Group has established three categories of curves (Bovee 1986). The categories are based on how the HSCs were developed. Category I curves are based on literature and professional judgement. Category II curves are derived from empirical data but not corrected for environmental bias, while Category III curves have been corrected for environmental bias. The development of Category II and III curves rely on the collection of sufficiently large random samples to adequately represent a range of salmonid spawning habitat conditions. This would have added considerable time and expense to the data collection effort.

The HSCs for spawning life stages of chinook and coho salmon were based on HSC developed during the Susitna Hydro Aquatic Studies (Su Hydro) (Vincent-Lang et al. 1984a and 1984b) and modified by fisheries biologists familiar with salmon stocks in the Unalakleet River (Figures 5 and 6). Chinook salmon HSCs were empirically derived in the Su Hydro studies. Coho salmon HSC were based on curves developed for the Terror Lake study and modified by biologists familiar with Susitna River coho salmon stocks (Vincent-Lang et al. 1984a and 1984b).

The Susitna River supports spawning populations of all species of salmon found in the Unalakleet River and salmon populations from both rivers exhibit similar life histories. The modified HSC of depth, velocity, and substrate for chinook and coho salmon spawning in the Unalakleet River represent the best estimation of the actual usability of spawning habitat conditions for these species.

Embeddedness

The amount of fines in the substrate matrix, or embeddedness, is directly related to salmonid egg development. Embeddedness is a visual assessment of the degree that dominant particles in the stream bed are surrounded or covered by fine-grained sediments (Gordon et al. 1992). The substrate criteria were adjusted to reflect the amount of embeddedness observed. Available literature has shown egg to alevin survival is inversely related to the amount of fine sediment in spawning substrate, but does not agree on magnitude of the relationship. Laboratory and field studies on salmon egg to alevin survival related to embeddedness show a high degree of variability. These effects have been summarized by Cordone and Kelly (1961) and Iwamoto et al. (1978). Consequently, to account for these effects, the modified Brusven index was used to describe substrate particle size along with embeddedness (Table 3) (Bovee 1982).

The embeddedness portions of the suitability criteria, although subjective, were derived from predictive

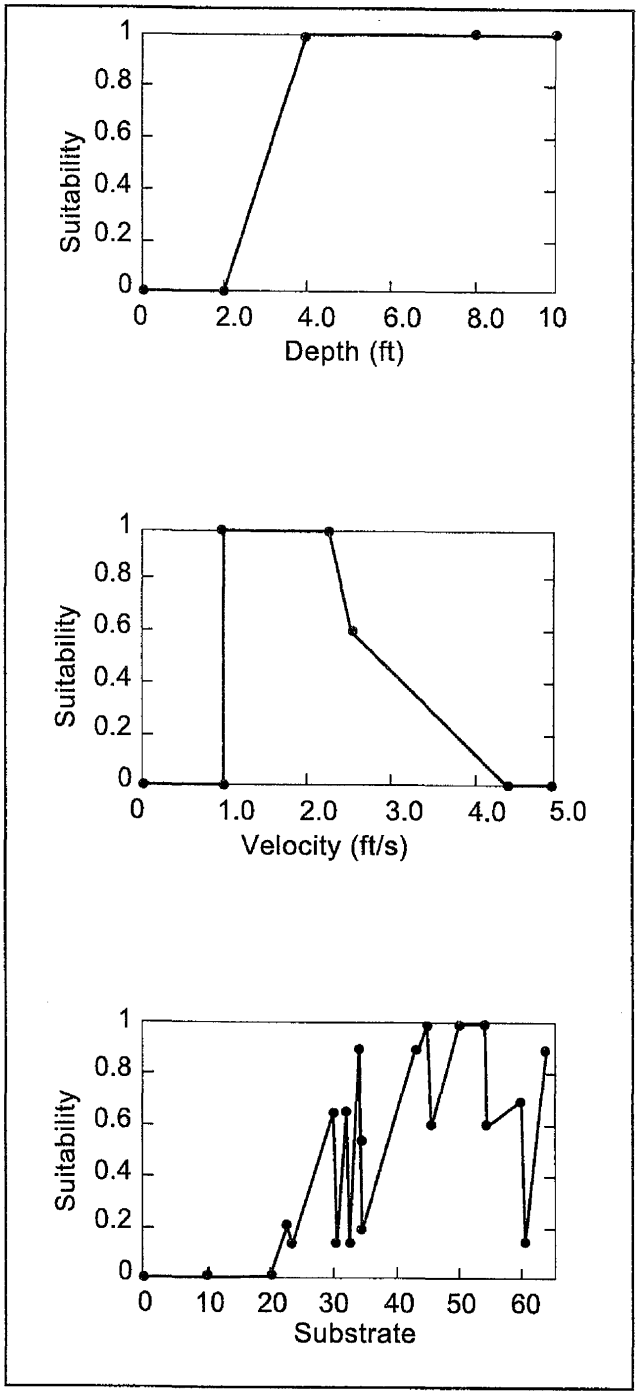


Figure 5. Chinook depth, velocity and substrate spawning habitat suitability curves.

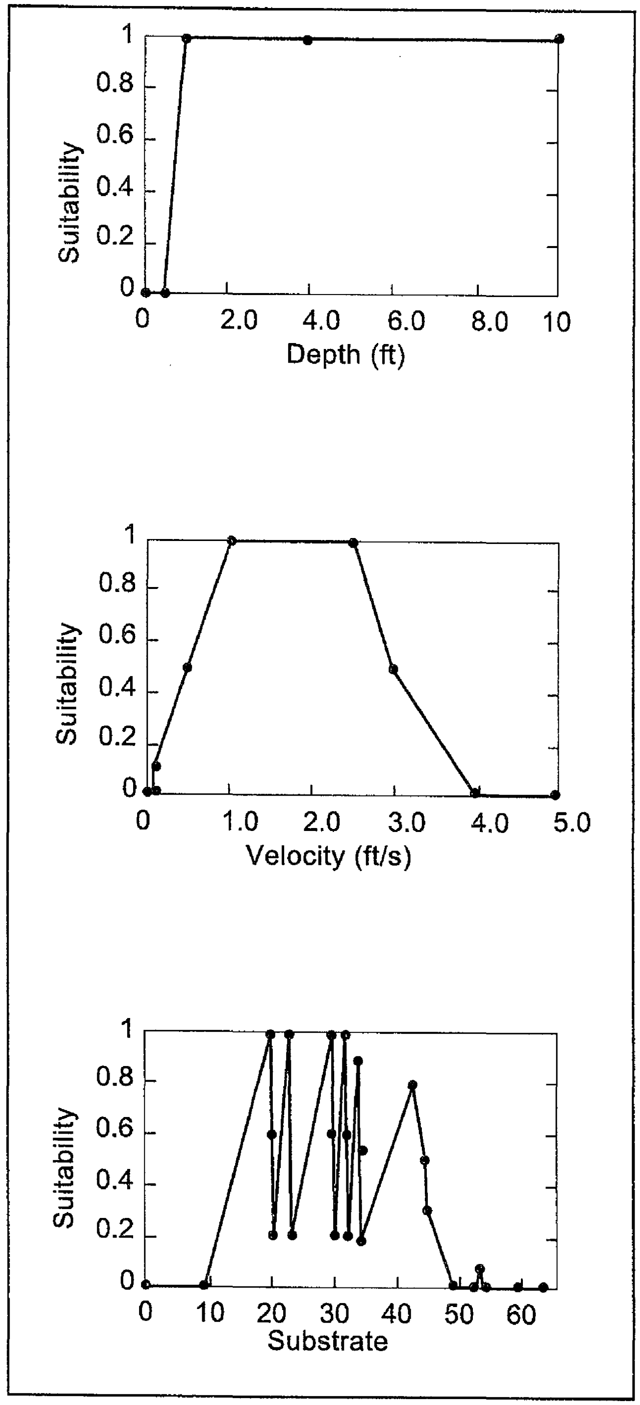


Figure 6. Coho depth, velocity and substrate spawning habitat suitability curves.

Table 3. Modified Brusven substrate codes.

Code	Substrate Description	Particle Size Range (inches)
1	Fines (sand & smaller)	< 0.16
2	Small gravel	.16 - 1
3	Medium gravel	1 - 2
4	Large gravel	2 - 3
5	Small cobble	3 - 6
6	Medium cobble	6 - 9
7	Large cobble	9 - 12
8	Small boulder	12 - 24
9	Large boulder	> 24

relationships between fines and salmon embryo survival based on a review of the literature (Platts 1989; Chapman and McLeod 1987; and Tappel 1981). Embeddedness was recorded according to the amount of fines in the substrate matrix (0-24, 25-49, 50-74, 75-99 percent). The original substrate suitability values were reduced by a factor of two-tenths and six-tenths for having fines in the third and fourth quartiles, respectively. For example, if chinook substrate suitability for large gravel (suitability index equal 0.90) was observed to contain between 50 and 74 percent embeddedness (third quartile), the resulting suitability index would be 0.90 x 0.8 = 0.72.

Critical Reach Site Habitat Suitability Curves

To evaluate salmon access into the "wild" portion of the river, HSC were adapted for a selected critical reach site. Criteria from the largest salmon species, chinook, were used to determine minimum passage for depth, velocity, and substrate suitabilities. For the depth suitability index, one foot was determined as a conservative minimum; for the velocity, only a minimal flow rate was needed, and, therefore, 0.1 feet per second was selected; the substrate index has no significance in the role of salmon passage at a critical reach in the river and was therefore set to optimal for all values. HSC for the critical reach site is shown in Figure 7.

Field Methods

Field data were collected at three calibration flows. WSE and above-water channel cross-sections were surveyed with a Spectra-Physics Lazerplane Survey System using standard survey techniques (Photo 5). Below-water channel cross-sections were determined by subtracting measured depths from the WSE at each flow.

Depth and velocity distributions at the three calibration flows were measured using a Marsh-McBirney portable water current meter. For depths accessible by wading, a standard top-setting USGS wading rod was used. For greater depths, a standard USGS fixed point-

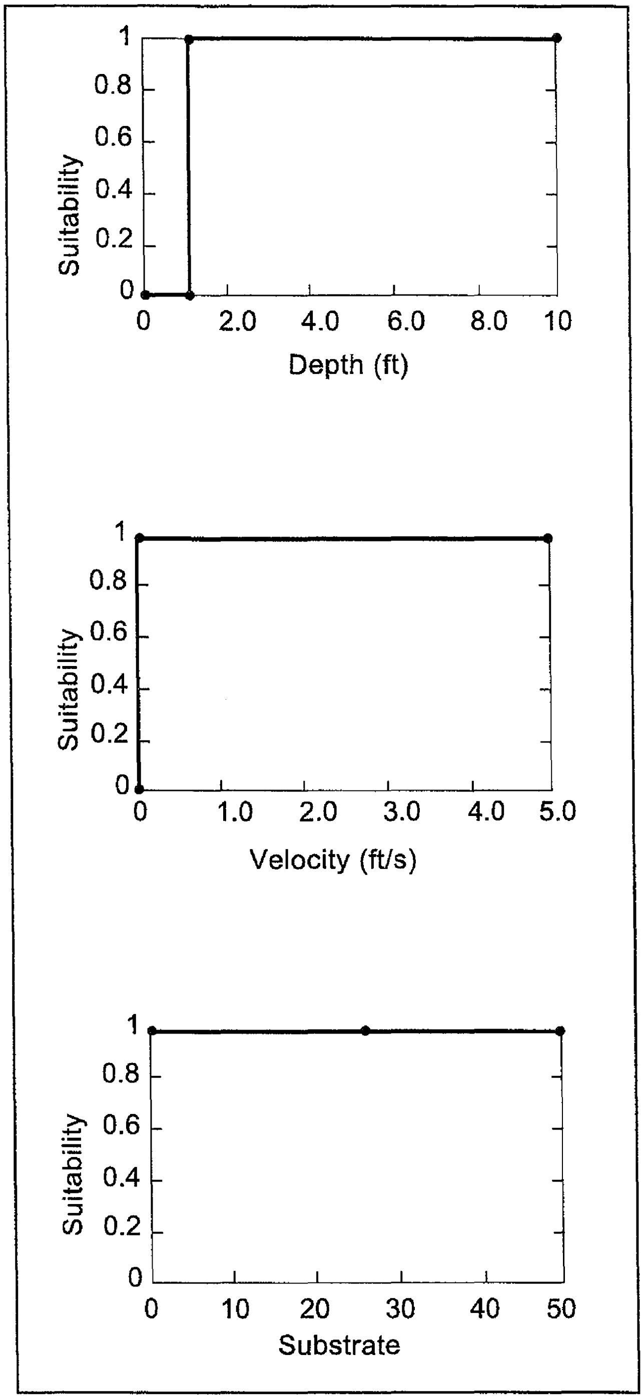


Figure 7. Depth, velocity, and substrate habitat suitability curves for the critical passage reach.

fixed line system was used with a 16 foot john boat (Photo 6). A 15 pound sounding weight and current meter for depth and velocity measurements was used at the desired locations along the tagline. A temporary staff gage, installed during each discharge measurement, in-

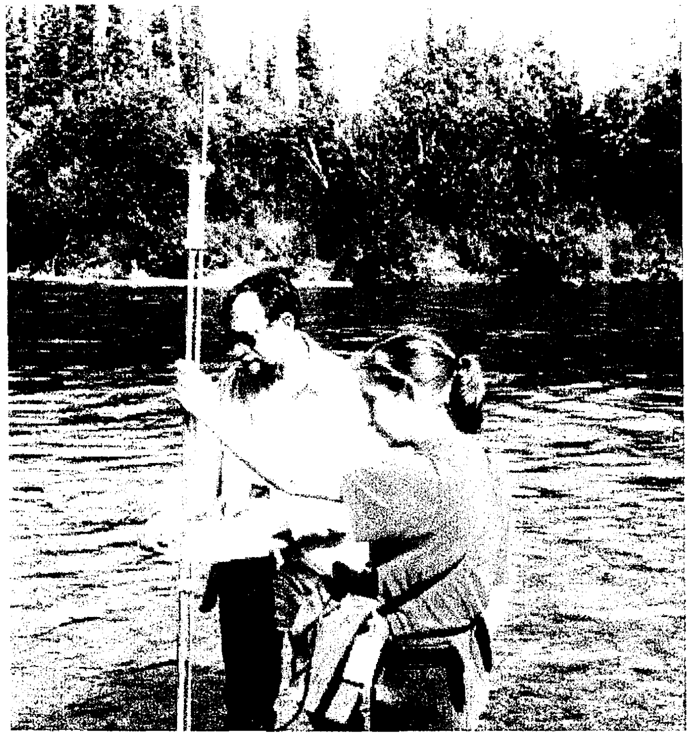


Photo 5. Standard discharge measurement techniques were used during this instream flow assessment.

dicated steady state flow during all measurements and, therefore, WSE adjustment was unnecessary.

