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SUSITNA
HYDROELECTRIC PROJECT

FEDERAL ENERGY REGULATORY COMMISSION
PROJECT No. 7114

CHARACTERIZATION OF AQUATIC HABITATS IN THE TALKEETNA-TO-DEVIL CANYON SEGMENT OF THE SUSITNA RIVER, ALASKA

PREPARED BY

Trihey & Associates
Aquatic Resource Specialists

FINAL REPORT

UNDER CONTRACT TO

HARZA-EBASCO
SUSITNA JOINT VENTURE

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Prepared by
E. Woody Trihey and Associates

and

Arctic Environmental Information and Data Center
University of Alaska-Fairbanks

Under Contract to
Harza-Ebasco Susitna Joint Venture

Prepared for
Alaska Power Authority

Final Report
October 1985

NOTICE

ANY QUESTIONS OR COMMENTS CONCERNING
THIS REPORT SHOULD BE DIRECTED TO
THE ALASKA POWER AUTHORITY
SUSITNA PROJECT OFFICE

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PREFACE

The goal of the Alaska Power Authority in identifying environmentally acceptable flow regimes for the proposed Susitna Hydroelectric Project is the maintenance of existing fish resources and levels of production. This goal is consistent with mitigation goals of the U.S. Fish and Wildlife Service and the Alaska Department of Fish and Game. Maintenance of naturally occurring fish populations and habitats is the preferred goal in agency mitigation policies.

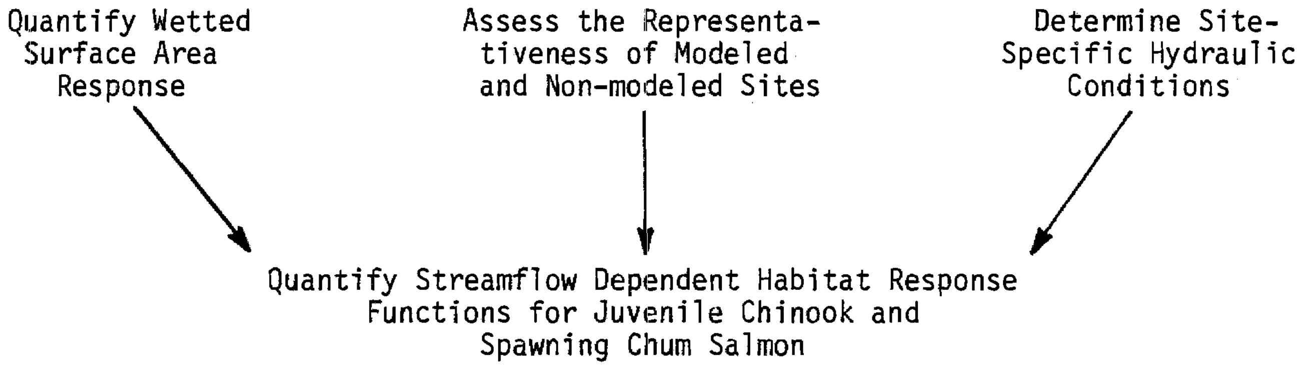
In 1982, following two years of baseline studies, a multi-disciplinary approach to quantify effects of the proposed Susitna Hydroelectric Project on existing fish habitats and to identify mitigation opportunities was initiated. The Instream Flow Relationships Studies (IFRS) focuses on the response of fish habitats in the middle Susitna River to incremental changes in mainstem discharge, temperature and water quality. As part of this multi-disciplinary effort, a technical report series was planned that would (1) describe the existing fish resources of the Susitna River and identify the seasonal habitat requirements of selected species, and (2) evaluate the effects of alternative project designs and operating scenarios on physical processes which most influence the seasonal availability of fish habitat.

The summary report for the IFRS, the Instream Flow Relationships Report (IFRR), (1) identifies the biologic significance of the physical processes evaluated in the technical report series, (2) integrates the findings of the technical report series, and (3) provides quantitative relationships and discussions regarding the influences of incremental changes in streamflow, stream temperature, and water quality on fish habitats in the middle Susitna River on a seasonal basis.

The IFRR consists of two volumes. Volume I uses project reports, data and professional judgement available before March 1985 to identify evaluation species, important life stages, and habitats. The report ranks a variety of physical habitat components with regard to their degree of influence on fish habitat at different times of the year. This ranking considers the biologic requirements of the evaluation species and life stage, as well as the physical characteristics of different habitat types, under both natural and anticipated with-project conditions. Volume II of the IFRR will address the third objective of the IFRR and provide quantitative relationships regarding the influences of incremental changes in streamflow, stream temperature and water quality on fish habitats in the middle Susitna River on a seasonal basis.

The influence of incremental changes in streamflow on the availability and quality of fish habitat is the central theme of the IFRR Volume II analysis. Project-induced changes in stream temperature and water quality are used to condition or qualify the forecasted responses of fish habitat to instream hydraulics. The influence of streamflow on fish habitat will be evaluated at the microhabitat level and presented at the macrohabitat level in terms of a composite weighted usable area curve. This composite curve will describe the combined response of fish habitat at all sites within the same representative group to incremental changes in mainstem discharge.

Four technical reports are being prepared by E. Woody Trihey and Associates in support of the IFRR Volume II analysis. The function of each report is depicted in a flow diagram and described below.



RESPONSE OF AQUATIC HABITAT SURFACE AREAS TO MAINSTEM DISCHARGE IN THE TALKEETNA-TO-DEVIL CANYON SEGMENT OF THE SUSITNA RIVER, ALASKA

This report identifies five aquatic habitat types within the middle Susitna River directly influenced by changes in mainstem discharge and presents the necessary photography and surface area measurements to quantify the change in wetted surface area associated with incremental decreases in mainstem discharge between 23000 and 5100 cfs. The report also describes the influence of mainstem discharge on habitat transformations and tabulates the wetted surface area responses for 172 specific areas using the ten representative groups presented in the Habitat Characterization Report. Surface area measurements presented in this report provide a basis for extrapolating results from intensively studied modeling sites to the remainder of the middle Susitna River.

CHARACTERIZATION OF AQUATIC HABITATS IN THE TALKEETNA-TO-DEVIL CANYON SEGMENT OF THE SUSITNA RIVER, ALASKA

This report describes the characterization and classification of 172 specific areas into ten representative groups that are hydrologically, hydraulically and morphologically similar. Emphasis is placed on the transformation of specific areas from one habitat type to another in response to incremental decreases in mainstem discharge from 23000 cfs to 5100 cfs. Both modeled and nonmodeled sites are classified and a structural habitat index is presented for each specific area based upon subjective evaluation of data obtained through field reconnaissance surveys. Representative groups and structural habitat indices presented in this report provide a basis for extrapolating habitat response functions developed at modeled sites to nonmodeled areas within the remainder of the river.

HYDRAULIC RELATIONSHIPS AND MODEL CALIBRATION PROCEDURES AT 1984 STUDY SITES IN THE TALKEETNA-TO-DEVIL CANYON SEGMENT OF THE SUSITNA RIVER, ALASKA

This report describes the influence of site-specific hydraulic conditions on the availability of habitat for juvenile chinook and spawning chum salmon. Two aquatic habitat models are applied to quantify site-specific habitat responses to incremental changes in depth and velocity for both steady and spatially varied streamflow conditions. Summaries of site-specific stage-discharge and flow-discharge relationships are presented as well as a description of data reduction methods and model calibration procedures. Weighted usable area forecasts are provided for juvenile chinook at 8 side channel sites and for spawning chum salmon at 14 side channel and mainstem sites. These habitat response functions provide the basis for the instream flow assessment of the middle Susitna River.

RESPONSE OF JUVENILE CHINOOK AND SPAWNING CHUM SALMON HABITAT TO MAINSTEM DISCHARGE IN THE TALKEETNA-TO-DEVIL CANYON SEGMENT OF THE SUSITNA RIVER, ALASKA

This report integrates results from the surface area mapping, habitat characterization, and hydraulic modeling reports to provide streamflow dependent habitat response functions for juvenile chinook and spawning chum salmon. Wetted surface area and weighted usable area are the principal determinants of habitat indices provided in Part A of the report for juvenile chinook at each specific area and the ten representative groups identified in the habitat characterization report. Part B of this report provides habitat response functions for existing chum salmon spawning sites. The habitat response functions contained in this report will be used for an incremental assessment of the rearing and spawning potential of the entire middle Susitna River under a wide range of natural and with-project streamflows.

