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Fish Habitat and Instream Flow Relationships in the Middle Reach of the Susitna River: An Extrapolation Methodology

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Abstract

This document outlines a methodology for extrapolating habitat data obtained at intensively studied areas to the remainder of the middle Susitna River in order to describe the integrated response of fish habitat within the river segment to streamflow variations under ice-free conditions. It is assumed that the habitat availability and responses determined at intensively studied sites are representative of habitat conditions in all nonstudied sites within the same category. The extrapolation is based on the supposition that the presence of upwelling is essential for the successful spawning of chum and sockeye salmon, and that rearing fish respond directly to instream hydraulic and water quality conditions.

The extrapolation method is applicable to evaluating existing and with-project habitat potential for a broad range of habitat categories, species, and life stages. At present we feel that only slough and side channel habitats, chum and sockeye spawning, and chum and chinook rearing may be profitably addressed on a quantitative basis.

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Introduction

This document outlines a methodology for evaluating the availability of rearing and spawning habitat for salmon within the Talkeetna-to-Devil Canyon segment, also known as the middle reach, of the Susitna River. Our intent is to provide a means of extrapolating habitat data obtained at intensively studied areas to the remainder of the middle river in order to describe system response to streamflow variations under ice-free conditions. The method ranks study sites at which salmon utilization and habitat data have been collected into discrete categories based upon several related physical and biological criteria. Areas in the middle river for which little or no fisheries data exists have been grouped with intensively studied sites having similar physical characteristics based on field observations and an examination of aerial photographs. It is important that a positive relationship be demonstrated between salmon utilization or habitat availability and the hydraulic, geomorphic, and hydrologic characteristics used to rank studied and non-studied areas into distinct categories such that spawning and rearing habitat availability indices developed for the intensively studied sites may be considered representative of associated non-studied sites. Since an estimate of the surface area of all sites is available for a wide range of mainstem discharges, a habitat availability index, determined separately for spawning and rearing salmon, may be expressed for each category as a function of streamflow. When habitat availability indices for all habitat categories are combined, a composite picture emerges of the existing relationship between habitat availability and discharge for the entire middle reach of the Susitna River.

This approach has the additional merit of being applicable to with-project impact analyses since the abiotic environment resulting from the with-project flow regimen may be forecast with a comparatively high degree of confidence. The assumption required is that expected changes in habitat quality and quantity will be attended by adjustments in the distribution and relative abundance of fish populations. Based on our current knowledge of annual variations in habitat utilization within specific areas as a function of year-to-year variations in discharge, this assumption appears justified.

Mention should be made of the terminology used in this paper. We are concerned with <u>fish habitat</u>, that is, the milieu of environmental conditions to which a typical individual of the species in question responds both behaviorally and physiologically. More specifically, we are interested in the environmental variables which influence the growth, reproduction, and survival of the fish. Important biological factors include food availability, parasitism or disease, and predation. It is generally recognized that temperature, water depth and velocity, cover or shelter, and streambed material are the most important physical variables affecting the amount and quality of instream fish habitat (Hynes 1972).

Although it may be assumed that varying these physical variables in time and space has direct consequences in terms of fish distribution and abundance, it should be emphasized that habitat variables are usually not independent of one another and must be considered in combination. Under some circumstances, however, the utility of specific areas as fish habitat may be determined by one or two dominant environmental factors whose importance overshadows the combined effects of all other biologic factors and physical variables. An example is the overriding importance of adequate passage depths for adult salmon downstream of spawning areas. In many cases, the factors which control or limit the fish population may not be known, primarily because their effects are exerted at locations outside the watershed or at times when no data are collected. Flooding, streambed instability, anchor ice buildup, and ice floe scouring are transient yet recurrent phenomena within the Susitna River which affect the long-term quality and persistence of fish habitat.

Care must be taken to distinguish between fish habitat and habitat type. The latter term designates major categories of aquatic habitat having visually recognizable hydraulic and morphologic characteristics that are apparent in aerial photography (Figure 1). Six habitat types have been identified within the middle reach of the Susitna River: mainstem, side channel, side slough, upland slough, tributary, and tributary mouth (ADF&G 1983). The geographical location and persistence of certain habitat types, such as tributaries and their mouths, are generally fixed. In other instances, a given section of the river may exist as one habitat type at high discharges and as another at lower flows. An example is the transformation of some side channels into side sloughs as mainstem stage recedes below the thalweg elevation at their heads. An important characteristic of these sites, in regard to their value as fish habitat, appears to be the frequency and duration of time they exist as side channels or side sloughs.

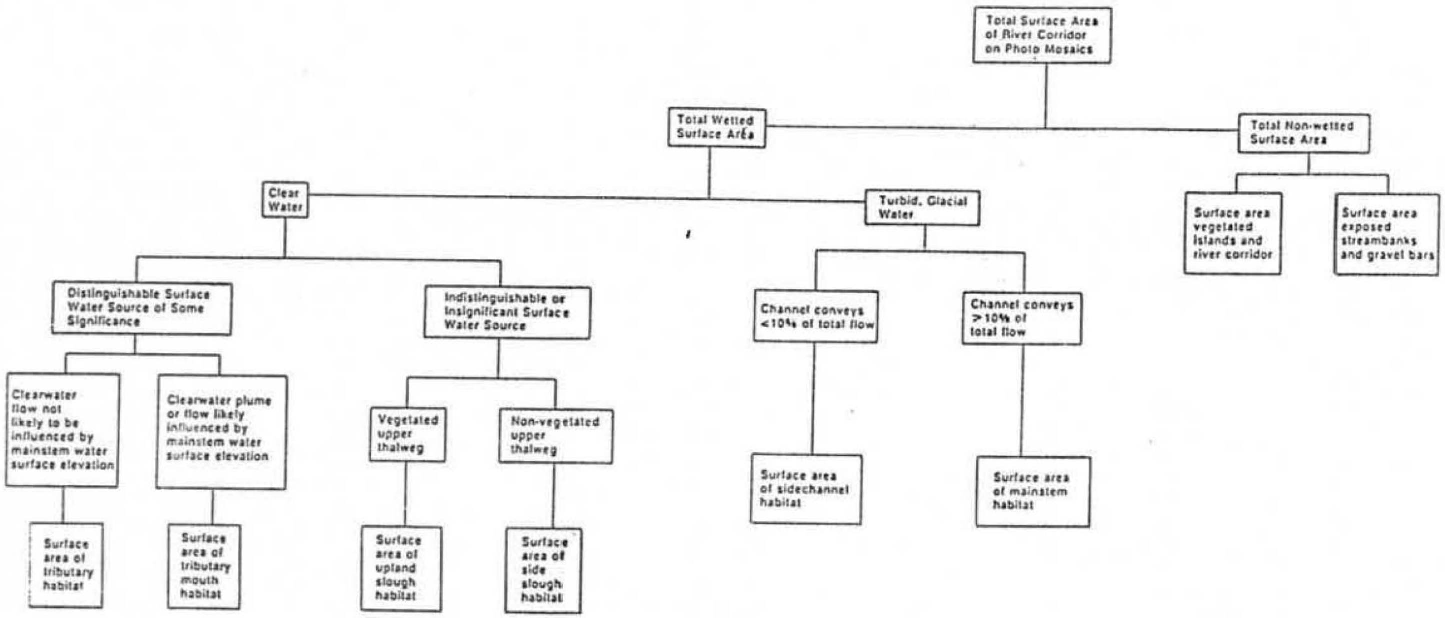

Figure 1. Classification of aquatic habitat types for the Talkeetna-to-Devil Canyon reach of the Susitna River. Source: E. Woody Trihey & Associates (1984).

Utilization of Habitat Types

Utilization data available from 1981-83 spawners surveys by the Alaska Department of Fish and Game (ADF&G 1984a) suggest that tributaries, side sloughs and, to a lesser extent, side channels are the primary spawning areas of the five species of salmon which occur in the Susitna River (Figure 2). A comparatively small number of fish spawn in mainstem, upland slough, and tributary mouth habitats. Since the extent and quality of tributary habitat is basically unaffected by mainstem discharge and temperature, we have chosen to omit evaluation of tributary habitat from the extrapolation analysis.

Chum and sockeye salmon are the most abundant of the three species which spawn in habitat types other than tributaries in the Talkeetna-to-Devil Canyon reach of the Susitna River. Small numbers of pink salmon utilize side channels and side sloughs for spawning during even numbered years and are thought to outmigrate within 3 to 5 days after emergence from spawning gravels. Therefore, pink salmon are not considered significant in an analysis of existing habitat conditions.

