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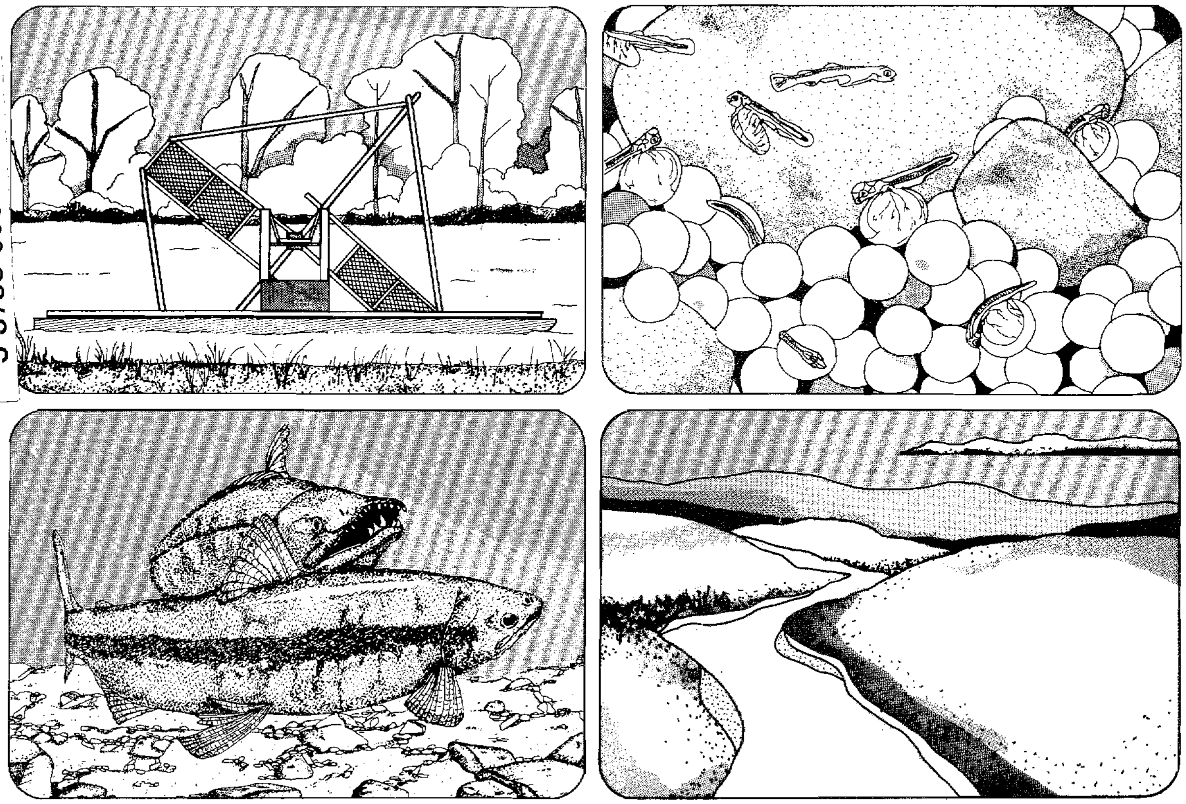

REPORT NO. 3

AQUATIC HABITAT AND INSTREAM FLOW INVESTIGATIONS (MAY-OCTOBER 1983)

Chapter 9: Habitat Suitability Criteria for Chinook, Coho, and Pink Salmon Spawning in Tributaries of the Middle Susitna River

ALASKA DEPARTMENT OF FISH AND GAME

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Chapter 9: Habitat Suitability Criteria for Chinook, Coho, and Pink Salmon Spawning in Tributaries of the Middle Susitna River

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PREFACE

This report is one of a series of reports prepared for the Alaska Power Authority (APA) by the Alaska Department of Fish and Game (ADF&G) to provide information to be used in evaluating the feasibility of the proposed Susitna Hydroelectric Project. The ADF&G Susitna Hydro Aquatic Studies program was initiated in November 1980. The five year study program was divided into three study sections: Adult Anadromous Fish Studies (AA), Resident and Juvenile Anadromous Studies (RJ), and Aquatic Habitat and Instream Flow Studies (AH). Reports prepared by the ADF&G prior to 1983 on this subject are available from the APA.

The information in this report summarizes the findings of the 1983 open water field season investigations. Beginning with the 1983 reports, all reports were sequentially numbered as part of the Alaska Department of Fish and Game Susitna Hydro Aquatic Studies Report Series.

TITLES IN THE 1983 SERIES

Report Number	Title	Publication Date
1	Adult Anadromous Fish Investigations: May - October 1983	April 1984
2	Resident and Juvenile Anadromous Fish Investigations: May - October 1983	July 1984
3	Aquatic Habitat and Instream Flow Investigations: May - October 1983	Sept 1984
4	Access and Transmission Corridor Aquatic Investigations: May - October 1983	Sept 1984

This report, "Aquatic Habitat and Instream Flow Investigations" is divided into two parts. Part I, the "Hydrologic and Water Quality Investigations", is a compilation of the physical and chemical data collected by th ADF&G Su Hydro Aquatic Studies team during 1983. These data are arranged by individual variables and geographic location for ease of access to user agencies. The combined data set represents the available physical habitat of the study area within the Cook Inlet to Oshetna River reach of the Susitna River. Part II, the "Adult Anadromous Fish Habitat Investigations", describes the subset of available habitat compiled in Part I that is utilized by adult anadromous fish studied in the middle and lower Susitna River (Cook Inlet to Devil Canyon) study area. The studies primarily emphasize the utilization of side slough and side channel habitats of the middle reach of the Susitna River for spawning (Figure A). It represents the first stage of development for an instream flow relationships analysis report which will be prepared by E.W. Trihey and Associates.

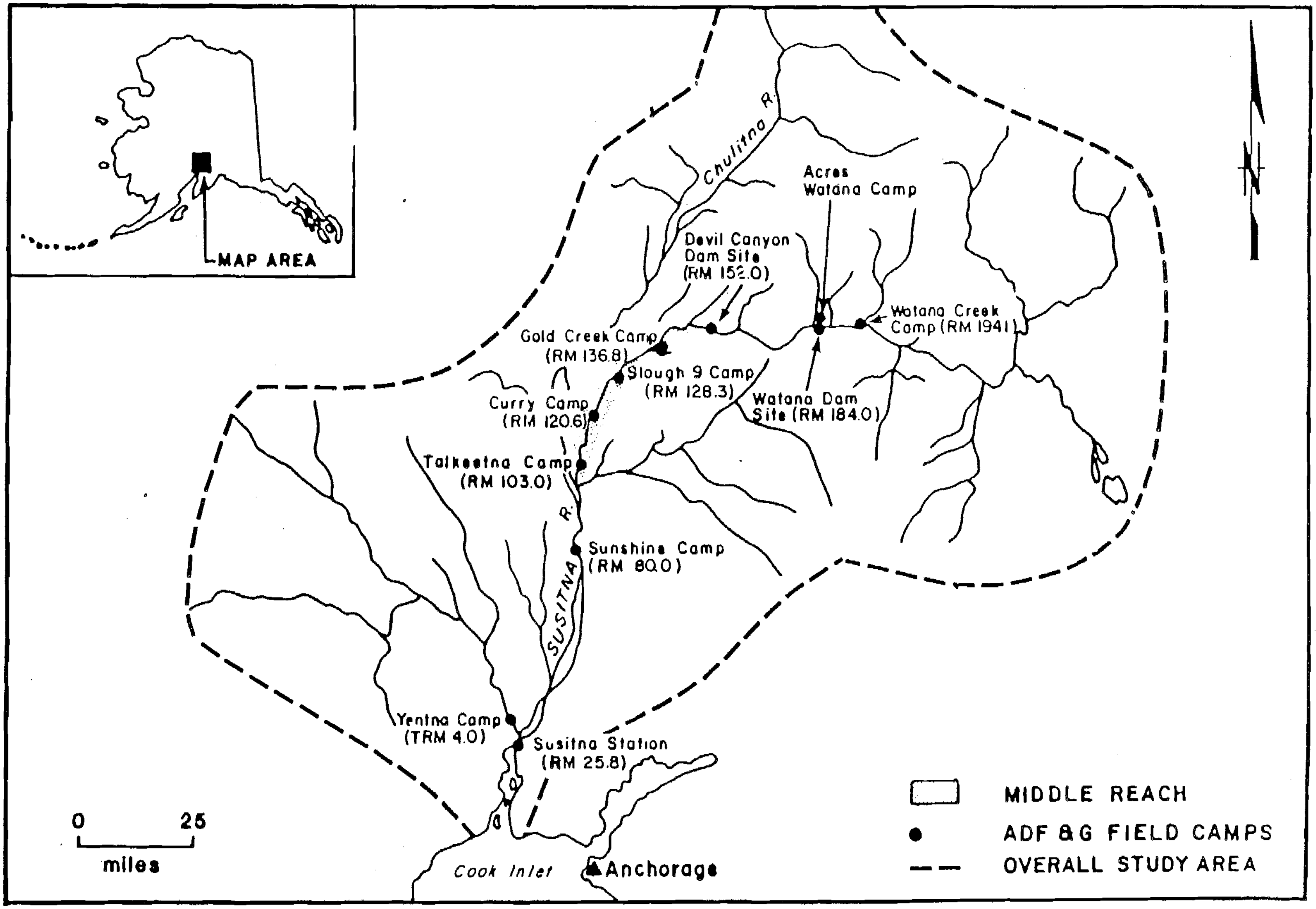

Figure A. Susitna River drainage basin.

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Part One

Part Two

Questions concerning this and prior reports should be directed to:

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HABITAT SUITABILITY CRITERIA FOR CHINOOK, COHO, AND PINK SALMON SPAWNING IN TRIBUTARIES OF THE MIDDLE SUSITNA RIVER

1984 Report No. 3, Chapter 9

By

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ABSTRACT

Utilization data for the habitat variables of depth, velocity, and substrate composition were collected at chinook salmon spawning sites in selected tributaries of the middle reach of the Susitna River. These data were modified using statistical methods and the professional judgments of project biologists familiar with Susitna River chinook salmon stocks to develop suitability criteria for chinook salmon spawning in tributaries of the middle Susitna River. These criteria show that depths ranging from 0.5 to 4.0 ft; mean water column velocities ranging from 0.3 to 4.5 ft/sec; and, substrates ranging from small gravels to cobbles are suitable for chinook salmon spawning in these habitats. Suitability criteria were also developed for coho and pink salmon spawning in tributaries of the middle Susitna River based on literature information as modified using the professional judgments of project biologists familiar with Susitna River coho and pink salmon stocks. These criteria show that depths ranging from 0.3 to 4.0 ft; mean water column velocities ranging from 0.1 to 5.0 ft/sec; and, substrates ranging from sand intermixed with small gravels to large rubbles are suitable for pink salmon spawning in these habitats. The criteria developed for coho salmon spawning in these habitats show the range of depths from 0.3 to 4.0 ft; mean water column velocities from 0.1 to 4.0 ft/sec; and, substrates from sand intermixed with small gravel to large rubbles are suitable for spawning in tributaries of the middle Susitna River. Suggested applications and limitations of these suitability criteria are discussed.

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1.0 INTRODUCTION

This chapter presents a discussion of chinook salmon spawning habitat utilization data collected in tributaries of the middle reach of the Susitna River, the methods used to analyze the data, and the resulting spawning habitat suitability criteria developed from these data. Additionally, a discussion is presented of suitability criteria developed for coho and pink salmon spawning in tributaries based solely on values reported in literature as modified by the professional opinion of ADF&G Su Hydro field biologists (Hoffmann et al. 1984), henceforward referred to as project biologists, familiar with Susitna River coho and pink salmon stocks. These criteria were developed so as to provide a spawning suitability criteria data for these species based on the accumulated field experience of project biologists.

Six major riverine habitat types have been identified in the middle reach of the Susitna River: mainstem, side channel, side slough, upland slough, tributary, and tributary mouth. Of these habitat types, tributary habitats support the majority of the documented chinook, coho, and pink salmon spawning occurring in the middle reach of the Susitna River (Barrett et al. 1984). Tributary habitat, however, is not expected to be affected significantly by the construction and operation of the proposed hydroelectric project. However, it is anticipated that suitable depth, velocity, and substrate conditions presently associated with tributary areas in which chinook, coho, and pink salmon spawn may become available in mainstem or side channel habitats under with - project condition. One means of evaluating such anticipated habitat changes is through habitat simulation modelling. A requirement for such modelling is the development of weighted habitat criteria representing the spawning habitat preferences of chinook, coho, and pink salmon.

Spawning habitat criteria analyses were thus initiated during the 1983 open water period with the objective of collecting sufficient measurements of selected habitat variables (depth, velocity, and substrate) at individual chinook, coho, and pink salmon redd sites (henceforth referred to as utilization data) to determine the behavioral responses of these species to the various levels of these selected habitat variables. To maximize use of available resources, these data were not collected for chum and sockeye salmon spawning in tributaries. The reader is referred to Chapter 7 of this report for a similar analyses conducted for chum and sockeye salmon spawning in sloughs and side channels of the middle reach of the Susitna River.

Low escapement and resource limitations prevented the collection of utilization data for spawning coho and pink salmon. Availability data, that is, the various combinations of the habitat variables which were available to spawners (Reiser and Wesche 1977; Baldrige and Amos 1982) were also not collected. For these reasons, the resultant spawning suitability criteria developed for chinook salmon are based on collected utilization data as modified using statistical analyses and the professional opinion of project biologists, whereas the suitability criteria for coho and pink salmon spawning are based solely on literature data as modified using qualitative field observations.

2.0 METHODS

2.1 Site Selection

Eleven tributaries in the middle reach of the Susitna River (Figure 9-1) were surveyed in their entirety by foot and helicopter to determine the timing and distribution of spawning chinook salmon. Based on these surveys, four of these tributaries (Portage Creek, Indian River, Fourth of July Creek, and Cheechako Creek) were selected for collection of chinook salmon spawning utilization data due to their relatively high utilization (Table 9-1). These four tributaries support greater than 98% of the 1983 chinook salmon spawning (Table 9-2) in the middle reach of the Susitna River the majority of which occurs in Portage and Indian Creeks. These four tributaries also support greater than 97% of the pink salmon spawning and greater than 70% of the coho salmon spawning in tributaries of the middle reach of the Susitna River (Barrett et al. 1983).

In each of the four tributaries selected for field study, specific sites for the collection of utilization data were chosen by flying over the stream in a helicopter to locate areas where high concentrations of fish were present and to identify field conditions conductive to the deployment of field personnel. Timing of peak chinook salmon spawning activity and resultant data collection in these tributaries occurred from July 10 and August 20.

2.2 Field Data Collection

Spawning salmon were located in each study stream by visual observation. Biologists observed fish activities from the stream bank for 10 to 30 minutes prior to entering the water to obtain measurements. An active redd was defined by the fanning of a female at least twice during this period and the presence of a male exhibiting aggressive or quivering behavior. The type of behavior observed for each redd was noted. Detailed descriptions of criteria used to identify active redd locations are presented in Estes et al. (1981) and ADF&G (1983 b).

Water depth and velocity measurements were collected at the upstream end of each active redd using a topsetting wading rod and a Marsh McBirney or Price AA meter using procedures described in ADF&G (1983a). The substrate composition in the depression of each redd was visually evaluated using the size classification scheme presented in Table 9-3.

2.3 Analytical Approach

The primary objective of this portion of the study was the development of weighted habitat criteria representing the habitat preferences of spawning chinook, coho, and pink salmon. Weighted habitat criteria are usually expressed in the form of "habitat curves". These curves describe the weighted usability of different levels of a selected variable for particular species/life phases with the peak indicating the greatest usability and the tails tapering towards less usable values. Curves are developed for each habitat variable believed to influence the selection of habitat for a life phase activity (Bovee 1982).

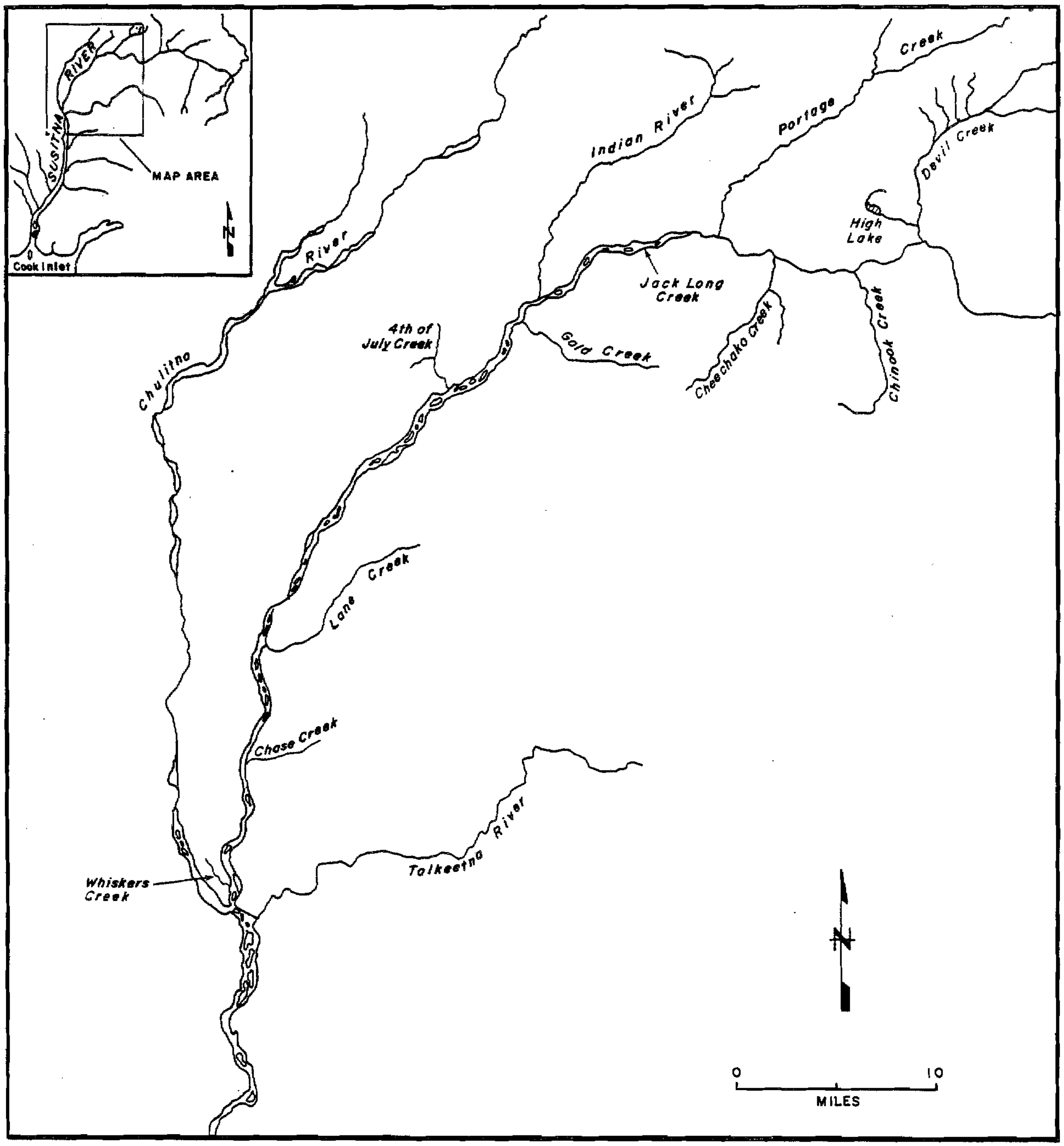


Figure 9-1. Locations of major tributaries surveyed for chinook salmon spawning, 1983.