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1. INTRODUCTION

The Alaska Power Authority has proposed the construction of two dams on the Susitna River. Construction of the proposed hydroelectric project will alter the flow regime downstream of the dam, resulting in corresponding changes to the quality and quantity of fish habitat. The most pronounced influences of the project are expected to occur in the Talkeetna-to-Devil Canyon segment of the Susitna River (the middle Susitna River). Two major tributaries, the Talkeetna and Chulitna rivers, will buffer the impacts of the project downstream of Talkeetna.

To evaluate the effects on fish habitat of this project, it is necessary to document natural conditions. To this end, fish habitat modeling techniques were applied at a spectrum of aquatic habitats and a methodology was developed to *extrapolate* results to other areas of the river. The extrapolation methodology has three components: 1) quantification; 2) stratification, or grouping of individual aquatic habitats on the basis of hydrologic, hydraulic, and morphologic similarities; and 3) simulation. This report focuses on the stratification pathway of analysis. For a detailed discussion of the quantification and simulation pathways, see Klinger-Kingsley (1985) and Steward et al. (1985). The basis of the extrapolation methodology is explained below.

To apply or extrapolate the results from modeled sites to nonmodeled areas of the middle Susitna River in order to determine the systemwide response of fish habitat quantity and quality to mainstem discharge, it is necessary to assess the *representativeness* of modeled sites to nonmodeled areas. In the application of the Instream Flow Incremental Methodology (IFIM), which is used in this study and described by Bovee (1982), extrapolation is typically done by identifying segments and subsegments of the subject river that are hydrologically, hydraulically, and morphologically *homogeneous*. By modeling a representative reach of a homogeneous subsegment and extrapolating to the rest of the subsegment on a proportional length basis, it is possible to develop systemwide habitat response to discharge relationships. This approach is commonly applied to single-thread rivers.

Although multiple-thread rivers can be divided into homogeneous segments and subsegments in a manner similar to single-thread rivers (Mosley 1982, Glova and Duncan 1985), extrapolation of modeling results from representative reaches of braided river subsegments on a proportional length basis cannot be done routinely with reliable results (Mosley 1983). The braided river environment is too dynamic and variable for the development of quantitative relationships between discharge and physical habitat variables such as depth, velocity, and channel structure on a *river corridorwide basis* for use in extrapolation (Mosley 1983).

Instead, an approach for evaluating habitat is needed that focuses on *portions* of the river corridor. By applying modeling techniques at individual channel branches of the braided river system, the variability of the physical environment is reduced to a level that permits the development of quantitative relationships between discharge and physical habitat variables. This allows the extrapolation of model results from the study reach (i.e., representative reach) to the rest of the channel branch with reliable results. Even with this approach, however, the problem remains of how to extrapolate results from modeled channel branches to the rest of the river to develop systemwide habitat response relationships. It would be impractical to apply modeling techniques at every channel branch.

In the fisheries habitat studies of the Talkeetna-to-Devil Canyon segment of the Susitna River, which is a large, frequently braided or split-channel river, an approach to extrapolating results from modeled sites to nonmodeled areas of the river was developed that relies on two data bases which are complementary but different in scope. One data base is used to develop detailed physical habitat models to *simulate* habitat response to discharge at a number of channel branches representing a spectrum of habitat types in the middle Susitna River. The second data base is much broader in scope and includes aerial photo coverage of the entire middle Susitna River at several selected discharges. It also includes reconnaissance level field surveys of selected physical habitat parameters at nearly all nonmainstem channel branches and several mainstem channels. This second data base is used to (1) quantify the relationship of surface area response to discharge of individual channel branches using aerial photography, and (2) stratify or group individual channel branches of the middle Susitna River based on common hydrologic, hydraulic, and morphologic characteristics. The three components of the extrapolation methodology (i.e., quantification, stratification, and simulation) and their integration are summarized in Figure 1. As mentioned earlier, this report focuses on the stratification component of the methodology.

Quantification

Quantity surface areas of individual channel branches in the middle Susitna River for each flow for which aerial photography is available to determine the surface area response to mainstem discharge.

Stratification

Use available information to stratify individual aquatic habitats into groups that are hydrologically, hydraulically, and morphologically similar.

Simulation

Simulate the response of aquatic habitat quality to discharge with habitat modeling techniques at selected areas of the middle Susitna River.

Integration

For each evaluation species/life stage:

Integrate the quantification, stratification, and simulation components to determine the aquatic habitat response to discharge for the entire middle Susitna River.

Figure 1. Flow chart for the extrapolation methodology.

There are three principal differences between the conventional IFIM approach to extrapolating model results for a single-thread river system and the methodology presented in this report for relatively complex multiple-thread river systems. First, for multiple-thread river systems, extrapolation from representative reaches to the rest of the homogeneous subsegment is done on a proportional area basis rather than a proportional length basis because of the greater variability in channel widths within homogeneous subsegments of braided river systems. This method of extrapolation is also necessary because of the greater variability in hydrologic and morphologic character within homogeneous subsegments of braided rivers compared to their single-thread counterparts.

Second, in the IFIM procedures for single-thread systems described by Bovee (1982), a segment or subsegment boundary is defined where there is a significant change in channel slope, flow regime, or morphology. In the context of the IFIM, the middle Susitna River would be considered a segment of the Susitna River because below Talkeetna the flow regime changes as the Chulitna and Talkeetna rivers contribute flow and above Devil Canyon the channel morphology changes significantly. At the subsegment level the boundaries are not so well-defined. It is at this level that there is a departure in the segmentation criteria for a braided river system as compared to a single-thread river system.

Inspection of aerial photography provides ample evidence of the variability of channel morphology in the middle Susitna River. Nevertheless, after closer inspection, even the casual observer can also identify considerable evidence of repetitive channel form. Examples include relatively long sinuous channels that are peripheral to the main river corridor and shorter, wider channel branches that trace a similar path in plan form. The significance of these morphologically similar channel branches is that they are spatially interspersed throughout the middle Susitna River. Although morphological similarities between parts of the river are evident, it is not possible to identify *continuous* homogeneous river subsegments containing them, as would be done for morphologically similar portions of a single-thread river system. The solution to this problem, then, is to identify *discontinuous* homogeneous subsegments based on common hydrologic, hydraulic, and morphologic characteristics (see Figure 2). This necessarily involves dividing the river into smaller homogeneous habitat units.

In this study, nearly all the individual nonmainstem channels plus several mainstem channels were delineated and labeled on aerial photo reproductions of the middle Susitna River (see Appendix 1). These delineated areas, termed *specific areas*, were then analyzed using aerial photo interpretation techniques and data from reconnaissance level field surveys. By evaluating the hydrologic, hydraulic, and morphologic character of each specific area, including modeled and nonmodeled sites, it was possible to assess which nonmodeled site should be associated with which modeled site. These groupings of similar specific areas were termed *representative groups*. In the context of the IFIM, each representative group is equivalent to a homogeneous subsegment. The only difference between representative groups and homogeneous subsegments is that representative groups are spatially discontinuous, whereas homogeneous subsegments in the IFIM are spatially continuous.