Substrate characteristics within a five-foot radius of each vertical were recorded according to a modified Brusven Index (Bovee, 1986, Table 3).

Substrate was classified using a four-digit code representing the most abundant particle size, the second-most abundant particle size, and the percentage of fines (sand and smaller) in the matrix, recorded to the nearest quartile. For example, a code of 52.25 would indicate small cobble was the most abundant particle size, small gravel was the second most abundant, and that 25 percent of the cell area was embedded with fines.

Visual estimates were made where water depth and clarity allowed. Substrate within two feet upstream and downstream of the transect was evaluated in each cell. A modified gravel scooper was used to sample substrate where visual estimates could not be made. The substrate sampler was fabricated from six inch diameter metal pipe

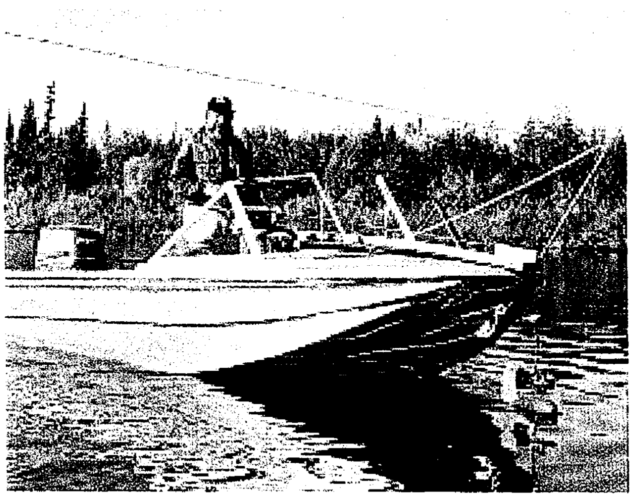


Photo 6. A fixed point line system was used on the Unalakleet River.

to which a three-foot metal survey rod was attached. Additional sections of the survey rod were screwed together to sample substrates at deeper depths.

Hydrology Methods

Several USGS gaging stations were evaluated for developing a long-term flow record. The Kobuk River gaging station provided the best correlation.

The BLM established an experimental discharge gaging station on the Unalakleet River in 1986. A datalogger was installed to record the water pressure that is calibrated to the river staff gage. This gaging station was operated intermittently from 1986 through 1992. Since the summer of 1993, it has operated continuously. Results from the station support establishing the site as a favorable for a permanent discharge gaging station. The USGS installed a permanent discharge gaging station in May 1997. Data collected from this station can be used to develop a site-specific hydrologic model when an appropriate period of record has been established.

Channel Maintenance Flow

A channel maintenance flow should be reserved during the spring snowmelt (mid-May to mid-June) to preserve natural channel development and to flush sediments from spawning substrates. A literature review suggests that a 48-hour, bankfull discharge is commonly requested for maintenance of stream channels (Rosgen et al. 1986; Gordon et al. 1992). To determine the flow, a two-day Log-Pearson III peak flow frequency analysis was calculated with the simulated May daily flows.

PHABSIM Analysis

The data collected during the field inventory were used to calibrate hydraulic models within PHABSIM. The models were then used to predict depths and velocities at flows different from those measured. A complete description of water surface elevation calibration, velocity calibration, and habitat simulation programs is provided by Milhous et al. (1989).

In summary, habitat modeling incorporates the HSC files with the hydraulic model to calculate weighted usable area (WUA). That is, the relationships for depth, velocity, and substrate are combined for a composite suitability index (CSI) and compared with the estimated depth, velocity, and substrate characteristics estimated by the physical model for each cell within the study reach for predetermined flows. The CSI corresponds to the particular suitability level of the three projected habitat components (depth, velocity, and substrate) in a cell value and are used to "weight" each cell as a percentage of surface area that is suitable as spawning habitat (Estes 1984). The procedure is repeated for a range of discharges to obtain spawning habitat values as a function of discharge. Results are normally presented in the form of a curve showing the relationship between available habitat area and stream discharge, and for a target species or a flow dependent attribute.

The three transects at each study site were weighted according to the amount of spawning habitat represented.

Transects for each study site were weighted as follows (Figure 8):

Transect one (downstream) – represented 25%

Transect two (middle) – represented 50%

Transect three (upstream) – represented 25%

Habitat Simulation

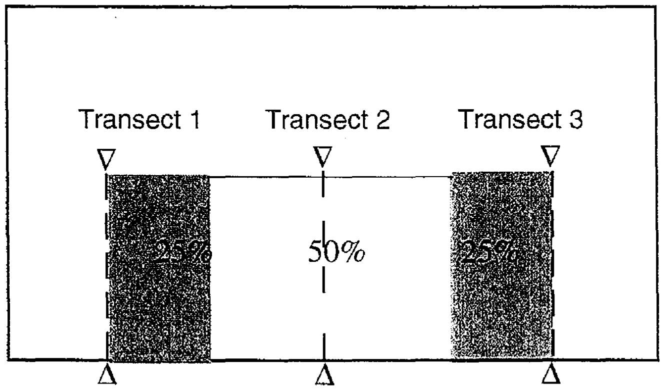
Three CSI functions are available in PHABSIM to simulate a relationship between stream flow and usable spawning habitat, specifically multiplication, geometric mean, and minimum. From a preliminary evaluation of the data, the geometric mean function was selected as the habitat simulation weighting function. The geometric mean function assumes input on the composite weighting factor to be based on all three suitability factors. This technique implies compensation effects: if two of the three variables are in the optimum range, the value of the third variable has less effect unless it is zero. This option provides a more conservative approach than either the multiplication or minimum option. This was important since HSC, by their dimensionless and relative-value nature, provide only an index of the target species response to the habitat variables (depth, velocity, and substrate) affecting the selection of spawning areas. In addition, a conservative approach was important to the planning team for the protection of the instream resources in the wild portion of the river.

Study sites in each segment were equally weighted and multiplied by the number of segment river miles in order to calculate the total spawning habitat in each river segment. The summation of all four segments provides total spawning habitat by target species for the study area.

Habitat Time Series Modeling Procedures

Habitat-discharge relationships developed from PHABSIM were used to produce spawning habitat time

Figure 8. Example of transect selected weight



series (HTS) for the months chinook and coho salmon are spawning. Total spawning habitat-discharge relationships by target species were calculated and combined with the simulated median monthly flow model for the Unalakleet River. A spawning habitat duration curve was constructed from the HTS for each month in which chinook and coho salmon are spawning. Flows associated with the median spawning habitat value were then identified.

Identification of Instream Flow Recommendations

The monthly median spawning habitat value for chinook and coho salmon, and hydrologic analysis for channel maintenance flow were evaluated to determine the appropriate quantity of instream flow to protect those values for which the river was designated as "wild."

Chapter 3 - Results

Chinook and coho salmon spawning habitat results were evaluated for flows which provide usable spawning habitat from June through October and channel maintenance flow during spring snowmelt (mid-May to mid-June).

Hydrologic Analysis

The USGS Kobuk River gaging station near Kiana, 200 miles north of the Unalakleet gage, was used to correlate the Unalakleet gage. The Kobuk River drainage area is 9,520 square miles with a period of record from 1976 to present.

A log-log linear regression analysis was used to correlate the Kobuk gaging station flows with observed Unalakleet River flows. Discharge measurements collected by USGS (1982 and 1983) and BLM (1986, 1991, 1993, and 1994) were used from the Unalakleet gaging station for the regression analysis (Figure 9). Unalakleet River mean daily flows showed a strong correlation ($r^2 = 0.93$, p-value < .01) with mean daily flows from the Kobuk station (Table 4).

Long-term daily discharge estimates of the maximum, minimum, and median monthly flows for the Unalakleet River are shown in Table 5. In May, the estimated daily flows ranged from 88 to 3,300 cfs. June estimated daily flows ranged from 1,500 to 6,000 cfs; July estimated daily flows from 700 to 2,600 cfs; August estimated daily flows from 560 to 5,400 cfs; September estimated daily flows from 640 to 5,400 cfs; and October estimated daily flows ranged from 360 to 1,900 cfs. The estimated median monthly flows were 1,400; 2,900; 1,400; 1,700; 1,500; and 870 cfs for May, June, July, August, September, and October, respectively.

A channel maintenance flow analysis was evaluated during the spring snowmelt (mid-May to early-June).

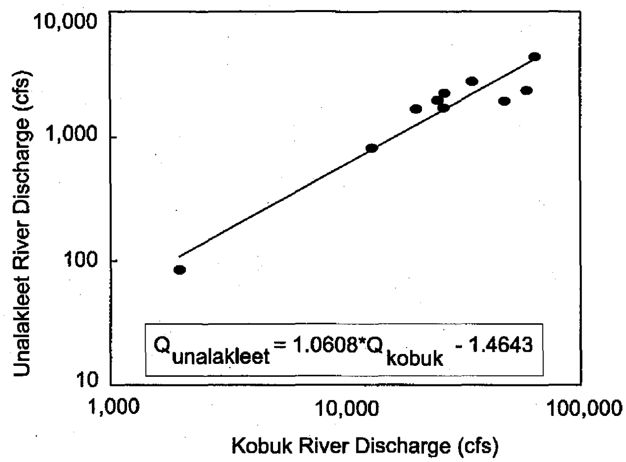


Figure 9. Log-log linear regression analysis of the Unalakleet River gaging station with the USGS Kobuk River gaging station.

The simulated flow record indicates a base flow of approximately 100 cfs (Figure 10, Table 5). Evaluation of the 48-hour (two-day) Log-Pearson III peak flow frequency analysis on the simulated flow record predicts a channel maintenance flow of approximately 5,000 cfs based on the two-year recurrence interval (Table 6).

PHABSIM Results

PHABSIM was used to quantify the amount of usable spawning habitat for chinook and coho salmon.

The Unalakleet River IFIM data decks were initially processed using the TREVI4 program. This program looks for errors in data placement, and produces a hard copy of pertinent information needed to run the model, including transect weighting factors, slopes, stage of zero flow, WSE, etc. A summary of the data decks for each study site is shown in Appendix A (Tables A-1 through A-8).

One goal of the hydraulic simulation is to have the model simulation accurately reflect measured velocities and depths at the calibration flows. A range of flows was selected for each river segment over which the model

Table 4. Unalakleet – Kobuk daily discharge regression analysis.

		UNALAKLEET (1,032 SQ Mi)		KOBUK (9520 SQ Mi)		PREDICTED	
YEAR	DATE	Q(cfs)	LOG(Q)	Q(cfs)	LOG(Q)	LOG(Q)	Q(cfs)
1982	27-AUG	1,990	3.299	24,700	4.393	3.195	1,570
1983	25-MAR	84	1.924	2,000	3.301	2.037	109
1986	10-JUL	822	2.915	13,000	4.114	2.900	794
1991	12-JUN	4,560	3.659	63,800	4.805	3.633	4,290
1993	31-AUG	1,700	3.230	20,000	4.301	3.098	1,250
1994	17-JUN	2,440	3.388	59,300	4.773	3.599	3,970
1994	20-JUN	1,980	3.297	47,500	4.677	3.497	3,140
1994	24-JUN	2,820	3.449	34,600	4.539	3.351	2,240
1994	30-JUN	2,270	3.356	26,700	4.427	3.231	1,700
1994	6-JUN	1,750	3.243	26,000	4.415	3.219	1,660

Regression Statistics

Multiple R	0.962263
R Square	0.92595
Adjusted R Square	0.916694
Standard Error	0.137989
Observations	10

would predict available spawning habitat. A range of 1,000 to 5,000 cfs was chosen for segment 1. For segments 2, 3, and 4, a range of 1,000 to 3,500 cfs, 500 to 2,500 cfs, and 300 to 900 cfs flows were chosen, respectively.

The water surface program (WSP) provides the best WSE calibration results and was used to calibrate segments 1, 2, and 3. MANSQ and WSP were used for calibrating WSEs in segment 4 because the two upper sites contained only one calibration flow.

Three measured velocity sets were collected at each study site except sites, 4001 and 4002. All three sets were evaluated for velocity calibration. The high flow velocity set provided the best calibration and was used for the range of flow simulations. Velocity adjustment factors (VAF) provide a measure of how well the model simulates velocities. VAFs are computed by dividing the simulated discharge into the calculated discharge. A VAF between 0.90 and 1.10 is considered good; between 0.85 and 1.15 is fair; between 0.80 and 1.20 is marginal; and below 0.80 or above 1.20 is considered poor. Appendix B summarizes the VAF transects. For the two headwater transects (sites 4001 and 4002), only one discharge was measured for each site and larger VAFs were observed. Ideally, three measured discharges are collected over the range for model simulations.