Of the chum salmon spawning observed within mainstem, side channel, and side slough areas, the latter habitat type appears to be the most preferred. Approximately 80% of all chum salmon spawning outside of tributaries has been documented in side sloughs (ADF&G 1981, 1982, 1984a). Side channel and mainstem areas, however, are often characterized by highly turbid water in which spawning fish or their redds are difficult to detect, possibly causing an underestimate of their value as spawning habitat. Tables 1 and 2 summarize spawner survey information obtained for side

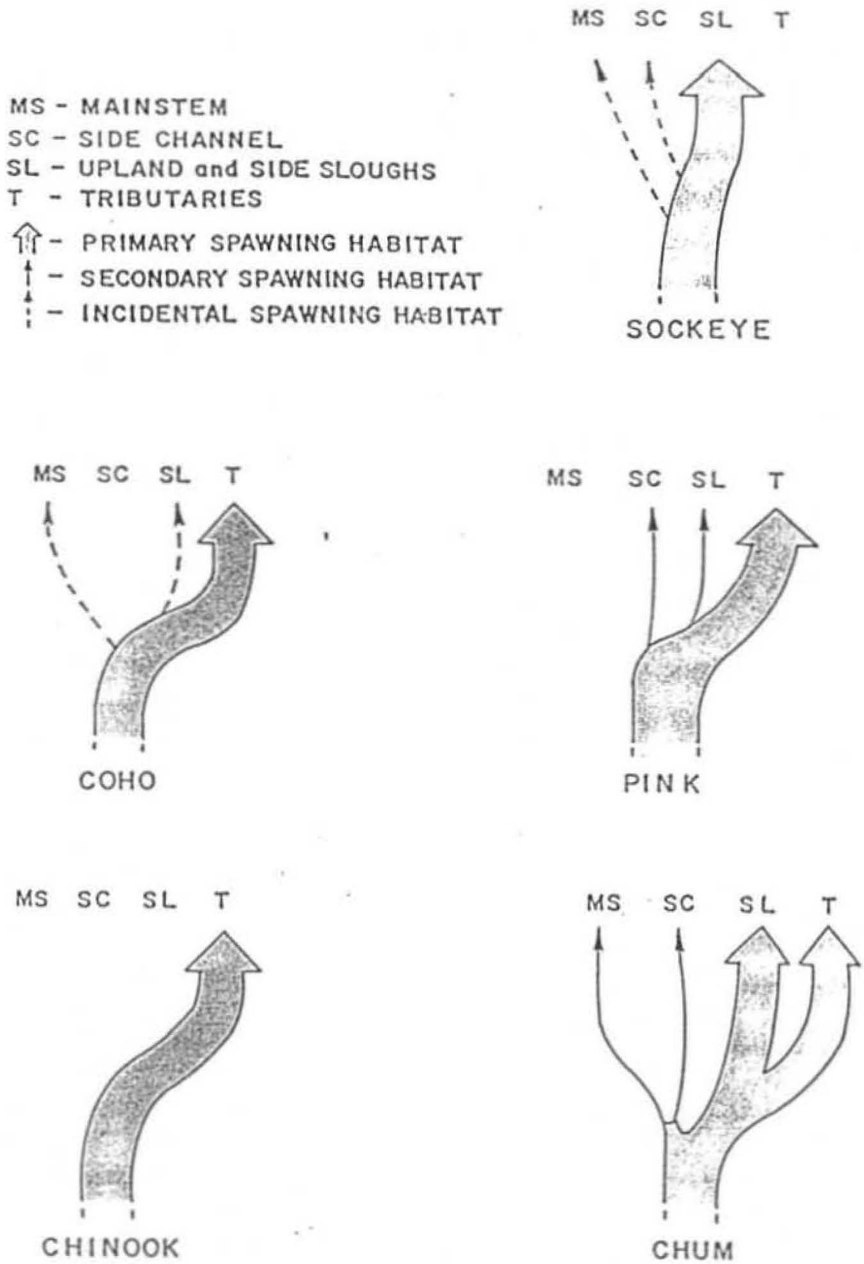

Figure 2. Relative distribution of salmon spawning within different habitat types of the middle Susitna River (ADF&G 1984c).

Table 1. Percent distribution of chum and sockeye (second run) salmon reported for side sloughs in the middle Susitna River based on data averaged for a three-year period (1981-83). Data obtained from ADF&G (1984a).

Slough	River Mile	Percent Distribution	
		Chum Salmon	Sockeye Salmon
1	99.6	0.1	0
2	100.2	1.3	0
3B	101.4	*	0.3
7	113.2	0	0
8	113.7	4.9	0
8C	121.9	0.9	0.1
8B	122.2	3.0	0.3
Moose	123.5	4.2	1.3
8A	125.4	16.1	13.7
B	126.3	1.6	0.6
9	128.3	11.8	0.7
9A	133.8	6.6	0.1
11	135.3	18.0	69.7
13	135.9	0.1	0
14	135.9	0	0
16	137.3	*	0
17	138.9	2.5	0.5
20	140.0	1.8	0.1
21	141.1	21.5	12.6
22	144.5	5.5	0
21A	145.3	0.1	0

* Trace

Table 2. Chum salmon spawning reported for mainstem and side channel areas in the middle Susitna River, 1981-83. Data obtained from ADF&G (1981, 1982, 1984a).

Approximate River Mile	Habitat Category 1/	Spawner Utilization 2/		
		1981	1982	1983
100.5	II	+	0	0
114.9	II	0	++	++
115.1	II	0	0	++
119.0		0	0	++
128.6	II	0	++	0
129.2	VII	+	0	0
129.8	II	+	+	0
130.5	II	+	0	0
131.1	VII	+	+	+
131.3	IV	0	++	+
136.0	II	+	++	+++
136.8		0	0	++
137.4	II	0	++	0
138.2		0	+	0
138.9	II	0	++	++ 3/
148.2		0	+++	0

1/ See Table 5 for habitat category descriptions. Sites which are not assigned a category number are found in areas which are classified as mainstem habitat at both 23,000 and 9,000 cfs.

2/ Utilization Codes:

0	No spawners or redds reported
+	Less than 10 spawners or redds reported
++	10 to 100 spawners reported
+++	Over 100 spawners reported

3/ Eleven spawning sockeye salmon observed 9/15/83 slough, side channel, and mainstem areas within the middle reach during 1981-83. The number of chum salmon reported from these three habitat types averaged 2,300 fish/year over this time period.

In 1983, 11 sockeye and 56 chum salmon adults were observed spawning in the mainstem Susitna River immediately upstream of the mouth of the Indian River (ADF&G 1984a). This is the only recorded occurrence of sockeye spawning in areas other than side slough habitats. In regard to side slough spawning, an average of 760 sockeye spawned annually in the Talkeetna-to-Devil Canyon reach. These fish were distributed among 12 of the 21 side sloughs found in the 50-mile long reach of the middle river (Table 1). It should be noted that chum and sockeye salmon spawning areas overlapped within all of the side sloughs in which sockeye redds were found (ADF&G 1984a).

Juvenile chum and chinook salmon are the most abundant salmonid species which rear in the side slough and side channel habitats of the middle Susitna River (Figure 3). They are therefore most susceptible in terms of overall numbers affected to rearing habitat perturbations. For this reason, these two species have been selected for evaluating rearing habitat within the entire middle reach of the Susitna River. Habitat for juvenile salmon is generally provided for by all habitat types; however, fish densities are usually highest in side slough and side channel areas. The sole exception is coho salmon, which rear predominatly in upland sloughs. Extensive sampling for juveniles has not been conducted in mainstem habitats, largely due to sampling gear inefficiency in the typically deep, fast and turbid waters of the mainstem river. Therefore, utilization of the