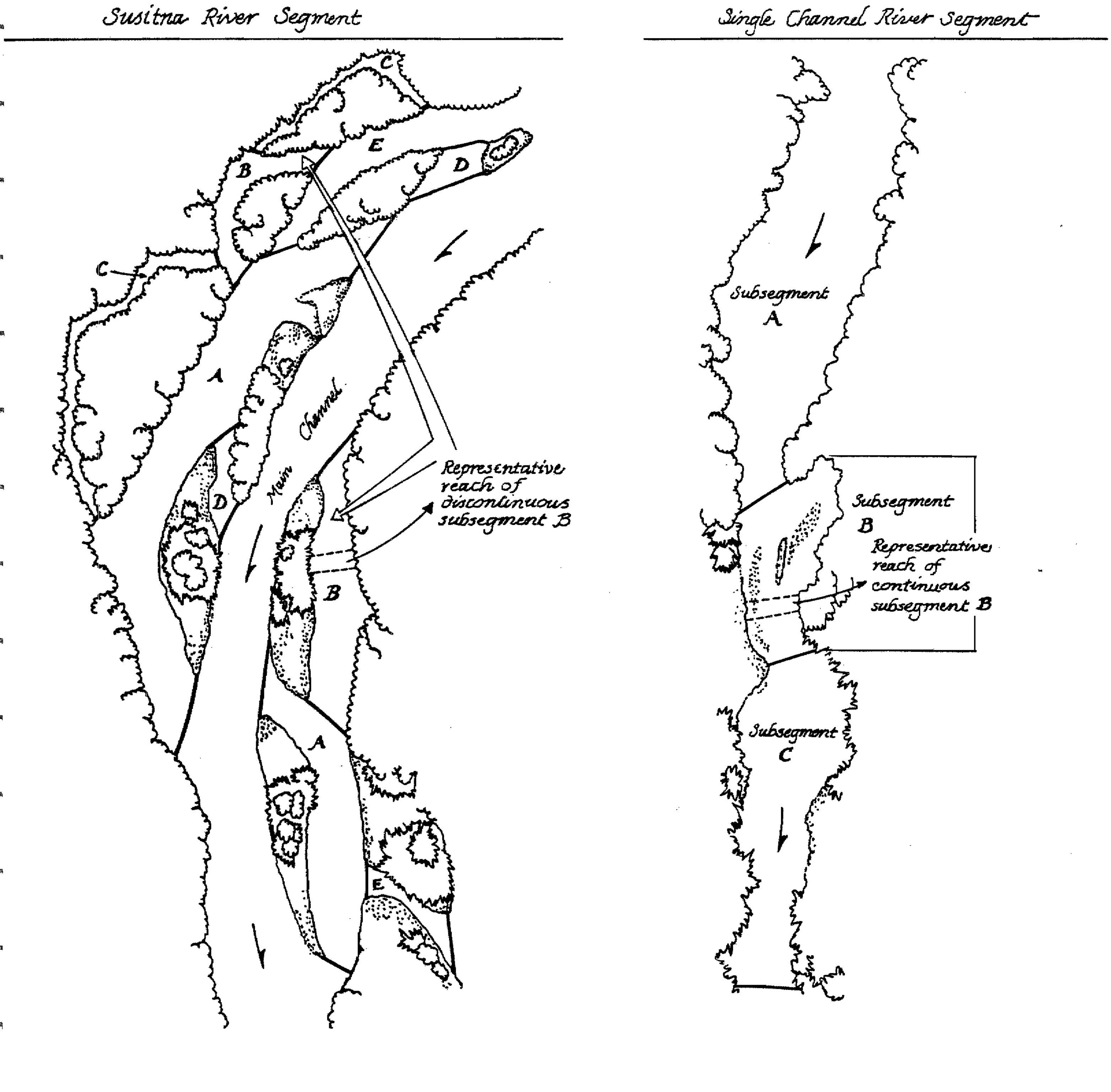


Figure 2. Examples of continuous and discontinuous subsegments.

The third difference between extrapolation methodologies for multiple-thread rivers vs. single-thread rivers is in recognition of the greater variability of nonhydraulic habitat attributes (i.e., structural cover, substrate composition) within representative groups of multiple-thread rivers than is typically associated with homogeneous subsegments of single-thread river systems. Although hydrologic, hydraulic, and morphologic similarities may be strong enough to associate several specific areas with the same representative group, structural inequalities between specific areas often preclude the conclusion that the specific areas have the same habitat value. A methodology for adjusting the habitat value of specific areas based on structural attributes is discussed in detail in a later section. Table 1 summarizes the differences between the IFIM extrapolation procedure for a single-thread river and that described in this report for multiple-thread river systems.

The specific area approach to extrapolating results from modeled sites to nonmodeled areas for multiple-thread river systems offers several advantages over conventional river corridorwide extrapolation schemes. Several of these advantages can be summarized as follows: (1) it provides quantitative physical habitat response to discharge relationships focused at the representative group level rather than river corridorwide; (2) it simplifies field data collection by reducing the effort of data collection in mainstem channels; (3) it simplifies individual model calibration by restricting calibration to one channel at a time; and (4) it increases the reliability of forecasts at modeled sites. Of these advantages, the first and fourth ones are of particular importance.

Table 1. Summary of the differences between the IFIM extrapolation procedure for a single-thread river and that developed for a multiple-thread river.

IFIM Extrapolation for Single-Thread River System	Extrapolation for Multiple-Thread River System
Proportional length basis	Proportional area basis
Continuous subsegments	Discontinuous subsegments termed representative groups
Intensively studied representative reaches	Intensively studied representative reaches plus general reconnaissance level survey of entire river system
Extrapolation from representative reaches to associated subsegments without adjustment	Extrapolation from representative reaches to associated representative groups with adjustment to account for inequalities in structural habitat between specific areas

The provision of relationships between quantitative physical habitat response to discharge at the representative group level is of key importance to the middle Susitna River studies since representative groups are often of differing habitat value to particular fish species. For example, in the middle Susitna River, juvenile chinook salmon (Oncorhynchus tshawytscha) have been identified as a fish evaluation species (E. Woody Trihey & Associates and Woodward-Clyde Consultants, 1985). The most important rearing habitat for juvenile chinook salmon is found in side channels, side sloughs, and tributaries (Schmidt et al. 1984). An extrapolation methodology with the capability of forecasting habitat response to a changed flow regime for particular habitat types is necessary in this instance to corroborate with juvenile chinook salmon utilization data bases. River corridorwide extrapolation methodologies do not provide this level of resolution, in addition to the problems associated with low reliability in their forecast capability. The extrapolation methodology developed for this study was designed to mitigate these problems.

The disadvantages of the specific area approach to extrapolating results from modeled sites to nonmodeled areas are primarily twofold: (1) it requires a substantial reconnaissance level data base and aerial photo coverage; and (2) it requires considerable analyses to develop representative groups. Since this approach to extrapolation will be applied for the first time on the Susitna River, many of the procedures, analyses, and criteria for discriminating representative groups had to be developed.

The objectives of this report are to: (1) introduce the concepts behind a new approach to extrapolation; (2) present the analyses and procedures used for characterizing individual aquatic habitats (specific areas); (3) discuss the aquatic habitat characteristics and associated criteria considered in the development of representative groups; and (4) present the representative groups developed for use in the extrapolation of habitat availability indices from modeled sites to nonmodeled areas of the middle Susitna River.

2. INVESTIGATIVE FRAMEWORK

The characterization of aquatic habitat can be approached from several perspectives and performed at several levels of detail. To fulfill the objectives of the analysis, the investigative framework pursued in this report is founded on the resolution of aquatic habitat into three components: (1) hydrologic; (2) hydraulic; and (3) channel structure (see Figure 3). Aquatic habitat was resolved in this manner to: (1) provide focus to the development of analytical procedures; (2) organize the data base into a manageable format; and (3) be consistent with the framework established in previous studies.

Two data sources were used primarily in the aquatic habitat characterization process: a site-specific habitat reconnaissance data base and aerial photography. Additional information was incorporated into the analyses from the Alaska Department of Fish and Game's (ADF&G) habitat modeling program, ADF&G fish utilization studies, and personal communications with ADF&G field personnel.

Five field trips provided the habitat reconnaissance data: a one-day trip on August 21, 1984; a five-day trip September 3-7, 1984; a five-day trip September 10-14, 1984; a four-day trip September 29 - October 2, 1984; and a three-day trip July 23-25, 1985. The corresponding U.S. Geological Survey (USGS) Gold Creek gage discharges were approximately 18000, 11000, 10000, 8000, and 25000 cfs, respectively. The one-day field trip was a trial for the refinement of field procedures and the planning of future field work. Observers completed a habitat inventory form for each of 172 specific areas over the course of the two five-day field trips. During the four-day field