Usable spawning habitat versus stream flow relationships were simulated for chinook and coho salmon using the geometric mean weighting option (Figures 11 and 12). PHABSIM predicts a parabolic relationship for chinook and coho salmon. Available spawning habitat increases with flow until it peaks at 2,510 and 1,480

Table 5. Unalakleet River synthetic monthly discharge (in cfs) data, 1976-1994 (rounded to 2 significant digits).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	MEDIAN	MAX	MIN
1976									710	540	320	220		710	220
1977	140	110	110	97	950	2,400	700	560	1,300	930	200	120	380	2,400	97
1978	110	100	95	89	1,600	2,000	1,500	980	1,500	760	300	230	530	2,000	89
1979	190	140	110	110	3,200	4,400	2,100	2,600	1,700	860	220	160	540	4,400	110
1980	160	150	140	210	3,100	4,300	2,600	1,100	950	360	150	120	290	4,300	120
1981	110	97	92	95	1,700	1,700	2,200	3,000	1,100	370	150	110	260	3,000	92
1982	86	78	75	69	1,200	5,900	1,600	1,900	3,100	1,100	410	240	780	5,900	69
1983	170	130	110	160	1,100	2,100	830	2,400	1,500	540	230	140	380	2,400	110
1984	97	71	59	52	430	2,300	1,200	3,600	1,100	510	170	120	300	3,600	52
1985	100	94	83	77	420	4,400	1,400	710	3,800	1,600	480	270	450	4,400	77
1986	180	130	96	74	150	2,500	830	1,700	5,400	990	340	220	280	5,400	74
1987	170	140	130	120	560	1,900	1,100	1,600	1,200	660	230	130	400	1,900	120
1988	100	90	86	99	2,900	2,100	750	2,100	1,200	1,100	370	220	560	2,900	86
1989	150	98	92	86	490	6,000	2,380	3,800	3,000	1,400	470	260	480	6,000	86
1990	190	150	130	120	2,200	1,500	820	560	2,200	890	350	210	450	2,200	120
1991	170	150	130	120	3,300	3,700	1,480	1,000	640	910	340	190	490	3,700	120
1992	120	91	80	75	88	4,000	1,000	1,500	1,000	560	300	200	250	4,000	75
1993	150	120	110	98	3,000	4,600	1,400	1,700	3,100	1,900	670	360	1,100	4,600	98
1994	230	160	130	130	2,300	3,200	2,400	5,400	2,800					5,400	130
MEDIAN	150	120	100	100	1,400	2,900	1,400	1,700	1,500	870	310	210	450		
MAX	230	160	140	210	3,300	6,000	2,600	5,400	5,400	1,900	670	360			
MIN	86	71	59	52	88	1,500	700	560	640	360	150	110			

cfs for chinook and coho salmon, respectively, and then predicts a continual decrease.

PHABSIM modeling results for the critical passage reach indicate that a discharge of 500 cfs provides a stream channel width of 204 feet with one foot of depth (Table 7).

Habitat Time Series Analysis

PHABSIM results were incorporated into the simulated flow record to develop a HTS model. The HTS analysis for June, July, August, September, and October are shown in Figures 13 through 17, respectively. The HTS analysis shows a positive relationship between available spawning habitat and the median monthly flow. Available spawning habitat decreases with extreme flows, and peaks as flows approach the median monthly flows for each month. Monthly spawning habitat duration curves were constructed from the HTS data (Figures 18 to 19). The median spawning habitat values were determined from these curves and are summarized in Table 8.

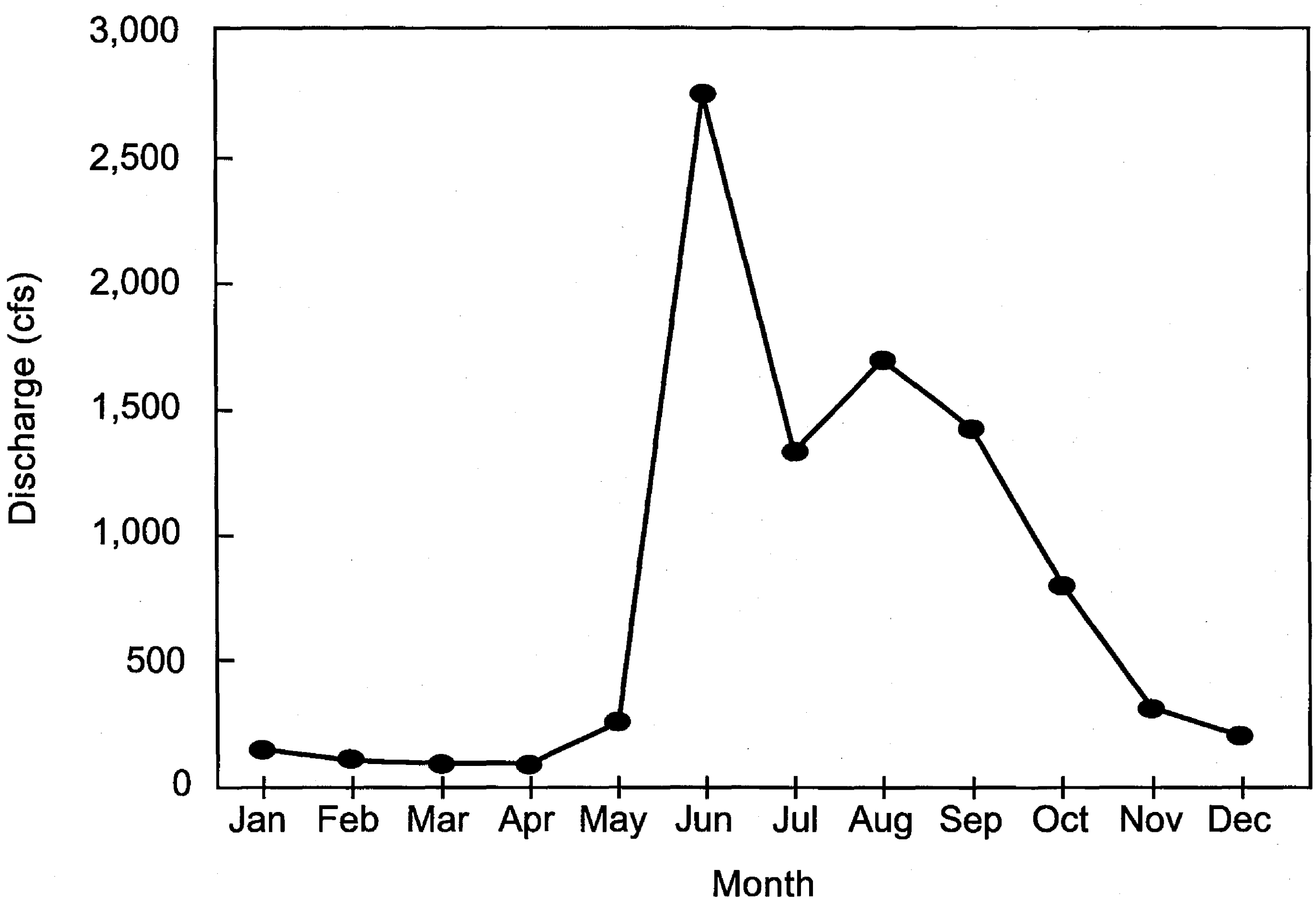


Figure 10. Simulated median monthly discharge summary for Unalakleet River.

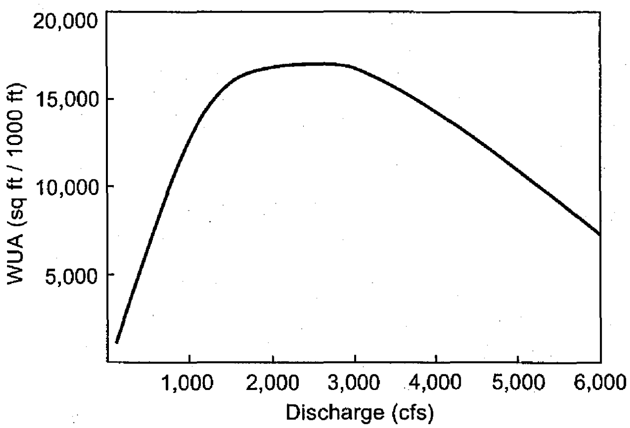


Figure 11. Chinook salmon spawning habitat (WUA) versus discharge relationship for the Unalakleet River.

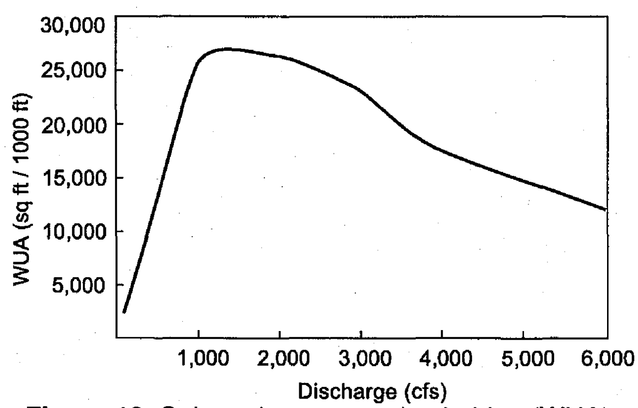


Figure 12. Coho salmon spawning habitat (WUA) versus discharge relationship for the Unalakleet River.

Table 6. May 2-day Log-Pearson III peak flow frequency analysis for the Unalakleet River.

RECURRENCE INTERVAL (Year)	FLOOD ESTIMATE (cfs)
2	5,000
5	7,900
10	8,800
25	9,300
50	9,500
100	9,600

Table 7. PHABSIM critical passage reach simulation summary of discharge versus minimum passage width for the Unalakleet River.

Discharge (cfs)	WSL (feet)	Mean Vel (ft/sec)	Surface Area (ft^2)	Usable Area (ft^2)	Weighted Area (ft^2)	C/S Volume	Percent Usable (%)	Percent WUA (%)
500	96.08	1.04	272	204	204	482	75.12	75.12
1,000	96.62	1.55	323	224	224	644	69.35	69.35
2,000	97.23	2.33	387	295	295	859	76.33	76.33
2,890	97.59	2.85	443	311	311	1,013	70.20	70.20
4,000	97.93	3.44	444	356	356	1,163	80.20	80.20
5,000	98.17	3.94	444	376	376	1,270	84.59	84.59

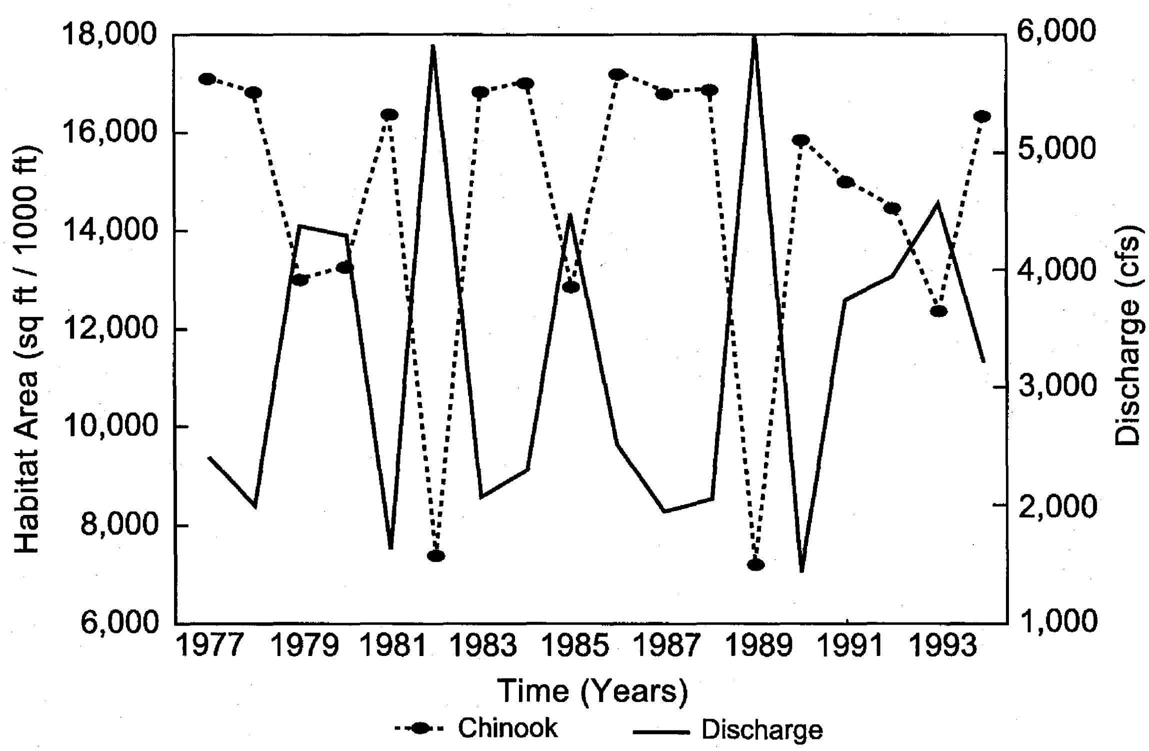


Figure 13. June chinook salmon spawning habitat time series from 1976 through 1994 for the Unalakleet River.

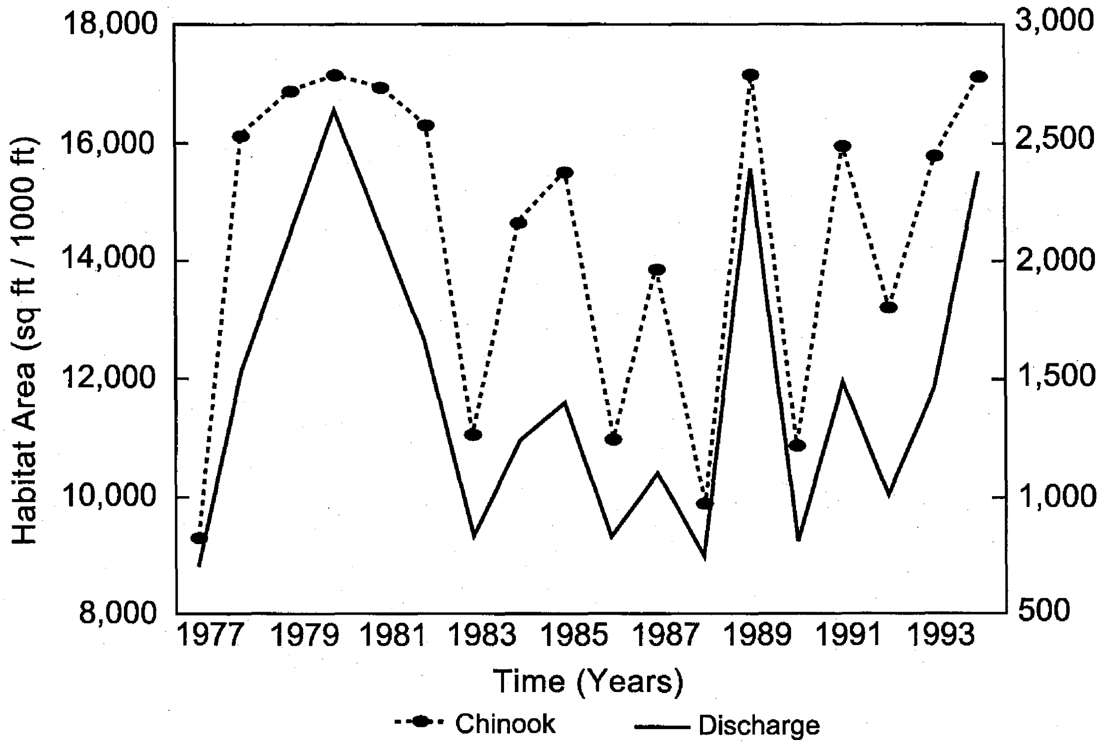


Figure 14. July chinook salmon spawning habitat time series from 1976 through 1994 for the Unalakleet River.