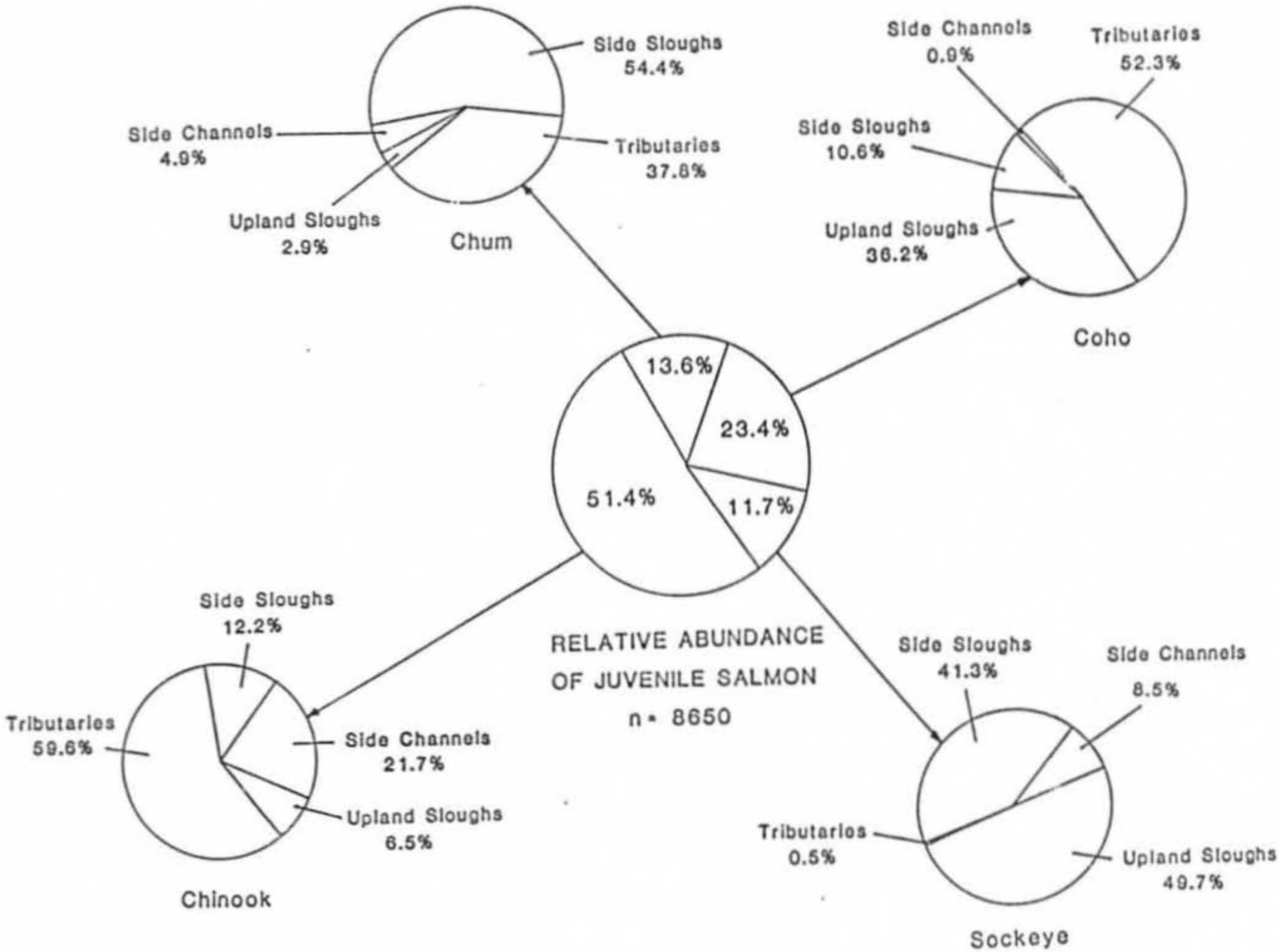

Figure 3. Relative abundance and distribution of juvenile salmon within different habitat types of the middle Susitna River (ADF&G 1984b).

lateral margins of these habitats by juvenile salmon may be greater than indicated by the available data.

Surface Area Response of Habitat Types

The total surface area of each habitat type in the Talkeenta-to-Devil Canyon reach has been estimated for mainstem discharges ranging from 9,000 to 23,000 cfs (USGS gage 15292000) using digital measurements on 1 inch = 1,000 feet aerial photographs (Figure 4). The surface areas associated with upland sloughs, tributaries and tributary mouths collectively represent less than 1.3% of the total surface area of the middle reach, and habitat types exhibit little change in response to mainstem discharge. At times surface areas of these habitat types may respond more to seasonal patterns of local precipitation and runoff than to variations in mainstem discharge.

Comparatively large differences in surface areas of mainstem, side channel, and side slough habitat is apparent between mainstem discharges of 9,000 and 23,000 cfs. From an inspection of Figure 4 it may be seen that side channel and side slough surface areas are inversely related. Fish distribution data also indicate side sloughs and side channels are the most extensively utilized portions of the river corridor. Hence, it is these habitat types which are of principal interest in terms of assessing existing and potential fisheries values.

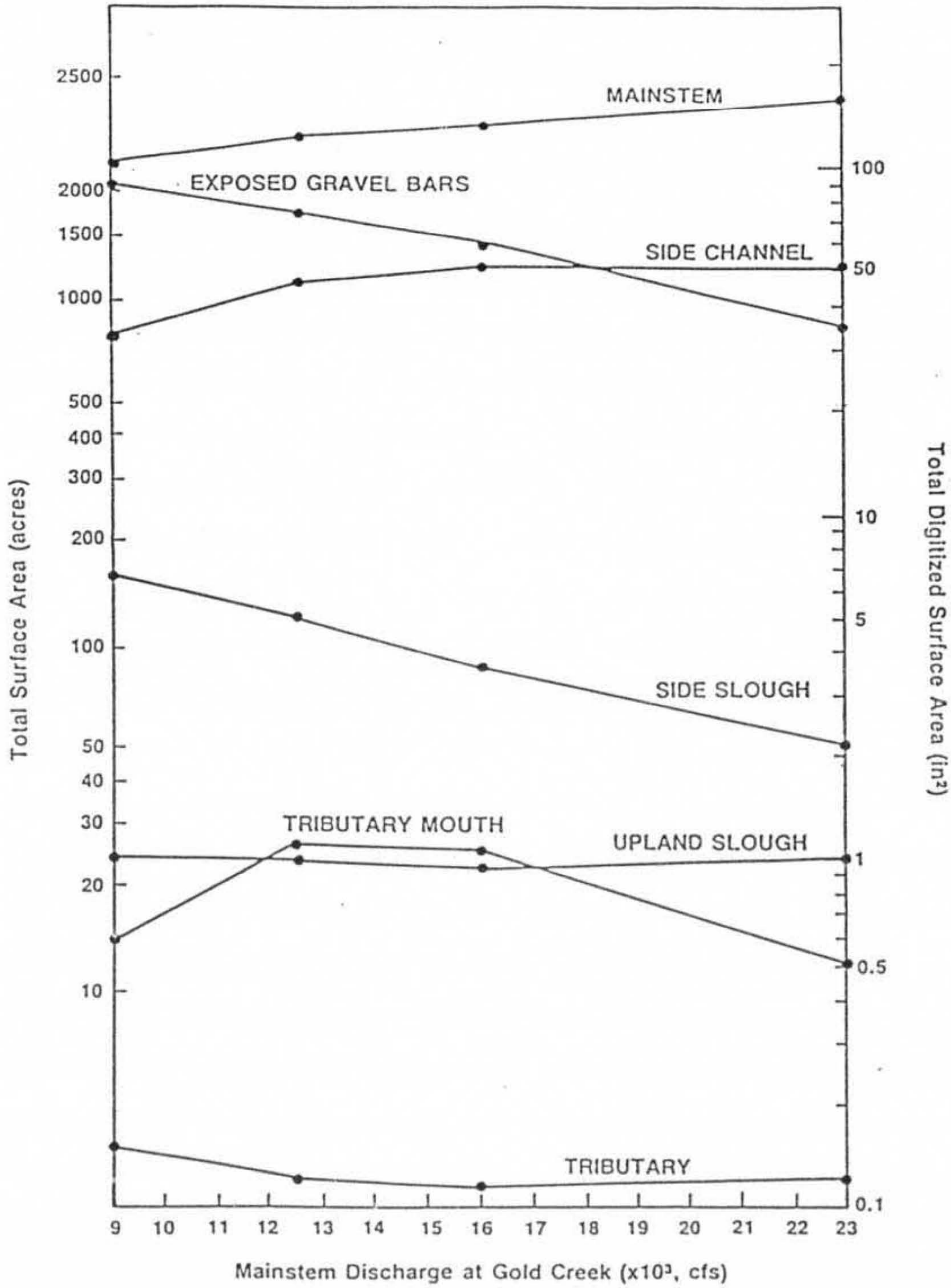

Figure 4. Surface area responses of habitat types to mainstem discharges in the middle Susitna River. Source: E. Woody Trihey & Associates (1984).

Habitat Attribute Preferences

Considerable information has been gained by ADF&G studies of the habitat preferences exhibited by spawning chum and sockeye salmon (ADF&G 1984c). Preference for a given habitat variable is expressed in the form of a suitability function which stochastically describes the relationship between the variable and fish behavior (Baldrige and Amos 1981). Species-specific suitability functions, or criteria, developed for spawning chum and sockeye salmon are based on a large number of measurements obtained at redd sites in side slough and side channel areas of the middle Susitna River. These data are modified slightly to account for the proportional distribution of acceptable habitat within the immediate areas in which redds were located. Suitability criteria have been defined for spawning chum and sockeye for several habitat attributes, including depth, velocity, substrate and upwelling (Figures 5 and 6). For both species, depths exceeding 0.8 feet were found to have a negligible effect on redd site selection in side sloughs and side channels. Velocities selected most frequently by chum and sockeye salmon fall within the range of 0.0 to 1.0 feet/second. Accordingly, maximal suitability values are assigned to these velocities. Utilization declines gradually at higher velocities but rapidly at lower velocities, resulting in slightly skewed, bell-shaped suitability curves. Substrate sizes preferred by the two species are similar, although chum salmon are capable of excavating larger bed materials than sockeye due to their larger body size. The presence of groundwater upwelling has been directly linked with redd site selection by both chum and sockeye salmon spawning within the middle reach of the Susitna River. Since measurements of upwelling rates are difficult to