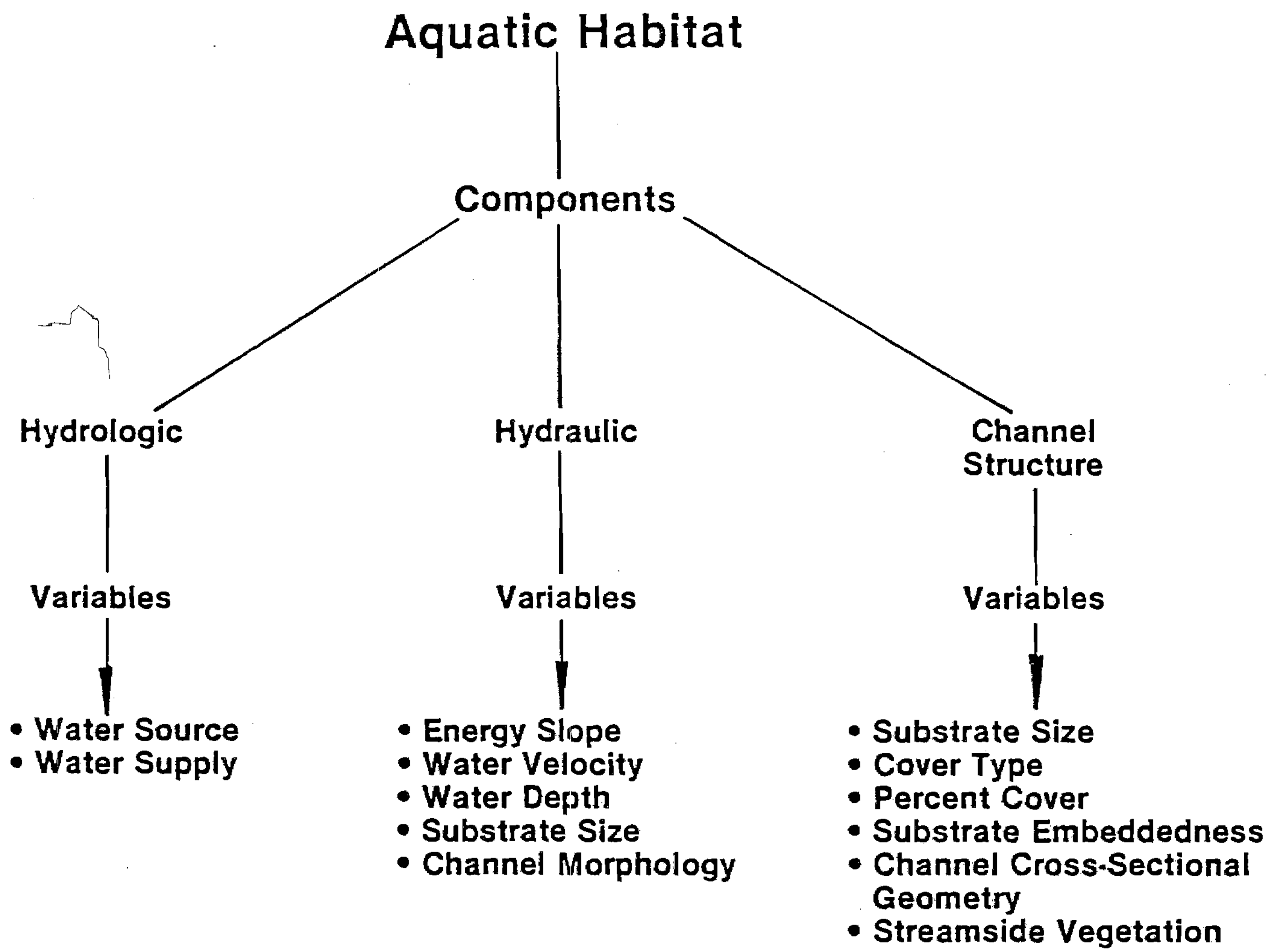


Figure 3. Schematic of aquatic habitat components and descriptive variables investigated to characterize aquatic habitats in the Talkeetna-to-Devil Canyon segment of the Susitna River.

trip additional information was collected to verify upwelling and side channel breaching flows as well as mean reach velocities and habitat transformation categories. The final field trip was used to confirm representative groupings of specific areas. A detailed explanation of field habitat inventory techniques appears in Appendix 2.

Black and white aerial photography was available at discrete middle Susitna River discharges of 5100, 7400, 9000, 10600, 12500, 16000, 18000, 23000, and 26900 cubic feet per second (cfs), as measured at the USGS Gold Creek gaging station (Table 2). An additional set of aerial photography was available which showed winter ice conditions.

Table 2. Black and white aerial photography used in the characterization of aquatic habitat.

Mainstem Discharge (cfs)	Date Taken	Scale	Comments
1500-2000	March 1983	1 in. = 1,000 ft	ice cover
5100	10-14-84	1 in. = 250 ft	open water
7400	10-04-84	1 in. = 250 ft	open water
9000	10-08-83	1 in. = 1,000 ft	some ice present
10600	09-09-84	1 in. = 250 ft	open water
12500	09-11-83	1 in. = 1,000 ft	open water
16000	09-06-83	1 in. = 1,000 ft	open water
18000	08-20-80	1 in. = 1,000 ft	open water
23000	06-01-82	1 in. = 1,000 ft	open water
26900	08-27-84	1 in. = 1,000 ft	open water

Nearly all nonmainstem channel branches plus several mainstem channels were delineated and labeled on aerial photo reproductions of the middle Susitna River (see Appendix 1). These specific areas, usually comprised of individual side channels, side sloughs, and upland sloughs, were used as a framework for the systematic evaluation of aquatic habitat. Occasionally a large side channel or slough was subdivided into two or more specific areas due to differences in habitat character. Each specific area was referenced to a river mile (RM) and the side of the main river channel looking upstream: left (L), right (R), or middle (M) if between two mainstem forks. A total of 172 specific areas were delineated, representing four of the six habitat types identified in the middle Susitna River by Klinger and Trihey (1984). These habitat types are described as follows:

Mainstem habitats are those channels of the river that convey more than approximately 10 percent of the total flow at a given site. During the open water season these channels are characterized as conveying water with high turbidity levels derived from glacial meltwater.

Side channel habitats are those channels of the river that convey less than approximately 10 percent of the total flow. During the open water season these channels generally convey highly turbid mainstem water.

Side slough habitats contain clear water. Local surface water runoff and upwelling groundwater are the primary sources of water in these habitats. Side sloughs have nonvegetated berms at the upstream ends that are overtopped during periods of moderate to high mainstem discharge. Once overtopped, side sloughs are considered side channels.

Upland sloughs are clearwater habitats that depend upon upwelling groundwater and/or local runoff for their water sources. The upstream ends of upland sloughs are vegetated and are seldom overtopped by mainstem discharge.

Tributary mouths are clearwater habitats at the confluences of tributaries. In the summer these habitats are readily apparent as clearwater plumes that extend into the turbid glacial flow of the mainstem or a side channel. The size of the plume is a function of both tributary discharge and mainstem discharge. Tributary mouth habitats can also occur in the tributary channel as a result of mainstem stage causing a backwater at the tributary mouth. If a backwater occurs, tributary mouth habitat extends into the tributary channel to the upstream extent of the backwater.

Tributary habitats are reaches of tributary streams upstream of the tributary mouth habitats.

Tributary habitats were not evaluated because they would not be affected by an altered mainstem flow regime. Neither were tributary mouth habitats evaluated because they constitute a small portion of the middle Susitna River habitat and would not be affected significantly.

Subhabitat types were required in this analysis to be consistent with the resolution provided by aerial photography and are as follows:

<u>Indistinct mainstem</u> habitats occur at the margins of some mainstem channels. In the 23000 cfs photography they appear to be an integral part of a mainstem habitat. In photographs taken at lower flows, however, they are distinct

channels separated from the mainstem by gravel bars or are shallow expanses (shoals) at the margins of a mainstem channel (Figure 4).