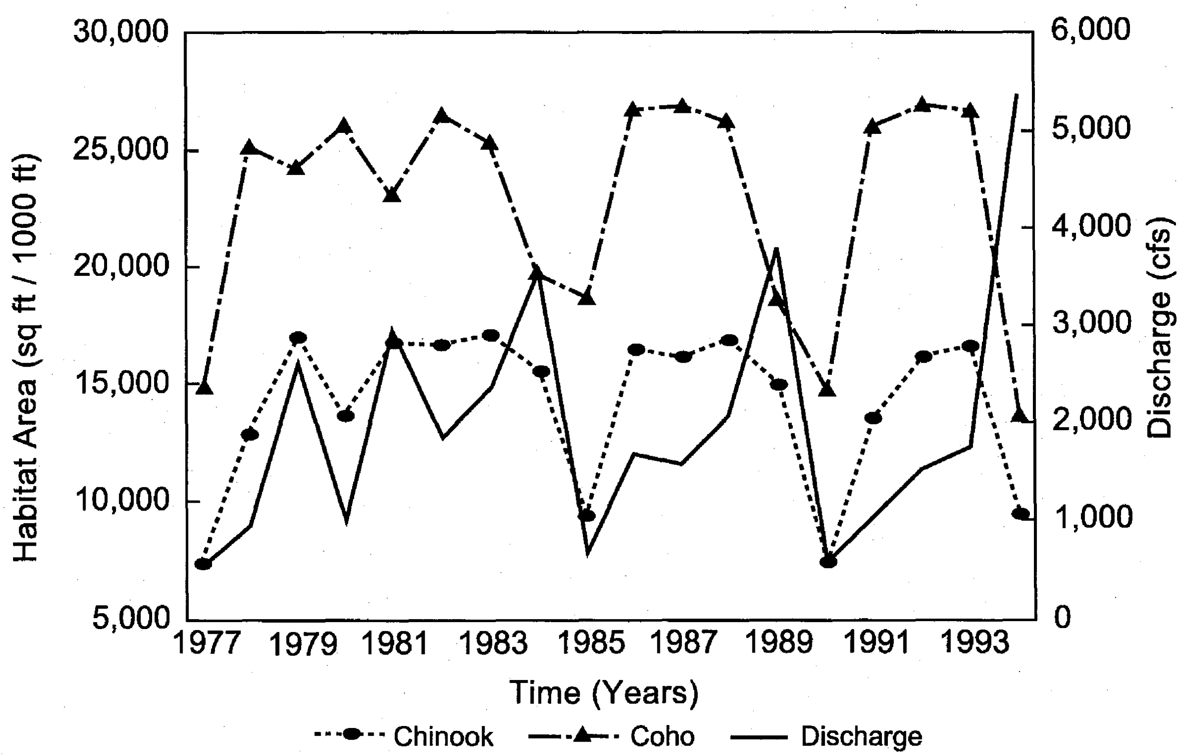


Figure 15. August chinook and coho salmon spawning habitat time series from 1976 through 1994 for the Unalakleet River.

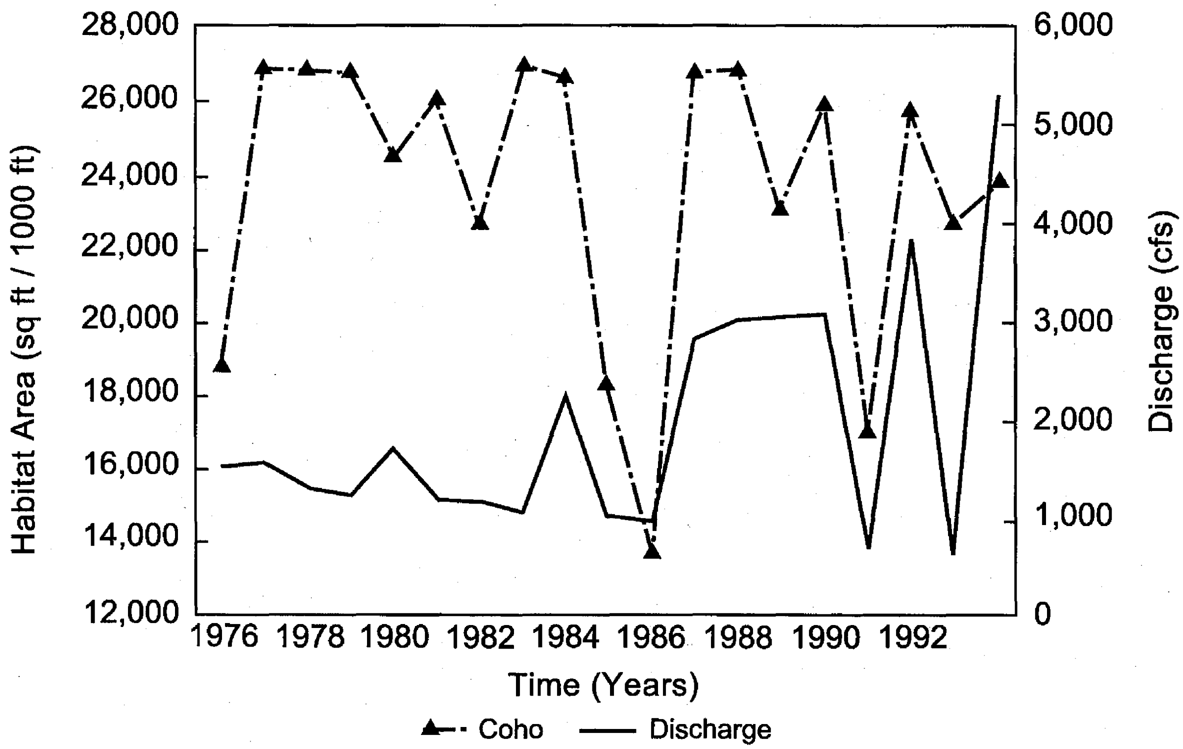


Figure 16. September coho salmon spawning habitat time series from 1976 through 1994 for the Unalakleet River.

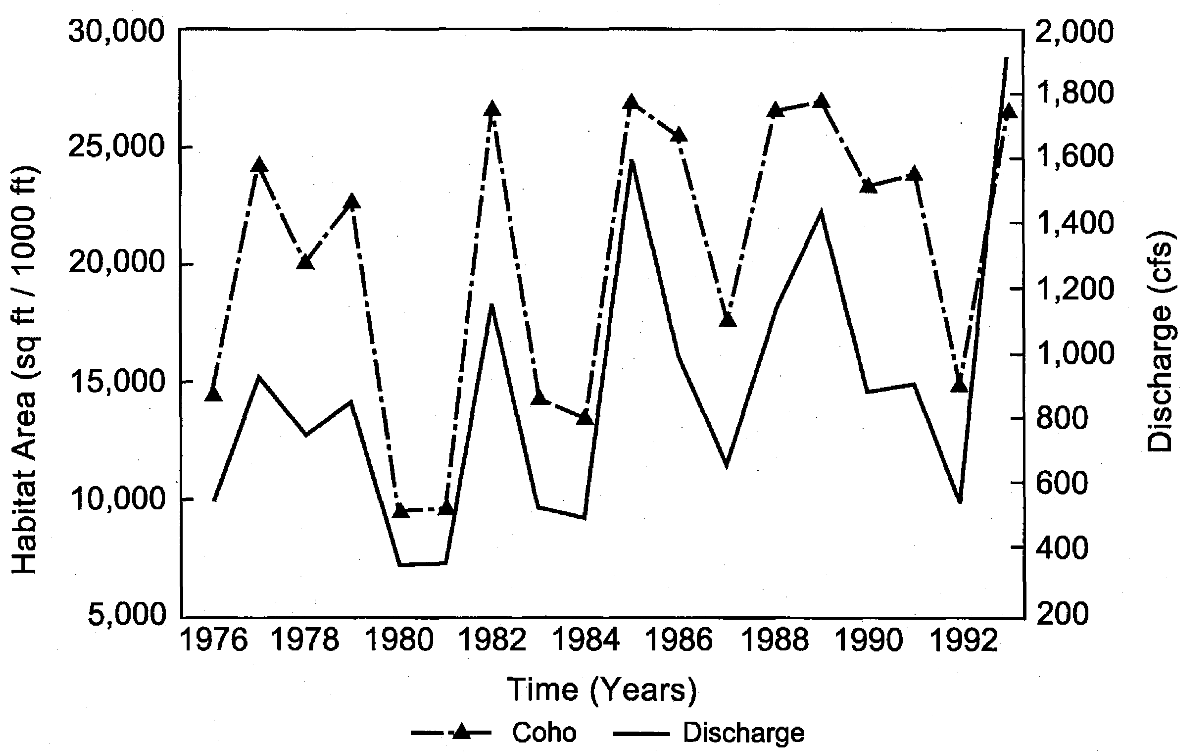


Figure 17 October coho salmon spawning habitat time series from 1976 through 1994 for the Unalakleet River.

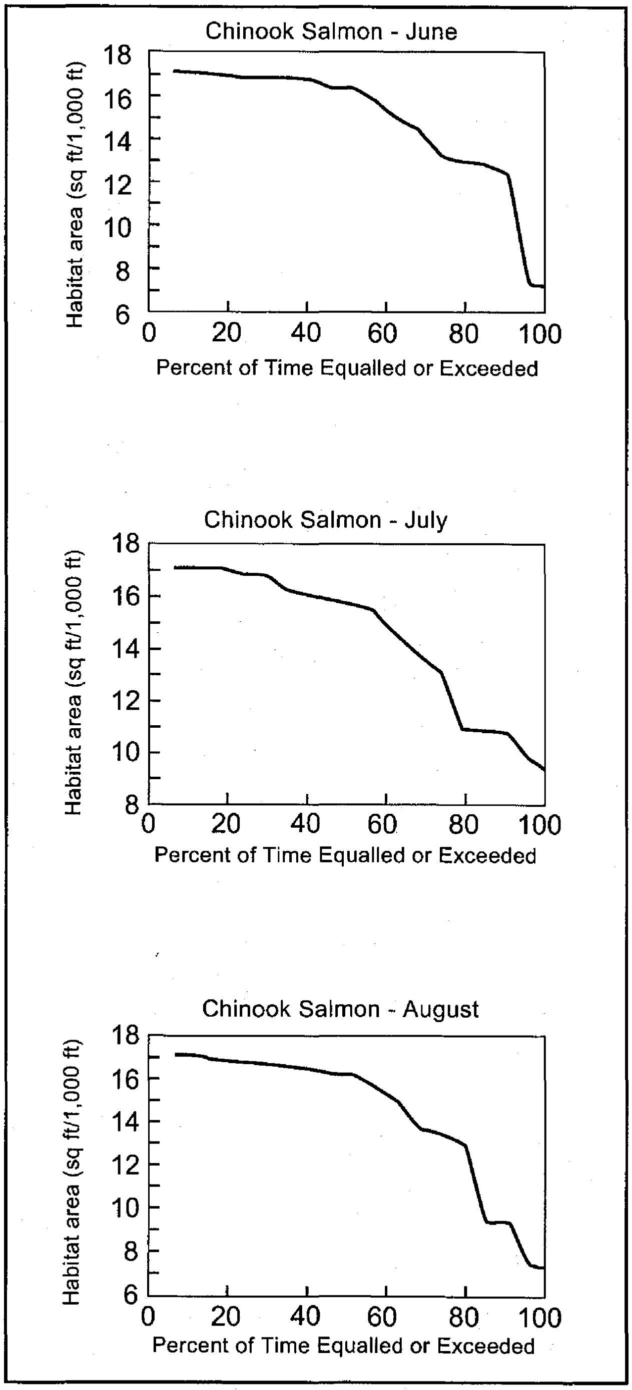


Figure 18. Chinook salmon spawning habitat duration curves from June through August.

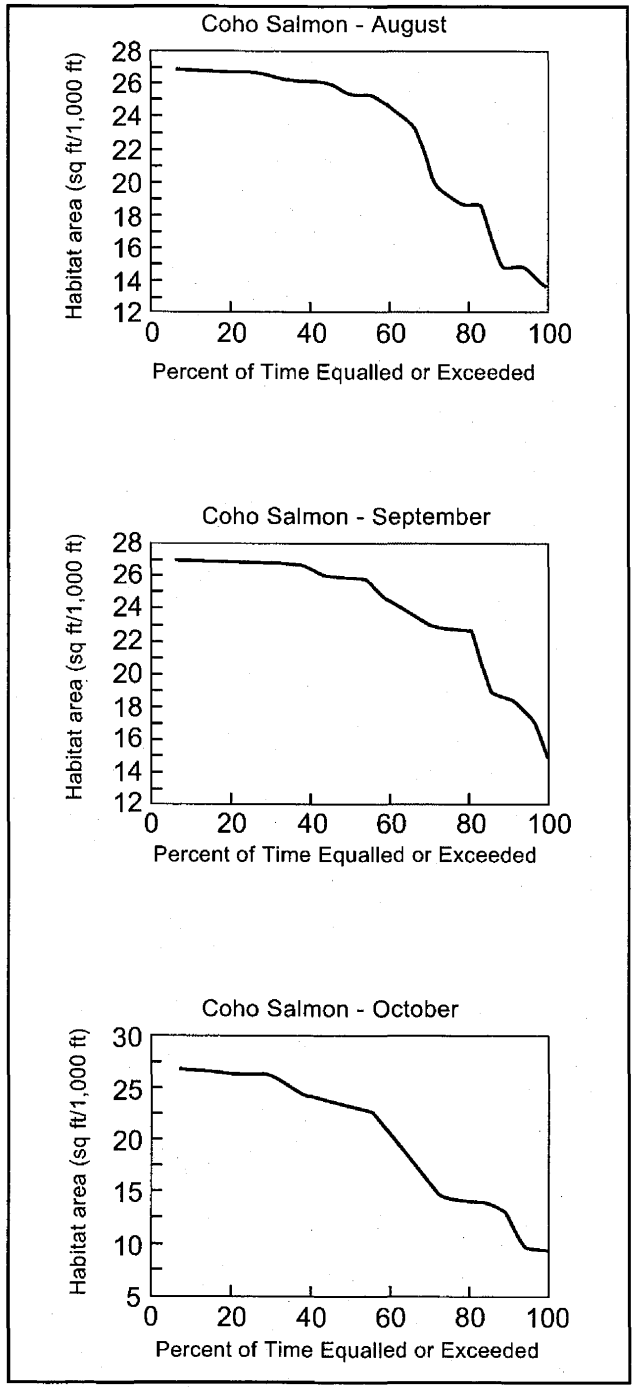


Figure 19. Coho salmon spawning habitat duration curves from June through August.