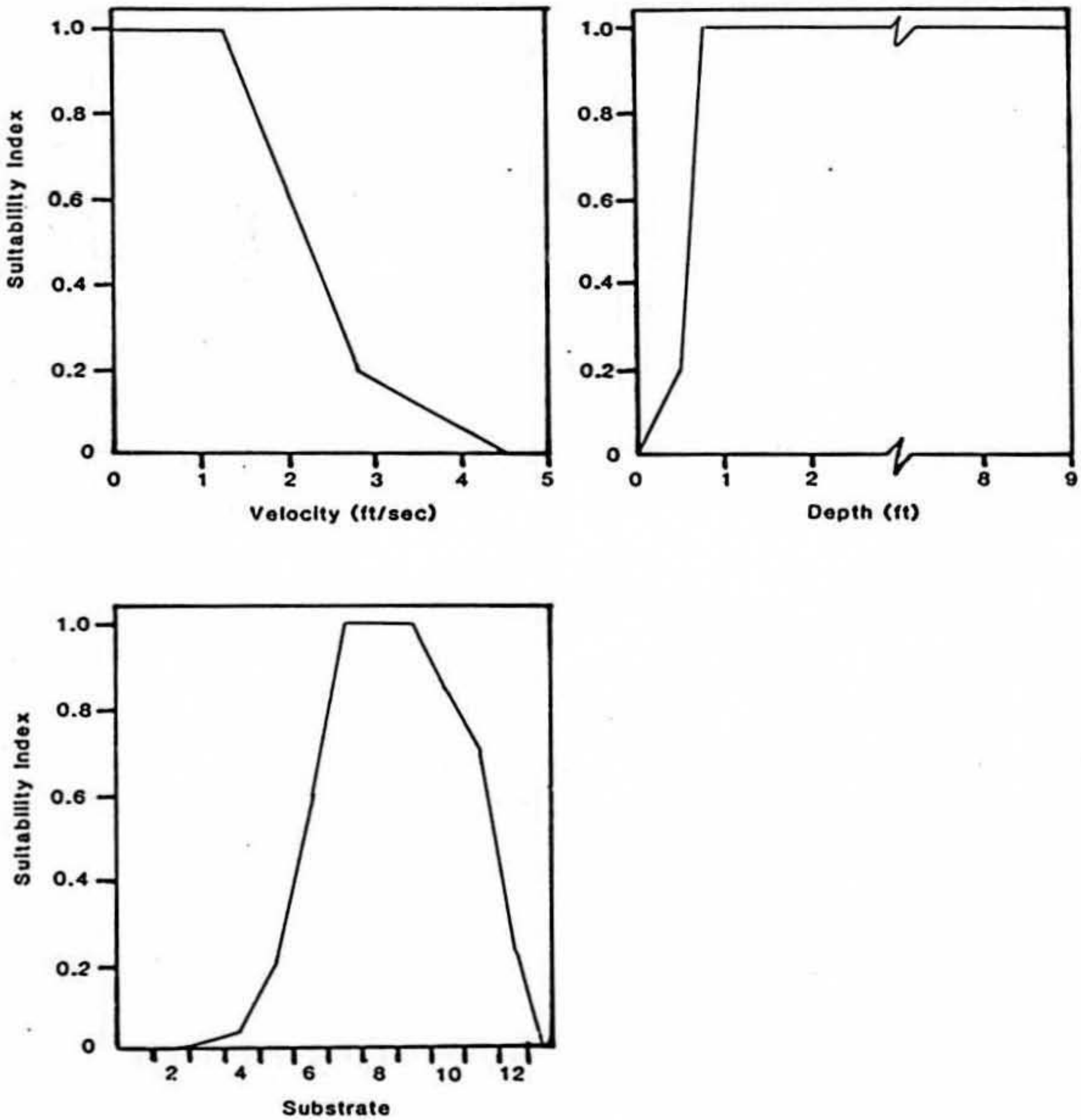

Figure 5. Velocity, depth, and substrate suitability criteria for spawning chum salmon in side sloughs and side channels of the middle Susitna River. Modified from ADF&G (1984c).

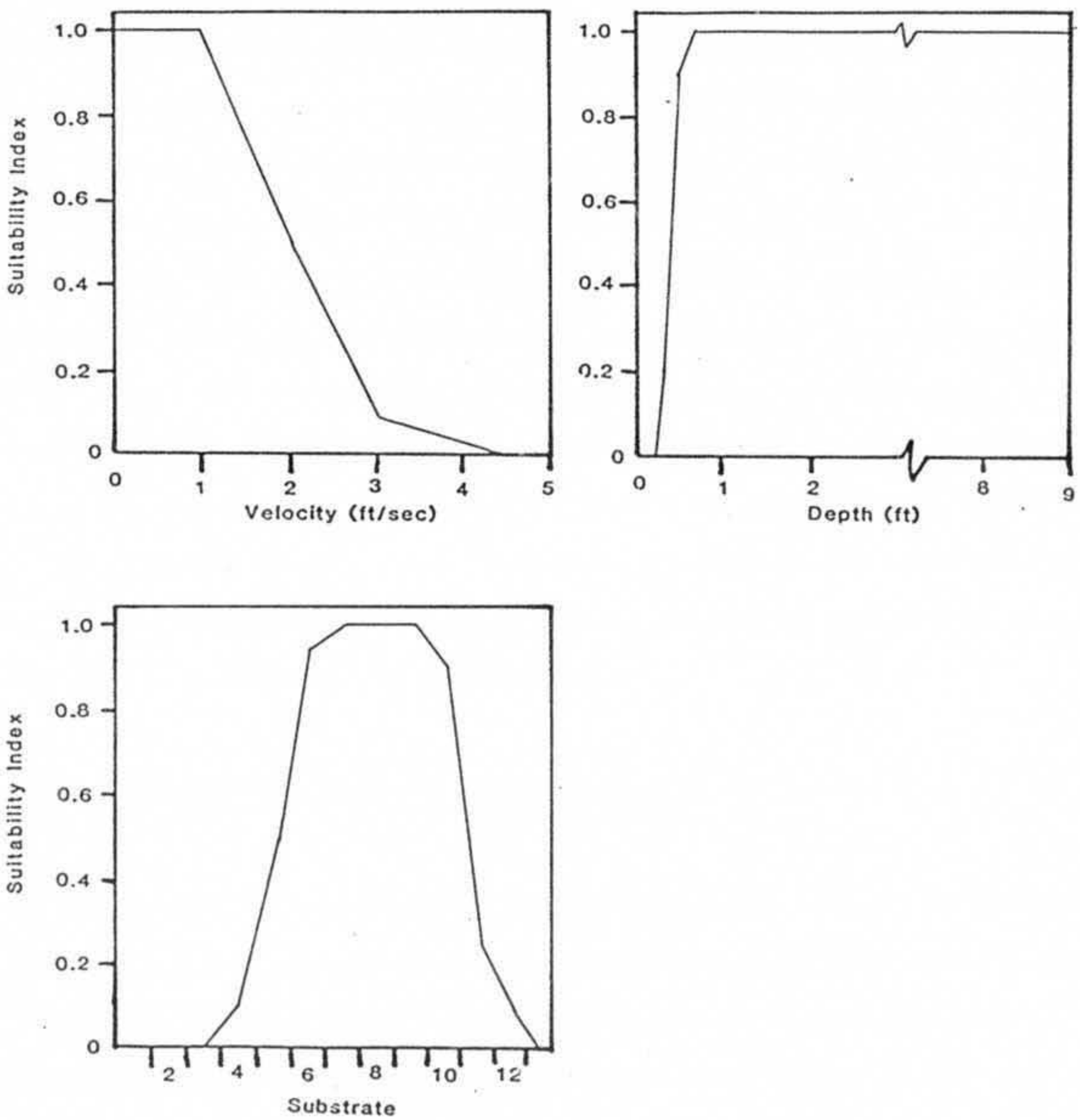

Figure 6. Velocity, depth, and substrate suitability criteria for spawning sockeye salmon in side sloughs and side channels of the middle Susitna River. Modified from ADF&G (1984c).

obtain in the field, a simple binary criteria indicating preference or no preference for areas in which upwelling is present or absent has been assigned to both species.

Suitability functions similar to those described above for spawning have been developed to assess rearing habitat availability in side sloughs and side channels for juvenile chinook and chum salmon (Figures 7 and 8). The physical variables generally considered important to rearing salmon include water depth, velocity, and the type and amount of cover present. Cover is used by salmonid juveniles as a means of avoiding predation and unfavorable water velocities. Instream objects, such as submerged macrophytes, large substrates and organic debris, and overhanging vegetation in near shore zones provide shelter for juvenile salmonids. A positive correlation between chinook juvenile densities and turbidity levels has also been reported, suggesting that highly turbid water may be preferred by this species for its cover value (ADF&G 1984b).