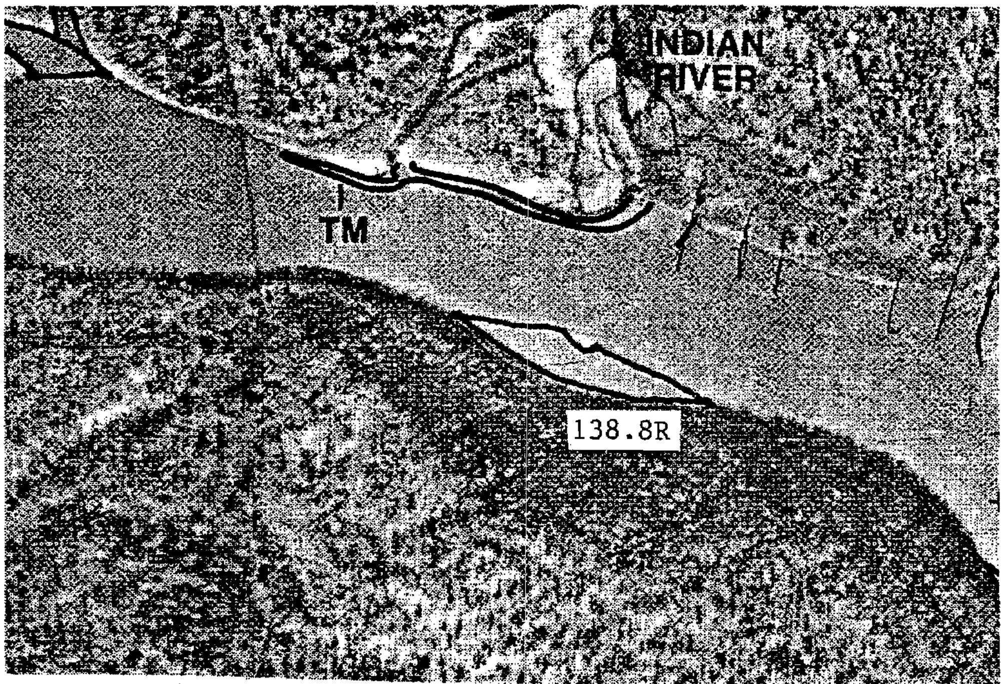
Indistinct side channel habitats occur at the margins of some mainstem and side channels. In the 23000 cfs photography they appear to be an integral part of a mainstem or side channel habitat. In photographs taken at lower flows, however, they are distinct channels separated from the mainstem or main side channel by gravel bars or are shoals at the margins of the mainstem or side channel. The primary distinction between indistinct mainstem and indistinct side channel habitats is flow volume as per the previous definitions of mainstem and side channel habitats.

2.1 HYDROLOGIC COMPONENT

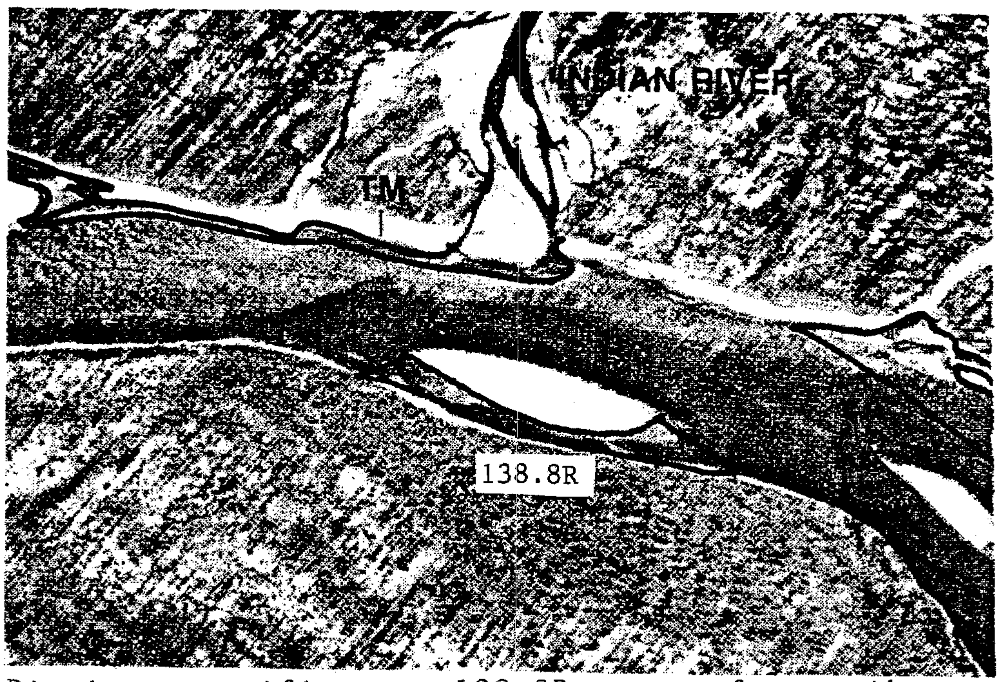
The suitability of a given specific area as aquatic habitat is dependent on the quantity and quality of water supplied to the site. This hydrologic component of aquatic habitat was evaluated for each specific area using up to five indices: (1) change of habitat type, or habitat transformation; (2) breaching flow; (3) cross-sectional geometry of side channel head berms; (4) cross-sectional geometry of the mainstem; and (5) the presence or absence of upwelling groundwater.

2.1.1 HABITAT TRANSFORMATION TRACKING

The development of a methodology to examine changes in habitat in reference to discharge is a prerequisite to the assessment of the response of aquatic



Indistinct specific area 138.8R across from tributary mouth habitat at Indian River at a mainstem discharge of 23000 cfs.



Distinct specific area 138.8R across from tributary mouth habitat at Indian River at a mainstem discharge of 9000 cfs

Figure 4. An indistinct mainstem channel that becomes a distinct side channel with decreasing mainstem discharge.

habitat quality to mainstem flow. Changes in habitat, or habitat transformations, are significant because they demonstrate the direct relationship between habitat type and quality and mainstem discharge. The most common habitat transformation occurs when a side channel becomes a side slough as mainstem stage recedes to a level that prevents the flow of turbid mainstem water through the side channel entrance. Another common transformation occurs when mainstem habitat becomes side channel habitat as mainstem discharge decreases.

Eleven *habitat transformation categories* were defined to describe the types of habitat transformation that a specific area may undergo as mainstem discharge decreases from a higher reference flow to a lower evaluation flow (Table 3). These categories were used to systematically evaluate habitat transformations at specific areas at successive mainstem discharges for which aerial photography was available.

Methods

Aerial photography of the middle Susitna River for mainstem discharges of 5100, 7400, 9000, 10600, 12500, 16000, 18000, and 23000 cfs was used in the analysis. Habitat transformations at each specific area were identified between 23000 cfs and lower evaluation flows through photo comparison, with the 23000 cfs aerial photography used as the reference flow for all lower flow photography. A flow chart for classifying the transformation of aquatic habitat types between two flows appears as Figure 5.

Table 3. Description of habitat transformation categories.*

Category 0	Tributary mouth habitats that persist as tributary mouth habitat at the evaluation flow.
Category 1	Upland slough and side slough habitats that persist as the same habitat type at the evaluation flow.
Category 2	Side channel habitats that transform to side slough habitats at the evaluation flow and possess upwelling which persists throughout winter.
Category 3	Side channel habitats that transform to side slough habitats at the evaluation flow but do not possess upwelling that persists throughout winter.
Category 4	Mainstem habitats that transform to side channel habitats and side channel habitats that persist as side channel habitats at the evaluation flow.
Category 5	Indistinct mainstem or side channel areas that transform into distinct side channels at the evaluation flow.
Category 6	Indistinct mainstem or side channel habitats that persist as indistinct areas at the evaluation flow.
Category 7	Indistinct mainstem or side channel areas that transform to side slough habitats at the evaluation flow and possess upwelling that persists throughout winter.
Category 8	Indistinct mainstem or side channel habitats that transform to side slough habitats at the evaluation flow but do not possess upwelling which persists throughout winter.
Category 9	Any water course that is wetted that dewaters or consists of isolated pools without habitat value at the evaluation flow.
Category 10	Mainstem habitats that persist as mainstem habitat at the evaluation flow.

*Habitats were based on a reference flow of 23000 cfs.