Table 9-1. Peak chinook salmon counts of major tributaries surveyed for chinook salmon spawning, 1983

TRIBUTARIES SURVEYED BY ADF&G	RIVER MILE	DATE OF SURVEY	PEAK COUNTS[1]
Whiskers Creek	101.4	8/4	3
Chase Creek	106.9	8/1	15
Lane Creek	113.6	8/2	12
Fourth of July Creek	131.0	8/2	6
Gold Creek	136.7	7/24	23
Indian River	138.6	7/25	1,193
Jack Long Creek	144.5	8/1	6
Portage Creek	148.9	7/25	3,140
Chinook Creek	156.8	8/1	8
Cheechako Creek	152.5	8/1	25
Devil Creek	161.0	8/1	1

[1] from Barrett et al. 1984

Table 9-2. Comparison of selected biological and physical characteristics of the four tributaries selected for collection of chinook salmon spawning utilization data.

Tributary	River Mile	Percent[a] Distribution In Tributaries Above RM 99	Period[b] Peak Spawning Activity	Typical Discharge (cfs) During Period of Peak Spawning Activity
Portage	148.9	70.8	7/15-8/15	500-2000
Indian	138.6	26.9	7/15-8/15	100-2000
Fourth of July	131.0	0.1	7/10-8/8	10-50
Cheechako	152.5	0.6	7/20-8/20	---[c]

a From Barrett et al. 1984

b From Chapter 1 of this report

c Discharge has not been measured in this tributary, however, it is estimated to have a discharge approximately equivalent to that of Fourth of July Creek.

Table 9-3. Substrate classification scheme utilized to evaluate substrate composition at spawning redds.

Substrate Category	Size Class
Silt	Very Fine
Sand	Fines
Small Gravel	¼-1"
Large Gravel	1-3"
Rubble	3-5"
Cobble	5-10"
Boulder	greater than 10"

Several types of curves are commonly constructed. Habitat utilization curves typically consist of a plot of values obtained from field observations and represent the range of conditions utilized by the species/life stage without taking into consideration the range and amount of habitat present (Bovee and Cochnauer 1977). Habitat preference curves take into consideration the range and amount of habitat present for the species/life stage to use and weight the utilization information accordingly, as discussed in Reiser and Wesche (1977), Baldrige and Amos (1982), and ADF&G (1983b). Habitat suitability curves are a modification of either a utilization or preference curve based on results from literature or the professional opinion of biologists familiar with species/life phase under study in order to extend the usable range of the curve beyond the range determined based on utilization and/or availability data.

Typically, each of these curves is constructed by plotting standardized scaled criteria index values indicating utilization, preference, or suitability (depending on the curve type being evaluated) on the y-axis versus levels versus the habitat variable to be evaluated on the x-axis. The criteria index is scaled between 0 and 1, with 1 denoting the greatest habitat utilization, preference, or suitability and 0 denoting no utilization, preference, or suitability.

Depending on the available data base, utilization, preference, or suitability criteria indices can be developed. In this report, suitability criteria indices were developed for spawning chinook salmon by using statistical analyses and the professional opinions of project biologists familiar with Susitna River chinook salmon stocks, to modify depth, velocity, and substrate utilization data collected within selected tributaries of the middle reach of the Susitna River. Coho and pink salmon spawning suitability criteria were derived from literature values as modified by the professional judgment of project biologists familiar with middle Susitna River coho and pink salmon stocks.

The first step in the development of suitability criteria indices for chinook salmon spawning involved an evaluation of spawning habitat utilization data plotted as frequency histograms. In this process, the data were standardized by dividing the frequency of observations in each increment of the appropriate habitat variable by the frequency of observations in the increment with the highest occurrence. This standardization achieved a 0 to 1 scaling index for frequency on the y-axis. The resultant scaled frequency histograms represent the utilization "curves" described earlier.

The original scale of the increments used in the frequency analysis corresponded to the measuring accuracy for the particular habitat variable of interest. Accordingly, depth and velocity histograms were initially divided into 0.1 ft and 0.1 ft/sec increments, respectively. The substrate histograms were divided into discrete substrate-class increments (e.g., silt, silt-sand, sand, etc.).

Additional histograms were constructed for the depth and velocity data in order to ensure development of utilization curves which did not exhibit spurious characteristics such as irregular fluctuations or multi-modal structures. Because utilization curves are developed for one species/life stage, it is assumed that there should only be one most utilized increment of a particular habitat variable and that the curves should be relatively smooth (i.e., no irregular fluctuations). As sample size is increased, it is expected that utilization curves developed from increments at the original measuring accuracy will approach the ideal of uni-modal structure and smoothness. Small sample sizes and increments, however, often lead to curves exhibiting multi-modes and irregularly fluctuations. For these reasons, additional scaled frequency histograms were developed for depth and velocity increments of size 0.2 ft and 0.2 ft/sec and 0.3 ft and 0.3 ft/sec.

Several groupings of the data are possible if increment sizes of 0.2 and 0.3 are used, depending on the starting value of the increment. For this reason, a series of six scaled histograms were developed for depth and velocity as summarized in Table 9-4. Incremental plots of substrate are not appropriate because substrate data are not continuous.

Following standardization, the six utilization curves developed from these data groupings were evaluated in order to select a "best" utilization curve based on the following criteria:

1. Minimal sample variance of frequency counts; that is, lower variability among the frequency counts;

2. Minimal coefficient of variation for the frequency counts (i.e., the sample standard deviation divided by the sample mean);

3. Minimal irregular fluctuations, "meaning grouped values should continually increase to the maximum grouped value, then continually decrease" as defined by a series of four indices proposed by Baldrige and Amos (1982); and,

4. Minimal peakedness, meaning a minimal difference between the maximum grouped value (i.e., increment) and the increments immediately below and above the maximum, as defined by a peakedness index described below.

The first three evaluation criteria are the same as those described by Baldrige and Amos (1982). The fourth evaluation criterion is proposed as a method of quantifying a characteristic of the utilization curves which has been evaluated subjectively in previous studies (pers. comm. D. Amos 1984). Subjective evaluation of curves would occur in previous studies if the first three evaluation criteria failed to indicate one "best" curve.

Table 9-4. Summary of histograms used to evaluate depth and velocity utilization data for spawning chinook salmon.

Histogram	Increment Size	Increment Starting Value
1	0.1	0.0
2	0.2	0.0
3	0.2	0.1
4	0.3	0.0
5	0.3	0.1
6	0.3	0.2

The four evaluation criteria were weighted in terms of their application as curve selection tools. The minimal variance and irregular fluctuation evaluation criteria were weighted most strongly, while the coefficient of variation was only used to separate curves which were otherwise indistinguishable. Peakedness was intermediate in importance between the irregular fluctuations and the coefficient of variation evaluation criteria.

The first of the above evaluation criteria (the minimal sample variance of frequency counts) is an adaptation of the chi-square criterion proposed by Bovee and Cochnauer (1977). Sample variance is used in order to allow for comparison of histograms developed with non-count type data, (e.g., the ratio of utilized versus available counts). Although use of the chi-square criterion is possibly more appropriate in the case of the count data used here, the use of the sample variance of counts (or ratios) can be applied in a wider variety of circumstances. In general, this criterion should only be applied when the total number of different increments utilized is reasonably large, probably greater than 5 but at least greater than 2. Basically, if the sample size is so small that very large increments sizes (e.g., 0.5 ft or 0.5 ft/sec in this case) are necessary to reduce irregular fluctuations or avoid multi-modes, then the variance criterion should not be used as it may lend to artificially flat (i.e., heavy-tailed) curves.

The minimal variance criterion was applied in only those instances where the difference between variances were statistically significant. Levene's W test for homogeneity of variance (Brown and Forsythe 1974; Glaser 1983) was executed to evaluate the similarity of the variance of frequency counts between the six scaled frequency histograms. The test is a robust since it does not require that the data be normally distributed. The hypotheses tested were:

H_o: All variances are equal, or

H_a: At least one of the variances is different.

If the null hypothesis were rejected, then individual pairs of variances were compared. The ratio of the larger variance value to the smaller variance value provided an F statistic which could be evaluated for significance using standard F tables (Dixon and Massey 1969). The hypotheses tested were:

H_o: One of the variances is the same as one particular variance of the other five, or

H_a: One of the variances is not the same as one particular variance of the other five,

A series of 15 pairwise comparisons were made between the six histograms. The comparisons between histograms with smaller variance values were those of primary interest (except in cases of violation of the third criteria above; that is, minimal irregular fluctuations).

Evaluation of the third criterion was based on a series of four indices as described in Baldrige and Amos (1982):

1. Number of irregular fluctuations (number of times grouped values decreased prior to the maximum value and increased after the maximum value);

2. Total magnitude of irregular fluctuations:

$$\sum_{i+2}^{M.V.} \text{group}_{(i-1)} - \text{group}_{(i)}{}^{*} \quad +$$

$$\sum_{i\,+\,M.V.+1}^{L.G.} \text{group}_{(i)} - \text{group}_{(i)}{}^{*}$$

where: M.V. = maximum value

L.G. = last group

* = only when this difference is greater than 0

3. Maximum of the individual irregular fluctuations (largest difference computed in number 2 above prior to any summing); and,

4. Average fluctuation (total magnitude of irregular fluctuations divided by the number of irregular fluctuations).

The best curve should have small values for all four indices.

The minimal irregular fluctuation criterion sometimes led to rejection of the minimal variance curve. The evaluation of histograms using this criteria frequently involved professional judgment as to the tradeoffs involved. These tradeoffs generally involved choosing between a non-smooth curve with many increments and a smooth curve with fewer increments (often with a higher variance). A non-smooth curve with many increments was often indicative of a low number of observations (i.e., frequencies).

The peakedness criterion was evaluated using a peakedness index defined as:

$$\text{Index} = \frac{(-F_{(m-1)} + 2(F_{(m)}) - F_{(m+1)})}{(F_{(m-1)} + F_{(m)} + F_{(m+1)})}$$

where:

$F_{(m-1)}$ represents the frequency of the increment immediately below the maximum increment;

$f_{(m)}$ represents the frequency of the maximum increment; and,

$F_{(m+1)}$ represents the frequency of the increment immediately above the maximum increment.

If more than one peak existed, the maximum index value was evaluated. This index has a range of 0, indicating a gradual peak, to 2 indicating a sharp peak. Generally, the lower the index, the better the curve.

The peakedness criterion, as defined above, is an index of difference between the most frequently occurring increment (i.e., with a scaled frequency of 1) and the increments to either side of this increment. As such, it does not necessarily preclude curves which are highly peaked (i.e., with a large degree of kurtosis), but does ensure against artificially high peaks due to an arbitrary choice of the method of grouping. This criterion should be applied only in situations where the width of individual increments is sufficiently small (i.e., when the total number of increments is greater than approximately 5) such that the peak increment would be expected to be surrounded by increments which are of similarly high occurrence. For example, if the increment size were 0.5 ft and the true optimal depth were 0.8 ft, then the increments of 0.0 to 0.4 ft and 1.0 to 1.4 ft would likely have low values as compared to the increment of 0.5 to 0.9 ft.

The peakedness criteria index was established primarily as a means of quantifying (and therefore allowing for repeatability) a subjective criterion which had been previously used to evaluate curves which could not otherwise be distinguished. The criterion of minimal peakedness was only evaluated when the resulting best curve did not seriously violate the minimal irregular fluctuation criteria. Peakedness indices were considered "distinguishable" when they differed by $\pm$ 10% from each other. Specific decisions made during the selection of the best utilization curves are presented more fully in the appropriate results section.

Caution is necessary when applying the above criteria for curve selection. Hypothetically, a curve which is radically different from the original observation curve (for example when the median or mean variable value is altered greatly) might be incorrectly selected as the best curve. Additionally, a curve which is artificially too flat (heavy-tailed) might result if sample sizes are very small. For these reasons, a comparison of the selected "best" utilization curve with the original observations as well as a review by biologists familiar with the species/life stage of interest was made. Specifically, comparisons of the mean and variance of non-grouped data with the means and variances of the grouped data were made. In no instance of the analysis presented in this chapter was a "best" utilization curve judged to be unrealistic based on these considerations.

The last step used in the development of the chinook salmon spawning suitability criteria indices for depth, velocity, and substrate was to modify the best utilization curves on the basis of professional opinions of project biologists familiar with Susitna River chinook salmon stocks. An analysis of preference could not be made since availability data were not collected.

An assumption applied in the development of the suitability criteria is that the habitat variables evaluated act independently in affecting the selection of spawning areas by chinook salmon. To determine the independence of the habitat variables evaluated, the relationship between utilized depths versus velocities, utilized depths versus substrates, and utilized velocities versus substrates were evaluated. It was not possible to evaluate the relationship of utilized depths, velocities, and substrates to upwelling due to the limited nature of the upwelling data. However, because upwelling criteria were assigned using a binary approach, independence is not necessary.

The independence of habitat variables evaluated were determined by constructing plots of utilized depths versus velocities, utilized depths versus substrates, and utilized velocities versus substrates. The degree of correlation between each of these variables was evaluated by determing the coefficient of linear correlation (r) for each relationship.

Pruitt (1982) suggest that r values which are less than or equal to an absolute value of 0.2 do not cause significant interdependence of habitat variables to effect WUA analysis. Accordingly, the calculated r values were evaluated in terms of the following hypothesis:

$$H_o: \quad r \leq |0.2|$$

$$H_a: \quad r > |0.2|$$

The test statistic evaluated is that suggested by Snedecor and Cochran (1980):

$$Z_d = \frac{|Z_o - Z_h|}{1 - \sqrt{n-3}}$$

where:

Z_d = standard normal deviate

$Z_o = \frac{1}{2} (\ln (1 + r) - \ln (1 - r))$

$Z_h = \frac{1}{2} (\ln (1 + 0.2) - \ln (1 - 0.2))$

$= 0.20273$

n = sample size

The standard normal deviate was then compared to standard statistical tables to determine probability values. Note that only large positive values of the standard normal deviate can lead to rejection of the null hypothesis due to the defining of Z_d as on absolute value.

The analytical approach described above was used to derive depth, velocity, and substrate suitability criteria for chinook salmon spawning in tributaries of the middle Susitna River. As no utilization data were collected for pink and coho salmon spawning, the suitability curves developed for depth, velocity, and substrate for these species were developed from previously published information as modified using opinions of project biologists familiar with the spawning phase of these species in the Susitna River drainage.

3.0 RESULTS

3.1 Chinook Salmon

A total of 265 chinook salmon redds were sampled during 1983 for the habitat variables of depth, velocity, and substrate (Table 9-5). Of this total, the majority of measurements were made in Portage Creek (137) and Indian River (125). Field data are presented in Appendix 9-A. The derivation of suitability criteria from these field data for each of these habitat variables is presented below by habitat variable.

3.1.1 Depth Spawning Suitability Criteria

The first step in the analysis of field data to develop depth suitability criteria for chinook salmon spawning was to evaluate the depth utilization data to select a best depth utilization curve. Depth measurements at 265 chinook salmon redds were grouped into six incremental groupings and plotted as histograms (Figure 9-2). Table 9-6 summarizes the statistics used to select the best utilization curve from the six histograms. The histogram with the statistically minimal variance curve is the histogram labelled A (see Appendix Table 9-B-1). However, histogram A exhibited large indices of irregular fluctuations and therefore was not chosen as the best curve. Histograms B through F were not distinguishable in terms of the minimal variance criteria, however, the minimal irregular fluctuation criterion indicated that histograms C and E were the most likely candidates for selection as the best utilization curve. Of these two histograms, histogram E had the lowest distinguishable peakedness index and was therefore selected as the best depth utilization curve (Figure 9-3). Histogram E also had grouped mean and variance values which compared favorably with the original non-grouped values (see Appendix Table 9-B-2).

The next step in the development of the depth suitability criteria was to modify the best depth utilization curve using the opinions of project biologists familiar with Susitna River chinook salmon stocks. An evaluation of preference could not be made due to the lack of availability data.

Based on the utilization curve, depths up to 0.5 ft were not utilized for spawning and thus were assigned a suitability index of 0.0. Additionally, depths ranging from 1.0 to 1.6 ft appeared to be most often utilized for spawning and were therefore assigned a suitability index of 1.0. Based on utilization patterns depicted in Figure 9-3, a linear relationship between depth and suitability was assumed for depths between 0.5 and 1.0 ft. It is the opinion of project biologists that depth alone (if greater than 1.6 ft) would not likely limit spawning. Consequently, the suitability index of 1.0 ft was extended out to 4.0 ft. A depth of 4.0 ft was chosen as an endpoint as this is the maximum depth commonly encountered in tributary habitats of the middle Susitna River.

The resultant depth suitability curve and criteria for chinook salmon spawning are presented in Figure 9-4.

Table 9-5. Number of measurements made at chinook salmon redds in tributaries of the middle Susitna River, 1983.