Habitat Availability (Spawning and Rearing WUA)

Sufficient data has been obtained to effectively model the availability of spawning and rearing habitat at several side slough and side channel study sites. The Weighted Usable Area (WUA)--an index of habitat availability--was calculated for each species/life stage and discharge of interest at each study site. The calculation of WUA roughly equates the area of sub-optimal fish habitat within the study site to an equivalent area of optimal habitat. A sample total surface area and WUA response curve (i.e., WUA expressed as a function of mainstem discharge) is presented in Figure 9 for chinook salmon rearing at Slough 21. Also shown in Figure 9 is the

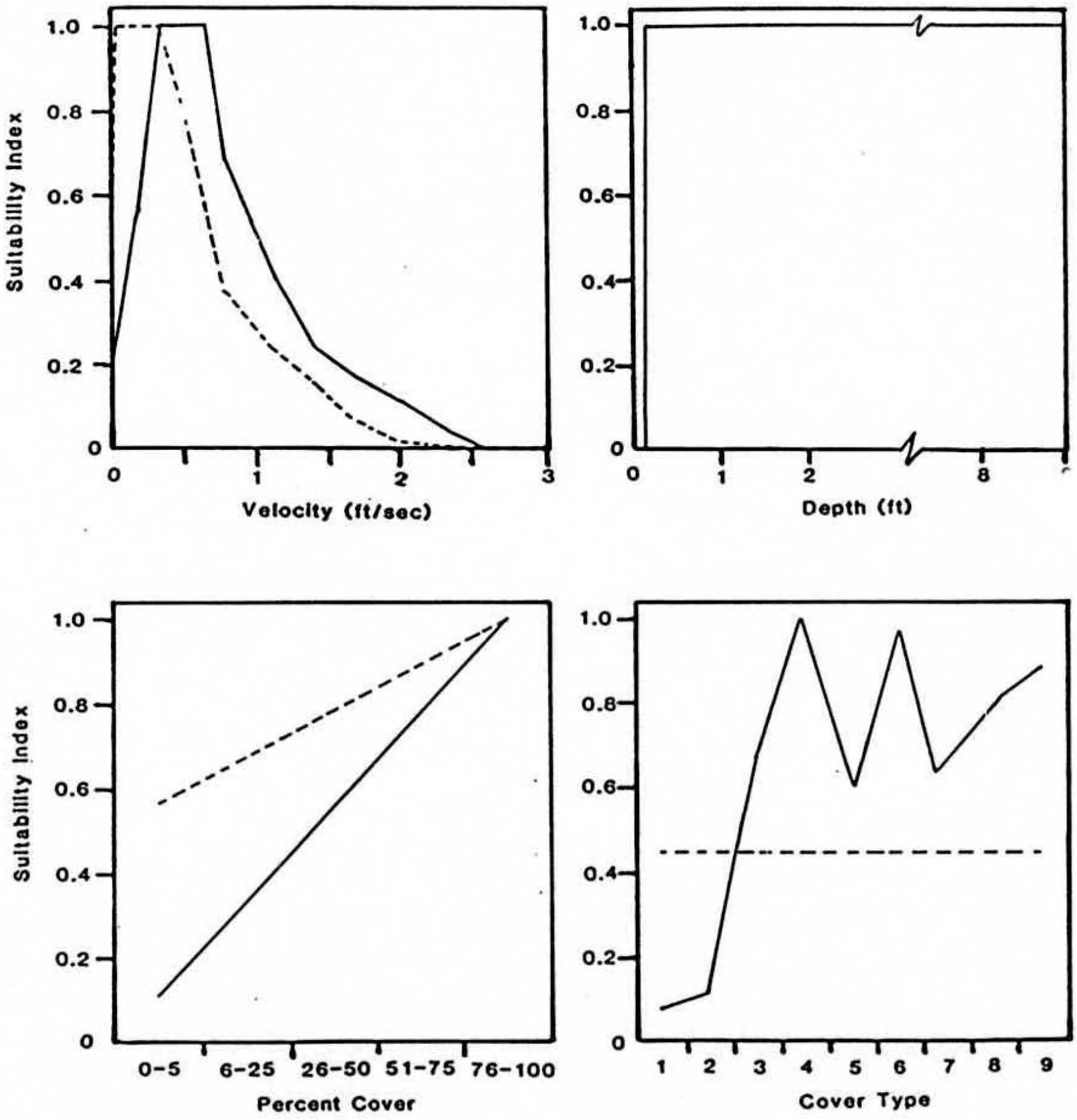

Figure 7. Velocity, depth and cover suitability criteria for juvenile chinook salmon under clear water (solid line) and turbid water (dashed line) conditions in side sloughs and side channels of the middle Susitna River. Cover type codes may be found in ADF&G (1984b).

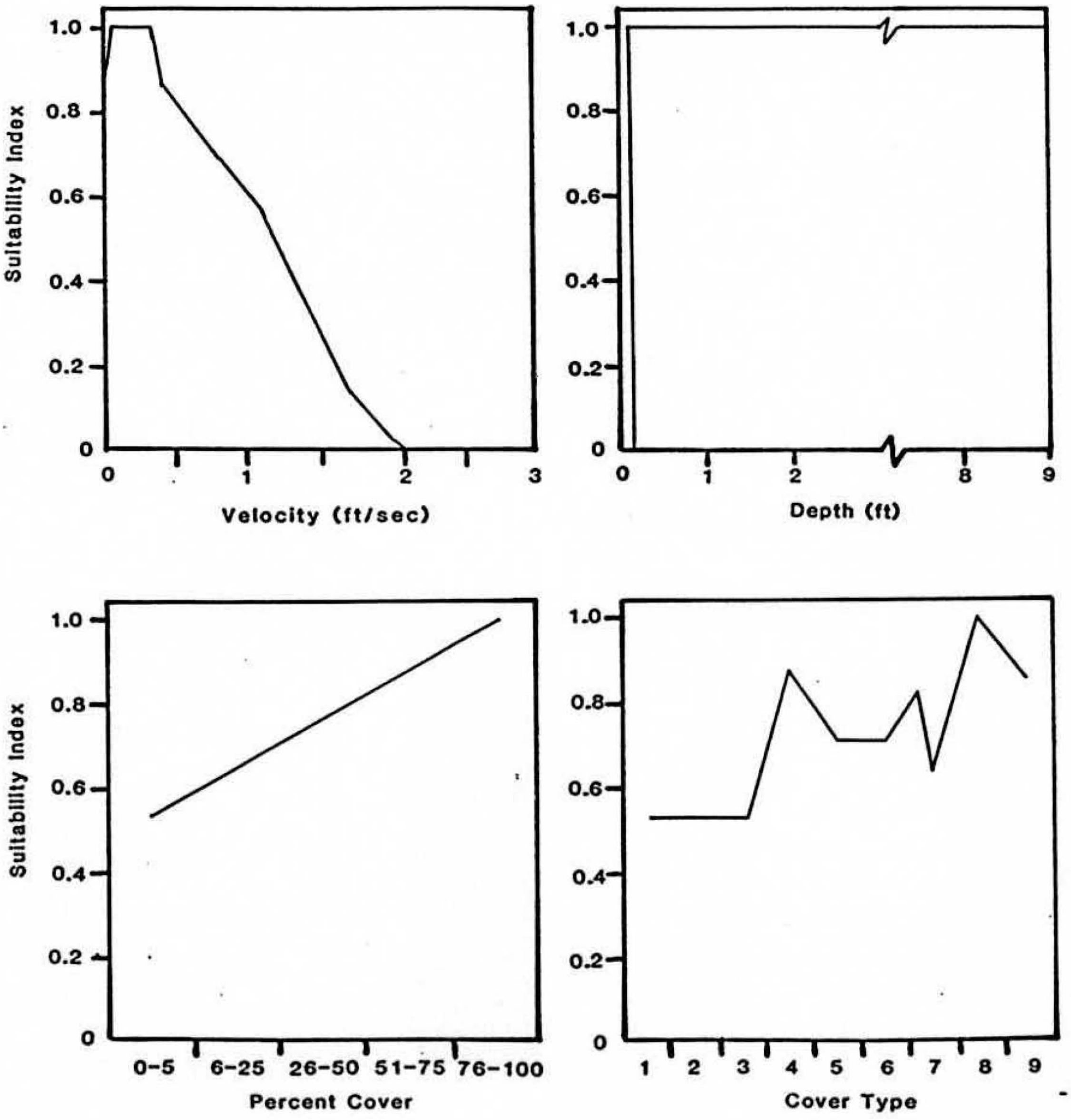

Figure 8. Velocity, depth and cover suitability criteria for juvenile chum salmon in side sloughs and side channels of the middle Susitna River. Cover type codes may be found in ADF&G (1984b).