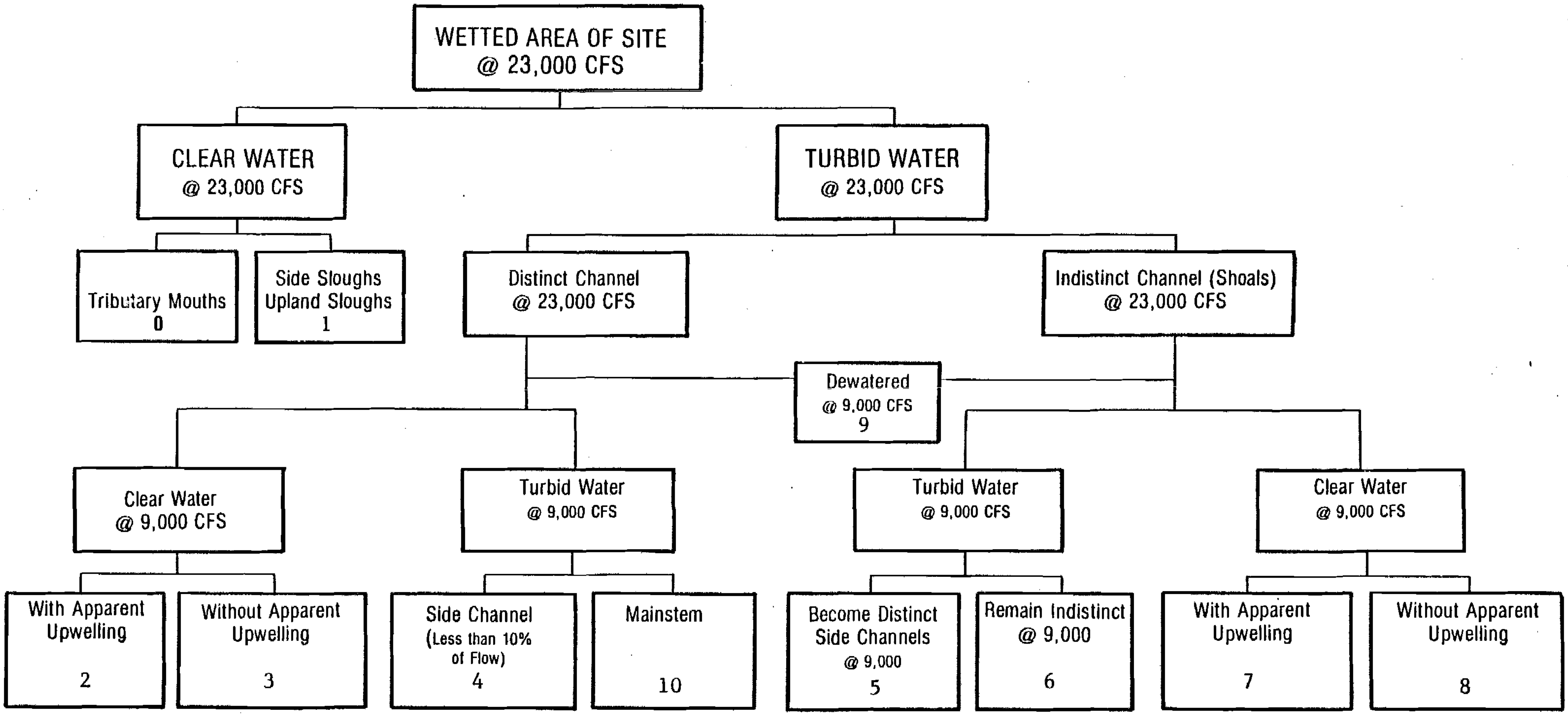
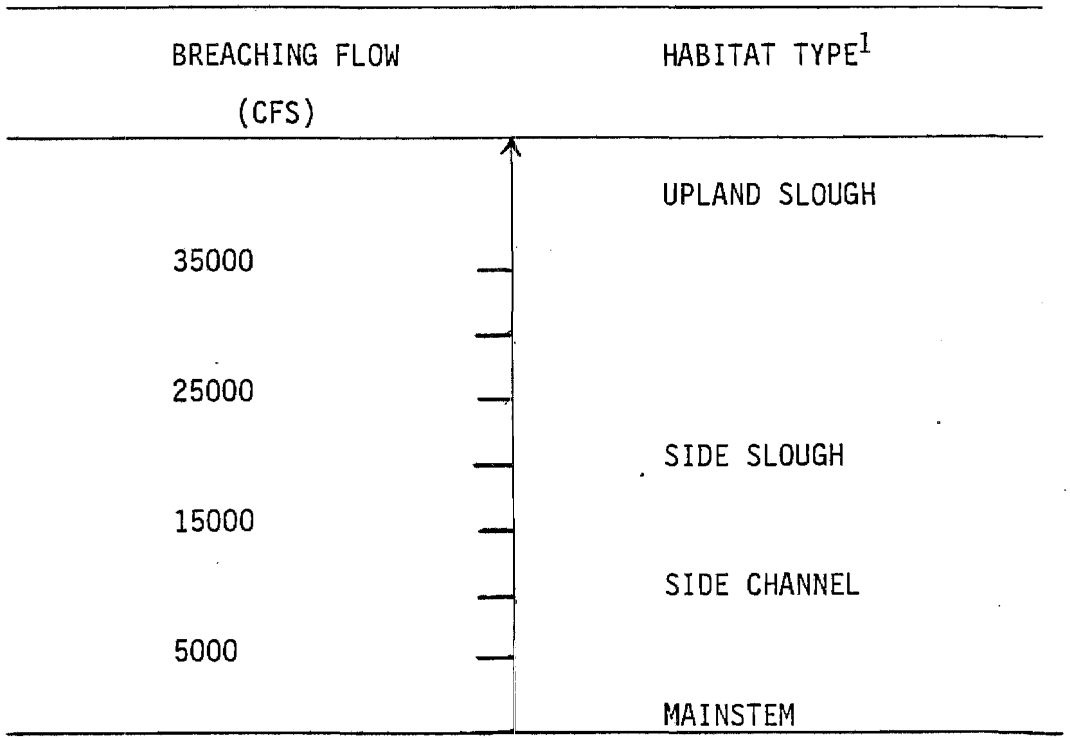


Figure 5. Flow chart for classifying the transformation of aquatic habitat types between two flows (Categories 0-10). It is important to note that habitat transformations can be monitored between any two flows of interest.

For example, consider specific area 139.5R (p. 75). This specific area can be described as a broad, relatively shallow expanse of turbid water that is not a distinct channel (indistinct) at 23000 cfs. Comparison of the 23000 and 18000 cfs aerial photography reveals that specific area 139.5R persists as an indistinct turbid water channel at 18000 cfs. From Table 3 it would thus be classified into habitat transformation category 6 at the 18000 cfs evaluation flow. This procedure can be repeated for each successively lower evaluation flow, always with reference to the 23000 cfs aerial photography. If this is done for specific area 139.5R for evaluation flows of 18000, 16000, 12500, 10600, 9000, 7400, and 5100 cfs, a habitat transformation category sequence of 6-6-6-5-5-7-7 will result. With reference to Table 3, this sequence indicates that specific area 139.5R is an indistinct channel at mainstem discharges of 12500 cfs and above, a well-defined channel at flows between 10600 and 9000 cfs, and side slough habitat at flows between 7400 and 5100 cfs. For the purposes of this study, the habitat transformation category sequence of a specific area can be abbreviated to display only the changes in habitat type that occur. For specific area 139.5R this would be 6-5-7. The habitat transformation category sequence is thus a concise reference of habitat types occurring at a specific area as well as a useful index of the site-specific hydrologic process.

2.1.2 BREACHING FLOW

In addition to habitat transformation sequence, breaching flow is useful in describing and classifying specific areas. It is the hydrologic focal point of habitat transformation and also identifies the relative position of specific area habitats in the hydrologic spectrum between mainstem and upland slough (Figure 6).



1. refers to the habitat type that occurs most frequently at a specific area during the open water season. Actual habitat type at a specific area depends on mainstem discharge.

Figure 6. General relationship between breaching flow and habitat type in the Talkeetna-to-Devil Canyon segment of the Susitna River.

Breaching flow is defined as the mainstem discharge at which the water surface elevation (stage) in the main channel is sufficiently high to overtop the head berm of a peripheral channel and allow mainstem water to flow through the area. Not all specific areas have readily identifiable breaching flows, and some areas are breached gradually over a range of mainstem flow. For example, the overtopping of mainstem and side channel shoals is frequently a subtle process as water laterally inundates these areas with increasing stage. Water seldom overtops heads of upland sloughs because of their elevation relative to the mainstem, while mainstem channels are always breached.