TRIBUTARY	DATE	TRM[a]	# REDDS
Portage Creek	7/24	12.4-13.4	9
	7/29	13.0-13.1	8
	7/29	12.5-12.6	7
	7/24	10.9-11.8	4
	7/25	10.4-10.9	14
	7/29	10.2-10.8	24
	7/30	8.0-10.2	25
	7/25	7.4-8.0	4
	7/27	4.6-6.4	18
	7/28	4.0-4.6	1
	7/28	3.4-4.0	23
			TOTAL 137
Indian River	7/27	14.7-16.2	29
	7/28	10.0-14.4	34
	7/29	4.9-7.8	27
	7/28	0.0-2.7	35
			TOTAL 125
Cheechako Creek	8/5	0.0-0.5	2
Fourth of July Creek	8/4	0.2-0.3	1
			GRAND TOTAL 265

[a] TRM = Tributary River Mile

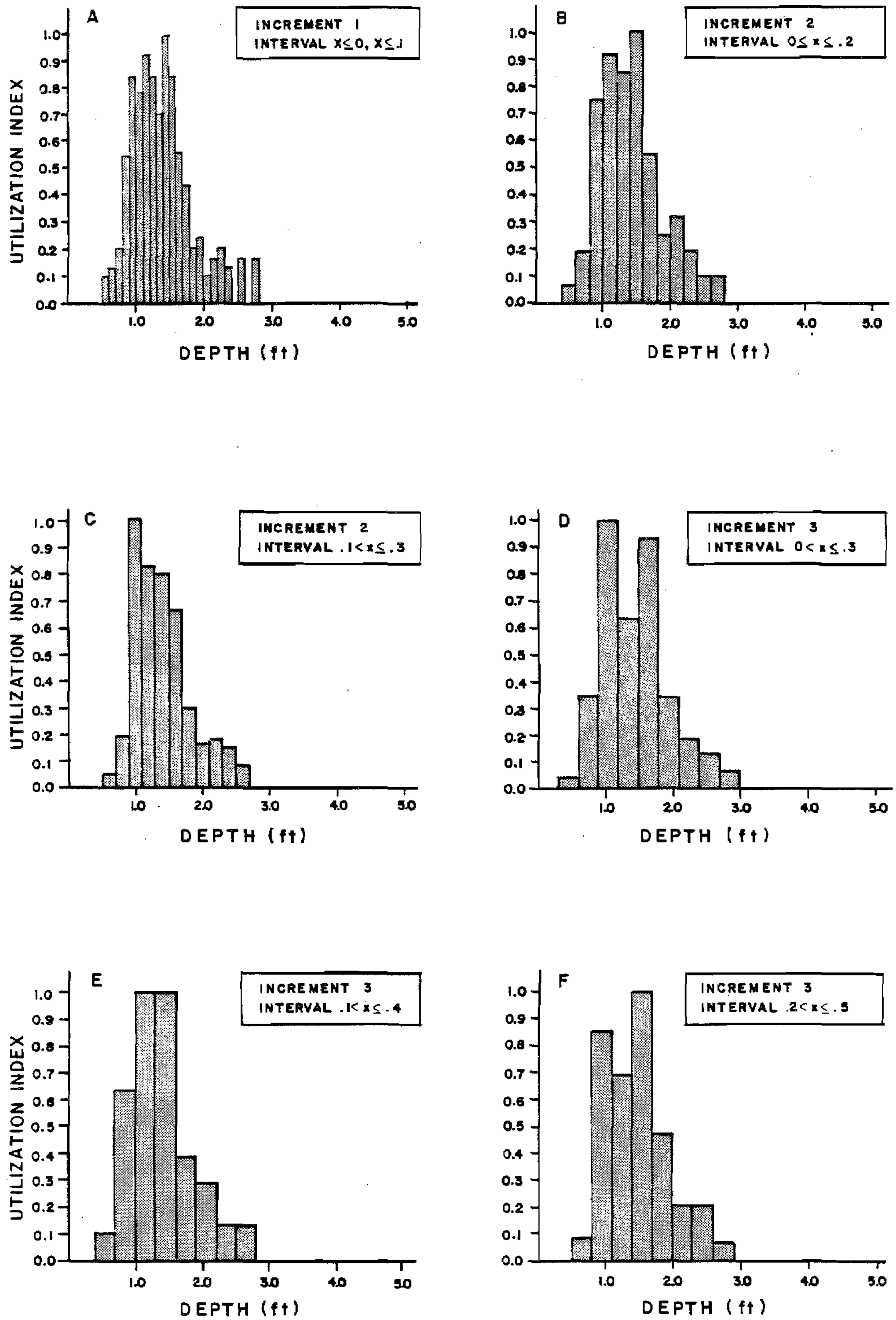


Figure 9-2. Incremental distribution of depths measured at chinook salmon redds.

Table 9-6. Summary of statistics on various incremental groupings for chinook salmon utilization depth histograms.

HISTOGRAM LABEL	A	B	C	D	E	F
INCREMENT SIZE	0.1	0.2	0.2	0.3	0.3	0.3
INCREMENT START	0.0	0.0	0.1	0.0	0.1	0.2
VARIANCE OF FREQUENCY COUNTS	87.5	353.5	440.1	682.0	727.0	632.0
COEFFICIENT OF VARIATION OF FREQUENCY COUNTS	0.81	0.85	0.87	0.89	0.81	0.76
IRREGULAR FLUCTUATIONS						
Magnitude	22	6	1	22	0	11
Number	8	2	1	1	0	1
Mean	2.75	3.00	1.00	22.00	---	11.00
Maximum	5	4	1	22	---	11
PEAKEDNESS	0.17	0.26	0.49	0.52	0.33	0.38

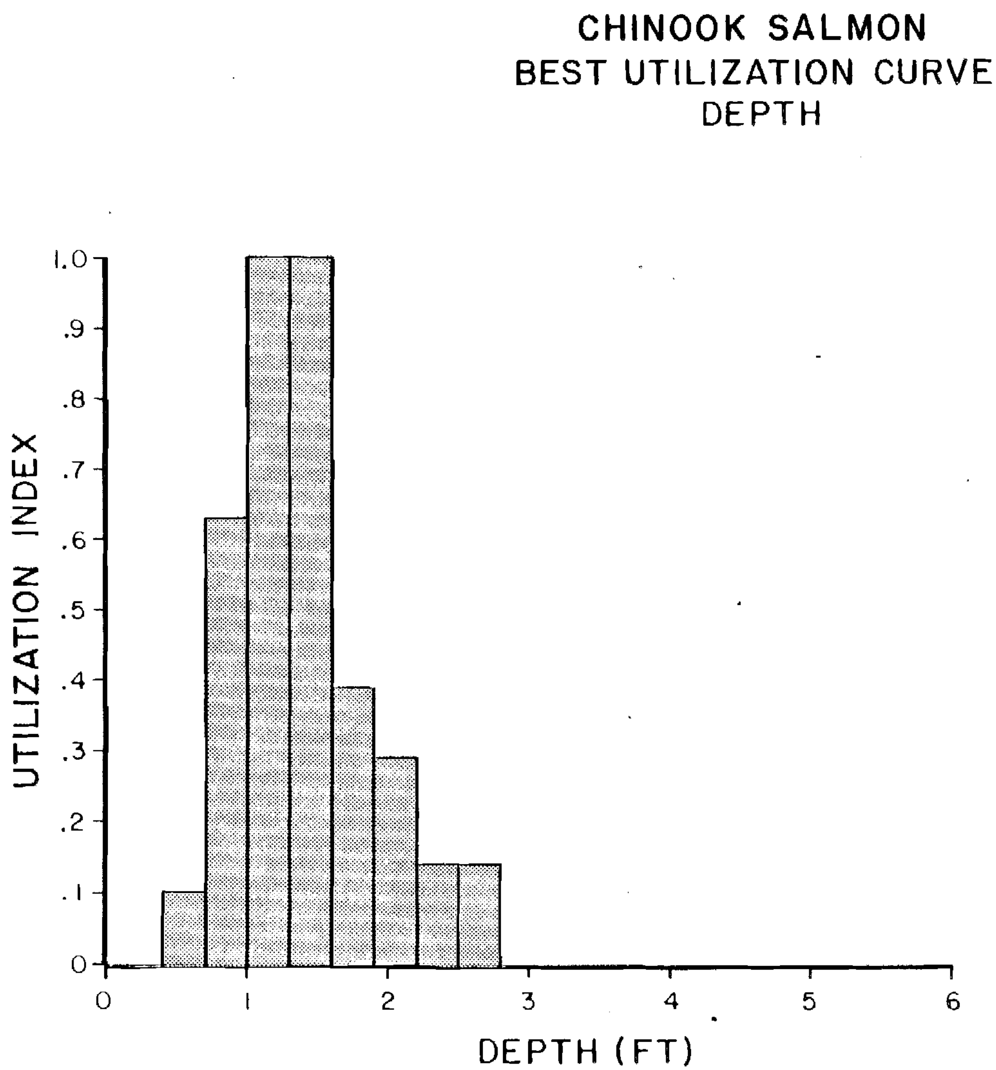
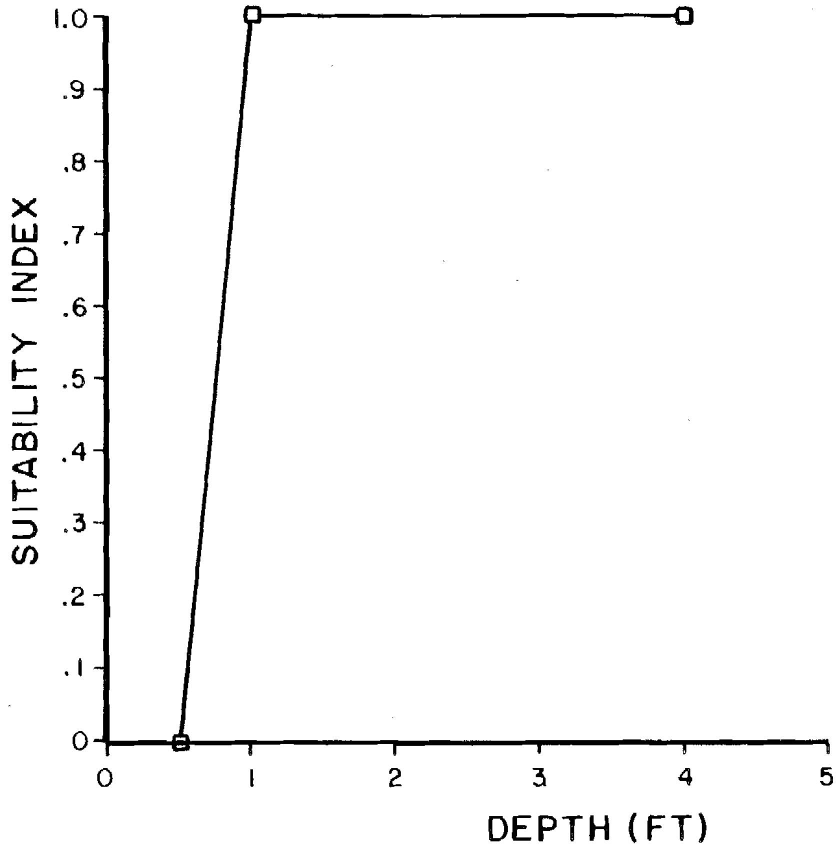


Figure 9-3. Best depth utilization curve for chinook salmon spawning.

CHINOOK SALMON
SUITABILITY CRITERIA CURVE
DEPTH



SUITABILITY CRITERIA

DEPTH	SUITABILITY INDEX
0.5	0.00
1.0	1.00
4.0	1.00

Figure 9-4. Depth suitability curve for chinook salmon spawning.

3.1.2 Velocity Spawning Suitability Criteria

The first step in the analysis of field data to develop of velocity suitability criteria for chinook salmon spawning was to analyze the velocity utilization data to select a best velocity utilization curve. Velocity measurements at 265 chinook salmon redds were grouped into six incremental groupings and plotted as histograms (Figure 9-5). Table 9-7 summarizes the statistics used to select the best utilization curve from the six histograms. The histogram with the statistically minimal variance is the histogram labelled A (see Appendix Table 9-B-3). However, histogram A had large indices of irregular fluctuations, and therefore was not chosen as the best curve. Histograms B and C both had a variances which were statistically less than the variance for histogram E, but were not distinguishable from each other or from histograms D and F. The minimal irregular fluctuation criteria indicated that histograms D and F were the most likely candidates for the best utilization curve. Histogram F had slightly lower values of irregular fluctuation indices. These two histograms were not distinguishable in terms of either peakedness, variance, or coefficient of variation. Accordingly, the slightly lower value for irregular fluctuation led to selection of histogram F as the best utilization curve (Figure 9-6). Histogram F also had grouped mean and variance values which compared favorably with the original non-grouped values (see Appendix Table 9-B-2).

The velocity suitability criteria for chinook salmon spawning were than developed by modifying the best velocity utilization curve using the opinions of project biologists familiar with Susitna River chinook salmon stocks. Preference could not be evaluated due to the lack of availability data.

Velocities ranging from 0.0-0.3 ft/sec were not utilized for spawning and thus were assigned suitability indices of 0.0. Based on the utilization curve, velocities ranging from 1.7 to 2.3 ft/sec were most often utilized for spawning and therefore were assigned suitability indices of 1.0. Suitability indices of 0.25 and 0.60 were assigned to velocities of 0.8 and 2.6 ft/sec, respectively, based on the utilization patterns depicted in Figure 9-6. Velocities greater than 4.5 ft/sec were considered unsuitable for spawning and were therefore assigned a suitability index value of 0.

The resultant velocity suitability curve and criteria for chinook salmon spawning is present in Figure 9-7.

3.1.3 Substrate Spawning Suitability Criteria

The first step in the analysis of field data to develop of substrate suitability criteria for chinook salmon spawning was to analyze the substrate utilization data to construct a plot of utilized substrates (Figure 9-8). Incremental plots of substrate are not appropriate because substrate data are not continuous. Therefore, the utilization data plot was deemed the best substrate utilization curve.

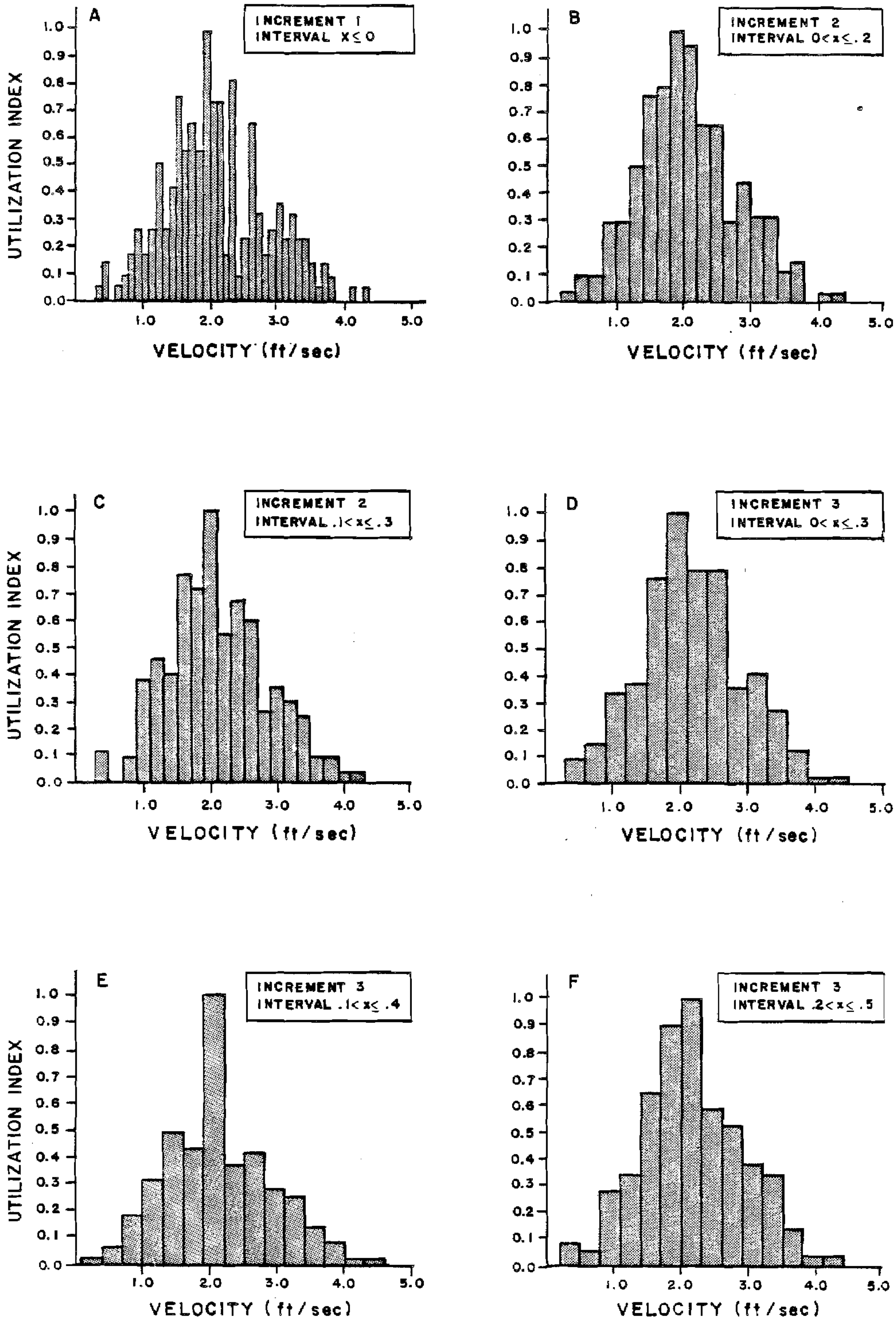


Figure 9-5. Incremental distribution of velocities measured at chinook salmon redds.

Table 9-7. Summary of statistics on various incremental groupings for chinook salmon utilization velocity histograms.