Table 8. Stream discharge (in cfs) associated with the median spawning habitat values for chinook and coho salmon for the Unalakleet River.

	June	July	August	September	October
Chinook	1,620	1,450	1,540		
Coho			980	1,010	890

Chapter 4 - Discussion

The mean daily discharge for the Unalakleet River gaging station correlated strongly with the mean daily flows from the USGS Kobuk gaging station to provide a 17-year simulation flow record. This was expected since both rivers had similar geomorphic characteristics and were in the same hydrologic basin influenced by similar weather patterns.

Field sampling for the instream flow study was conducted during the 1994 summer season, one of the wettest on record. The high flows were helpful in collecting a high flow calibration measurement for all the study sites except upper study sites 7 and 8. The higher-than-normal measured flow conditions combined with the inherent assumptions of the PHABSIM limited our ability to simulate lower flow conditions.

Study sites 7 and 8 were sampled only once at a flow below the median monthly flow. Only one calibration flow was measured at these sites. The range of simulation flow predictions were narrower than sites measured for three calibration flows.

Winter is a critical period for arctic aquatic resources. Low flows and freezing can limit habitat which can significantly affect incubation and rearing life history stages of salmon. Salmonid eggs, if kept moist, can withstand extended periods of dewatering without experiencing significant mortalities (Becker et al. 1982, and Reiser and White 1983). However, the length of time that an embryo or alevin can withstand dewatering decreases dramatically with each subsequent stage of development (Becker et al.1983). Typically, the Unalakleet River is frozen over from late October through early May. Instantaneous March flow measurements correspond with the simulated hydrograph developed from the Kobuck River gage. The data suggest a base flow of approximately 100 cfs.

Overwintering areas in rivers generally occur in specific areas, although specific pools or channels where fish spend the winter may vary from one year to the next (Wilson et al. 1977). Studies by Yoshihara (1972), Craig and McCart (1974), Furniss (1975), Kogl and Schell (1975), and Craig (1976) document the importance of winter fish habitat in arctic rivers. Wilson et al. (1977) concludes that winter withdrawal from any arctic freshwater habitat poses a potential, and often significant threat to aquatic organisms and may affect subsistence, sport and commercial fisheries.

Information related to the importance of winter flows to arctic aquatic life was the basis for November to April flow recommendation. June through October flow recommendations are based on the analysis of the spawning phases of chinook and coho salmon.

Potential habitat availability is different among species and life phases. The flows that support optimal habitat availability for any one species and one life phase may be less favorable to another life phase of the same species or other species. The analysis of two species and one life phase to determine recommended flows during May through October may not provide optimal habitat for other species and their life phases. However, under any given natural flow regime, flows will not be optimal for any given species for their entire life phase. The recommended flows mimic the simulated hydrograph developed for the Unalakleet River and provide quality spawning habitat for the target species. These recommended flows should also provide adequate habitat for those species endemic to the drainage and their life phases.

Chapter 5 - Recommendations

1. Submit a State of Alaska "Application for Reservation of Water" to the Alaska Department of Natural Resources, Division of Mining, Land and Water, Water Resources section with the monthly discharge recommendation listed in Table 9 to preserve and protect the natural values of the Unalakleet Wild River and its immediate corridor.

2. Develop a site-specific hydrologic model from the newly installed USGS discharge gaging station when an appropriate period of record has been established.

3. Develop chinook and coho salmon HSCs specific to the Unalakleet River, or collect the necessary data to test the transferability of the curves developed for the Susitna hydro study. Either of these efforts would prove better resolution of the instream flows required to protect the salmon spawning habitat.

4. Identify future requirements needed to protect this recommendation. Evidentiary standards need to meet the State of Alaska's mandatory 10-year review of instream flow reservations. These requirements may be defined at the time of adjudication.

Table 9. Monthly discharge (in cfs) recommendation for Unalakleet River above Chiroskey River.

Nov - April	May	June	July	August	September	October
100% of Flow	100[a]	1,620	1,450	1,540	1,010	890

[a]with a 48-hour channel maintenance flow of 5,000 cfs in the event an impoundment is built in the watershed and would alter the flow regime in the study area.

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Appendix A

Table A-1. MASTER DATASET SITE 1001 UNALAKLEET RIVER

```
IOC       0000100100001001000000
NSLP            -0.3
QARD  1000
QARD  1100
QARD  1200
QARD  1300
QARD  1400
QARD  1500
QARD  1600
QARD  1700
QARD  1800
QARD  1900
QARD  2000
QARD  2100
QARD  2200
QARD  2300
QARD  2400
QARD  2500
QARD  3000
QARD  3500
QARD  4000
QARD  5000
XSEC    0.0        0.0 .50      90.70     .00034
        0.0  0.0 99.2  6.6 95.8 17.3 94.5 27.3 93.8 37.3 93.4 47.3 92.9
        0.0 57.3 92.6 67.3 92.5 77.3 92.3 87.3 92.0 97.3 91.7102.3 91.6
        0.0107.3 91.6112.3 91.5117.3 91.6122.3 91.7127.3 91.5132.3 91.5
        0.0137.3 91.5142.3 91.4147.3 91.5152.3 91.5157.3 91.4162.3 91.4
        0.0167.3 91.2172.3 91.2177.3 91.1182.3 91.1187.3 90.9192.3 90.9
        0.0197.3 90.7202.3 90.7207.3 91.0212.3 91.3217.3 91.3222.3 91.2
        0.0227.3 91.7236.6 95.8245.2102.0
NS      0.0     10.00      34.50      34.50      34.50      34.50      34.50
NS      0.0     34.50      34.25      34.25      32.25      32.25      32.25
NS      0.0     32.25      32.25      32.25      32.25      32.25      32.25
NS      0.0     32.25      32.25      32.25      32.25      32.25      32.25
NS      0.0     32.25      32.25      32.25      32.25      32.25      32.25
NS      0.0     32.25      32.25      32.25      32.25      30.75      30.75
NS      0.0     10.00      10.00      10.00
WSL     0.0     93.63      93.82      93.99      94.15      94.29      94.43
WSL     0.0     94.56      94.68      94.80      94.91      95.02      95.12
WSL     0.0     95.22      95.32      95.41      95.50      95.59      95.67
WSL     0.0     95.76      95.84      95.92      96.29      96.63      96.94
WSL     0.0     97.51
CAL1    0.0     95.80    2350.00
VEL1    0.0                2.30 2.60 3.20 2.60 3.40 3.40 3.30 3.50 3.10 3.40
VEL1    0.0 3.40 3.50 3.20 3.20 3.10 3.20 2.90 3.10 2.90 2.90 2.80 2.70
VEL1    0.0 2.80 2.70 2.30 2.60 2.50 2.40 2.30 2.20 2.20 2.00 1.80 1.50
VEL1    0.0 1.20
CAL2    0.0     95.64    2200.00
VEL2    0.0
VEL2    0.0
VEL2    0.0
VEL2    0.0
CAL3    0.0     95.24    1720.00
VEL3    0.0
VEL3    0.0
VEL3    0.0
VEL3    0.0
XSEC  276.0      276.0 .50      90.70     .00034
      276.0  0.0102.1  3.5 95.9 10.8 92.6 15.8 91.0 20.8 90.2 27.8 89.3
      276.0 34.8 88.7 39.8 88.6 44.8 88.5 49.8 88.7 56.8 88.8 63.8 89.1
```

Table A-1. (cont'd)

```
     276.0 70.8 89.3 77.8 89.5 87.8 90.0 97.8 90.6107.8 91.1117.8 91.5
     276.0127.8 92.2137.8 92.6149.8 93.5161.8 94.0176.8 94.5196.5 95.9
     276.0208.6100.0
NS   276.0      0.00      0.00     30.50     30.25     30.25     30.25
NS   276.0     30.25     30.25     30.25     30.25     30.25     30.25
NS   276.0     30.25     30.25     30.25     30.25     32.25     32.50
NS   276.0     32.50     32.50     32.50     32.50     32.50      0.00
NS   276.0      0.00
WSL  276.0     94.07     94.21     94.35     94.47     94.59     94.70
WSL  276.0     94.81     94.91     95.02     95.11     95.21     95.29
WSL  276.0     95.38     95.47     95.55     95.63     95.72     95.79
WSL  276.0     95.87     95.94     96.02     96.36     96.69     96.98
WSL  276.0     97.52
CAL1 276.0     95.90   2350.00
VEL1 276.0           1.00 1.90 2.30 2.40 2.70 2.80 2.80 2.50 2.80 2.50
VEL1 276.0 2.60 2.70 2.70 2.60 2.50 2.80 2.70 2.40 2.60 2.20 1.80
VEL1 276.0
CAL2 276.0     95.77   2200.00
VEL2 276.0
VEL2 276.0
VEL2 276.0
CAL3 276.0     95.34   1720.00
VEL3 276.0
VEL3 276.0
VEL3 276.0
XSEC 781.0     505.0 .50      90.70     .00034
     781.0  0.0103.1  7.1 96.0 15.5 91.6 21.0 91.5 28.0 92.1 35.0 92.5
     781.042.0 92.5 49.0 92.6 59.0 92.6 69.0 92.5 79.0 92.5 86.0 92.3
     781.0 92.0 92.2100.0 92.1107.0 92.1117.0 91.9124.0 91.9131.0 91.7
     781.0138.0 91.6145.0 91.5152.0 91.5159.0 91.4166.0 91.3173.0 91.3
     781.0180.0 91.5190.0 92.2200.0 93.1208.0 93.8221.0 96.0237.0101.2
NS   781.0                         32.25     32.25     32.25     32.25
NS   781.0     32.25     32.25     32.25     32.25     32.25     32.25
NS   781.0     32.25     32.25     32.25     32.25     32.25     32.25
NS   781.0     32.25     32.25     32.25     32.25     32.25     32.25
NS   781.0     32.25     32.25     32.25     32.25
WSL  781.0     94.48     94.58     94.67     94.77     94.86     94.95
WSL  781.0     95.04     95.12     95.21     95.29     95.38     95.45
WSL  781.0     95.53     95.61     95.68     95.76     95.83     95.90
WSL  781.0     95.98     96.05     96.11     96.44     96.75     97.04
WSL  781.0     97.57
CAL1 781.0     96.00   2350.00
VEL1 781.0           1.00 2.30 2.00 2.80 2.70 2.80 3.10 2.80 3.20 3.20
VEL1 781.0 3.20 3.10 3.20 3.20 3.30 3.20 3.20 3.20 3.30 3.40 3.10 3.00
VEL1 781.0 3.00 2.90 4.90 2.20
CAL2 781.0     95.90   2200.00
VEL2 781.0
VEL2 781.0
VEL2 781.0
CAL3 781.0     95.59   1720.00
VEL3 781.0
VEL3 781.0
VEL3 781.0
ENDJ
```

```
IOC       000010010000010010000
NSLP            -0.8
QARD  1000
QARD  1100
QARD  1200
QARD  1300
QARD  1400
QARD  1500
QARD  1600
QARD  1700
QARD  1800
QARD  1900
QARD  2000
QARD  2100
QARD  2200
QARD  2300
QARD  2400
QARD  2500
QARD  3000
QARD  3500
QARD  4000
QARD  5000
XSEC   0.0       0.0 .50     89.80    .00030
       0.0  0.099.45  5.097.15 15.0 93.2 28.0 95.5 38.0 93.8 43.0 93.3
       0.0 48.0 93.1 58.0 93.0 68.0 92.9 78.0 92.7 88.0 92.5 98.0 92.3
       0.0108.0 91.9113.0 91.8118.0 91.6123.0 91.4128.0 91.3133.0 91.1
       0.0138.0 91.0143.0 90.8148.0 90.5153.0 90.5158.0 90.4163.0 90.7
       0.0168.0 90.7173.0 90.6178.0 90.4183.0 90.2188.0 89.9193.0 89.9
       0.0198.0 89.8203.0 90.1208.0 91.0217.097.15220.099.45
NS     0.0                        10.00     10.00     10.00     10.00
NS     0.0     20.00     20.00    20.00     20.00     20.00     20.00
NS     0.0     20.00     20.00    30.00     30.00     30.00     30.00
NS     0.0     30.00     30.00    30.00     30.00     30.00     30.00
NS     0.0     30.00     30.00    30.00     30.00     30.00     30.00
NS     0.0     30.00
WSL    0.0     94.69     94.89    95.07     95.23     95.37     95.51
WSL    0.0     95.63     95.75    95.86     95.96     96.06     96.15
WSL    0.0     96.24     96.33    96.41     96.49     96.57     96.64
WSL    0.0     96.71     96.78    96.85     97.17     97.45     97.70
WSL    0.0     98.13
CAL1   0.0     97.15   2970.00
VEL1   0.0           1.50  .90 1.70 2.10 2.00 2.30 2.30 2.70 2.70 3.30
VEL1   0.0 3.10 3.30 3.20 3.40 3.40 3.50 3.40 3.40 3.40 3.50 3.40 3.40
VEL1   0.0 3.60 3.60 3.80 3.30 3.20 3.10 2.60 2.10  .90
CAL2   0.0     96.05   1430.00
VEL2   0.0
VEL2   0.0
VEL2   0.0
CAL3   0.0     96.60   2220.00
VEL3   0.0
VEL3   0.0
VEL3   0.0
XSEC 340.0     340.0 .50     89.80    .00030
     340.0  0.0101.7  6.897.35 18.5 94.2 29.2 93.7 38.0 94.0 48.0 94.2
     340.0 58.0 94.0 68.0 93.8 78.0 93.6 88.0 93.4 98.0 93.1108.0 92.9
     340.0118.0 92.6128.0 92.3138.0 92.0148.0 91.3153.0 91.2158.0 91.2
     340.0165.0 90.8172.0 90.5180.0 90.5190.0 90.2195.0 90.0200.0 89.7
     340.0205.0 89.9210.0 90.3215.0 90.6228.997.35236.9100.9
NS   340.0      0.00      0.00    10.00     10.00     10.00     10.00
NS   340.0     20.00     20.00    20.00     20.00     20.00     20.00
```