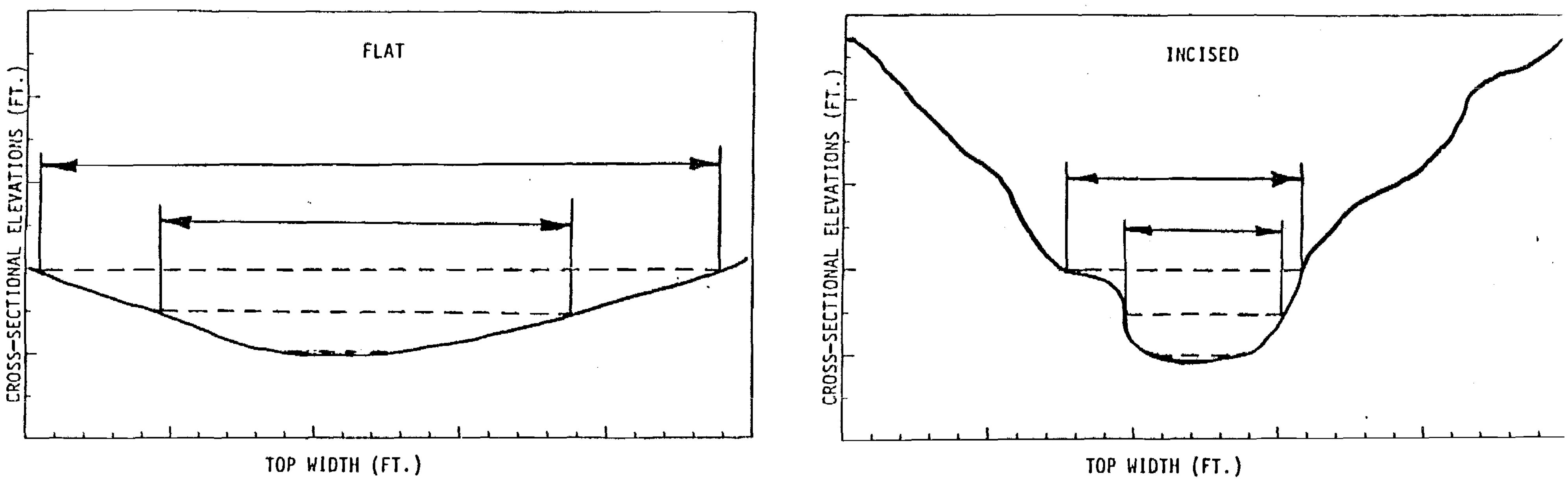
Methods

The series of black and white aerial photography from 5100 to 26900 cfs was used as a visual reference frame for estimating breaching flows for specific areas. Breaching flows were interpolated between photographed flows using interpretive judgement and information provided by field observations where applicable. For example, if a specific area was breached in the 18000 cfs photography and nonbreached in the 16000 cfs photography, the breaching flow was estimated between these flows. Interpretive judgement as to "how breached" the area appeared in the 18000 cfs photography refined the breaching flow estimate. It was not possible to refine breaching flow estimates for specific areas that breached significantly below 5100 cfs because of the lack of available information. Some specific areas appeared "barely breached" in the 5100 cfs photography, and breaching flows slightly below 5100 cfs were estimated for those sites. Breaching flow estimates above 26900 cfs relied exclusively on available ADF&G field information.

2.1.3 CROSS-SECTIONAL GEOMETRY OF SIDE CHANNEL HEAD BERMS

Just as breaching flow is an index of flow frequency in a specific area, the cross-sectional geometry of the channel at the head berm determines the magnitude of flow at the site. Breaching flow and channel geometry might thus be considered an index of what would normally be termed climatic and basin characteristics in conventional basin hydrology. The significance of the cross-sectional geometry at the head berm of channels in classifying aquatic habitat can be summarized best by examining the hypothetical flow apportionment to two parallel channels with comparable breaching flows but different cross-sectional geometry (Figure 7). Note that for the same increase in stage at the head berm, a channel that is broad with gentle-sloping sides will receive more flow than a channel with a relatively narrow cross-sectional geometry. The wetted surface area of the broad channel will likewise be greater than that for the narrow channel, and will increase at a faster rate per incremental increase in stage. In short, the broad channel will provide more, but less stable, aquatic habitat per unit of mainstem stage than will the narrow channel. In a hydrologic sense, the broad channel would be termed responsive or perhaps, "flashy."

Understanding the hydrology of individual channel branches is a prerequisite to the development of representative groups. Towards this end, a study to identify the characteristic site-specific flow to mainstem discharge response associated with the cross-sectional geometry of middle Susitna River side channels was undertaken. Because of limitations in the aerial photo coverage of the middle Susitna River, it was not possible to study the cross-sectional geometry of every specific area. Instead, the objective was to develop a



LEGEND
Water surface _ _ _

Figure 7. Cross-sectional geometry at the head berm of two channels having the same breaching flow. Note how differences in cross-sectional geometry affects the rate of wetted surface area development for a comparable increase in mainstem stage.

qualitative appreciation of the types and range of site flow response that could be expected at middle Susitna River specific areas. This information aids the subjective consideration of cross-sectional geometry in the development of representative groups.

Methods

The wetted top widths at the head berm of 46 distinct side channels were used in the analysis of channel cross-sectional geometry. The project team identified the head berm for each channel using the 5100 cfs aerial photography, and wetted top width at the head berm cross section was measured at all photographed flows with a 40-division-per-inch scale. Top width versus mainstem discharge was then plotted for each channel and subjectively classified as steep, moderate, flat, or irregular, based on the characteristic slope.

2.1.4 CROSS-SECTIONAL GEOMETRY OF MAINSTEM

An analysis of available cross-sectional geometry in the mainstem was performed in conjunction with the site-specific analysis of channel geometry. The rate of change in mainstem water surface elevation to an incremental increase in discharge varies between mainstem reaches. A reach of the mainstem that is constricted will have a steeper stage/discharge relationship than one that is less confined. The effect on side channels adjacent to constricted areas is an increase in responsiveness of site flows to incremental changes in mainstem discharge. The opposite is true for side channels associated with reaches where the mainstem stage/discharge curve is flatter.

This analysis was undertaken to supplement the understanding of site flow response gained from the study of cross-sectional geometry of side channel head berms. The results will further aid the evaluation of the effects of cross-sectional geometry on specific area hydrology and will be considered in the development of representative groups.

Methods

Mainstem cross-sectional data from R&M Consultants (1982) was analyzed over a stage increase from 9700 to 23400 cfs at selected cross sections distributed throughout the middle Susitna River. The difference between the 9700 and 23400 cfs water surface elevations at each section was scaled and the resultant stage increase was recorded in feet.

2.1.5 EVALUATION OF UPWELLING

The presence of an upwelling groundwater source that persists through winter is the most important habitat variable influencing the selection of spawning areas by chum salmon (O. keta) (Estes and Vincent-Lang 1984). Upwelling also has a positive influence on the success of overwintering juvenile chinook salmon as well as on egg-to-fry survival for chum salmon (Vining et al. 1985).

Methods

The project team examined each specific area in the winter photography for the presence or absence of open leads in the ice cover. While open leads can be caused by high velocities, it was assumed that leads were caused by the heat of upwelling groundwater. The presence of clear water in the 5100 cfs photography also suggested upwelling in many areas.

Field observers made on-site evaluations at each specific area. In clearwater areas, upwelling was indicated visually by the presence of small volcano-like structures in the substrate caused by upwelling flow. The presence of upwelling was difficult to determine in most breached areas because the turbidity restricted visibility. Upwelling in these specific areas was determined primarily by the evaluation of aerial photography. Site visits provided the opportunity to evaluate whether open leads visible in the winter photography were caused by velocity or groundwater upwellings.

2.2 HYDRAULIC COMPONENT

While the hydrologic component of an aquatic habitat may indicate favorable conditions for fish, the site's suitability for fish may be limited by hydraulic, or energy-related, conditions, such as high velocities. Three indices of hydraulic energy were used in characterizing specific areas for this report: (1) estimated and measured mean reach velocity; (2) dominant bed material size; and (3) channel morphology. While slope is the conventional index of the rate of energy required to move water and sediments downstream in an open channel, due to the large number of side channels, it was impractical to determine the slope of each channel by differential leveling. Therefore, these particular indices were chosen.

2.2.1 MEAN REACH VELOCITY

In the hydraulic component, mean reach velocity offers the best estimate of channel slope with the additional advantage of being a significant index of habitat quality. The weakness of mean reach velocity as an index of slope, however, is its dependence on flow. A comparison of mean reach velocities of several individual channels, therefore, is meaningful only if the relationship between mean reach velocity, site-specific discharge, and mainstem discharge is understood. Generally, it is necessary to collect mean reach velocity data at several mainstem and site-specific discharges to adequately describe this relationship. However, site-specific breaching flow defines the highest mainstem flow in which site-specific discharge and mean reach velocity have a magnitude of approximately zero. Breaching flows can thus be used to normalize mean reach velocity values with respect to mainstem discharge and provide a basis for comparing velocities of specific areas that have different breaching flows.