HISTOGRAM LABEL	A	B	C	D	E	F
INCREMENT SIZE	0.1	0.2	0.2	0.3	0.3	0.3
INCREMENT START	0.0	0.0	0.1	0.0	0.1	0.2
VARIANCE OF FREQUENCY COUNTS	33.8	116.3	117.8	224.8	284.2	236.8
COEFFICIENT OF VARIATION OF FREQUENCY COUNTS	0.90	0.85	0.89	0.83	0.95	0.81
IRREGULAR FLUCTUATIONS						
Magnitude	55	7	16	3	7	1
Number	14	3	5	1	2	1
Mean	3.93	2.33	3.20	3.00	3.50	1.00
Maximum	14	5	5	3	4	1
PEAKEDNESS	0.32	0.10	0.34	0.19	0.67	0.20

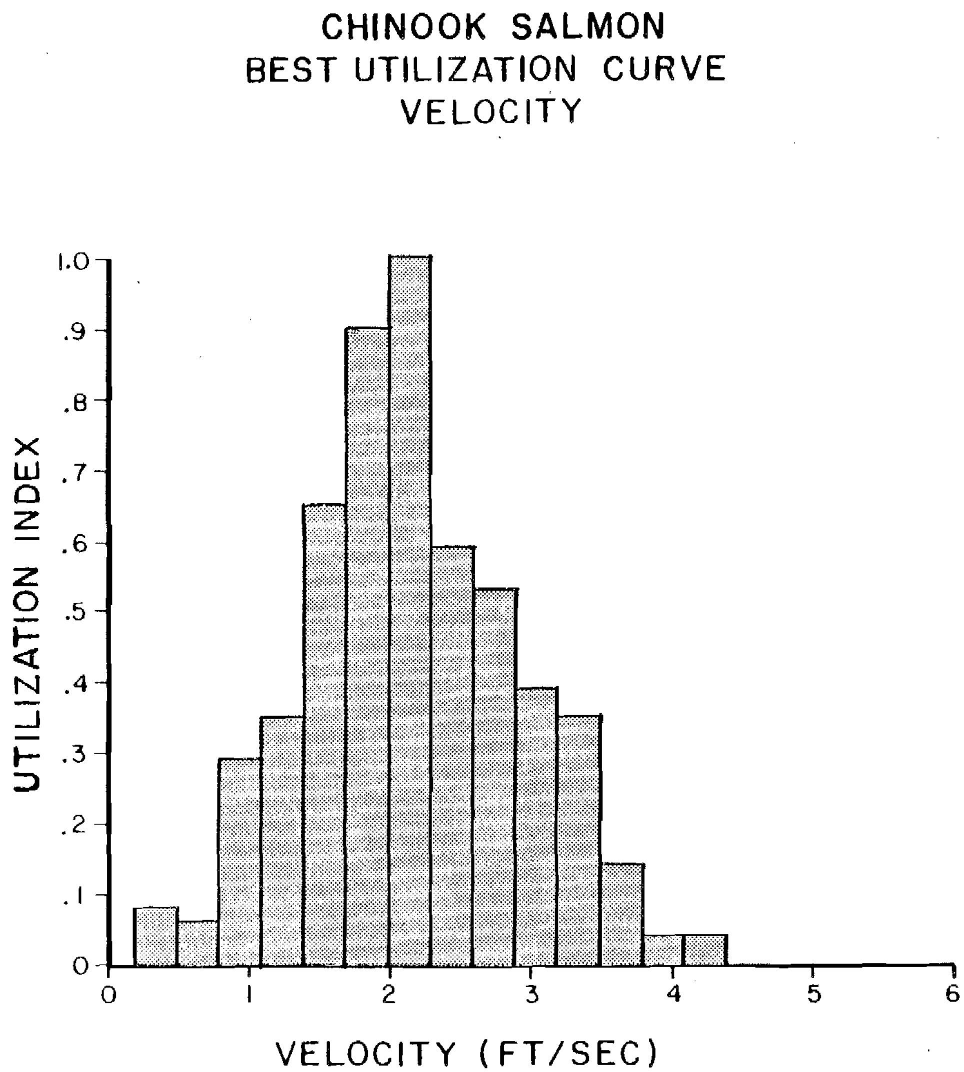
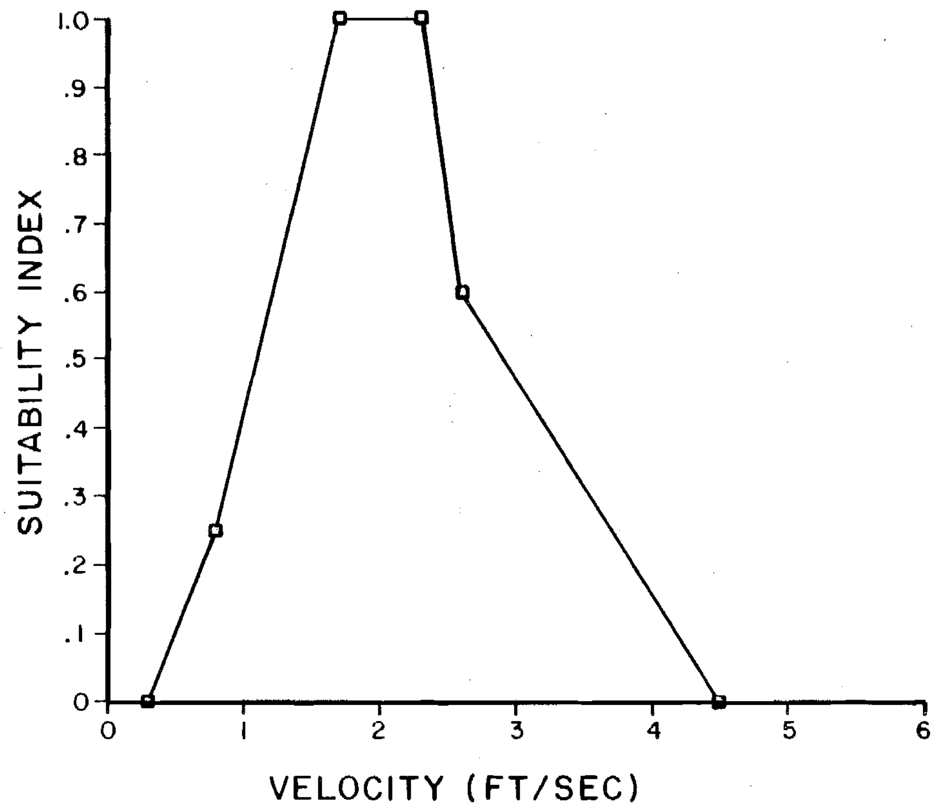


Figure 9-6. Best velocity utilization curve for chinook salmon spawning.

CHINOOK SALMON
SUITABILITY CRITERIA CURVE
VELOCITY

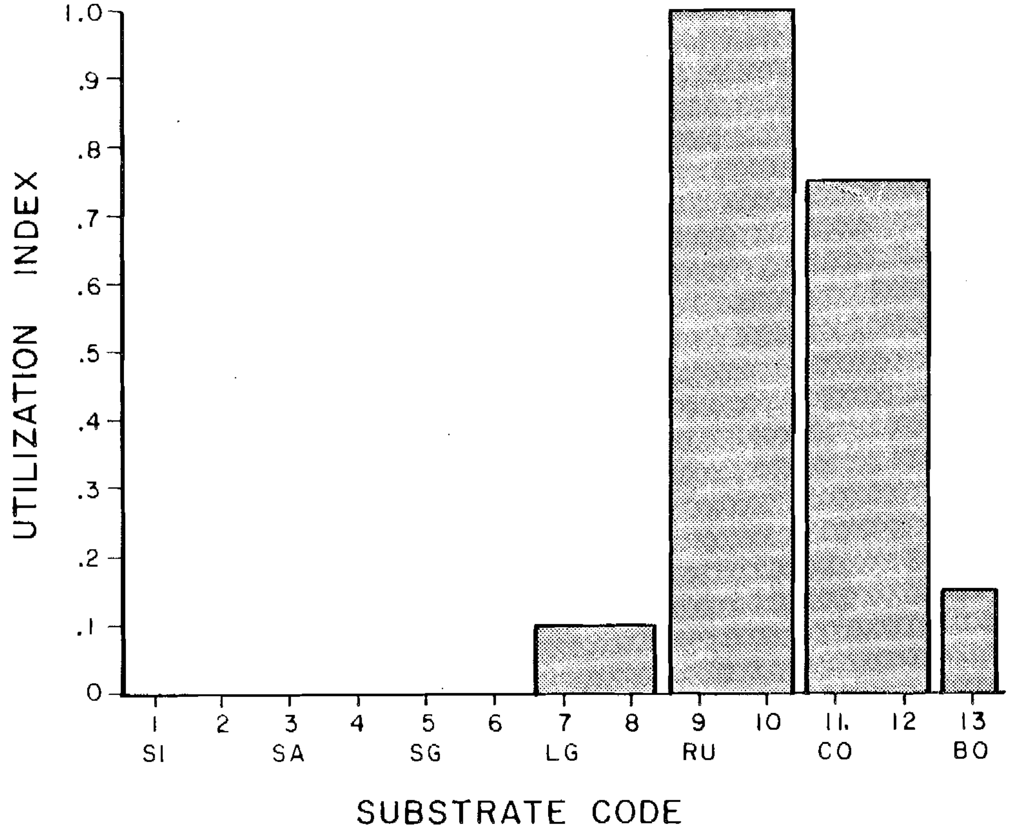


SUITABILITY CRITERIA

VELOCITY	SUITABILITY INDEX
0.3	0.00
0.8	0.25
0.7	1.00
2.3	1.00
2.6	0.60
4.5	0.00

Figure 9-7. Velocity suitability curve for chinook salmon spawning.

CHINOOK SALMON
BEST UTILIZATION CURVE
SUBSTRATE



SUBSTRATE CODE		PARTICLE SIZE
1	SI	SILT
2		
3	SA	SAND
4		
5	SG	1/8 - 1"
6		
7	LG	1 - 3"
8		
9	RU	3 - 5"
10		
11	CO	5 - 10"
12		
13	BO	>10"

Figure 9-8. Substrate utilization curve for chinook salmon spawning.

Substrate utilization data were collected using the substrate size classification scheme presented in Table 9-3. However, to maintain consistency with the substrate suitability criteria developed for chum and sockeye salmon spawning presented in Chapter 7 of this report, a more detailed substrate size classification scheme was used in the derivation of the suitability curve (Table 9-8).

The plot of utilized substrates indicates that substrate classes 9 and 10 (rubbles) appear to be most often utilized for spawning. For this reason, these size classes were assigned a suitability index of 1.0. Based on literature information (Beauchamp et al. 1983; Estes et al. 1981), the suitability index of 1.0 was extended to include substrate class 8 (large gravels/rubbles). Substrate classes 1 through 6 (silt to small gravel substrates) were not utilized; however, literature data (Beauchamp et al. 1983; Estes et al. 1981) indicates that small to large gravel substrates (substrate class 6) may be used by spawning chinook salmon. Therefore, a linear relationship between substrate and suitability was assumed for substrates ranging from small gravel (with a suitability of 0.0) to large gravel/rubble (with a suitability of 1.0).

Cobble and boulder substrates (substrate classes 11, 12, and 13) were also utilized for spawning by chinook salmon, but to a lesser extent that rubble substrates (substrate classes 9 and 10). The apparent utilization of the larger substrate classes was biased toward larger substrates than smaller substrates since field personnel were more likely to record larger substrate sizes than smaller substrate sizes. Furthermore, literature information indicates that cobble and boulder substrates are less preferred than large gravel and rubble substrates by spawning chinook salmon (Beauchamp et al. 1983; Estes et al. 1981). Consequently, substrate class 11 was assigned a suitability index of 0.7 and substrate class 12 a suitability index of 0.35. Substrate class 13 (boulder) was assigned a suitability index of 0.0 after taking into account the probable sampling bias and the opinion of field biologists that substrates consisting solely of boulders would not be suitable for spawning.

The resultant substrate suitability curve and criteria for chinook salmon spawning is presented in Figure 9-9.

3.1.4 Statistical Independence of Habitat Variables Evaluated

Plots depicting the relationship between utilized depths versus velocities, utilized depths versus substrates, and utilized velocities versus substrates for chinook spawning utilization data are depicted in Figure 9-10. Included on each plot are the number of measurements and the coefficient of linear correlation (r) computed for each relationship. Computed r values and their derived statistics indicate that an acceptable level of independence as defined by Pruitt (1980) occurs among these habitat variables (Appendix Table 9-B-4).

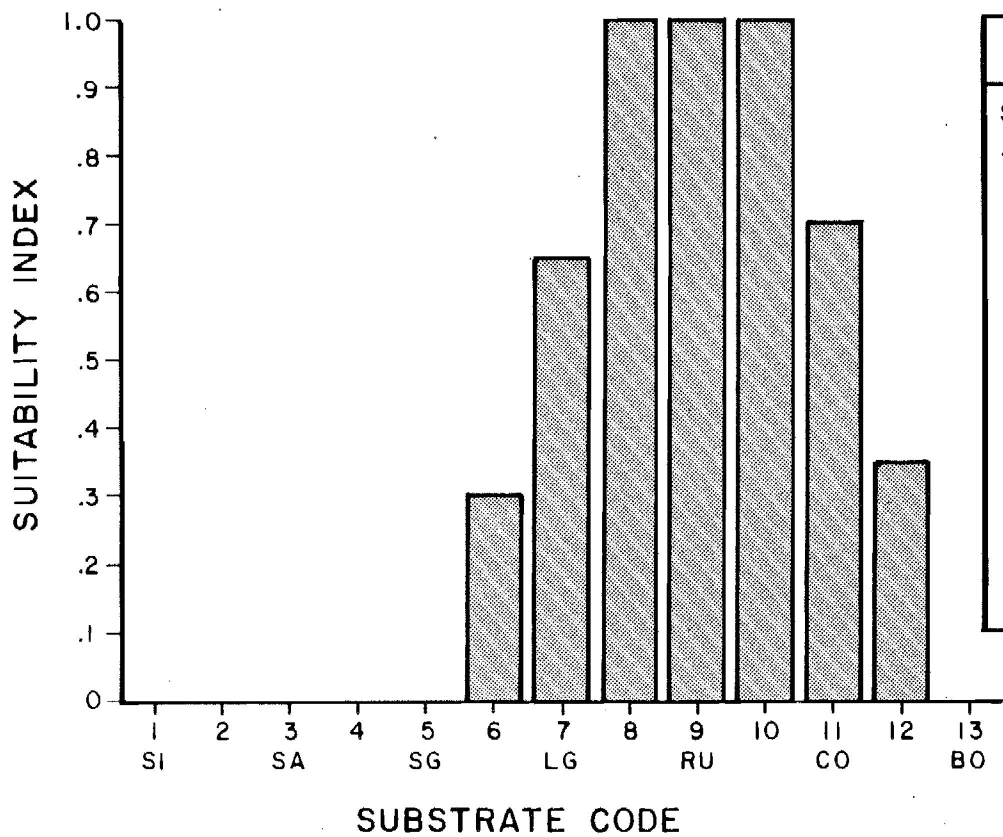
3.2 Pink Salmon

Utilization data have not been collected for pink salmon spawning in tributaries of the middle Susitna River. Therefore, the depth,

Table 9-8. Detailed substrate classification scheme used in the derivation of the substrate suitability criteria.

General Substrate Category	Particle Size	Detailed Substrate Classification
Silt	Silt	1
		2
Sand	Sand	3
		4
Small Gravel	1/4-1"	5
		6
Large Gravel	1-3"	7
		8
Rubble	3-5"	9
		10
Cobble	5-10"	11
		12
Boulder	10"	13

CHINOOK SALMON
SUITABILITY CRITERIA CURVE
SUBSTRATE



SUITABILITY CRITERIA

SUBSTRATE CODE		PARTICLE SIZE	SUITABILITY INDEX
1	SI	SILT	0.00
2			0.00
3	SA	SAND	0.00
4			0.00
5	SG	1/8 - 1"	0.00
6			0.30
7	LG	1 - 3"	0.65
8			1.00
9	RU	3 - 5"	1.00
10			1.00
11	CO	5 - 10"	0.70
12			0.35
13	BO	> 10"	0.00

Figure 9-9. Substrate suitability curve for chinook salmon spawning.

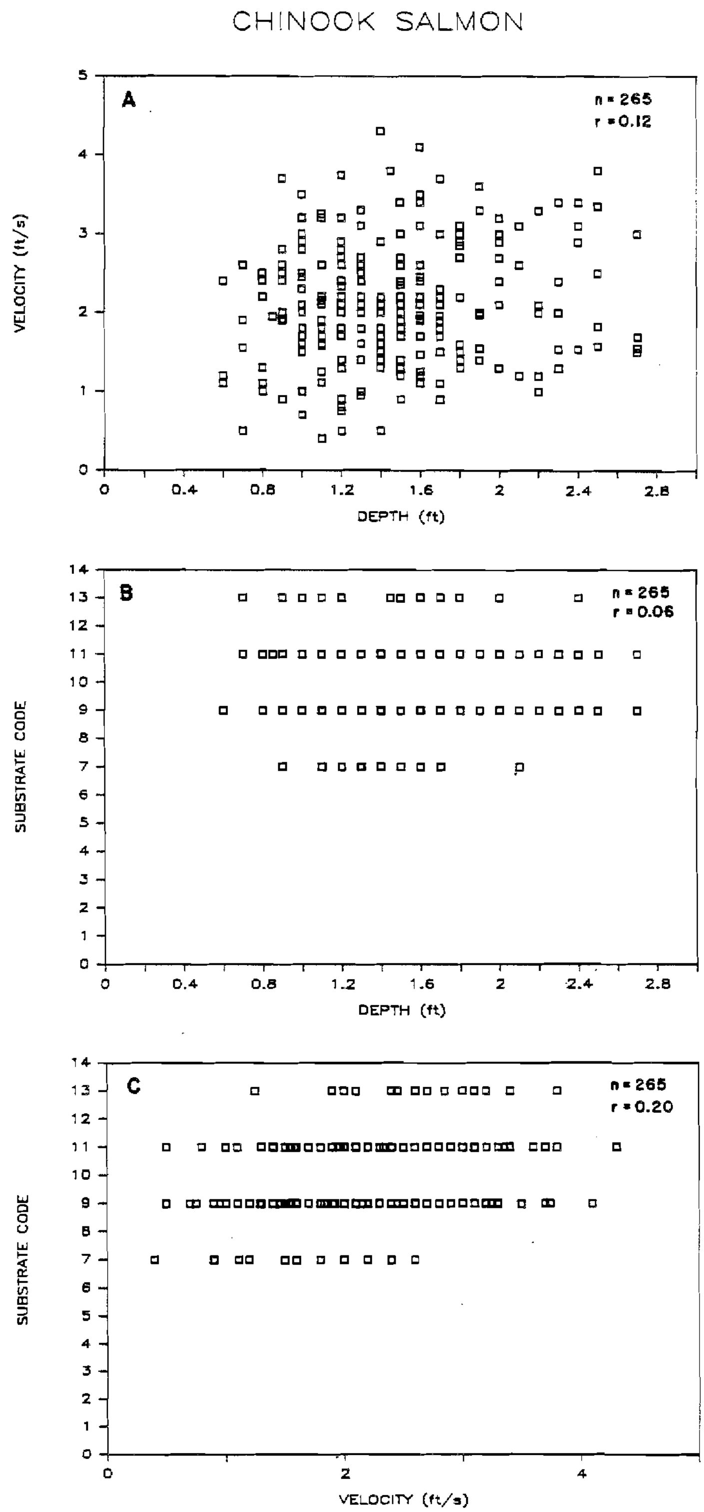


Figure 9-10. Plots depicting the relationships between utilized depths versus velocities (A), utilized depths versus substrates (B), and utilized velocities versus substrates (C) for chinook salmon spawning.

velocity, and substrate suitability curves and criteria developed for this species were based solely on previously published information as modified by the opinions of project biologists familiar with Susitna River pink salmon stocks. Since limited information is available on pink salmon spawning habitat suitability in the Susitna River watershed (Estes et al. 1981), the pink salmon spawning habitat suitability curves developed in the Terror Lake environmental assessment (Wilson et al. 1981) were chosen as the basis for modification.

The Terror River is a clear water stream located on the northeast portion of Kodiak Island in southeastern Alaska. Like many of the clear water tributaries of the Susitna River (Table 9-9), it supports populations of pink and coho salmon spawning. Because the Terror River has hydraulic and physical characteristics similar to many of the larger clear water tributaries of the middle Susitna River, the curves developed for pink salmon depth, velocity, and substrate spawning suitability in this assessment are well suited as a basis for modification in this study.

The depth suitability criteria curve developed for pink salmon spawning approximates the depth suitability curve developed for the Terror Lake system (Figure 9-11), with the exception that the suitability index of 0.0 was extended from 0.1 to 0.3 ft. Furthermore, it is the opinion of project biologists that depths alone (if less than 0.3 ft) would not be suitable for pink salmon spawning. Additionally, the suitability index of 1.0 was extended out to 4.0 feet based on the opinion of field biologists that depth alone, if greater than 2.5 ft (the depth at which suitability in the Terror Lake curves begin to decline) would not likely limit pink salmon spawning in tributaries of the middle Susitna River.

The velocity suitability criteria curve developed for pink salmon spawning generally matches the velocity suitability curve developed for the Terror Lake system (Figure 9-12), with the exception that velocities ranging from 2.0 to 5.0 ft/sec were assigned slightly higher suitability indices. This modification was justified by the opinions of project biologists that these velocities are utilized to a greater degree by spawning pink salmon in tributaries of the middle reach of the Susitna River.

The substrate suitability criteria curve developed for pink salmon spawning in the Terror Lake system was judged representative of substrate suitability for pink salmon spawning in the middle reach of the Susitna River (Figure 9-13).