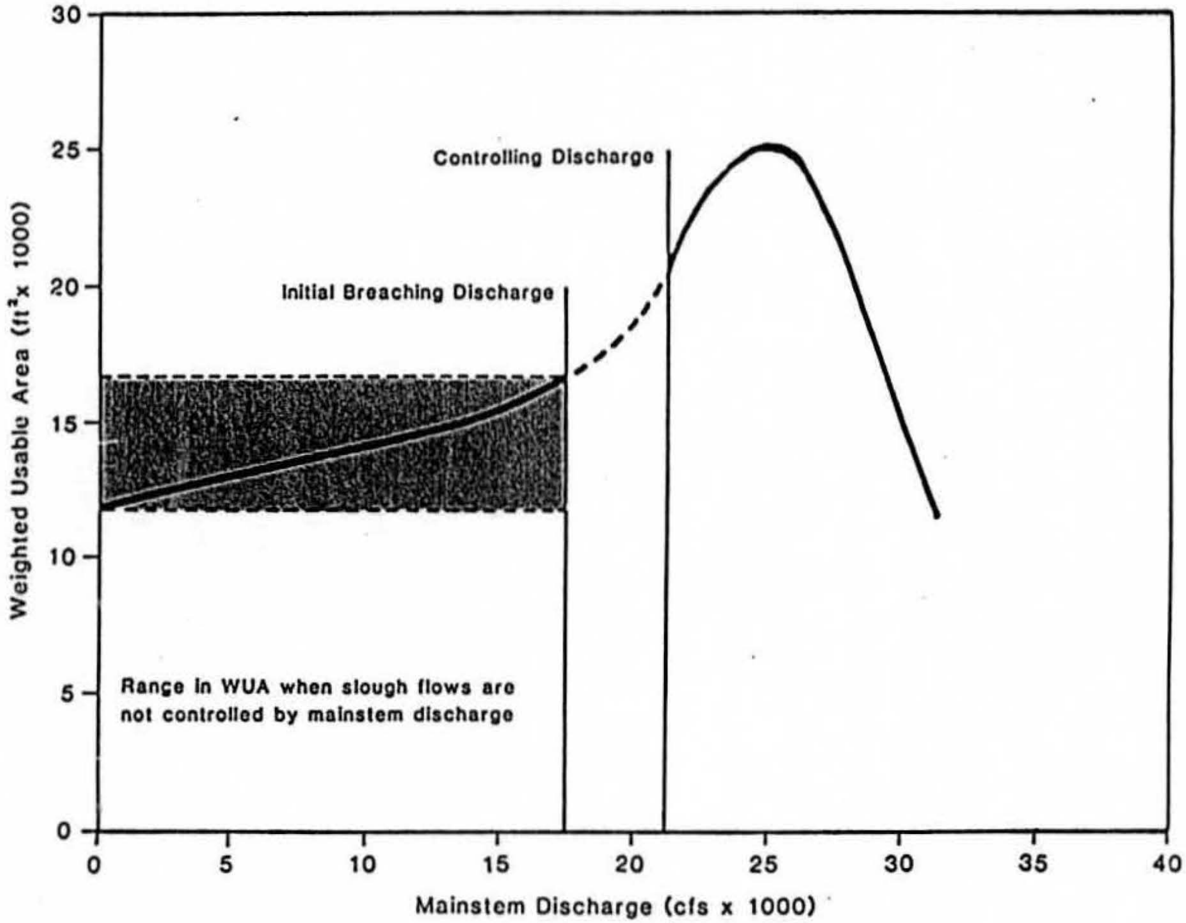

Figure 9. Habitat response curve for juvenile chinook salmon at Slough 21 (RM 141.8) within the extrapolation limits of the habitat model. Clear and turbid water suitability criteria were used to simulate habitat availability for discharges less than 18,000 cfs and greater than 22,700 cfs, respectively. The range in WUA indicated for the unbreached condition is based on slough flows of 5 to 10 cfs. Modified from ADF&G (1984b).

mainstem discharge at which the head of Slough 21 is overtopped. It can be seen that the WUA for chinook juveniles is maximal when the study site possesses side channel characteristics.

A total of three side slough and four side channel study sites have been evaluated to date for chum and chinook rearing and chum and sockeye spawning habitat availability. The rearing and spawning WUA present at each of these sites is listed in Tables 3 and 4 for mainstem discharges of 9,000, 12,500, 16,000, and 23,000 cfs. Habitat could not be modeled for several flow-site combinations due to hydraulic data limitations. The general impression imparted by the tabled values is that both rearing and spawning WUA tend to peak in the 16,000 to 23,000 cfs range for most study sites.

There are two distinct advantages associated with the use of WUA as an index of available fish habitat. The first is that a wide range of flow conditions may be simulated and compared, including flows typical of wet, normal, and dry water years. It is therefore possible to evaluate habitat availability under projected post-project flow conditions. A second advantage to modeling WUA is the modest expenditure of time and money it requires relative to an extensive fish sampling program, often spread out over several years, which attempts to define habitat quality on the basis of utilization data. For a river as large and complex as the Susitna, an exhaustive survey of fish populations is cost prohibitive. Sufficient fisheries data has been collected, however, to conclude that fish distribution and abundance varies considerably between sites within each habitat type. Superimposed on this spatial variability are short- and

Table 3. Chinook and chum salmon rearing habitat WUA determined for selected modeling sites in the middle Susinta River at mainstem discharges of 9,000, 12,500, 16,000 and 23,000 cfs. The maximum WUA and the associated mainstem discharge (Qmax) for each study site is indicated.

Modeling[1/] Site	Base Slough Flow (cfs)	Over-topping Discharge (cfs)	Species	Qmax (cfs)	WEIGHTED USABLE AREA (x 1,000)				
					Maximum WUA	9,000	12,500	16,000	23,000
Slough 8A	10	33,000	chinook	-	-	2.1	2.1	2.1	2.1
			chum	-	-	22.2	22.2	22.2	22.2
Slough 9	10	16,000	chinook	21,700	33.4	1.8	1.8	30.2	30.4
			chum	22,900	25.8	22.3	22.3	22.3	25.8
Side Channel 10	5	19,000	chinook	21,100	16.6	3.7	3.7	3.7	15.2
			chum	21,600	17.1	10.8	10.8	10.8	16.5
Lower Side Channel 11	-	5,000	chinook	5,900	27.0	25.4	15.0	11.8	-
			chum	5,900	37.2	35.9	21.0	14.0	-
Upper Side Channel 11	5	13,000	chinook	16,000	32.5	10.1	10.1	32.5	25.6
			chum	18,000	31.7	22.9	22.9	27.3	26.4
Side Channel 21	20	9,000	chinook	14,900	33.5	31.9	31.9	30.6	25.1
			chum	14,900	42.3	40.6	40.6	39.9	32.2
Slough 21	5	18,000	chinook	25,000	25.2	1.2	1.2	1.2	20.8
			chum	25,700	20.7	16.4	16.4	16.4	17.2

[1/] Only those sites for which hydraulic simulation data were obtained are presented.

Table 4. Chum and sockeye salmon spawning habitat WUA determined for selected modeling sites in the middle Susitna River at mainstem discharges of 9,000, 12,500, 16,000 and 23,000 cfs. The maximum WUA and the associated mainstem discharge (Qmax) for each study site is indicated.

Modeling[1] Site	Base Slough Flow (cfs)	Over-topping Discharge (cfs)	Species	Qmax (cfs)	WEIGHTED USABLE AREA (x 1,000)				
					Maximum WUA	9,000	12,500	16,000	23,000
Slough 8A	10	33,000	chum	-	-	5.1	5.1	5.1	5.1
			sockeye	-	-	6.0	6.0	6.0	6.0
Slough 9	10	16,000	chum	26,700	9.1	3.4	3.4	3.4	8.5
			sockeye	24,800	7.0	5.6	5.6	5.6	6.8
Side Channel 10	5	19,000	chum	24,900	6.1	0.4	0.4	0.4	3.5
			sockeye	22,900	7.3	1.0	1.0	1.0	7.3
Lower Side Channel 11	-	5,000	chum	5,900	32.8	27.2	24.4	19.3	-
			sockeye	5,900	28.2	20.8	16.6	12.8	-
Upper Side Channel 11	5	13,000	chum	22,800	14.4	5.7	5.7	6.1	14.3
			sockeye	20,600	14.4	8.2	8.2	9.4	11.8
Side Channel 21	20	9,000	chum	12,700	3.8	3.0	3.5	3.2	1.3
			sockeye	12,000	4.8	4.4	3.8	2.6	0.8
Slough 21	5	18,000	chum	28,700	16.4	6.9	6.9	6.9	5.9
			sockeye	27,300	13.7	8.0	8.0	8.0	7.5

[1] Only those sites for which hydraulic simulation were obtained are presented.

long-term temporal fluctuations in population sizes as well as sampling biases associated with deep, fast, and turbid water.

The apparent heterogeneity among study sites within each habitat type is corroborated by the differences observed in WUA estimates. Side channels, for example, do not provide spawning or rearing habitat which is proportional to their wetted surface area or the volume of water which they convey. Similarly, habitat availability varies considerably among the different side sloughs studied. To illustrate this point, chum salmon spawning WUA is plotted in Figure 10 as a function of surface area for six modeled sloughs at typical clear water base flows for each site. The WUA:surface area ratio may be viewed as an efficiency index since it implies that the availability of habitat may be more economical or productive with regard to stream surface area at certain streamflows. Figure 10 indicates that Slough 10 contains far less WUA per unit surface area than do Sloughs 21, 8A, and Upper Side Channel 11 (the latter site is a slough at mainstem discharges of less than 16,000 cfs). Note that the general ranking of sloughs based on their efficiency index values is similar to their percentile ranking based on utilization data (c.f., Table 1).