Table A-2 (Cont'd)

```
NS   340.0     20.00     20.00     20.00     30.00     30.00     30.00
NS   340.0     30.00     30.00     30.00     30.00     30.00     30.00
NS   340.0     30.00     30.00     30.00
WSL  340.0     94.88     95.08     95.26     95.42     95.56     95.70
WSL  340.0     95.82     95.94     96.05     96.15     96.25     96.34
WSL  340.0     96.43     96.52     96.60     96.68     96.76     96.83
WSL  340.0     96.90     96.97     97.04     97.36     97.64     97.90
WSL  340.0     98.33
CAL1 340.0     97.35   2970.00
VEL1 340.0               1.20 1.50 1.90 2.50 2.80 2.70 3.00 3.30 3.20 3.20
VEL1 340.0 3.50 3.60 3.70 3.50 3.60 3.40 3.40 2.50 2.20 2.50 2.00 1.60
VEL1 340.0 1.90 1.50 1.00
CAL2 340.0     96.19   1430.00
VEL2 340.0
VEL2 340.0
VEL2 340.0
CAL3 340.0     96.75   2220.00
VEL3 340.0
VEL3 340.0
VEL3 340.0
XSEC 806.0     466.0 .50      89.80     .00030
     806.0  0.099.77  5.097.37 15.0 94.7 22.0 94.4 33.0 94.2 42.0 94.0
     806.0 52.0 93.7 62.0 93.3 72.0 92.8 82.0 92.3 92.0 91.9102.0 91.4
     806.0112.0 90.7122.0 90.0129.0 89.7136.0 89.1143.0 89.1150.0 89.1
     806.0156.0 89.1160.0 89.1166.0 89.3173.0 89.2180.0 88.9186.0 88.9
     806.0191.0 89.2196.0 91.1203.297.37207.0101.1
NS   806.0                         10.00     10.00     10.00     10.00
NS   806.0     20.00     20.00     20.00     20.00     20.00     20.00
NS   806.0     20.00     20.00     30.00     30.00     30.00     30.00
NS   806.0     30.00     30.00     30.00     30.00     30.00     30.00
NS   806.0     30.00     30.00
WSL  806.0     94.89     95.09     95.27     95.43     95.57     95.71
WSL  806.0     95.83     95.95     96.07     96.17     96.27     96.36
WSL  806.0     96.45     96.54     96.62     96.70     96.78     96.85
WSL  806.0     96.92     96.99     97.06     97.38     97.67     97.92
WSL  806.0     98.35
CAL1 806.0     97.37   2970.00
VEL1 806.0               1.10 1.30 1.60 2.00 3.00 2.50 2.60 2.70 2.90 3.00
VEL1 806.0 3.10 2.90 3.00 3.10 3.10 3.10 3.00 2.80 2.80 2.60 2.50 2.10
VEL1 806.0 2.00 1.20
CAL2 806.0     96.30   1430.00
VEL2 806.0
VEL2 806.0
VEL2 806.0
CAL3 806.0     96.84   2220.00
VEL3 806.0
VEL3 806.0
VEL3 806.0
ENDJ
```

Table A-3.   MASTER DATASET   SITE 1003   UNALAKLEET RIVER

```
IOC        00001001000010000000
QARD  1000
QARD  1100
QARD  1200
QARD  1300
QARD  1400
QARD  1500
QARD  1600
QARD  1700
QARD  1800
QARD  1900
QARD  2000
QARD  2100
QARD  2200
QARD  2300
QARD  2400
QARD  2500
QARD  3000
QARD  3500
QARD  4000
QARD  5000
XSEC   0.0       0.0 .50     87.10     .00011
       0.0  0.099.26  7.092.19 12.0 90.0 17.0 88.6 23.6 88.9 30.6 88.5
       0.0 35.6 87.8 40.6 87.5 45.6 87.2 50.6 87.2 55.6 87.2 60.6 87.2
       0.0 65.6 87.1 70.6 87.1 75.6 87.1 80.6 87.1 87.6 87.1 94.6 87.2
       0.0101.6 87.3108.6 87.4115.6 87.5122.6 87.7129.6 87.8136.6 88.0
       0.0143.6 88.2150.6 88.4160.6 88.8170.6 89.3180.6 90.0190.6 90.6
       0.0200.6 91.0211.292.19231.699.66
NS     0.00.035  0.00.035  0.00.035 10.00.035 10.00.035 10.00.035 10.0
NS     0.00.000 30.70.000 30.70.000 20.70.000 20.70.000 20.70.000 20.7
NS     0.00.000 20.70.000 20.70.000 20.70.000 20.70.000 20.70.000 20.7
NS     0.00.000 20.70.000 30.50.000 30.50.000 30.50.000 30.50.000 30.5
NS     0.00.000 32.50.000 32.50.000 32.50.000 32.50.000 32.50.000 32.5
NS     0.00.020 32.70.020  0.00.020  0.0
WSL    0.0      89.91     90.15     90.37     90.58     90.77     90.95
WSL    0.0      91.13     91.29     91.45     91.60     91.74     91.88
WSL    0.0      92.02     92.15     92.28     92.40     92.52     92.64
WSL    0.0      92.76     92.87     92.98     93.50     94.00     94.45
WSL    0.0      95.28
CAL1   0.0      92.19   1830.00
VEL1   0.0                .40  .60 1.00 1.20 1.50 1.80 1.90 2.00 2.00 2.20
VEL1   0.0 2.40 2.20 2.50 2.60 2.60 2.80 2.90 2.80 3.10 3.10 3.10 3.10
VEL1   0.0 3.20 3.20 3.00 2.70 2.10 1.60 1.20
CAL2   0.0      91.91   1620.00
VEL2   0.0
VEL2   0.0
VEL2   0.0
CAL3   0.0      92.11   1770.00
VEL3   0.0
VEL3   0.0
VEL3   0.0
XSEC 160.0     160.0 .50     87.10     .00011
     160.0  0.0101.2 25.092.21 32.0 90.2 39.0 90.0 49.0 90.1 59.0 90.0
     160.0 69.0 90.0 79.0 89.8 86.0 89.5 93.0 89.1100.0 88.6107.0 88.3
     160.0114.0 88.1121.0 87.9128.0 87.7135.0 87.5140.0 87.3145.0 87.1
     160.0150.0 87.0155.0 86.9160.0 86.8165.0 86.8170.0 86.7175.0 86.7
     160.0180.0 86.6185.0 86.7190.0 86.8195.0 87.0200.0 87.3205.0 87.7
     160.0212.0 88.0217.0 88.8226.192.21235.099.96
NS   160.00.030  0.00.030  0.00.030 10.00.030 30.75.030 30.75.000 23.7
NS   160.00.000 20.50.000 20.50.000 20.50.000 20.50.000 32.20.000 32.2
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Table A-3 (Cont'd)

```
NS   160.00.000 32.20.000 32.20.000 32.20.000 32.20.000 32.20.000 32.2
NS   160.00.000 32.20.000 32.20.000 32.20.000 32.20.000 32.20.000 32.2
NS   160.00.000 32.20.000 32.20.000 32.20.000 32.20.000 32.20.030 32.2
NS   160.00.030 30.50.030 30.70.030  0.00.030  0.0
WSL  160.0     90.47     90.56     90.68     90.81     90.94     91.08
WSL  160.0     91.23     91.37     91.51     91.65     91.78     91.92
WSL  160.0     92.05     92.17     92.30     92.42     92.53     92.65
WSL  160.0     92.77     92.88     92.99     93.50     94.00     94.45
WSL  160.0     95.28
CAL1 160.0     92.21   1830.00
VEL1 160.0           0.00  .20  .60 1.00 1.30 1.80 2.00 2.00 2.20 2.50
VEL1 160.0 2.60 2.40 2.50 2.50 2.60 2.70 2.70 3.00 2.80 2.90 2.80 2.90
VEL1 160.0 2.80 2.80 3.20 2.80 2.40 2.40 1.20  .30
CAL2 160.0     91.94   1620.00
VEL2 160.0
VEL2 160.0
VEL2 160.0
CAL3 160.0     92.14   1770.00
VEL3 160.0
VEL3 160.0
VEL3 160.0
XSEC 378.0     218.0 .50      87.10     .00011
     378.0  0.098.26 24.092.23 39.0 91.7 54.0 91.4 69.0 91.0 79.0 90.5
     378.0 89.0 89.9 99.0 89.6109.0 89.4119.0 89.1126.0 88.8133.0 88.6
     378.0140.0 88.3147.0 88.0154.0 87.7161.0 87.3168.0 87.0175.0 86.8
     378.0182.0 86.4187.0 86.3192.0 86.2197.0 86.2202.0 86.3207.0 86.6
     378.0212.0 86.8219.0 87.6225.092.23238.0100.1
NS   378.00.020  0.00.020  0.00.020 23.50.020 23.50.020 23.50.000 23.5
NS   378.00.000 23.50.000 23.50.000 23.50.000 23.50.000 23.50.000 23.5
NS   378.00.000 23.50.000 23.50.000 23.50.000 23.50.000 23.50.000 23.5
NS   378.00.000 30.20.000 30.20.000 30.20.000 30.20.000 30.20.020 23.5
NS   378.00.020 20.70.020 10.00.020  0.00.020  0.0
WSL  378.0     90.98     90.97     91.00     91.07     91.15     91.24
WSL  378.0     91.36     91.47     91.59     91.71     91.83     91.95
WSL  378.0     92.08     92.19     92.31     92.42     92.54     92.65
WSL  378.0     92.77     92.88     92.99     93.50     94.00     94.45
WSL  378.0     95.28
CAL1 378.0     92.23   1830.00
VEL1 378.0             .20  .90 2.00 2.30 2.30 2.70 2.90 2.90 2.80 2.90
VEL1 378.0 2.90 3.00 3.20 3.00 3.20 3.20 3.10 2.90 3.10 3.00 3.00 2.60
VEL1 378.0 1.80  .30
CAL2 378.0     91.99   1620.00
VEL2 378.0
VEL2 378.0
VEL2 378.0
CAL3 378.0     92.16   1770.00
VEL3 378.0
VEL3 378.0
VEL3 378.0
ENDJ
```

Table A-4. MASTER DATASET   SITE 2001   UNALAKLEET RIVER

```
IOC        100010010000100100000000
NSLP             -1.4
QARD  1000
QARD  1100
QARD  1200
QARD  1300
QARD  1400
QARD  1500
QARD  1600
QARD  1700
QARD  1800
QARD  1900
QARD  2000
QARD  2100
QARD  2200
QARD  2300
QARD  2400
QARD  2500
QARD  3000
QARD  3500
XSEC   0.0        0.0 .50      84.80     .00030
       0.0   0.0 99.7 13.093.45 23.0 92.6 35.0 91.4 45.0 90.4 55.0 89.1
       0.0 65.0 87.6 73.0 86.5 81.0 85.8 89.0 85.1 95.0 85.0101.0 85.0
       0.0107.0 84.8112.0 84.9118.0 85.1124.0 85.2130.0 86.1136.0 86.7
       0.0144.0 87.9151.0 88.8159.0 91.0168.093.45174.0 99.6
NS     0.0                          30.75     30.75     30.50     30.50
NS     0.0       30.25     30.00    30.00     30.00     30.00     30.00
NS     0.0       30.00     30.00    30.00     30.00     30.50     30.50
NS     0.0       30.50     30.75    30.75
WSL    0.0       91.90     92.10    92.28     92.43     92.57     92.70
WSL    0.0       92.81     92.92    93.02     93.12     93.20     93.28
WSL    0.0       93.36     93.45    93.53     93.60     93.66     93.73
WSL    0.0       93.79     93.85    93.90     94.16     94.38     94.57
WSL    0.0       94.91
CAL1   0.0       93.45    1800.00
VEL1   0.0               .10   .30 1.00 1.60 2.30 2.50 2.80 2.90 2.90 2.90
VEL1   0.0 2.80 2.40 2.20 2.30 2.40 2.00 1.50 1.30 1.10
CAL2   0.0       92.84    1160.00
VEL2   0.0
VEL2   0.0
CAL3   0.0       93.26    1510.00
VEL3   0.0
VEL3   0.0
XSEC  88.0       88.0 .50      84.80     .00030
      88.0   0.0 98.2  1.0 93.5  7.0 89.1 17.0 89.1 27.0 88.9 37.0 88.1
      88.0 45.0 87.3 53.0 87.2 59.0 87.3 65.0 87.3 71.0 86.9 77.0 86.5
      88.0 83.0 86.1 89.0 85.8 95.0 85.4101.0 84.6107.0 85.5113.0 85.5
      88.0119.0 86.5127.0 86.8135.0 86.8145.0 87.9157.0 88.6163.0 90.5
      88.0175.0 93.5177.0100.5
NS    88.0                          30.75     30.50     32.50     32.50
NS    88.0       32.50     32.50    32.50     32.50     32.50     32.50
NS    88.0       32.50     32.50    32.50     32.50     32.50     32.50
NS    88.0       32.50     10.00    10.00     10.00     10.00     30.75
NS    88.0
WSL   88.0       91.91     92.11    92.30     92.45     92.59     92.72
WSL   88.0       92.84     92.95    93.05     93.15     93.24     93.32
WSL   88.0       93.40     93.50    93.58     93.65     93.72     93.79
WSL   88.0       93.85     93.92    93.97     94.25     94.49     94.70
WSL   88.0       95.09
CAL1  88.0       93.50    1800.00
```

Table A-4 (Cont'd)