Table 9-9. Comparison of selected hydraulic and physical characteristics of selected larger clear water tributaries of the middle Susitna River to those of the Terror River (Wilson et al. 1981).

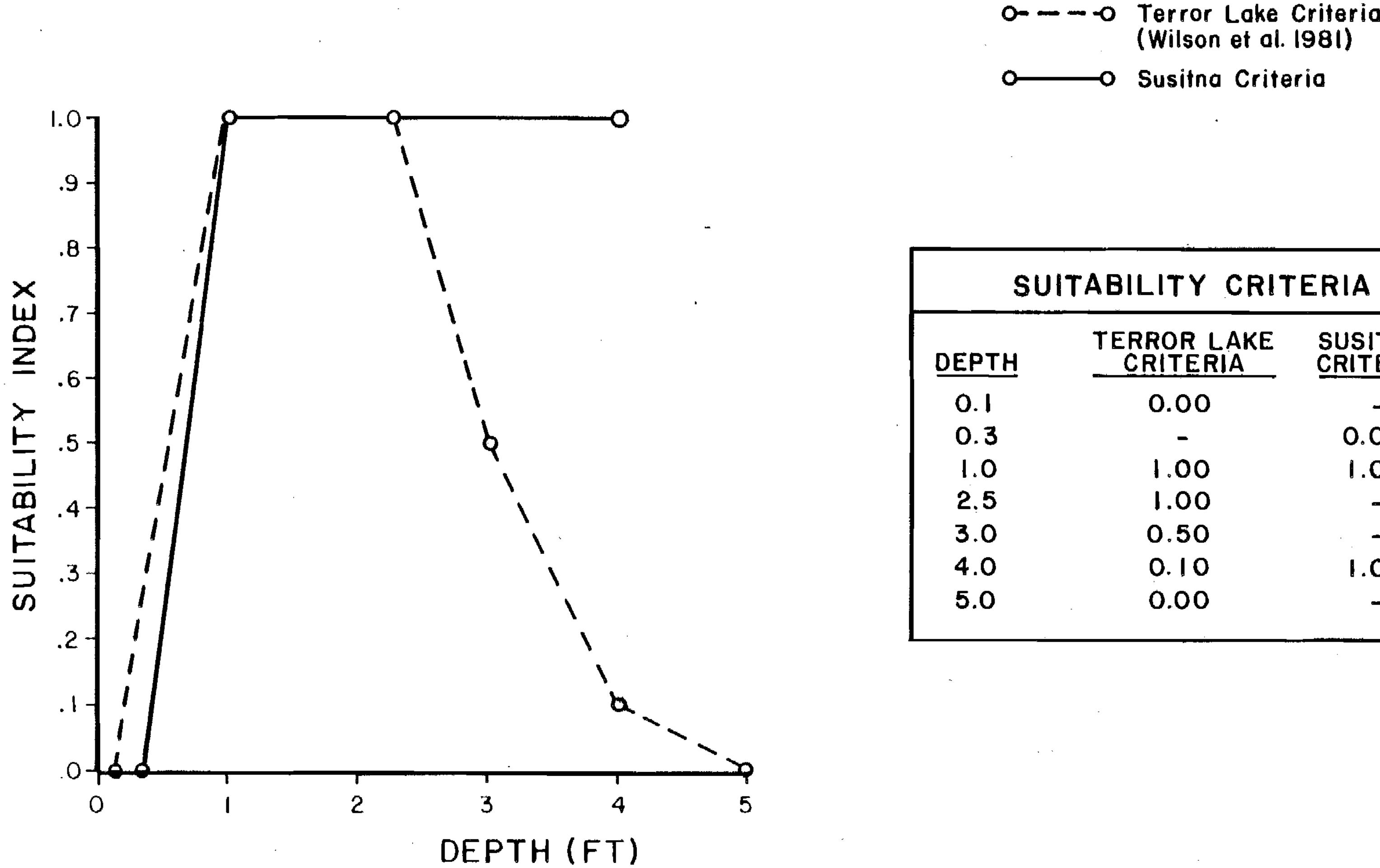
Stream	Typical Discharge (cfs)	Typical Channel structure[a]	Typical Substrate[b]	Typical Water Clarity[c]
Middle Susitna River				
Portage Creek	100-2000	S, R	C, B	clearwater
Indian River	50-2000	S, R	R, C, B	clearwater
Fourth of July Creek	5-50	S, R	R, C, B	clearwater
Lane Creek	5-60	S, T	C, B	clearwater
Whiskers Creek	10-150	S, R	R, C, B	clearwater
Terror River	35-600	S, T	C, B	clearwater

[a] S=Single channel, B=Braided channel, T=Triangular, R=Rectangular

[b] R=Rubble, C=Cobble, B=Boulder

[c] clearwater or turbid glacial

PINK SALMON
SUITABILITY CRITERIA CURVE
DEPTH

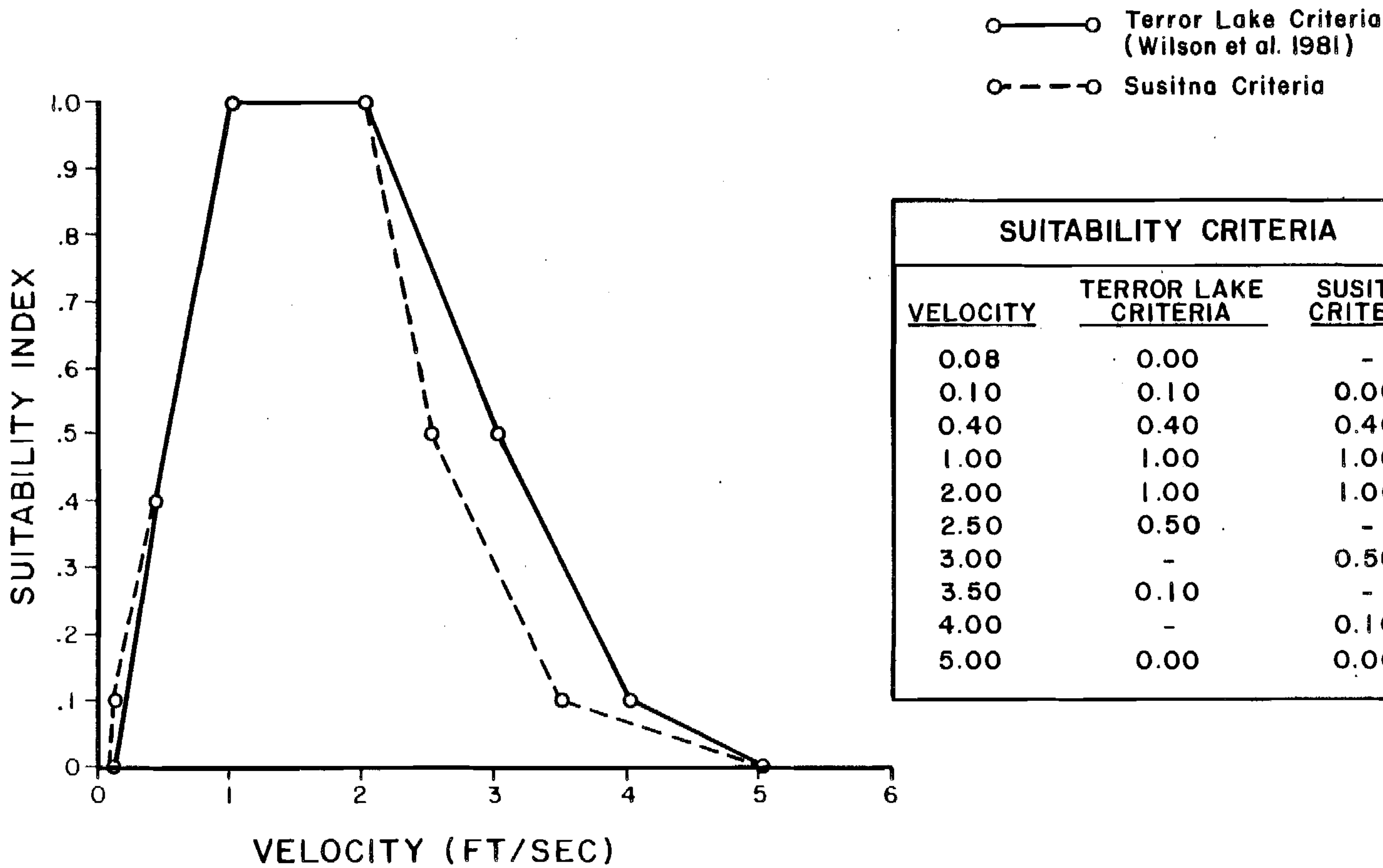


SUITABILITY CRITERIA

DEPTH	TERROR LAKE CRITERIA	SUSITNA CRITERIA
0.1	0.00	-
0.3	-	0.00
1.0	1.00	1.00
2.5	1.00	-
3.0	0.50	-
4.0	0.10	1.00
5.0	0.00	-

Figure 9-11. Depth suitability curve for pink salmon spawning.

PINK SALMON
SUITABILITY CRITERIA CURVE
VELOCITY

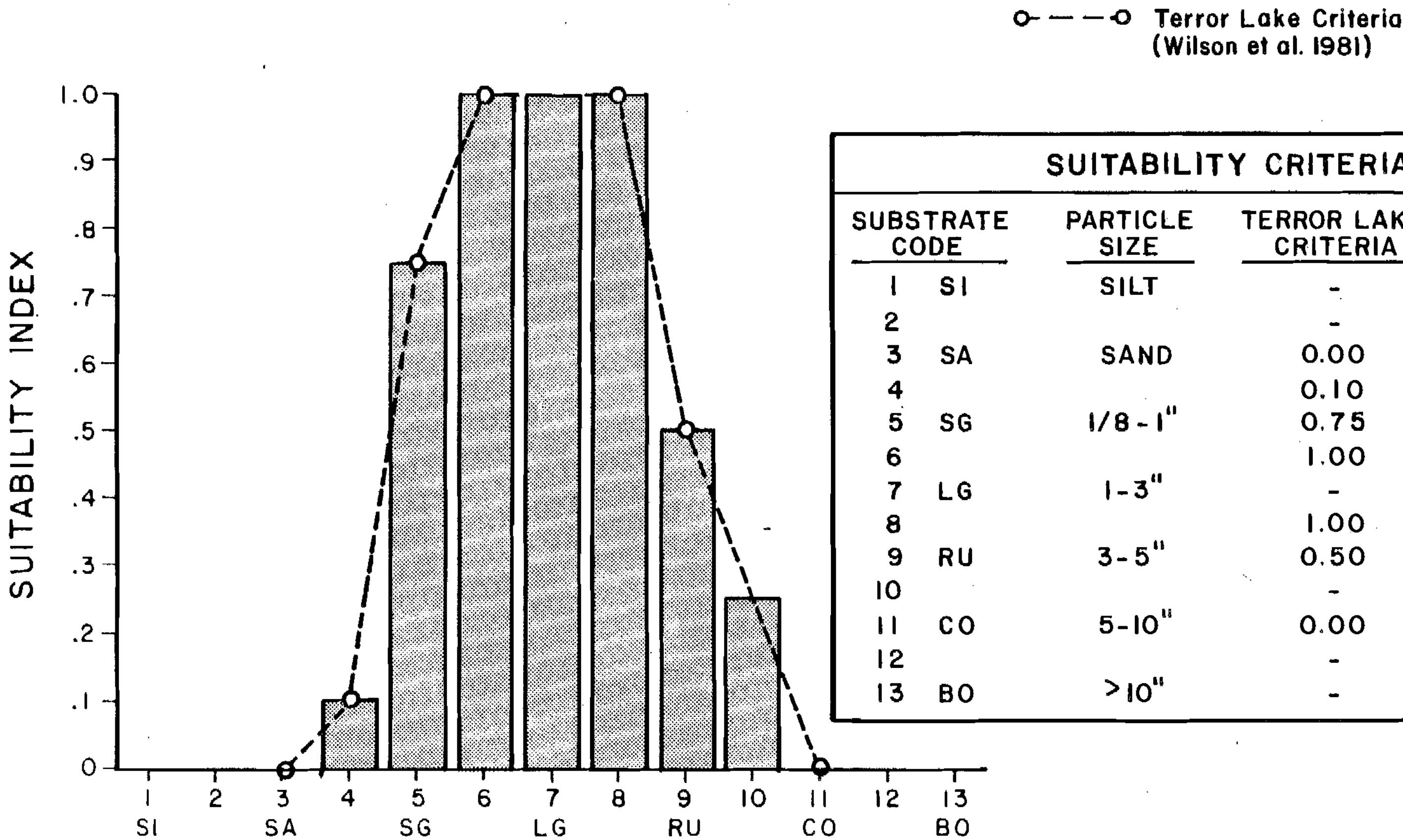


SUITABILITY CRITERIA

VELOCITY	TERROR LAKE CRITERIA	SUSITNA CRITERIA
0.08	0.00	-
0.10	0.10	0.00
0.40	0.40	0.40
1.00	1.00	1.00
2.00	1.00	1.00
2.50	0.50	-
3.00	-	0.50
3.50	0.10	-
4.00	-	0.10
5.00	0.00	0.00

Figure 9-12. Velocity suitability curve for pink spawning.

PINK SALMON
SUITABILITY CRITERIA CURVE
SUBSTRATE



SUITABILITY CRITERIA

SUBSTRATE CODE		PARTICLE SIZE	TERROR LAKE CRITERIA	SUSITNA CRITERIA
1	SI	SILT	-	0.00
2			-	0.00
3	SA	SAND	0.00	0.00
4			0.10	0.10
5	SG	1/8 - 1"	0.75	0.75
6			1.00	1.00
7	LG	1-3"	-	1.00
8			1.00	1.00
9	RU	3-5"	0.50	0.50
10			-	0.25
11	CO	5-10"	0.00	0.00
12			-	0.00
13	BO	>10"	-	0.00

Figure 9-13. Substrate suitability curve for pink salmon spawning.

3.3 Coho Salmon

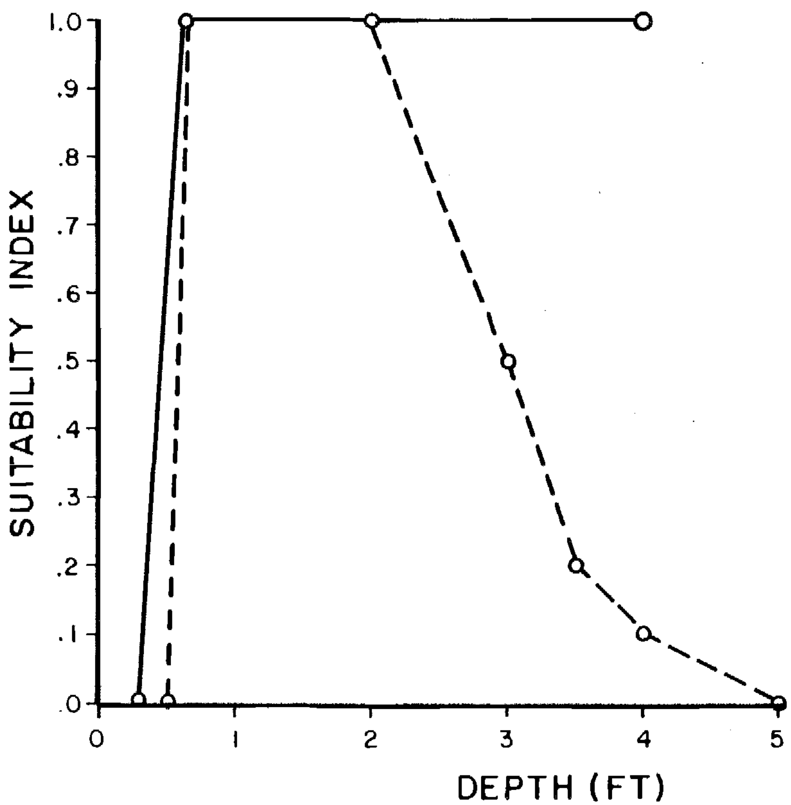
Utilization data have not been collected for coho salmon spawning in the Susitna River. Therefore, the suitability curves and criteria developed for the habitat variables of depth, velocity, and substrate were based entirely on previously published information as modified using opinion of field biologists familiar with Susitna River salmon stocks. As with pink salmon, due to limited published information available on coho, salmon spawning habitat requirements in the Susitna River watershed the coho salmon spawning habitat suitability curves developed for the Terror Lake environmental assessment (Wilson et al. 1981) were chosen as the basis for modification.

The depth suitability criteria curve developed for coho salmon spawning generally follows the Terror Lake system curve (Figure 9-14), with the exception that the curve developed in this study deflects upward at a depth of 0.3 ft as opposed to 0.5 ft in the Terror Lake curve. This is based on the opinion of project biologists that depths less than 0.5 ft but greater than 0.3 ft, would be suitable for coho spawning. Additionally, the suitability index of 1.0 was extended out to a depth of 4.0 ft. This extension was based on the opinion of project biologists that depth alone, if greater than 2.0 ft (the depth at which suitability on the Terror Lake curves begins to decline) would not likely limit coho salmon spawning.

The velocity suitability criteria curve developed for coho salmon spawning generally coincides with the velocity suitability curve developed for the Terror Lake system (Figure 9-15). The curve was smoothed slightly to reflect the opinion of field biologists familiar with coho salmon spawning in the Susitna River watershed.

The substrate suitability criteria curve developed for coho salmon spawning in the Terror Lake system is thought to be representative of substrate suitability for coho salmon spawning in the middle reach of the Susitna River (Figure 9-16).