Extrapolation Method

Due to the natural variability within habitat types, we have divided non-tributary areas of the middle river into discrete categories, each consisting of a population of sites having similar large-scale physical characteristics. A necessary assumption is that the biological potential of all sites within a category may be accurately described by habitat

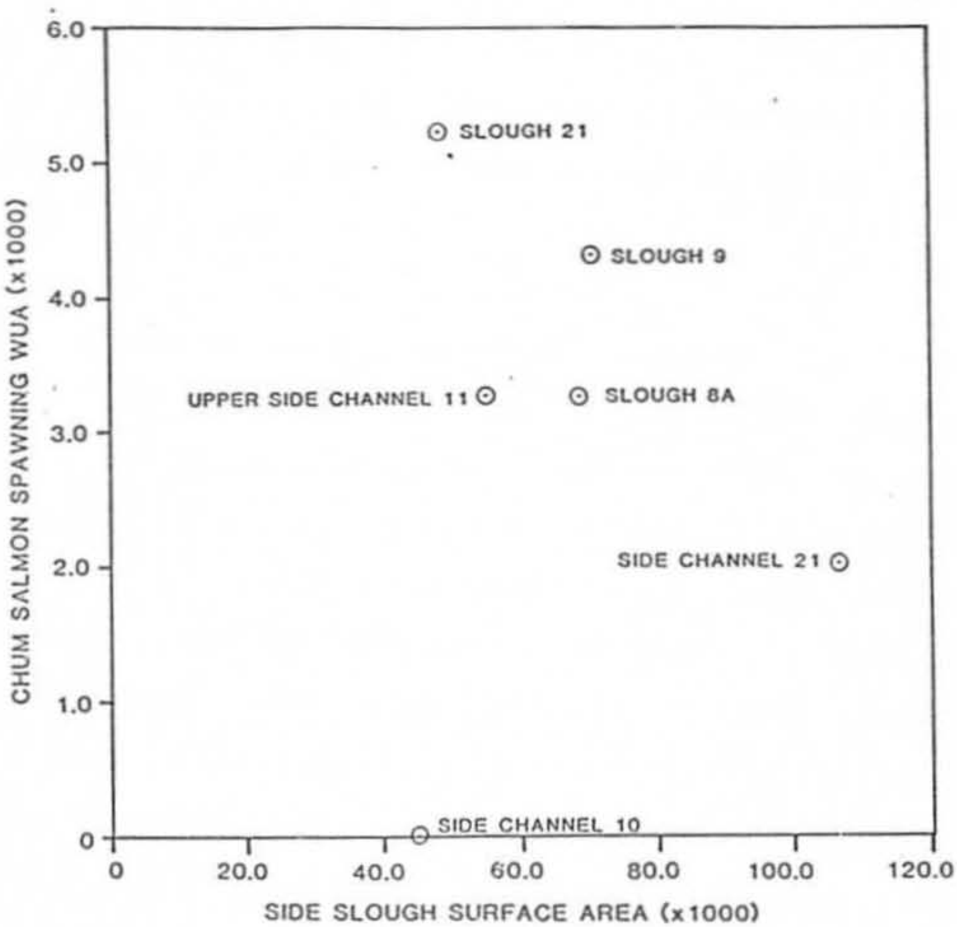

Figure 10. Relationship between WUA and surface area at typical base slough flows for six modeling sites within the middle Susitna River.

indices determined for one or more representative study sites. This assumption is valid if (1) the physical variables incorporated into the habitat model are the dominant environmental factors affecting fish distribution, and (2) the suitability functions relating fish behavior to the physical variables are accurate. In cases where the availability of habitat is determined by a single controlling factor, this factor will be used to initially screen sites prior to the application of modeling results. For example, chum and sockeye sockeye spawning haibtat will be evaluated for each site only if it is determined that passage depths are suitable and upwelling is present.

The physical data necessary to stratify side channel and side slough habitat types falls into two general categories. The first category includes existing data which may be compiled from published and unpublished sources. These data and the preliminary analyses conducted with them are discussed below in the context of study site selection. A second category consists of physical and biological data which may be collected during the 1984 field season. These include variables identified as important in the preliminary analysis, and additional information to be gathered at both modeled and unmodeled sites. As discussed below, the second category of data will also be used to assess the representativeness of the selected modeling sites.

<u>Analytical Constraints</u>

The habitat types which are to be initially evaluated for spawning and rearing habitat availability include side sloughs and side channels. At present, these are the only habitat types meeting the following criteria: (1) they represent a significant proportion of total spawning and rearing habitat within the middle reach of the Susitna River; (2) their distribution and cumulative surface areas may be expected to change significantly under post-project flow conditions; and (3) the existing data base is sufficient to support a quantitative analysis. It is anticipated that selected mainstem and upland slough areas will be included as the analysis progresses.

Chum and sockeye salmon are the primary species of interest in regard to spawning habitat availability within side sloughs and side channels. Rearing habitat availability will be evaluated for chum and chinook salmon within these habitat types. These species have been initially selected due to their relative abundance within side sloughs and side channels, and because habitat suitability criteria are available for use in estimating WUA. Spawning and rearing life stages are to be evaluated for similar reasons. On a population level, the perpetuation of these life history phases at levels supported by existing side sloughs and side channels is of critical importance to the maintenance of salmon stocks within the middle Susitna River.

At present, we feel that only side slough and side channel habitats, chum and sockeye spawning, and chum and chinook rearing may be profitably addressed on a quantitative basis. It should be stressed that the extrapolation method is theoretically applicable to a much wider range of habitat types, species and life stages. Given reasonable cause and sufficient data, additional habitat types and species/life stages can be added to the analysis at a later date.

Analysis of ADF&G data and aerial reconnaissance photography has revealed consistent patterns in the morphological and hydrological features of side slough and side channel sites located in the middle river. The observed patterns form the basis for a preliminary stratification of these habitat types into several categories, and will be discussed separately below for spawning and rearing habitat evaluations. They should not be construed as the final array of categories to be used in the extrapolation analysis. The classification represents an initial attempt at stratification and its principal value at this time is to facilitate study site selection for FY85 field studies in the middle river. The study sites are currently being investigated for rearing and spawning habitat utilization and availability following procedures which are consistent with the extrapolation methodology.

Rearing Habitat

Site-specific investigations of rearing habitat have indicated that rearing fish are directly influenced by cover and velocity. These habitat attributes are functions of streamflow, channel structure and, in the Susitna River, turbidity. Hence a fundamental assumption for extrapolating site-specific habitat responses to nonstudied areas is that portions of the river with channel structure, hydraulic characteristics and turbidity levels similar to the studied areas will possess similar habitat potential and responses.

Based on this assumption, slough, side channel, and mainstem areas pertinent to the evaluation of existing and potential rearing habitat were categorized using various morphologic and hydraulic features discernible in aerial photography obtained at mainstem discharges of 23,000, 16,000, 12,500, and 9,000 cfs. Primary emphasis was placed on the transformation occurring to mainstem and side channel areas in the 23,000 and 9,000 cfs photography. These flows fall within the range of moderate to low discharges conveyed by the middle Susitna River during the ice-free months of the year. Aerial photographs obtained March 2, 1983 when the river was covered with ice were also inspected and open leads which appeared to be caused by upwelling were identified. A visual comparison of the three sets of photographs provided the basis for a preliminary categorization of more than 100 sites. A description of the categories and number of sites within each of the categories is presented in Table 5. The categories are arranged in descending order of importance based on the following criteria: (1) relevance to analyses of existing and potential (i.e., post-project) rearing habitat; (2) total number of sites and surface areas affected; and, (3) ease and reliability of model application to representative study sites. Also indicated is the number of sites for which chum and chinook salmon rearing models have been developed and habitat availability indices have been calculated. Given sufficient time and money, we would recommend that a minimum of three habitat modeling sites be established for each category. Resource constraints, however, dictate that a smaller number of categories and study sites be sampled.

Habitat modeling results for intensively studied sites can be used to estimate the total amount of rearing habitat presently available for juvenile chum and chinook salmon at similar locations within the middle river. For this analysis the ratio between WUA and total surface area of the site will be determined at four mainstem discharges (9,000, 12,500,

Table 5. Rearing habitat categories, the approximate number of middle river sites within each category, and the number of habitat modeling sites completed and recommended for future study for each category.

Category	Description	Approximate Number of Sites	Number of Modeling Sites: Completed	Recommended 1/: 6	8	10
I	Distinct channels with clear water visible in 23,000 and 9,000 cfs photography and apparent thermal leads in March, 1983 photography.	35	4	0	0	1
II	Distinct side channel areas at 23,000 cfs which contain clear water at 9,000 cfs and have apparent thermal leads in March photography.	21	7	0	1	1
III	Distinct side channel areas at 23,000 cfs which contain clear water at 9,000 cfs without apparent thermal leads in March photography.	14	1	1	2	2
IV	Distinct mainstem or side channel areas at 23,000 cfs which become or remain side channels at 9,000 cfs.	18	1	2	2	2
V	Indistinct mainstem or side channel areas (shoals) at 23,000 cfs which become distinct side channels at 9,000 cfs.	14	0	1	1	1
VI	Indistinct mainstem or side channel areas (shoals) at 23,000 cfs which remain indistinct at 9,000 cfs.	11	0	1	1	1
VII	Indistinct mainstem or side channel areas (shoals) at 23,000 cfs which contain clear water at 9,000 cfs and have apparent leads in March photography.	5	0	1	1	1
VIII	Indistinct mainstem or side channel areas (shoals) at 23,000 cfs which contain clear water at 9,000 cfs without apparent thermal leads in March photography.	3	0	0	0	1
IX	Distinct and indistinct side channel areas at 23,000 cfs which become dewatered at 9,000 cfs.	9	0	0	0	0

1/ Recommended habitat modeling sites are based on possible totals of 6, 8, or 10 modeling sites.