```
VEL1  88.0             .10 1.30 2.30 2.80 3.10 3.30 3.50 3.40 3.10 3.60
VEL1  88.0 3.30 3.00 2.70 2.60 1.80 2.00 1.40  .80  .50  .10 0.00 0.00
VEL1  88.0
CAL2  88.0      92.88   1160.00
VEL2  88.0
VEL2  88.0
VEL2  88.0
CAL3  88.0      93.27   1510.00
VEL3  88.0
VEL3  88.0
VEL3  88.0
XSEC 220.0      132.0 .50     84.80    .00030
     220.0  0.0100.3  6.093.51 15.0 89.4 25.0 89.4 29.0 89.4 33.0 89.6
     220.0 37.0 89.5 41.0 89.6 45.0 89.5 50.0 89.6 55.0 89.5 60.0 89.5
     220.0 66.0 89.4 71.0 89.3 76.0 89.2 81.0 89.1 86.0 88.9 91.0 88.8
     220.0 96.0 89.0101.0 88.9106.0 89.0111.0 89.0116.0 89.0121.0 89.0
     220.0126.0 89.0131.0 88.6138.0 88.6155.0 91.4165.0 89.5176.0 89.5
     220.0186.0 89.2196.0 90.5204.093.51211.0 98.7
NS   220.0                          32.25     32.25     32.25     32.25
NS   220.0      32.25     32.25     32.25     32.25     32.25     32.25
NS   220.0      32.25     32.25     32.25     32.25     32.25     32.25
NS   220.0      32.25     32.25     32.25     32.25     32.25     32.25
NS   220.0      32.25     30.50     30.50     10.00     10.00     10.00
NS   220.0      10.00     10.00
WSL  220.0      91.94     92.14     92.32     92.47     92.61     92.74
WSL  220.0      92.85     92.96     93.07     93.17     93.25     93.33
WSL  220.0      93.42     93.51     93.59     93.66     93.73     93.80
WSL  220.0      93.86     93.92     93.98     94.25     94.49     94.70
WSL  220.0      95.09
CAL1 220.0      93.51   1800.00
VEL1 220.0            1.90 2.80 2.80 3.60 3.00 3.20 3.10 3.40 3.40 3.70
VEL1 220.0 3.60 3.40 3.50 3.10 3.30 3.30 3.40 3.40 3.10 2.90 2.70 2.60
VEL1 220.0 2.20 1.20  .30  .10  .40  .40 1.00  .40
CAL2 220.0      92.89   1160.00
VEL2 220.0
VEL2 220.0
VEL2 220.0
CAL3 220.0      93.28   1510.00
VEL3 220.0
VEL3 220.0
VEL3 220.0
ENDJ
```

Table A-5. MASTER DATA SET   SITE 2002   UNALAKLEET RIVER

```
IOC       00001001000010100000
NMAX           0.070
QARD  1000
QARD  1100
QARD  1200
QARD  1300
QARD  1400
QARD  1500
QARD  1600
QARD  1700
QARD  1800
QARD  1900
QARD  2000
QARD  2100
QARD  2200
QARD  2300
QARD  2400
QARD  2500
QARD  3000
QARD  3500
XSEC   0.0       0.0 .50     87.50     .00200
       0.0   0.0 99.7  7.0 93.7 11.0 89.8 18.0 88.4 23.0 88.0 28.0 88.0
       0.0 33.0 87.8 38.0 87.5 43.0 87.6 48.0 87.7 53.0 88.0 58.0 88.3
       0.0 63.0 88.5 70.0 89.4 80.0 90.2 90.0 90.9100.0 91.2110.0 91.6
       0.0120.0 91.9130.0 92.1140.0 92.4150.0 92.6160.0 92.7170.0 93.0
       0.0184.0 92.9210.0 93.7275.0100.3
NS     0.0                          10.00       23.25       23.25       30.25
NS     0.0      30.25       30.25   30.25       30.25       30.25       32.25
NS     0.0      32.25       32.25   32.25       34.25       34.25       34.25
NS     0.0      34.25       34.25   34.25       34.25       32.25       32.25
NS     0.0      32.25
WSL    0.0      91.57       91.81   92.01       92.20       92.37       92.53
WSL    0.0      92.67       92.80   92.92       93.04       93.14       93.24
WSL    0.0      93.34       93.43   93.52       93.60       93.68       93.76
WSL    0.0      93.84       93.91   93.98       94.29       94.58       94.83
WSL    0.0      95.29
CAL1   0.0      93.70     2120.00
VEL1   0.0                .80 2.90 2.90 3.50 4.00 3.80 4.00 4.20 4.50 4.50
VEL1   0.0 4.40 4.50 4.10 4.30 4.20 4.20 4.50 4.00 4.20 4.20 3.30 2.50
VEL1   0.0 2.50
CAL2   0.0      92.90     1210.00
VEL2   0.0
VEL2   0.0
VEL2   0.0
CAL3   0.0      93.37     1700.00
VEL3   0.0
VEL3   0.0
VEL3   0.0
XSEC  81.0      81.0 .50     87.50     .00200
      81.0   0.0100.1 13.093.95 26.0 89.8 32.0 89.6 39.0 90.1 46.0 90.2
      81.0 54.0 90.4 62.0 90.6 72.0 90.9 82.0 91.0 92.0 91.0102.0 91.0
      81.0112.0 90.9122.0 90.6131.0 90.6140.0 90.5149.0 90.6159.0 90.6
      81.0167.0 90.7176.0 91.1186.0 91.4196.0 91.6206.0 92.2217.0 93.3
      81.0235.093.95263.0100.1
NS    81.0                          10.25       30.25       30.25       30.25
NS    81.0      30.25       30.25   30.25       30.25       30.25       30.25
NS    81.0      30.25       30.25   34.25       34.25       34.25       34.25
NS    81.0      34.25       34.25   34.25       34.25       45.50
NS    81.0
WSL   81.0      91.76       91.98   92.17       92.36       92.53       92.70
```

```
WSL   81.0      92.85     92.98     93.11     93.24     93.35     93.45
WSL   81.0      93.56     93.66     93.75     93.84     93.92     94.01
WSL   81.0      94.09     94.17     94.24     94.58     94.89     95.17
WSL   81.0      95.67
CAL1  81.0      93.95   2120.00
VEL1  81.0             1.20 2.60 3.20 3.80 3.80 3.80 3.90 3.90 4.30 4.50
VEL1  81.0 4.60 4.40 4.40 4.00 3.90 3.80 3.90 3.90 3.10 3.00 2.40 1.10
VEL1  81.0
CAL2  81.0      93.05   1210.00
VEL2  81.0
VEL2  81.0
VEL2  81.0
CAL3  81.0      93.54   1700.00
VEL3  81.0
VEL3  81.0
VEL3  81.0
XSEC 250.0      169.0 .50      87.50     .00200
     250.0   0.0101.1 49.0 94.1 60.0 91.7 70.0 90.8 78.0 91.3 88.0 91.1
     250.0 98.0 90.5108.0 90.6118.0 90.4128.0 90.3138.0 89.9147.0 89.9
     250.0155.0 89.6163.0 89.3170.0 89.3177.0 89.0184.0 88.9191.0 88.6
     250.0198.0 88.5205.0 88.5212.0 88.5218.0 88.4224.0 88.3229.0 88.2
     250.0239.0 94.1245.0100.1
NS   250.0                          10.00     20.75     32.50     34.50
NS   250.0      34.25     34.25     34.25     34.25     34.25     34.25
NS   250.0      34.25     34.25     34.25     34.25     34.25     34.25
NS   250.0      34.25     34.25     34.25     30.50     30.50     30.50
NS   250.0
WSL  250.0      91.93     92.14     92.33     92.51     92.68     92.84
WSL  250.0      92.99     93.13     93.26     93.38     93.50     93.60
WSL  250.0      93.71     93.81     93.91     93.99     94.08     94.17
WSL  250.0      94.25     94.33     94.41     94.75     95.07     95.35
WSL  250.0      95.87
CAL1 250.0      94.10   2120.00
VEL1 250.0             1.20 1.00 2.60 2.60 2.90 2.70 3.00 3.00 3.20 3.10
VEL1 250.0 2.90 3.00 3.30 2.90 3.10 2.80 3.00 2.60 2.10 1.50 1.00 0.50
VEL1 250.0
CAL2 250.0      93.18   1210.00
VEL2 250.0
VEL2 250.0
VEL2 250.0
CAL3 250.0      93.67   1700.00
VEL3 250.0
VEL3 250.0
VEL3 250.0
ENDJ
```

Table A-6. MASTER DATA SET   SITE 3001   UNALAKLEET RIVER

```
IOC       0000100100001010000000
NMAX            0.08
QARD 500.0
QARD 600.0
QARD 700.0
QARD 800.0
QARD 900.0
QARD  1000
QARD  1100
QARD  1200
QARD  1300
QARD  1400
QARD  1500
QARD  1600
QARD  1700
QARD  1800
QARD  1900
QARD  2000
QARD  2100
QARD  2200
QARD  2300
QARD  2400
QARD  2500
XSEC   0.0       0.0 .50     87.50    .00300
       0.0  0.0 98.1  6.0 94.2 35.0 94.2 53.0 95.5 70.7 94.2 85.0 92.7
       0.0 97.3 92.5110.0 91.8120.0 90.8128.0 90.7135.0 90.6142.0 90.1
       0.0147.0 89.5151.0 88.8155.0 88.0159.0 87.6163.0 87.5168.0 87.5
       0.0172.5 89.0179.0 94.2183.5 99.7
NS     0.0                                                       30.75
NS     0.0     23.50     23.25     23.25     23.25     23.25     30.25
NS     0.0     30.25     30.25     30.25     30.25     30.25     30.25
NS     0.0     10.00
WSL    0.0     91.33     91.98     92.40     92.72     92.98     93.19
WSL    0.0     93.38     93.55     93.70     93.84     93.97     94.09
WSL    0.0     94.21     94.32     94.41     94.51     94.59     94.67
WSL    0.0     94.75     94.82     94.90     94.96     95.03     95.09
WSL    0.0     95.15
CAL1   0.0     94.20   1290.00
VEL1   0.0                          .10  .20 2.30 3.30 3.80 4.10 4.60
VEL1   0.0 5.10 5.10 5.30 4.90 4.80 3.40 1.50
CAL2   0.0     93.50    750.00
VEL2   0.0
VEL2   0.0
CAL3   0.0     93.60    850.00
VEL3   0.0
VEL3   0.0
XSEC  84.0      84.0 .50     87.50    .00300
      84.0  0.0 96.4132.5 94.4142.5 94.1152.5 94.0162.5 93.5172.5 92.8
      84.0182.5 92.3191.5 91.8200.5 91.4204.5 91.2208.5 91.0212.5 90.8
      84.0216.5 90.5220.5 90.4224.5 90.3228.5 90.3232.5 90.2236.5 89.7
      84.0241.5 89.6246.5 89.3251.0 90.9257.5 94.4257.5 98.8
NS    84.0                         32.50     32.50     32.50     32.50
NS    84.0     32.50     32.50     30.00     30.00     30.00     30.00
NS    84.0     30.00     30.00     30.00     30.00     30.00     30.00
NS    84.0     30.00     30.00     20.75
WSL   84.0     91.43     92.07     92.49     92.82     93.08     93.30
WSL   84.0     93.49     93.67     93.83     93.97     94.11     94.23
WSL   84.0     94.36     94.47     94.57     94.67     94.76     94.84
WSL   84.0     94.93     95.01     95.09     95.16     95.23     95.30
WSL   84.0     95.36
CAL1  84.0     94.40   1290.00
VEL1  84.0               .30  .90 1.40 2.50 2.70 4.70 5.30 5.50 5.50 5.80
```

Table A-6 (Cont'd)

```
VEL1  84.0 5.90 6.10 5.80 5.50 5.20 5.10 3.70 3.40 1.20
CAL2  84.0     93.52    750.00
VEL2  84.0
VEL2  84.0
CAL3  84.0     93.61    850.00
VEL3  84.0
VEL3  84.0
XSEC 281.0     197.0 .50     87.50    .00300
     281.0  0.0 97.8 16.5 95.1 30.0 94.4 40.0 94.1 50.0 93.3 60.0 93.1
     281.0 65.0 93.0 70.0 92.9 75.0 92.8 80.0 91.8 85.0 92.3 90.0 92.1
     281.0 95.0 92.0100.0 91.9105.0 91.9110.0 91.7115.0 91.6120.0 91.6
     281.0125.0 91.5130.0 91.8137.0 92.3145.0 93.2158.0 93.1168.0 92.8
     281.0175.0 92.1182.0 92.5188.8 95.1195.5 99.6
NS   281.0                         45.50     34.25     34.25     34.25
NS   281.0     34.25     34.25     34.25     34.25     34.25     34.25
NS   281.0     34.25     34.25     34.25     34.25     34.25     34.25
NS   281.0     34.25     34.25     34.25     34.25     34.25     23.25
NS   281.0     23.25     23.25
WSL  281.0     92.65     93.05     93.35     93.61     93.84     94.05
WSL  281.0     94.23     94.41     94.57     94.73     94.87     95.02
WSL  281.0     95.15     95.27     95.40     95.51     95.62     95.72
WSL  281.0     95.82     95.91     96.01     96.09     96.18     96.27
WSL  281.0     96.34
CAL1 281.0     95.10   1290.00
VEL1 281.0           1.50 3.50 4.00 3.40 3.70 4.70 4.80 4.60 4.80 4.60
VEL1 281.0 4.80 4.40 4.80 5.30 5.00 5.40 5.40 5.00 4.80 3.00 2.60 1.50
VEL1 281.0 1.20  .80
CAL2 281.0     94.39    750.00
VEL2 281.0
VEL2 281.0
VEL2 281.0
CAL3 281.0     94.47    850.00
VEL3 281.0
VEL3 281.0
VEL3 281.0
ENDJ
```

Table A-7. MASTER DATA SET   SITE 4001   UNALAKLEET RIVER