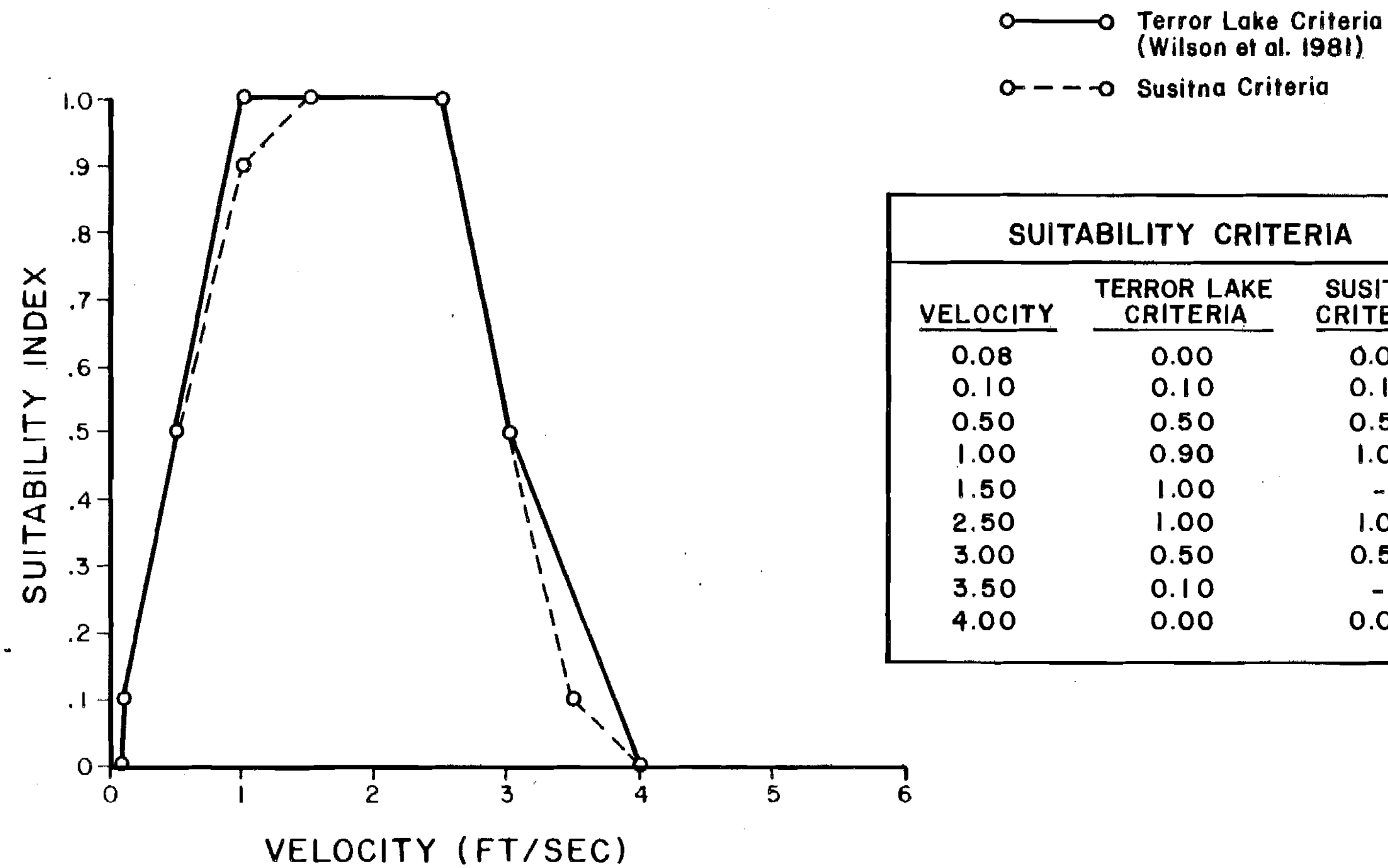
COHO SALMON
SUITABILITY CRITERIA CURVE
DEPTH



SUITABILITY CRITERIA		
DEPTH	TERROR LAKE CRITERIA	SUSITNA CRITERIA
0.3	-	0.00
0.5	0.00	-
0.7	1.00	1.00
2.0	1.00	-
3.0	0.50	-
3.5	0.20	-
4.0	0.10	1.00
5.0	0.00	-

Figure 9-14. Depth suitability curve for coho salmon spawning.

COHO SALMON
SUITABILITY CRITERIA CURVE
VELOCITY

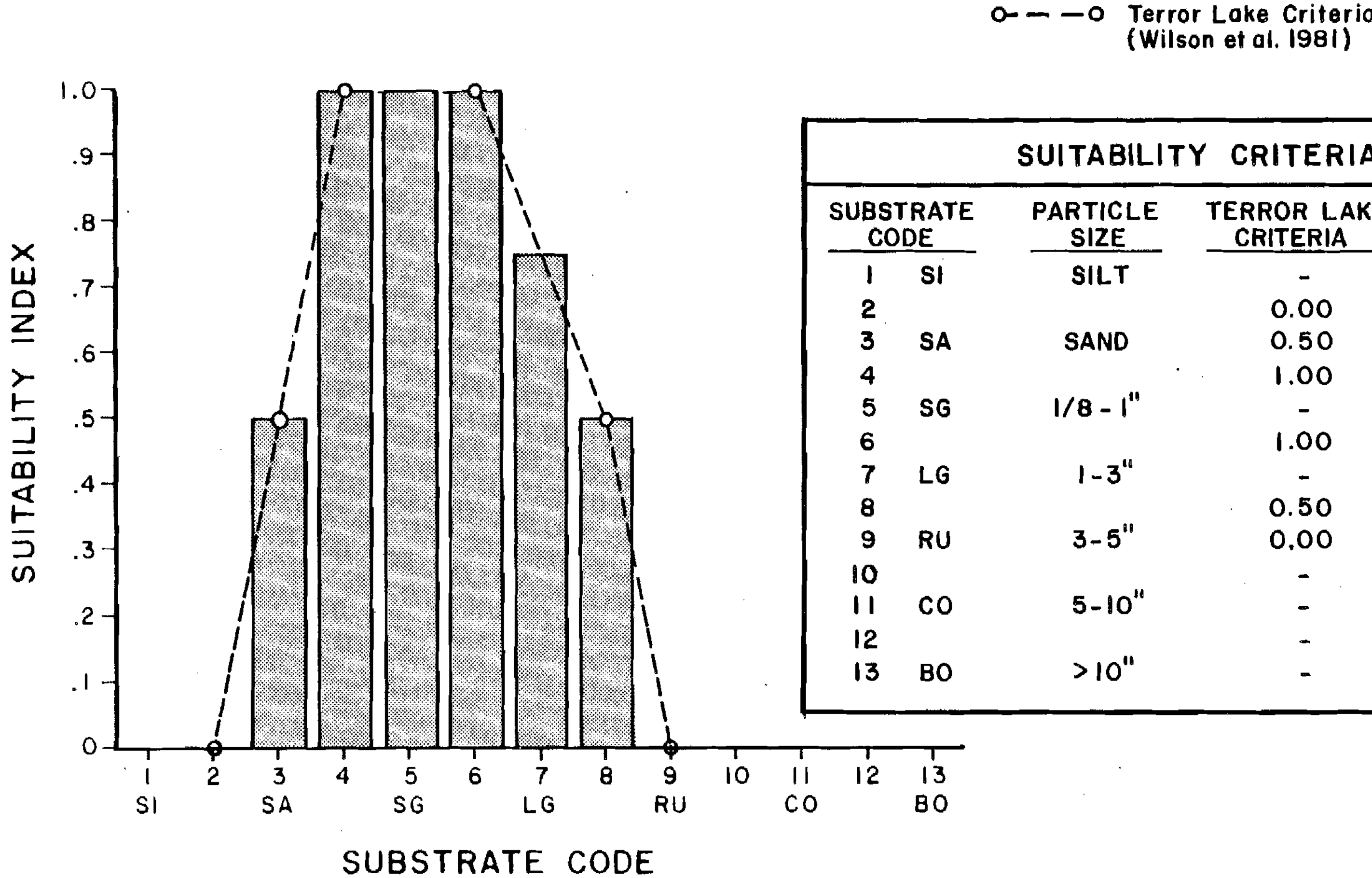


SUITABILITY CRITERIA

VELOCITY	TERROR LAKE CRITERIA	SUSITNA CRITERIA
0.08	0.00	0.00
0.10	0.10	0.10
0.50	0.50	0.50
1.00	0.90	1.00
1.50	1.00	-
2.50	1.00	1.00
3.00	0.50	0.50
3.50	0.10	-
4.00	0.00	0.00

Figure 9-15. Velocity suitability curve for coho salmon spawning.

COHO SALMON
SUITABILITY CRITERIA CURVE
SUBSTRATE



SUITABILITY CRITERIA

SUBSTRATE CODE		PARTICLE SIZE	TERROR LAKE CRITERIA	SUSITNA CRITERIA
1	SI	SILT	-	0.00
2			0.00	0.00
3	SA	SAND	0.50	0.50
4			1.00	1.00
5	SG	1/8 - 1"	-	1.00
6			1.00	1.00
7	LG	1-3"	-	0.75
8			0.50	0.50
9	RU	3-5"	0.00	0.00
10			-	0.00
11	CO	5-10"	-	0.00
12			-	0.00
13	BO	>10"	-	0.00

Figure 9-16. Substrate suitability curve for coho salmon spawning.

4.0 DISCUSSION

4.1 Assumptions and Limitations of the Data Base

The techniques used in the derivation of the habitat suitability criteria presented in this report are an adaptation of those presented in Baldrige and Amos (1982), Bovee and Cochnauer (1977), and Reiser and Weschel (1977). Several underlying assumptions are made in developing and applying suitability criteria as they relate to chinook, coho, and pink salmon spawning. These include:

1) Depth, velocity, and substrate, are the most critical habitat variables affecting the selection of tributary spawning areas by chinook, coho, and pink salmon;

2) These habitat variables are mutually independent; that is, varying the level of one variable does not affect the level of another;

3) A sufficiently large random sample was obtained to accurately represent the range of utilized chinook salmon spawning habitat conditions;

4) The suitability of a selected set of habitat variables for spawning is based on an actual preference of a set of habitat variables at a site by the spawning salmon; and,

5) Suitability criteria developed from data collected at representative study sites are applicable to the analysis of similar habitats within other tributary areas.

In the present analysis, it is assumed that the suitability of spawning habitat at a specific location can be accurately determined if all the variables affecting the behavior of a spawning fish are known. Since this is not likely, we have identified three habitat variables which appear to be the most critical habitat variables for spawners: depth, velocity, and substrate. Although other habitat variables, notably water quality and temperature, may also potentially affect the spawning suitability of a site, they are believed to exert only a limited influence under prevailing conditions.

The question of whether these three habitat variables act independently of one another was addressed by statistically analyzing the relationship between these habitat variables. Based on correlation values and their derived statistics (Appendix Table 9-B-4), there appears to be an acceptable level of independence, as defined by Pruitt (1982), among these habitat variables for chinook salmon spawning; that is, they appear to act independent of one another. Because limited utilization data are available, coho and pink salmon spawning, these relationships could not be analyzed for these species.

Although systematic random sampling of the entire spawning population was attempted, portions of the populations were undoubtedly overlooked.

High flows during spawning periods made it difficult to locate and evaluate active chinook salmon redds in deep and fast flowing portions of tributaries. Because of this, the measured data set is likely biased toward slower and shallower water. Modification of the utilization curves in the process of developing suitability criteria, however, attempted to correct for this bias.

Only limited utilization and no availability data were collected in this study. Therefore, it is not possible to evaluate whether the derived suitability criteria for each habitat variable is based on an actual preference for that habitat variable. Modification of the criteria, however, attempted to correct for this inadequacy. Thus although it is questionable whether the fifth assumption holds true, it is likely that the derived suitability data base can be used to evaluate spawning habitat suitability in other tributary habitats assuming that the variables depth, velocity, and substrate limit the spawning that occurs in these habitats.

In summary, the inherent assumptions used in the development of the suitability criteria presented in this chapter appear justified, although specific assumptions may have been violated under certain circumstances. The extent to which these violations influence our analysis is difficult to evaluate; however, it is believed that such violations exert only a limited influence.

4.2 Suitability Criteria

4.2.1 Chinook Salmon

The suitability criteria developed in this chapter for depth, velocity, and substrate represent our best estimation of the suitability of various levels of these habitat variables for chinook salmon spawning in tributaries in the middle reach of the Susitna River. The criteria are based on a limited utilization data base without corresponding availability data to support a preference analysis. Professional opinion of project biologists familiar with Susitna River chinook salmon stocks and literature information were used to modify the utilization data base to develop the suitability criteria.

These data and analyses may be compared with information available in literature to assess their adequateness. Two literature sources were located summarizing chinook salmon spawning data which could be used to evaluate the suitability criteria developed in the study. These include the literature survey by Beauchamp et al. (1983) and a study of Willow Creek by Estes et al. (1981).

Utilization data collected in this study are similar to the ranges summarized in Beauchamp et al. (1983) However, since the author did not develop criteria curves, comparisons of suitability criteria could not be made. In the Willow Creek study, Estes et al. (1981) developed utilization curves for chinook salmon spawning. The utilization curves developed in this study generally follow the utilization curves developed for Willow Creek, although specific differences do occur. For example, the depth criteria developed for chinook salmon spawning in Willow Creek decline to zero suitability at a depth of approximately 3.0 ft; whereas the depth suitability curve developed in this study remains at a value of 1.0 up to the maximum depth plotted (4.0 ft). Additionally, the chinook salmon velocity curves developed for tributaries of the Susitna River indicate a peak suitability in slower waters than the Willow Creek curves.

4.2.2 Pink and Coho Salmon

The suitability criteria developed in this chapter for the habitat variables of depth, velocity, and substrate for pink and coho salmon spawning represent our best estimation of the suitability of various levels of these habitat variables for spawning of these species in tributaries in the middle reach of the Susitna River. Due to the lack of utilization and availability data, the suitability criteria developed in this study are based on literature data as modified using professional opinion of field biologists familiar with Susitna River pink and coho salmon stocks. The spawning habitat suitability curves developed for the Terror Lake environmental assessment (Wilson et al. 1981) were chosen as a basis for modification. To our knowledge, this is the only literature source summarizing suitability criteria for pink and coho salmon spawning in Alaskan waters, although utilization data are available (Estes et al. 1981).

The Terror Lake environmental assessment evaluated the impacts associated with construction of a hydroelectric facility on the Terror River, a clearwater stream located on the northeast portion of Kodiak Island. The suitability criteria developed in this assessment for the habitat variables of depth, velocity, and substrate for pink and coho salmon spawning were used to quantify, using an instream flow incremental methodology approach, project effects on pink salmon habitat. Like many of the larger clearwater tributaries of the middle Susitna River, the Terror River system supports spawning populations of pink and coho salmon. Because this river system has similar hydraulic and physical characteristics of many of the larger tributaries of the middle Susitna River, the spawning suitability criteria developed in this environmental assessment are well suited as a basis for modification in this study.

4.3 Recommended Application and Limitations of the Suitability Criteria

The suitability criteria developed in this section represent the incremental usability of several critical habitat variables important for chinook, pink, and coho salmon spawning (depth, velocity, and substrate) in tributaries of the middle Susitna River reach. Depending on the species, they represent a varied synthesis of limited utilization data using statistical methods, literature information, and professional opinion of field biologists familiar with Susitna River salmon stocks. As such, they represent our best estimation of the suitability of various levels of these habitat variables for chinook, coho, and pink salmon spawning in tributaries of the middle Susitna River. Because of the limited utilization data base used in these analyses, application of these criteria to tributary and other habitat types in the middle Susitna River reach must be approached cautiously and determined on a case-by-case basis.

One typical application of suitability criteria is in habitat simulation modelling. Habitat simulation modelling is one method commonly used to project a weighted usable area index of usable habitat for selected habitat variables for a particular species/life phase as a function of flow. Tributary habitat is not anticipated to be affected by the operation of the proposed hydroelectric development. However, it is anticipated that suitable depth, velocity, and substrate conditions presently associated tributary areas in which chinook, coho, and pink salmon spawn may become available in mainstem or side channel habitats under with-project conditions. One means of evaluating such projected habitat changes is through habitat simulation modelling. Prior to modelling applications it is recommended that additional field data be obtained to evaluate the validity of extending these criteria to other habitats. Evaluation criteria would include determining whether the habitat variables depth, velocity, and substrate composition are the habitat variables that limit the spawning in these habitats and whether seasonal habitat conditions for other life phases necessary for overall reproductive success are suitable for overall survival (e.g., passage, incubation, and rearing). Moreover, the availability of microhabitat variables in the mainstem and side channel habitats must be considered as they may be substantially different from those present in tributaries which could result in altered patterns of utilization and ultimately suitability criteria.

5.0 GLOSSARY

Availability Data - Data collected, or synthesized by a computer model, which represents range and frequency of selected environmental condition present which are available to be used by a particular species/life phase.

Best Curve - Utilization curve, usually with grouped increments, which represents the distribution with the least variability, lowest level of irregular fluctuations, minimal peakedness, and minimal coefficient of variation.

Fish Curve - Generic name, used interchangeably with habitat curve, applied to suitability/preference/utilization curves for fish; see also habitat curve.

Habitat Curve - Generic name, used interchangeably with fish curve, applied to suitability/preference/utilization curves for fish; see also fish curve.

Habitat Variable - One element of the total spectrum of elements (physical and chemical conditions) needed to support the life functions of a particular species and life stage (e.g., streamflow, channel geometry, depth, velocity, substrate, upwelling etc.).

Kurtosis - The peakedness or flatness of a histogram.

Maximum Grouped Value - The x-value associated with the increment in a scaled frequency histogram plot which has an associated y-value of 1.0, that is the increment with the maximum scaled frequency.

Measured Data - Values derived through the process of obtaining a direct measurement.

Middle Reach (of the Susitna River): - The segment of the Susitna River between the Chulitna River confluence and Devil Canyon. (See also lower reach and upper reach).

Minimal Irregular Fluctuations - Grouped values in a frequency histogram plot should continually increase to the maximum grouped value, then continually decrease (Baldridge and Amos 1982), as defined by a series of four indices proposed by Baldridge and Amos (1982).

Minimal Peakedness - Meaning a minimal difference between the maximum grouped value (i.e., increment) and the increments immediately below and above the maximum, as defined by a peakedness index.

Minimal Sample Variance - The condition of minimal variability in the frequency counts used to denote a "best curve".

Non-controlling Condition - The range of discharges at Gold Creek associated with unbreached through intermediate breaching conditions at a side slough or side channel.

GLOSSARY (continued)

Observed Data - Values derived through a visual estimate or evaluation.

Parameter - A quantity that describes a statistical population or a set of physical properties whose values determine the behavior of a population.

Peakedness Index - A measure of the difference between the maximum grouped value or increment (e.g., in a scaled frequency histogram plot) and the increments to either side of the maximum grouped value or increment. The index ranges from zero, indicating no peak, to two, indicating a maximum peak.

Preference - An apparent behavioral selection for a particular habitat component value as indicated by observed or measured data.

Preference Curve - A utilization curve modified to account for selection of a particular value within the available range of habitat conditions. Preference curves can be constructed by dividing the utilized values by values of available habitat in each increment. The x and y axes are established in the same manner as the utilization curves.

Spawning Habitat Curve Types - See utilization curve, preference curve, suitability criteria curve, habitat curve, fish curve.

Suitability - How well a particular habitat condition meets the life stage needs of a particular species.

Suitability Criteria Curve - A utilization or preference curve, modified by additional information (e.g., observations, professional judgment, field and literature data, etc.) to represent the suitability of habitat for a particular species and life/stage over the range of habitat components expected to be encountered. This is the curve used to calculate weighted usable area. The x and y axes are established in the same manner as the utilization curves.

Suitability Curve - See suitability criteria curve.

Suitability Index - The label for the y-axis indicating standardization to the 0 - 1 scale for a suitability curve. Suitability index can also be used to denote a value determined from a suitability curve.

Utilization Curve - Habitat data (e.g., depth, velocity, substrate, upwelling, etc.), collected during selected periods of life stage activity (i.e., passage, spawning, incubation, and rearing) plotted to show distribution of actual field measurements. The scale on the x-axis corresponds to the accuracy of the measuring device and is often grouped into increments to smooth the distribution. The relative number of observations representing each increment is standardized to 0 to 1 scale by setting the largest increment to 1 and dividing each increment by this maximum to assign a proportional value.

GLOSSARY (continued)

Utilization Data - Data collected at an active life stage site (e.g., depth, velocity and substrate data collected at an active salmon redd).