16,000, and 23,000 cfs). Total WUA for each category will be estimated by multiplying the mean WUA:surface area ratio determined at intensively studied sites by the cumulative surface area of all sites within the same category. Category WUAs will be summed to estimate the total amount of rearing habitat available in the middle river for juvenile chum and chinook salmon at each discharge.

The information used to stratify the middle river and evaluate the habitat potential of various categories will be considerably refined on the basis of data obtained in FY85. It will be necessary to verify the preliminary classification scheme, determine the representativeness of modeling sites, and define existing relationships within nonstudied categories.

Spawning Habitat

A sufficient number of side slough study sites have been evaluated in previous ADF&G investigations to support an extrapolation of chum and sockeye spawning WUA determined for these sites to the remainder of the side sloughs in the middle river having similar morphological and hydrological characteristics. These studies conclude that upwelling is a prerequisite for successful chum and sockeye spawning, with substrate, depth and velocity being important secondary considerations.

The extrapolation methodology for chum and sockeye salmon spawning is based on the premise that successful spawning under existing streamflow, thermal, and sediment regimes is dependent upon the presence of upwelling and conditioned by substrate, depth, and velocity attributes. However, spawning can only occur in those portions of side sloughs or side channels possessing adequate passage depths.

High resolution aerial photographs of the middle Susitna River were obtained on March 2, 1983 when the river was covered with ice. All side slough areas in which open leads are visible have been categorized as possessing an active groundwater source. These sites will be re-examined in aerial photography obtained when the mainstem discharge was 23,000, 16,000, 12,500 and 9,000 cfs in order to identify their overtopping discharge and flow characteristics such that they can be stratified using the same methods and classification scheme used to stratify rearing sites (see Table 5).

The categorization and stratification of both modeled and nonmodeled side slough sites will be further refined on the basis of site-specific hydraulic, morphologic and hydrologic data available in project reports issued by ADF&G, EWT&A, and R&M Consultants, Inc. In addition to access and upwelling, site-specific attributes of particular interest include the frequency of overtopping, hydraulic slope, top width or surface area, substrate composition, and the velocity and depth distribution at representative transects under various flow conditions. The analysis of data pertaining to these attributes will be used to interpret and qualify WUA forecasts available for the modeled side sloughs within similar categories.

The evaluation of chum and sockeye spawning habitat availability in side channel and peripheral mainstem areas will also be founded on the assumption that only those locations where upwelling exists are capable of supporting spawning activities, and then only if access, substrate composition, and velocity and depth conditions are suitable. A visual analysis of the March 2, 1983 aerial photography revealed 45 mainstem or side channel sites with open leads that are likely to result from upwelling. Comparisons between these sites and chum and sockeye spawning locations reported by the ADF&G (ADF&G 1981, 1982, 1984a) indicate that open lead areas exist at 10 of 13 reported mainstem spawning sites.

The 1984 Task 12 field studies relating to middle river chum and sockeye spawning habitat will focus on known spawning sites and suspected upwelling areas where spawning has not been reported. A total of 48 candidate sites exist; 13 known spawning sites, including three locations for which open leads are not apparent in the March photography, and 35 potential spawning sites where no spawning has been reported but upwelling is suspected. The known spawning sites have been tentatively stratified using the same classification scheme described above for rearing sites (Table 2). At present, the 48 candidate sites are believed representative of known or potential chum and sockeye spawning sites within mainstem and side channel areas that might be directly affected by streamflow alterations.

All 48 locations will be visited at least once during FY85 to collect spawner utilization and channel structure data and to confirm the presence of upwelling. Sixteen habitat sites have been selected for detailed study; eight of these will be locations where chum or sockeye spawning has occurred at least once during the 1981-83 period. Habitat modeling data will also be collected at eight locations where upwelling is present but spawning has not been reported. A quantitative comparison will be made of the hydraulic and morphologic attributes of both modeled and nonmodeled sites in an attempt to further refine the stratification of known or potential spawning sites, and to identify factors which may be responsible for the long-term absence or year-to-year variation of spawning at certain sites under existing conditions. This information will be used in combination with WUA and surface area estimates from modeled sites to assess chum and sockeye salmon spawning habitat availability in mainstem and side channel areas of middle Susitna River at discharges of 9,000, 12,500, 16,000, and 23,000 cfs.

Summary

In order to validate the classification and stratification of study sites within the middle Susitna River, reconnaissance grade field surveys will be conducted during 1984 at a large number of sites within each category, including all candidate spawning and rearing study sites. Habitat inventory procedures have been developed as a systematic, cost-effective means of obtaining a semi-quantitative description of the physical attributes present at each site. Figure 11 indicates the principal habitat inventory form to be completed at each surveyed site. Supplemental forms allow for detailed remarks, photographs, and sketches of site-specific observations. Our intent is to use this information to describe habitat attributes which appear to be important to the distribution and abundance of salmonid populations, such that nonmodeled sites can be linked to modeled sites.

Whereas the primary focus of the extrapolation methodology is its utility in describing existing habitat conditions within the middle river, the method appears to be well-suited to forecasting with-project effects. This

Habitat Inventory

Crew: ______________________ Date: ______________
______________________ Time: ______________
______________________ R.M.: ______________

Location: __________ ______________ Category: __________

Mainstem Discharge: ______________ Breached? Yes/No

Mean Reach Velocity: ______________ Estimated/Measured

Site Specific Discharge: ______________ Estimated/Measured

Does Upwelling Occur? Yes/No/Cannot Be Detected Visually

Do Tributaries Enter the Slough or Side Channel? Yes/No

If Yes, Description of Tributary(size,location,habitat): ______________
____
____
____

Head Gage: ______________ WSEL: __________ Remarks:

Mid-Reach Gage: __________ WSEL: __________

Mouth Gage: ______________ WSEL: __________

Substrate: 1 2 3 4 5 6 7 8 9 10 11 12 13

Substrate Embeddedness: 1 2 3

Dominant Cover Code: 1 2 3 4 5 6 7 8 9

Percent Cover: 1 2 3 4 5 6

Streambank Slope: 1 2 3 Stable/Unstable

Streambank Vegetation: 1 2 3 4

Representative Top Width: __________ Bankfull Top Width: __________

Representative Depth: ______________ Bankfull Depth: ______________

Secchi Disk Measurement: 1st: ________ 2nd: ________ Average: ________

Length of Backwater(non-breached): ____________ Estimated/Measured

Were Fish Observed or Seined? Yes/No

Adult: Chinook _____ Coho _____ Sockeye _____ Chum _____ Pink _____

Juvenile: Chinook _____ Coho _____ Sockeye _____ Chum _____ Pink _____

Remarks:

EWT&A

Figure 11. Primary data recording form to be used in 1984 field surveys of mainstem and side channel sites in the middle Susitna River.

is particularly true if the present status of fish habitat within the river has been adequately documented, and the relationship between discharge and habitat availability is known. Because the stratification and extrapolation concepts outlined in this paper represent a logical and effective means of assessing existing and potential habitat availability, we recommend their adoption as a framework for future studies within the middle Susitna River.

Literature Cited

Alaska Department of Fish and Game (ADF&G). 1981. Adult anadromous fisheries project, phase I final draft report. Alaska Department of Fish and Game, Su Hydro Aquatic Studies Program. Anchorage, Alaska.

_____. 1982. Adult anadromous fish studies, volume 2, phase II final data report. Alaska Department of Fish and Game, Su Hydro Aquatic Studies Program. Anchorage, Alaska.

_____. 1983. Susitna hydro aquatic studies, phase II basic data report. Vol. 4: Aquatic habitat and instream flow stuties, 1982. Anchorage, Alaska.

_____. 1984a. Susitna hydro aquatic studies. Report No. 1. Adult anadromous fish investigations (May-October 1983). Anchorage, Alaska.

_____. 1984c. (In press). Susitna hydro aquatic studies. Report No. 3. Aquatic habitat and instream flow investigations (May-October 1983). Anchorage, Alaska.

Baldrige, J.E., and D. Amos. 1981. A technique for determining fish habitat suitability criteria: a comparison between habitat utilization and availability. Pp. 251-258 in N.B. Armantrout (ed.), Aquisition and Utilization of Aquatic Habitat Inventory Information. American Fisheries Society. 376 pp.

E. Woody Trihey and Associates. 1984. Response of aquatic habitat surface areas to mainstem discharges in the Talkeetna to Devil Canyon reach of the Susitna River, Alaska. Susitna Hydroelectric Proj. Doc. No. 1693. 15 pp.

Hynes, H.B.N. 1972. The Ecology of Running Waters. Univ. of Toronto Press. 555 pp.