```
IOC       1000100100001
QARD 300.0
QARD 400.0
QARD 500.0
QARD 600.0
QARD 700.0
QARD 800.0
QARD 900.0
XSEC   0.0       0.0 .50     96.20    .00600
       0.0  0.099.74   .497.98  5.0 96.7 10.0 95.8 15.0 96.9 27.0 97.8
       0.0 43.097.98 46.0 97.4 56.0 97.1 66.0 97.1 76.0 96.7 86.0 96.5
       0.0 96.0 96.2106.0 96.5116.0 96.8128.097.98231.0100.3
NS     0.0                         10.00     10.00     10.00     10.00
NS     0.0     10.00     23.10     64.10     64.10     64.10     64.10
NS     0.0     64.10     64.10     64.10
WSL    0.0     97.30     97.60     97.83     97.98     98.05     98.20
WSL    0.0     98.34     98.47     98.59     98.70     98.80
CAL1   0.0     97.98    360.00
VEL1   0.0           0.00 0.00 0.00 0.00 0.00 3.20 3.10 4.10 4.40 4.40
VEL1   0.0 4.10 4.20 3.20
XSEC  54.0      54.0 .50     96.20    .00600
      54.0  0.099.96  3.598.57  5.5 98.1  7.598.57 25.098.95 55.098.57
      54.0 65.0 98.2 75.0 98.1 83.0 96.0 91.0 95.5 99.0 95.3107.0 95.4
      54.0115.0 95.2123.0 96.4128.098.57228.099.96
NS    54.00.070     0.070     0.07020.000.06030.000.06030.00     30.00
NS    54.0     30.00     64.00     64.10     64.10     64.10     64.10
NS    54.00.06064.100.06064.100.070          0.070
WSL   54.0     96.93     97.57     98.15     98.57     99.06     99.28
WSL   54.0     99.46     99.62     99.77     99.90    100.01
CAL1  54.0     98.57    360.00
VEL1  54.0           0.00                1.00 1.30 1.90 2.00 2.60 2.50
VEL1  54.0 2.50 1.50
XSEC 120.0      66.0 .50     96.20    .00600
     120.0  0.099.71 52.598.66 63.0 98.2 73.0 97.3 83.0 96.9 93.0 96.9
     120.0103.0 95.4113.0 95.4123.0 95.4133.0 95.3143.0 96.7150.099.71
NS   120.0                         10.10     60.80     43.50     54.10
NS   120.0     54.10     54.10     54.10     54.10     54.10
WSL  120.0     97.26     97.89     98.39     98.66     98.88     99.30
WSL  120.0     99.62     99.84    100.02    100.20    100.36
CAL1 120.0     98.66    360.00
VEL1 120.0             .10  .50  .80 2.00 2.00 2.20 2.40 2.50 1.50
ENDJ
```

Table A-8. MASTER DATA SET SITE 4002 UNALAKLEET RIVER

```
IOC        100010010000101000
NMAX       0.070
QARD 300.0
QARD 400.0
QARD 500.0
QARD 600.0
QARD 700.0
QARD 800.0
QARD 900.0
XSEC   0.0        0.0 .50     96.30     .00370
       0.0  1.0101.6  4.798.58 13.0 96.6 21.0 96.3 29.0 96.5 37.0 96.5
       0.0 45.0 97.4 53.0 98.2 61.098.58 75.0 99.3 93.098.58102.097.22
       0.0105.098.58107.0101.7
NS     0.0      10.00      10.00      53.10      53.10      53.10      53.10
NS     0.0      43.10      43.10      43.10      43.10      43.10      10.00
NS     0.0      10.00      10.00
WSL    0.0      97.63      98.12      98.49      98.58      98.79      99.04
WSL    0.0      99.24      99.39      99.51      99.63      99.74
CAL1   0.0      98.58     330.00
VEL1   0.0            2.20 5.00 5.40 4.70 2.90 1.80
VEL1   0.0
XSEC  72.0       72.0 .50     96.30     .00370
      72.0  0.0101.5  5.098.91  8.0 96.0 13.0 95.5 21.0 96.1 29.0 96.3
      72.0 37.0 96.9 45.0 97.7 53.0 98.2 60.098.91 92.0100.5113.099.29
      72.0120.0 97.0128.0101.4
NS    72.0      10.00      10.00      53.10      53.10      53.10      53.10
NS    72.0      53.10      43.10      43.10      43.10      43.10      43.10
NS    72.0      10.00      10.00
WSL   72.0      97.66      98.34      98.79      98.91      99.19      99.57
WSL   72.0      99.88     100.13     100.35     100.53     100.67
CAL1  72.0      98.91     330.00
VEL1  72.0            2.30 4.20 3.40 3.10 2.40 1.90 1.20
VEL1  72.0
XSEC 273.0      201.0 .50     96.30     .00370
     273.0 12.0100.6 12.0 99.6 15.099.75 20.0 97.2 28.0 97.5 36.0 98.1
     273.0 44.0 98.3 52.0 98.8 62.0 98.9 72.0 98.9 82.0 99.1 91.0 99.6
     273.0106.5100.7115.0 99.6117.0 99.4120.0 98.1120.0102.7
NS   273.0                            50.00      50.00      54.10      54.10
NS   273.0      54.10      54.10      54.10      54.10      54.10      54.10
NS   273.0      54.10      54.10      10.00      10.00
WSL  273.0      98.93      99.30      99.54      99.60      99.75      99.91
WSL  273.0     100.06     100.20     100.33     100.45     100.56
CAL1 273.0      99.60     330.00
VEL1 273.0            4.80 5.60 3.40 4.10 3.80 3.20 3.70 2.10 1.70
VEL1 273.0
ENDJ
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Appendix B

Appendix B

Table B-1. Velocity Adjustment Factors for the Unalakleet River, Segement 1.

SITE 1001			SITE 1002			SITE 1003		
XSEC	DISCHRG (cfs)	VAF	XSEC	DISCHRG (cfs)	VAF	XSEC	DISCHRG (cfs)	VAF
0	1000	0.987	0	1000	0.784	0	1000	0.985
0	1100	0.991	0	1100	0.804	0	1100	0.984
0	1200	0.997	0	1200	0.818	0	1200	0.988
0	1300	0.999	0	1300	0.833	0	1300	0.989
0	1400	1.002	0	1400	0.849	0	1400	0.991
0	1500	1.003	0	1500	0.861	0	1500	0.996
0	1600	1.006	0	1600	0.876	0	1600	0.998
0	1700	1.006	0	1700	0.887	0	1700	0.998
0	1800	1.006	0	1800	0.897	0	1800	1.001
0	1900	1.007	0	1900	0.909	0	1900	1.002
0	2000	1.007	0	2000	0.919	0	2000	1.005
0	2100	1.006	0	2100	0.927	0	2100	1.008
0	2200	1.007	0	2200	0.939	0	2200	1.009
0	2300	1.004	0	2300	0.949	0	2300	1.009
0	2400	1.003	0	2400	0.957	0	2400	1.012
0	2500	1.002	0	2500	0.965	0	2500	1.014
0	3000	0.993	0	3000	1.000	0	3000	1.023
0	3500	0.983	0	3500	1.032	0	3500	1.025
0	4000	0.972	0	4000	1.062	0	4000	1.032
0	5000	0.948	0	5000	1.119	0	5000	1.044
276	1000	0.809	340	1000	0.955	160	1000	0.986
276	1100	0.845	340	1100	0.969	160	1100	1.009
276	1200	0.880	340	1200	0.978	160	1200	1.031
276	1300	0.907	340	1300	0.987	160	1300	1.048
276	1400	0.938	340	1400	0.998	160	1400	1.062
276	1500	0.961	340	1500	1.006	160	1500	1.077
276	1600	0.989	340	1600	1.016	160	1600	1.085
276	1700	1.011	340	1700	1.024	160	1700	1.094
276	1800	1.030	340	1800	1.029	160	1800	1.106
276	1900	1.050	340	1900	1.037	160	1900	1.111
276	2000	1.069	340	2000	1.043	160	2000	1.118
276	2100	1.081	340	2100	1.048	160	2100	1.128
276	2200	1.100	340	2200	1.057	160	2200	1.132
276	2300	1.113	340	2300	1.064	160	2300	1.136
276	2400	1.129	340	2400	1.069	160	2400	1.142
276	2500	1.138	340	2500	1.073	160	2500	1.147
276	3000	1.193	340	3000	1.094	160	3000	1.172
276	3500	1.228	340	3500	1.115	160	3500	1.184
276	4000	1.263	340	4000	1.130	160	4000	1.200
276	5000	1.311	340	5000	1.171	160	5000	1.225
781	1000	0.803	806	1000	0.713	378	1000	0.892
781	1100	0.831	806	1100	0.739	378	1100	0.925
781	1200	0.860	806	1200	0.761	378	1200	0.956
781	1300	0.879	806	1300	0.779	378	1300	0.978
781	1400	0.900	806	1400	0.800	378	1400	0.996
781	1500	0.913	806	1500	0.819	378	1500	1.011
781	1600	0.934	806	1600	0.838	378	1600	1.022
781	1700	0.947	806	1700	0.855	378	1700	1.026
781	1800	0.958	806	1800	0.870	378	1800	1.037
781	1900	0.972	806	1900	0.887	378	1900	1.040
781	2000	0.979	806	2000	0.901	378	2000	1.046
781	2100	0.990	806	2100	0.914	378	2100	1.046
781	2200	0.999	806	2200	0.930	378	2200	1.049
781	2300	1.002	806	2300	0.944	378	2300	1.047
781	2400	1.009	806	2400	0.956	378	2400	1.048
781	2500	1.020	806	2500	0.968	378	2500	1.048
781	3000	1.043	806	3000	1.020	378	3000	1.051
781	3500	1.058	806	3500	1.063	378	3500	1.044
781	4000	1.070	806	4000	1.105	378	4000	1.044
781	5000	1.087	806	5000	1.183	378	5000	1.043

Table B-2. Velocity Adjustment Factors for the Unalakleet River, Segments 2 and 3

SITE 2001

XSEC	DISCHRG (cfs)	VAF
0	1000	0.794
0	1100	0.828
0	1200	0.857
0	1300	0.886
0	1400	0.911
0	1500	0.940
0	1600	0.967
0	1700	0.991
0	1800	1.007
0	1900	1.026
0	2000	1.047
0	2100	1.071
0	2200	1.088
0	2300	1.108
0	2400	1.126
0	2500	1.148
0	3000	1.233
0	3500	1.313
88	1000	0.729
88	1100	0.754
88	1200	0.777
88	1300	0.801
88	1400	0.821
88	1500	0.842
88	1600	0.864
88	1700	0.884
88	1800	0.893
88	1900	0.908
88	2000	0.926
88	2100	0.942
88	2200	0.956
88	2300	0.973
88	2400	0.984
88	2500	1.003
88	3000	1.067
88	3500	1.127
220	1000	1.117
220	1100	1.117
220	1200	1.110
220	1300	1.099
220	1400	1.093
220	1500	1.100
220	1600	1.104
220	1700	1.097
220	1800	1.087
220	1900	1.084
220	2000	1.086
220	2100	1.086
220	2200	1.084
220	2300	1.088
220	2400	1.091
220	2500	1.093
220	3000	1.104
220	3500	1.114

SITE 2002

XSEC	DISCHRG (cfs)	VAF
0	1000	0.909
0	1100	0.923
0	1200	0.935
0	1300	0.946
0	1400	0.951
0	1500	0.962
0	1600	0.969
0	1700	0.972
0	1800	0.978
0	1900	0.982
0	2000	0.988
0	2100	0.993
0	2200	0.995
0	2300	0.995
0	2400	1.000
0	2500	1.003
0	3000	1.026
0	3500	1.039
81	1000	1.041
81	1100	1.012
81	1200	0.997
81	1300	0.982
81	1400	0.966
81	1500	0.961
81	1600	0.961
81	1700	0.953
81	1800	0.950
81	1900	0.952
81	2000	0.952
81	2100	0.956
81	2200	0.953
81	2300	0.954
81	2400	0.955
81	2500	0.960
81	3000	0.977
81	3500	0.992
250	1000	0.801
250	1100	0.816
250	1200	0.831
250	1300	0.846
250	1400	0.862
250	1500	0.875
250	1600	0.893
250	1700	0.906
250	1800	0.920
250	1900	0.932
250	2000	0.951
250	2100	0.964
250	2200	0.974
250	2300	0.987
250	2400	0.999
250	2500	1.010
250	3000	1.073
250	3500	1.125

SITE 3001

XSEC	DISCHRG (cfs)	VAF
0	500	0.823
0	600	0.875
0	700	0.916
0	800	0.951
0	900	0.980
0	1000	1.004
0	1100	1.024
0	1200	1.040
0	1300	1.050
0	1400	1.056
0	1500	1.064
0	1600	1.065
0	1700	1.068
0	1800	1.068
0	1900	1.066
0	2000	1.064
0	2100	1.058
0	2200	1.055
0	2300	1.048
0	2400	1.042
0	2500	1.035
84	500	0.839
84	600	0.864
84	700	0.890
84	800	0.909
84	900	0.931
84	1000	0.955
84	1100	0.972
84	1200	0.994
84	1300	1.006
84	1400	1.023
84	1500	1.042
84	1600	1.058
84	1700	1.075
84	1800	1.096
84	1900	1.109
84	2000	1.124
84	2100	1.138
84	2200	1.155
84	2300	1.170
84	2400	1.184
84	2500	1.202
281	500	0.925
281	600	0.898
281	700	0.886
281	800	0.867
281	900	0.856
281	1000	0.842
281	1100	0.837
281	1200	0.824
281	1300	0.819
281	1400	0.817
281	1500	0.809
281	1600	0.809
281	1700	0.807
281	1800	0.809
281	1900	0.809
281	2000	0.813
281	2100	0.811
281	2200	0.817
281	2300	0.817
281	2400	0.817
281	2500	0.824

Table B-3. Velocity Adjustment Factors for the Unalakleet River, Segment 4

SITE 4001			SITE 4002		
XSEC	DISCHRG (cfs)	VAF	XSEC	DISCHRG (cfs)	VAF
0	300	0.719	0	300	0.934
0	400	0.828	0	400	1.017
0	500	0.953	0	500	1.071
0	600	1.056	0	600	1.130
0	700	1.140	0	700	1.164
0	800	1.230	0	800	1.206
0	900	1.171	0	900	1.162
54	300	1.030	72	300	0.962
54	400	1.243	72	400	1.073
54	500	1.452	72	500	1.152
54	600	1.607	72	600	1.214
54	700	1.768	72	700	1.258
54	800	1.902	72	800	1.293
54	900	2.063	72	900	1.321
120	300	0.863	273	300	1.120
120	400	1.023	273	400	1.172
120	500	1.173	273	500	1.186
120	600	1.283	273	600	1.219
120	700	1.368	273	700	1.177
120	800	1.431	273	800	1.141
120	900	1.477	273	900	1.112