Variable - A characteristic that may have a number of different values.

Weighted Usable Area (WUA) - An index of the capacity of a siTE in terms of both quantity and quality of habitat to support the species and life stage being considered. WUA is expressed as square feet (ft^2) or percentage (%) of wetted surface habitat area predicted to be available per 1,000 linear feet or habitat reach at a given flow.

GLOSSARY OF SCIENTIFIC NAMES

Scientific Name	Common Name
Oncorhynchus tshawytscha (Welbaum)	Chinook salmon
Oncorhynchus gorbuscha (Walbaum)	Pink salmon
Oncorhynchus kisutch (Walbaum)	Coho salmon

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7.0 ACKNOWLEDGEMENTS

The authors express their appreciation to the following for their assistance in preparing this report.

-- The other ADF&G Su Hydro Aquatic Studies Program staff who provided their support to this report.

-- The ADF&G Su Hydro Adult Anadromous Studies Program staff who surveyed the tributaries for salmon.

-- Special appreciation is extended to D. Amos for assisting with the analytical approach.

-- We are also grateful to C. Steward (EWT&A) and S. Crumley (WWC) for their review and critique of this report.

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9.0 APPENDICES

APPENDIX 9-A
Chinook Salmon Spawning Habitat Utilization Data

Table 9-A-1. Chinook salmon spawning habitat data.

LOCATION	DATE	DEPTH (FT)	WATER VELO-CITY (FT/S)	SUBSTRATE		WATER TEMPERATURE (C)		REDD NO.
				PRIMARY	SECONDARY	INTRAGRAVEL	SURFACE	
4TH OF JULY CREEK 200 FT ABOVE Q SITE	830804	1.70	1.10	RUBBLE	COBBLE	13.2	13.2	1
INDIAN RIVER	830727	1.70	1.90	COBBLE	RUBBLE	9.8	9.8	1
INDIAN RIVER	830727	.80	2.50	RUBBLE	COBBLE	9.5	9.8	2
INDIAN RIVER	830727	1.20	2.40	COBBLE	RUBBLE	8.4	9.9	3
INDIAN RIVER	830727	1.30	2.40	COBBLE	RUBBLE	8.8	9.9	4
INDIAN RIVER	830727	1.30	1.80	RUBBLE	COBBLE	9.6	9.9	5
INDIAN RIVER	830727	1.00	.70	RUBBLE	COBBLE	9.1	9.9	6
INDIAN RIVER	830727	1.60	2.10	COBBLE	RUBBLE	9.6	9.9	7
INDIAN RIVER	830727	1.30	3.30	RUBBLE	COBBLE	9.6	9.9	8
INDIAN RIVER	830727	1.00	3.20	RUBBLE	COBBLE		9.9	9
INDIAN RIVER	830727	1.60	4.10	RUBBLE	COBBLE		9.9	10
INDIAN RIVER	830727	1.20	.50	RUBBLE	LARGE GRAVEL		10.0	11
INDIAN RIVER	830727	1.30	2.00	RUBBLE	COBBLE		10.0	12
INDIAN RIVER	830727	1.30	1.80	RUBBLE	LARGE GRAVEL		10.1	13
INDIAN RIVER	830727	1.60	2.60	RUBBLE	COBBLE		10.1	14
INDIAN RIVER	830727	.70	.50	COBBLE	RUBBLE		10.1	15
INDIAN RIVER	830727	1.10	3.20	RUBBLE	COBBLE		10.3	16
INDIAN RIVER	830727	1.50	3.00	COBBLE	RUBBLE		10.3	17
INDIAN RIVER	830727	1.20	2.33	COBBLE	RUBBLE		10.3	18
INDIAN RIVER	830727	.90	2.00	RUBBLE	COBBLE		10.3	19
INDIAN RIVER	830727	1.00	3.00	RUBBLE	COBBLE		10.4	20
INDIAN RIVER	830727	1.50	2.20	COBBLE	RUBBLE		10.4	21
INDIAN RIVER	830727	2.50	3.80	COBBLE	RUBBLE		10.5	22
INDIAN RIVER	830727	1.80	2.70	RUBBLE	COBBLE		10.5	23
INDIAN RIVER	830727	1.50	3.00	RUBBLE	COBBLE		10.5	24

Note: Intragravel temperatures were taken at a depth from 6 to 8 inches.

Table 9-A-1. Continued.

LOCATION	DATE	DEPTH (FT)	WATER VELO-CITY (FT/S)	SUBSTRATE PRIMARY	SUBSTRATE SECONDARY	WATER TEMPERATURE (C) INTRAGRAVEL	WATER TEMPERATURE (C) SURFACE	REDD NO.
INDIAN RIVER	830727	1.60	3.50	RUBBLE	COBBLE		10.5	25
INDIAN RIVER	830727	1.80	1.50	RUBBLE	COBBLE		10.7	26
INDIAN RIVER	830727	1.10	1.60	COBBLE	RUBBLE		10.8	27
INDIAN RIVER	830727	1.60	1.10	COBBLE	RUBBLE		10.[illegible]	28
INDIAN RIVER	830727	1.50	3.00	RUBBLE	COBBLE		11.0	29
INDIAN RIVER	830728	1.20	3.20	RUBBLE	COBBLE	10.2	10.2	1
INDIAN RIVER	830728	1.80	1.40	COBBLE	RUBBLE			1
INDIAN RIVER	830728	2.00	3.20	RUBBLE	LARGE GRAVEL	10.2	10.2	2
INDIAN RIVER	830728	1.70	1.80	COBBLE	RUBBLE			2
INDIAN RIVER	830728	1.00	1.80	COBBLE	RUBBLE	10.5	10.6	3
INDIAN RIVER	830728	2.00	2.40	BOULDER	COBBLE			3
INDIAN RIVER	830728	1.40	1.70	RUBBLE	COBBLE	10.3	10.6	4
INDIAN RIVER	830728	.90	2.60	COBBLE	RUBBLE			4
INDIAN RIVER	830728	1.60	1.70	RUBBLE	LARGE GRAVEL	10.7	10.8	5
INDIAN RIVER	830728	1.20	.75	RUBBLE	COBBLE			5
INDIAN RIVER	830728	1.50	1.30	RUBBLE	LARGE GRAVEL	10.7	10.8	6
INDIAN RIVER	830728	1.30	2.40	RUBBLE	COBBLE			6
INDIAN RIVER	830728	1.00	2.00	RUBBLE	COBBLE	10.9	11.0	7
INDIAN RIVER	830728	1.60	2.40	RUBBLE	COBBLE			7
INDIAN RIVER	830728	1.00	1.60	RUBBLE	LARGE GRAVEL	11.1	11.0	8
INDIAN RIVER	830728	1.50	2.60	BOULDER	COBBLE			8
INDIAN RIVER	830728	.90	2.50	RUBBLE	LARGE GRAVEL	11.0	11.1	9
INDIAN RIVER	830728	1.30	.95	RUBBLE	LARGE GRAVEL			9
INDIAN RIVER	830728	1.30	2.50	RUBBLE	LARGE GRAVEL	11.1	11.1	10
INDIAN RIVER	830728	1.10	2.60	RUBBLE	LARGE GRAVEL			10

Table 9-A-1. Continued.

LOCATION	DATE	DEPTH (FT)	WATER VELOCITY (FT/S)	SUBSTRATE PRIMARY	SUBSTRATE SECONDARY	WATER TEMPERATURE (C) INTRAGRAVEL	WATER TEMPERATURE (C) SURFACE	REDD NO.
INDIAN RIVER	830728	1.10	2.60	RUBBLE	COBBLE	10.6	11.1	11
INDIAN RIVER	830728	1.20	2.40	RUBBLE	LARGE GRAVEL			11
INDIAN RIVER	830728	.90	.90	RUBBLE	LARGE GRAVEL	9.2	11.4	12
INDIAN RIVER	830728	1.10	3.25	RUBBLE	LARGE GRAVEL			12
INDIAN RIVER	830728	1.30	1.40	COBBLE	RUBBLE	10.3	11.3	13
INDIAN RIVER	830728	1.50	3.40	COBBLE	RUBBLE			13
INDIAN RIVER	830728	1.50	1.70	COBBLE	RUBBLE	10.8	11.5	14
INDIAN RIVER	830728	2.40	3.10	BOULDER	COBBLE			14
INDIAN RIVER	830728	1.50	2.40	RUBBLE	LARGE GRAVEL	10.2	11.6	15
INDIAN RIVER	830728	1.60	3.40	BOULDER	COBBLE			15
INDIAN RIVER	830728	.60	1.10	RUBBLE	LARGE GRAVEL	11.5	11.7	16
INDIAN RIVER	830728	1.20	1.70	COBBLE	RUBBLE			16
INDIAN RIVER	830728	1.30	2.40	RUBBLE	LARGE GRAVEL	11.6	11.6	17
INDIAN RIVER	830728	1.50	2.35	COBBLE	RUBBLE			17
INDIAN RIVER	830728	1.00	1.50	RUBBLE	COBBLE	11.6	11.7	18
INDIAN RIVER	830728	1.30	2.40	COBBLE	RUBBLE			18
INDIAN RIVER	830728	1.50	1.80	COBBLE	RUBBLE	11.5	11.7	19
INDIAN RIVER	830728	1.00	2.90	RUBBLE	COBBLE			19
INDIAN RIVER	830728	2.10	3.10	COBBLE	RUBBLE	10.9	11.7	20
INDIAN RIVER	830728	1.20	1.40	RUBBLE	LARGE GRAVEL			20
INDIAN RIVER	830728	.90	1.90	RUBBLE	LARGE GRAVEL	11.7	11.7	21
INDIAN RIVER	830728	.60	2.40	RUBBLE	LARGE GRAVEL			21
INDIAN RIVER	830728	1.40	2.00	RUBBLE	LARGE GRAVEL	11.7	11.8	22
INDIAN RIVER	830728	1.20	2.20	LARGE GRAVEL	RUBBLE			22
INDIAN RIVER	830728	1.00	2.30	RUBBLE	LARGE GRAVEL	11.8	11.8	23
INDIAN RIVER	830728	1.00	2.45	RUBBLE	COBBLE			23

Table 9-A-1. Continued.

LOCATION	DATE	DEPTH (FT)	WATER VELOCITY (FT/S)	SUBSTRATE PRIMARY	SUBSTRATE SECONDARY	WATER TEMPERATURE (C) INTRAGRAVEL	WATER TEMPERATURE (C) SURFACE	REDD NO.
INDIAN RIVER	830728	1.00	1.70	RUBBLE	LARGE GRAVEL	11.9	11.8	24
INDIAN RIVER	830728	.90	3.70	RUBBLE	COBBLE			24
INDIAN RIVER	830728	1.30	2.40	RUBBLE	LARGE GRAVEL	11.9	11.8	25
INDIAN RIVER	830728	.90	1.90	COBBLE	RUBBLE			25
INDIAN RIVER	830728	1.00	2.30	RUBBLE	LARGE GRAVEL	11.7	11.8	26
INDIAN RIVER	830728	1.90	1.55	RUBBLE	COBBLE			26
INDIAN RIVER	830728	1.30	2.60	RUBBLE	COBBLE	11.8	11.8	27
INDIAN RIVER	830728	1.50	1.30	COBBLE	RUBBLE			27
INDIAN RIVER	830728	1.50	2.70	RUBBLE	COBBLE	11.8	11.8	28
INDIAN RIVER	830728	1.10	1.70	COBBLE	RUBBLE			28
INDIAN RIVER	830728	1.30	3.30	RUBBLE	COBBLE	11.8	11.7	29
INDIAN RIVER	830728	1.00	3.20	COBBLE	RUBBLE			29
INDIAN RIVER	830728	1.50	2.40	RUBBLE	LARGE GRAVEL	11.8	11.8	30
INDIAN RIVER	830728	1.70	1.50	LARGE GRAVEL	RUBBLE			30
INDIAN RIVER	830728	1.60	2.20	RUBBLE	LARGE GRAVEL	11.6	11.5	31
INDIAN RIVER	830728	1.10	2.20	COBBLE	RUBBLE			31
INDIAN RIVER	830728	1.80	2.70	COBBLE	RUBBLE	11.5	11.5	32
INDIAN RIVER	830728	.90	2.00	RUBBLE	COBBLE			32
INDIAN RIVER	830728	1.40	1.80	RUBBLE	LARGE GRAVEL	11.7	11.4	33
INDIAN RIVER	830728	1.70	3.00	BOULDER	COBBLE			33
INDIAN RIVER	830728	1.50	2.20	RUBBLE	COBBLE	11.6	11.4	34
INDIAN RIVER	830728	1.10	2.10	BOULDER	RUBBLE			34
INDIAN RIVER	830728	.80	1.00	RUBBLE	COBBLE			35
INDIAN RIVER	830729	.70	1.55	COBBLE	RUBBLE			1
INDIAN RIVER	830729	1.60	2.45	BOULDER	COBBLE			2

Table 9-A-1. Continued.

LOCATION	DATE	DEPTH (FT)	WATER VELOCITY (FT/S)	SUBSTRATE PRIMARY	SUBSTRATE SECONDARY	WATER TEMPERATURE (C) INTRAGRAVEL	WATER TEMPERATURE (C) SURFACE	REDD NO.
INDIAN RIVER	830729	1.45	3.80	BOULDER	COBBLE			3
INDIAN RIVER	830729	.90	2.80	COBBLE	BOULDER			4
INDIAN RIVER	830729	1.10	1.25	BOULDER	COBBLE			5
INDIAN RIVER	830729	.90	2.00	COBBLE	RUBBLE			6
INDIAN RIVER	830729	1.40	1.80	COBBLE	BOULDER			7
INDIAN RIVER	830729	1.30	3.10	COBBLE	RUBBLE			8
INDIAN RIVER	830729	.80	1.30	COBBLE	RUBBLE			9
INDIAN RIVER	830729	1.80	2.85	BOULDER	COBBLE			10
INDIAN RIVER	830729	1.00	3.50	RUBBLE	COBBLE			11
INDIAN RIVER	830729	.90	1.90	BOULDER	COBBLE			12
INDIAN RIVER	830729	1.00	3.50	RUBBLE	COBBLE			13
INDIAN RIVER	830729	1.00	2.30	COBBLE	RUBBLE			14
INDIAN RIVER	830729	1.20	3.20	BOULDER	COBBLE			15
INDIAN RIVER	830729	1.00	2.50	COBBLE	BOULDER			16
INDIAN RIVER	830729	1.10	2.15	RUBBLE	COBBLE			17
INDIAN RIVER	830729	1.10	2.10	COBBLE	RUBBLE			18
INDIAN RIVER	830729	.85	1.95	COBBLE	RUBBLE			19
INDIAN RIVER	830729	1.00	2.10	BOULDER	COBBLE			20
INDIAN RIVER	830729	.80	2.20	RUBBLE	COBBLE			21
INDIAN RIVER	830729	1.20	2.10	BOULDER	COBBLE			22
INDIAN RIVER	830729	.80	2.40	COBBLE	RUBBLE			23
INDIAN RIVER	830729	1.20	2.70	BOULDER	COBBLE			24
INDIAN RIVER	830729	1.20	2.10	COBBLE	RUBBLE			25
INDIAN RIVER	830729	1.10	2.20	COBBLE	RUBBLE			26
INDIAN RIVER	830729	1.50	2.60	COBBLE	RUBBLE			27

Table 9-A-1. Continued.

LOCATION	DATE	DEPTH (FT)	WATER VELOCITY (FT/S)	SUBSTRATE PRIMARY	SUBSTRATE SECONDARY	WATER TEMPERATURE (C) INTRAGRAVEL	WATER TEMPERATURE (C) SURFACE	REDD NO.
PORTAGE CREEK	830724	1.50	2.10	RUBBLE	LARGE GRAVEL	7.7	7.8	1
PORTAGE CREEK	830724	1.10	1.80	LARGE GRAVEL	RUBBLE	9.9	10.1	1
PORTAGE CREEK	830724	.80	1.10	COBBLE	LARGE GRAVEL	11.2	11.3	1
PORTAGE CREEK	830724	1.70	2.20	RUBBLE	LARGE GRAVEL	7.9	7.9	2
PORTAGE CREEK	830724	1.40	1.30	RUBBLE	COBBLE	9.2	10.2	2
PORTAGE CREEK	830724	1.10	2.10	RUBBLE	LARGE GRAVEL	11.3	11.3	2
PORTAGE CREEK	830724	1.80	2.20	COBBLE	LARGE GRAVEL	7.7	8.0	3
PORTAGE CREEK	830724	1.40	2.20	RUBBLE	COBBLE	10.4	10.5	3
PORTAGE CREEK	830724	1.90	3.30	RUBBLE	LARGE GRAVEL	11.3	11.3	3
PORTAGE CREEK	830724	2.10	1.20	LARGE GRAVEL	RUBBLE	7.8	8.0	4
PORTAGE CREEK	830724	1.00	1.00	COBBLE	RUBBLE	9.6	10.6	4
PORTAGE CREEK	830724	2.00	3.00	RUBBLE	COBBLE	11.3	11.3	4
PORTAGE CREEK	830724	1.40	1.60	LARGE GRAVEL	RUBBLE	7.8	8.0	5
PORTAGE CREEK	830724	1.70	1.80	LARGE GRAVEL	RUBBLE	8.1	8.3	6
PORTAGE CREEK	830724	2.70	1.55	RUBBLE	LARGE GRAVEL	8.3	9.0	7
PORTAGE CREEK	830724	2.70	1.70	RUBBLE	LARGE GRAVEL	9.1	9.4	8
PORTAGE CREEK	830724	1.40	2.90	RUBBLE	LARGE GRAVEL	9.0	9.6	9
PORTAGE CREEK	830725	1.40	2.00	COBBLE	RUBBLE	9.0	9.3	1
PORTAGE CREEK	830725	1.00	1.60	RUBBLE	COBBLE	9.0	9.4	2
PORTAGE CREEK	830725	1.30	2.00	RUBBLE	COBBLE	8.7	9.5	3
PORTAGE CREEK	830725	1.40	1.50	RUBBLE	COBBLE	9.4	9.5	4
PORTAGE CREEK	830725	1.70	1.70	RUBBLE	LARGE GRAVEL	10.0	10.0	5
PORTAGE CREEK	830725	1.80	1.30	COBBLE	RUBBLE	10.1	10.4	6
PORTAGE CREEK	830725	2.00	2.10	COBBLE	RUBBLE	9.7	10.1	7
PORTAGE CREEK	830725	1.70	1.50	RUBBLE	COBBLE	9.5	9.7	8

Table 9-A-1. Continued.

LOCATION	DATE	DEPTH (FT)	WATER VELOCITY (FT/S)	SUBSTRATE PRIMARY	SUBSTRATE SECONDARY	WATER TEMPERATURE (C) INTRAGRAVEL	WATER TEMPERATURE (C) SURFACE	REDD NO.
PORTAGE CREEK	830725	2.30	2.40	COBBLE	RUBBLE	8.4	9.7	9
PORTAGE CREEK	830725	2.20	2.00	COBBLE	RUBBLE	9.6	9.9	10
PORTAGE CREEK	830725	1.10	2.10	COBBLE	RUBBLE	10.4	10.5	11
PORTAGE CREEK	830725	1.00	1.00	RUBBLE	LARGE GRAVEL			12
PORTAGE CREEK	830725	1.50	1.80	COBBLE	RUBBLE			13
PORTAGE CREEK	830725	1.30	2.60	LARGE GRAVEL	RUBBLE			14
PORTAGE CREEK	830727	2.50	1.58	COBBLE	LARGE GRAVEL	9.6	10.0	1
PORTAGE CREEK	830727	1.70	1.90	COBBLE	RUBBLE	9.4	10.1	2
PORTAGE CREEK	830727	2.50	3.35	COBBLE	RUBBLE	9.6	10.2	3
PORTAGE CREEK	830727	2.30	2.00	COBBLE	RUBBLE	10.0	10.2	4
PORTAGE CREEK	830727	.90	1.90	RUBBLE	LARGE GRAVEL	9.9	10.3	5
PORTAGE CREEK	830727	2.00	1.30	COBBLE	LARGE GRAVEL	10.5	10.7	6
PORTAGE CREEK	830727	1.50	1.20	RUBBLE	LARGE GRAVEL	8.9	10.7	7
PORTAGE CREEK	830727	1.40	1.40	COBBLE	RUBBLE	10.5	10.7	8
PORTAGE CREEK	830727	1.60	2.10	RUBBLE	LARGE GRAVEL	10.0	10.7	9
PORTAGE CREEK	830727	1.50	1.30	RUBBLE	SMALL GRAVEL	10.7	10.7	10
PORTAGE CREEK	830727	1.30	2.60	COBBLE	RUBBLE	10.9	10.9	11
PORTAGE CREEK	830727	1.90	2.00	COBBLE	LARGE GRAVEL	11.1	11.3	12
PORTAGE CREEK	830727	1.80	2.70	COBBLE	RUBBLE	11.2	11.4	13
PORTAGE CREEK	830727	1.70	2.10	RUBBLE	LARGE GRAVEL	10.7	11.4	14
PORTAGE CREEK	830727	1.60	1.90	COBBLE	LARGE GRAVEL	11.3	11.5	15
PORTAGE CREEK	830727	1.50	1.70	RUBBLE	LARGE GRAVEL	11.2	11.6	16
PORTAGE CREEK	830727	1.30	2.70	RUBBLE	LARGE GRAVEL	11.6	11.8	17
PORTAGE CREEK	830727	1.40	1.60	RUBBLE	LARGE GRAVEL	12.0	12.2	18

Table 9-A-1. Continued.

LOCATION	DATE	DEPTH (FT)	WATER VELOCITY (FT/S)	SUBSTRATE PRIMARY	SUBSTRATE SECONDARY	WATER TEMPERATURE (C) INTRAGRAVEL	WATER TEMPERATURE (C) SURFACE	REDD NO.
PORTAGE CREEK	830728	1.90	3.60	COBBLE	RUBBLE	11.3	11.5	1
PORTAGE CREEK	830728	1.70	3.70	COBBLE	RUBBLE	11.9	11.9	2
PORTAGE CREEK	830728	1.50	2.20	RUBBLE	COBBLE	10.5	12.3	3
PORTAGE CREEK	830728	2.20	2.10	RUBBLE	LARGE GRAVEL	12.1	12.1	4
PORTAGE CREEK	830728	1.80	3.10	RUBBLE	LARGE GRAVEL	12.2	12.2	5
PORTAGE CREEK	830728	1.30	1.60	LARGE GRAVEL	RUBBLE	11.5	12.2	6
PORTAGE CREEK	830728	1.30	2.10	RUBBLE	LARGE GRAVEL	11.3	12.2	7
PORTAGE CREEK	830728	2.30	2.00	RUBBLE	COBBLE	11.7	12.3	8
PORTAGE CREEK	830728	2.30	1.30	RUBBLE	LARGE GRAVEL	11.2	12.3	9
PORTAGE CREEK	830728	2.40	2.90	RUBBLE	LARGE GRAVEL	12.3	12.4	10
PORTAGE CREEK	830728	1.20	.80	COBBLE	LARGE GRAVEL	13.0	13.1	11
PORTAGE CREEK	830728	1.90	1.97	COBBLE	LARGE GRAVEL	13.0	13.1	12
PORTAGE CREEK	830728	1.80	2.90	RUBBLE	LARGE GRAVEL	13.2	13.1	13
PORTAGE CREEK	830728	1.80	1.60	RUBBLE	LARGE GRAVEL	11.7	13.1	14
PORTAGE CREEK	830728	1.90	1.40	RUBBLE	LARGE GRAVEL	12.5	13.2	15
PORTAGE CREEK	830728	2.20	1.20	RUBBLE	LARGE GRAVEL	13.3	13.1	16
PORTAGE CREEK	830728	1.70	.90	RUBBLE	LARGE GRAVEL	13.3	13.2	17
PORTAGE CREEK	830728	1.20	.90	LARGE GRAVEL	COBBLE	13.2	13.2	18
PORTAGE CREEK	830728	1.50	.90	LARGE GRAVEL	COBBLE	13.0	13.2	19
PORTAGE CREEK	830728	1.40	.50	RUBBLE	LARGE GRAVEL	11.9	13.3	20
PORTAGE CREEK	830728	1.10	.40	LARGE GRAVEL	RUBBLE	13.3	13.3	21
PORTAGE CREEK	830728	1.60	2.60	RUBBLE	COBBLE	10.6	13.6	22
PORTAGE CREEK	830728	1.20	2.00	LARGE GRAVEL	COBBLE	13.6	13.6	23
PORTAGE CREEK	830728	2.10	2.60	RUBBLE	COBBLE	14.5	13.6	24
PORTAGE CREEK	830729	1.20	1.29	RUBBLE	LARGE GRAVEL	9.0	9.6	1

Table 9-A-1. Continued.

LOCATION	DATE	DEPTH (FT)	WATER VELOCITY (FT/S)	SUBSTRATE PRIMARY	SUBSTRATE SECONDARY	WATER TEMPERATURE (C) INTRAGRAVEL	WATER TEMPERATURE (C) SURFACE	REDD NO.
PORTAGE CREEK	830729	1.60	3.40	COBBLE	LARGE GRAVEL	9.2	9.1	1
PORTAGE CREEK	830729	2.40	1.54	RUBBLE	LARGE GRAVEL	9.3	10.0	2
PORTAGE CREEK	830729	1.60	3.10	COBBLE	BOULDER	9.9	9.9	2
PORTAGE CREEK	830729	2.50	1.83	RUBBLE	LARGE GRAVEL	9.7	10.1	3
PORTAGE CREEK	830729	1.40	1.50	COBBLE	LARGE GRAVEL	10.1	10.1	3
PORTAGE CREEK	830729	2.30	1.54	COBBLE	LARGE GRAVEL	9.5	10.[illegible]	4
PORTAGE CREEK	830729	1.70	2.20	RUBBLE	LARGE GRAVEL	8.2	9.1	4
PORTAGE CREEK	830729	1.10	1.11	LARGE GRAVEL	RUBBLE	10.3	10.3	5
PORTAGE CREEK	830729	2.00	2.70	COBBLE	RUBBLE	10.5	10.5	5
PORTAGE CREEK	830729	1.40	2.10	RUBBLE	LARGE GRAVEL	12.0	12.1	6
PORTAGE CREEK	830729	1.50	1.40	RUBBLE	LARGE GRAVEL	10.7	10.1	6
PORTAGE CREEK	830729	1.60	1.47	RUBBLE	COBBLE	11.6	12.1	7
PORTAGE CREEK	830729	1.00	1.60	RUBBLE	LARGE GRAVEL	10.4	10.9	7
PORTAGE CREEK	830729	1.10	1.58	COBBLE	LARGE GRAVEL	11.8	12.2	8
PORTAGE CREEK	830729	1.50	1.70	RUBBLE	LARGE GRAVEL	10.9	11.0	8
PORTAGE CREEK	830729	1.40	2.10	RUBBLE	COBBLE	12.1	12.5	9
PORTAGE CREEK	830729	1.10	1.80	RUBBLE	LARGE GRAVEL	10.9	10.9	9
PORTAGE CREEK	830729	1.70	1.96	COBBLE	RUBBLE	12.3	12.5	10
PORTAGE CREEK	830729	.60	1.20	RUBBLE	LARGE GRAVEL	10.4	10.7	10
PORTAGE CREEK	830729	1.40	1.51	RUBBLE	LARGE GRAVEL	12.5	12.5	11
PORTAGE CREEK	830729	1.10	1.80	COBBLE	RUBBLE	11.4	11.1	11
PORTAGE CREEK	830729	1.60	2.20	RUBBLE	LARGE GRAVEL	11.8	12.5	12
PORTAGE CREEK	830729	1.00	2.80	COBBLE	RUBBLE	11.1	11.4	12
PORTAGE CREEK	830729	1.60	1.96	COBBLE	RUBBLE	11.7	12.6	13
PORTAGE CREEK	830729	1.10	1.90	RUBBLE	LARGE GRAVEL	11.0	11.3	13
PORTAGE CREEK	830729	1.60	1.92	RUBBLE	LARGE GRAVEL	12.6	12.6	14

Table 9-A-1. Continued.

LOCATION	DATE	DEPTH (FT)	WATER VELO-CITY (FT/S)	SUBSTRATE PRIMARY	SUBSTRATE SECONDARY	WATER TEMPERATURE (C) INTRAGRAVEL	WATER TEMPERATURE (C) SURFACE	REDD NO.
PORTAGE CREEK	830729	1.30	2.20	RUBBLE	LARGE GRAVEL	11.2	11.3	14
PORTAGE CREEK	830729	1.20	3.74	RUBBLE	LARGE GRAVEL	12.5	12.6	15
PORTAGE CREEK	830729	1.20	1.70	COBBLE	RUBBLE	11.6	11.5	15
PORTAGE CREEK	830729	1.40	1.70	COBBLE	RUBBLE	11.8	11.7	16
PORTAGE CREEK	830729	1.50	1.90	BOULDER	RUBBLE	11.7	11.7	17
PORTAGE CREEK	830729	1.80	3.00	BOULDER	COBBLE	11.7	11.7	18
PORTAGE CREEK	830729	.70	1.90	COBBLE	RUBBLE	9.6	11.1	19
PORTAGE CREEK	830729	1.10	2.20	RUBBLE	LARGE GRAVEL	10.7	10.9	20
PORTAGE CREEK	830729	1.60	1.20	LARGE GRAVEL	SMALL GRAVEL	11.7	12.6	21
PORTAGE CREEK	830729	1.30	1.00	COBBLE	RUBBLE	12.6	12.2	22
PORTAGE CREEK	830729	2.50	2.50	RUBBLE	LARGE GRAVEL	13.0	12.9	23
PORTAGE CREEK	830729	2.70	1.50	RUBBLE	LARGE GRAVEL	13.0	12.9	24
PORTAGE CREEK	830730	1.50	2.00	BOULDER	RUBBLE	8.9	8.9	1
PORTAGE CREEK	830730	1.60	1.25	BOULDER	COBBLE	9.3	9.0	2
PORTAGE CREEK	830730	.90	2.00	COBBLE	RUBBLE	9.2	9.0	3
PORTAGE CREEK	830730	1.20	2.80	RUBBLE	LARGE GRAVEL	9.2	9.1	4
PORTAGE CREEK	830730	1.00	1.50	COBBLE	RUBBLE	9.4	9.4	5
PORTAGE CREEK	830730	.70	2.60	BOULDER	COBBLE	9.4	9.5	6
PORTAGE CREEK	830730	1.20	2.00	RUBBLE	LARGE GRAVEL	9.6	9.6	7
PORTAGE CREEK	830730	1.20	2.90	COBBLE	RUBBLE	9.8	9.7	8
PORTAGE CREEK	830730	1.40	2.00	RUBBLE	LARGE GRAVEL	10.1	10.0	9
PORTAGE CREEK	830730	2.30	3.40	COBBLE	RUBBLE	9.7	9.8	10
PORTAGE CREEK	830730	1.20	1.80	COBBLE	RUBBLE	9.9	10.0	11
PORTAGE CREEK	830730	2.70	3.00	COBBLE	RUBBLE	10.0	9.9	12
PORTAGE CREEK	830730	1.60	2.40	COBBLE	RUBBLE	10.0	9.8	13

Table 9-A-1. Continued.

LOCATION	DATE	DEPTH (FT)	WATER VELO-CITY (FT/S)	SUBSTRATE PRIMARY	SUBSTRATE SECONDARY	WATER TEMPERATURE (C) INTRAGRAVEL	WATER TEMPERATURE (C) SURFACE	REDD NO.
PORTAGE CREEK	830730	2.00	2.90	COBBLE	RUBBLE	9.9	9.9	14
PORTAGE CREEK	830730	1.20	2.60	COBBLE	LARGE GRAVEL	10.0	9.9	15
PORTAGE CREEK	830730	2.20	3.30	COBBLE	LARGE GRAVEL	9.9	9.8	16
PORTAGE CREEK	830730	2.40	3.40	COBBLE	RUBBLE	9.7	9.6	17
PORTAGE CREEK	830730	1.60	2.60	BOULDER	COBBLE	9.9	9.6	18
PORTAGE CREEK	830730	1.30	1.80	COBBLE	RUBBLE	9.9	9.7	19
PORTAGE CREEK	830730	1.20	1.80	RUBBLE	LARGE GRAVEL	9.6	9.6	20
PORTAGE CREEK	830730	1.40	4.30	COBBLE	RUBBLE	9.8	9.7	21
PORTAGE CREEK	830730	1.60	1.90	COBBLE	RUBBLE	9.7	9.7	22
PORTAGE CREEK	830730	1.70	2.30	COBBLE	RUBBLE	9.7	9.6	23
PORTAGE CREEK	830730	1.20	2.60	COBBLE	RUBBLE	9.5	9.3	24
PORTAGE CREEK	830730	2.70	1.55	RUBBLE	LARGE GRAVEL	9.6	9.3	25
CHEECHAKO CREEK	830805	2.20	1.00	COBBLE	LARGE GRAVEL	11.9	11.7	1
CHEECHAKO CREEK	830805	.90	2.40	LARGE GRAVEL	RUBBLE	11.4	11.3	2

APPENDIX 9-B
Chinook Salmon Utilization Statistics

Table 9-B-1 Summary of variance statistics and tests for various groupings for chinook salmon utilization depth histograms..

HISTOGRAM LABEL	INCREMENT SIZE	INCREMENT START	VARIANCE	df
A	Ø.1	Ø.Ø	87.5336	22
B	Ø.2	Ø.Ø	353.5379	11
C	Ø.2	Ø.1	44Ø.Ø9Ø9	1Ø
D	Ø.3	Ø.Ø	682.Ø278	8
E	Ø.3	Ø.1	726.9821	7
F	Ø.3	Ø.2	632.41Ø7	7

LEVENE'S TEST

F STATISTIC	df	PROB
5.99ØØØØ	5,65	Ø.ØØØ1

PAIRWISE COMPARISONS

PAIR	df	F VALUE	PROB
A,B	11,22	4.Ø38882	Ø.ØØ26
A,C	1Ø,22	5.Ø2768Ø	Ø.ØØØ8
A,D	8,22	7.791611	Ø.ØØØ1
A,E	7,22	8.3Ø5178	Ø.ØØØ1
A,F	7,22	7.224777	Ø.ØØØ2
B,C	1Ø,11	1.24482Ø	Ø.36ØØ
B,D	8,11	1.92915Ø	Ø.15ØØ
B,E	7,11	2.Ø563Ø6	Ø.14ØØ
B,F	7,11	1.7888Ø6	Ø.19ØØ
C,D	8,1Ø	1.549743	Ø.25ØØ
C,E	7,1Ø	1.651891	Ø.23ØØ
C,F	7,1Ø	1.437ØØØ	Ø.29ØØ
D,E	7,8	1.Ø65913	Ø.46ØØ
D,F	8,7	1.Ø78457	Ø.47ØØ
E,F	7,7	1.149541	Ø.43ØØ

Table 9-B-2. Comparison of incremented mean and standard deviation values with non-incremented values for various groupings for chinook salmon depth and velocity histograms.

Variable	Histogram Label	Incremented Mean	Non-Incremented Mean	Percent Deviation From Non-Incremented Mean	Incremented Stand. Dev.	Non-Incremented Stand. Dev.	Percent Deviation Fron Non-Incremented Stand. Dev.
Depth (ft)	A	1.40	1.44	3.2	0.46	0.45	2.2
	B	1.40	1.44	3.4	0.46	0.45	1.5
	C	1.41	1.44	2.5	0.43	0.45	4.1
	D	1.45	1.44	0.5	0.50	0.45	11.4
	E	1.40	1.44	3.0	0.48	0.45	6.6
	F	1.46	1.44	0.9	0.49	0.45	8.5
Velocity (ft/sec)	A	2.11	2.13	0.8	0.77	0.73	4.4
	B	2.08	2.13	2.4	0.73	0.73	0.3
	C	2.09	2.13	1.6	0.73	0.73	0.6
	D	2.17	2.13	1.9	0.75	0.73	2.2
	E	2.12	2.13	0.4	0.77	0.73	5.2
	F	2.16	2.13	1.8	0.76	0.73	3.6

Table 9-B-3. Summary of variance statistics and tests for various groupings for chinook salmon utilization velocity histograms.

HISTOGRAM LABEL	INCREMENT SIZE	INCREMENT START	VARIANCE	df
A	0.1	0.0	33.7549	40
B	0.2	0.0	116.3476	20
C	0.2	0.1	117.7763	19
D	0.3	0.0	244.8407	13
E	0.3	0.1	284.2381	14
F	0.3	0.2	236.8407	13

LEVENE'S TEST

F STATISTIC	df	PROB
5.300000	5,119	0.0002

PAIRWISE COMPARISONS

PAIR	df	F VALUE	PROB
A,B	20,40	3.446836	0.0004
A,C	19,40	3.489162	0.0004
A,D	13,40	7.253486	0.0000
A,E	14,40	8.420647	0.0000
A,F	13,40	7.016484	0.0000
B,C	19,20	1.012280	0.4900
B,D	13,20	2.104390	0.0650
B,E	14,20	2.443008	0.0330
B,F	13,20	2.035630	0.0740
C,D	13,19	2.078862	0.0720
C,E	14,19	2.413373	0.0380
C,F	13,19	2.010937	0.0810
D,E	14,13	1.160910	0.4000
D,F	13,13	1.033778	0.4800
E,F	14,13	1.200124	0.3700

Appendix Table 9-B-4. Bivariate correlation statistics for evaluating independence of habitat variables used in the development of suitability criteria curves for chinook salmon.

Comparison	n	r	Zd	Approximate Probability*
Chum				
Depth Vs. Velocity	265	0.12	-1.33	0.90
Substrate Vs. Depth	265	0.06	-2.37	0.99
Substrate Vs. Velocity	265	0.20	0.07	0.47

* Probabilities associated with the hypothesis that H_0: $|\rho| \leq 0.2$.

Note that low values of probability lead to rejection of H_0.