Other variables, such as differences in channel bed roughness (n, dimensionless) and hydraulic radius (R, in feet) affect the relationship between velocity (V, in feet per second (fps), and channel bed slope (S, in feet per feet). Channel bed roughness is an empirical energy loss coefficient, and the hydraulic radius is a function of stage and channel cross-sectional geometry, although for wide channels it is effectively dependent on depth of flow. Manning's Equation relates the variables as follows:

$$V = \frac{1.49}{n} R^{2/3} S^{1/2}$$

Mean reach velocities used in conjunction with corroborating evidence, such as substrate size and channel morphology, reveal much about channel hydraulics.

Methods

Three methods were used to determine mean reach velocity. The first method involved estimating the surface velocity by recording the time it took a floating object to travel a known distance. The mean reach velocity was estimated as 85 percent of this surface velocity (Linsley and Franzini 1979). The second method involved measuring the height (h) that water "climbed" a survey rod held perpendicular to the flow (i.e., potential head). The relationship between h and mean reach velocity is depicted in Figure 8. Tabulated values of velocity corresponding with particular heights appear in Table 4. On rare occasions, a Marsh McBirney Type 201 portable current meter with wading rod was used to measure velocity. Velocity was measured at a point 0.6 times the depth from the water surface elevation for depths less than or equal to 2.5 ft. Velocity was determined as the average of measurements made at 0.2 and 0.8 times the depth from the water surface elevation for depths greater than 2.5 ft. The Marsh McBirney was used primarily to check the accuracy of the two approximate methods of estimating mean reach velocities.

2.2.2 SUBSTRATE SIZE

Substrate, or bed material size, is also related to channel slope, as can be deduced from tractive force theory (Chow 1959):

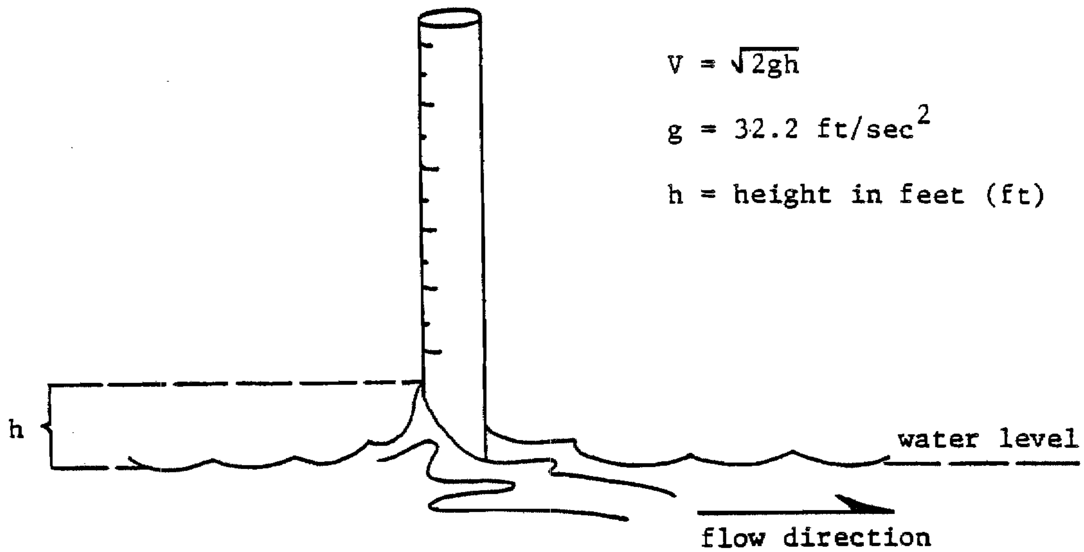


Figure 8. The relationship between height (h) and mean reach velocity as depicted by the rise of the water column against a staff held perpendicular to the flow.

Table 4. The relationship between the height (h) that water climbs a staff when held perpendicular to the flow and mean reach velocity.

Height (ft)	Velocity (fps)	Height (ft)	Velocity (fps)
0.01	0.8	0.14	3.0
0.02	1.1	0.15	3.1
0.03	1.4	0.15	3.2
0.04	1.6	0.17	3.3
0.05	1.8	0.18	3.4
0.06	2.0	0.19	3.5
0.07	2.1	0.20	3.6
0.08	2.3	0.21	3.7
0.09	2.4	0.22	3.8
0.10	2.5	0.24	3.9
0.11	2.6	0.26	4.1
0.12	2.8	0.28	4.2
0.13	2.9	0.30	4.4

$$\tau c = \gamma YS$$

where τc = tractive force, pounds per square foot (psf)
γ = unit weight of water, pounds per cubic foot (pcf)
Y = depth (ft)
S = energy slope (ft/ft)

Tractive force is the force that water exerts on the channel bed. The threshold size of bed material that can be moved is directly proportional to τc.

where $\tau c = d_s (\gamma_s - \gamma) F_s$ (Shields 1936)

d_s = particle size (ft)

γ_s = specific weight of sediment (pcf)

F_s = dimensionless shear stress

Bed material sizes larger than the threshold size associated with a typical high flow event would theoretically make up the substrate.

The elevation, configuration, and orientation of head berms strongly affect the composition and size range of sediments delivered by mainstem flow into side channel areas. Local geology and alluvial deposits also influence the substrate composition of side channel beds. Smaller suspended sediments, skimmed from the upper portion of the mainstem water column, tend to dominate the sediment load entering side channels.

Despite these considerations, characteristic bed material size can be useful in the assessment of available energy in individual channels. Large substrate would suggest a steep channel gradient, whereas accumulation of fine substrate in side channels and side sloughs is indicative of a mild (or low energy) channel slope.

Methods

Field observers coded the characteristic size of the bed materials of a specific area using methods and codes described in Estes and Vincent-Lang (1984). Frequently, more than one code was selected because of the evenly balanced mixture of fine and coarse substrate size classes at many specific areas. The substrate type and corresponding code numbers are presented in Appendix 2.

2.2.3 CHANNEL MORPHOLOGY

Channel morphology is the least direct index of instream hydraulics considered in the analysis. The rationale for its use is that since the form of a river is a function of river processes, river reaches undergoing similar processes would be expected to display similar form. There is little precedent in the literature concerning the relationships between conventional morphological indices of river form, such as sinuosity or radius of curvature, and site-specific characteristics of individual side channels in a split channel or braided river such as the Susitna. Nonetheless, careful inspection of aerial photography reveals considerable evidence of repetitive form throughout the middle Susitna River.

Specific areas may be grouped subjectively and through statistical analyses that focus on correlating the morphologic variables that comprise the plan form of an area (such as channel length, channel width, and channel sinuosity). Statistics may also be applied to identify the variable that most strongly defines each group. In this study, statistics were used to corroborate subjective groupings of specific areas based on channel morphology.

Methods

Plan form analysis of each distinct side channel entailed measurement of selected physical parameters, such as angular orientation to the mainstem, total length, straight line length from channel head to mouth, and representative bankfull top width. Length and width were measured using a Numonics Corporation Electronic Graphics Calculator and Model 2400 Digi Tablet from aerial photographs that had been enlarged to a scale of 1 inch = 250 feet. Orientation angle was determined by drawing two lines, one parallel to the mainstem flow, and one parallel to the flow of the side channel near the head. The inside angle formed by these lines was measured using a protractor.

Sinuosity was calculated for each specific area as the ratio of total channel length to straight-line length between channel head and mouth. A straight-line channel has a 1:1 ratio. This ratio increases with increased sinuousity. Channel length-to-width ratios were also calculated for each specific area.

The following groups of variables were subject to cluster analysis using Ward's method: length, width, length-to-width ratio, sinuosity, and number of bends. These analyses were followed by a discriminant analysis using the direct entry method. The number of cases (specific areas) utilized in the analysis was limited to 70 distinct side channels.

Cluster analysis is undertaken to sort cases into groups such that the degree of association is high between members of the same group and low between members of different groups (Wishart 1978). Seven clustering methods are available from the SPSS-X package (Statistical Procedures for the Social Sciences - Version X): Between groups average, within groups average, single, complete, centroid, median, and Ward. Of these seven methods, Wishart (1978) considers Ward's method the best method for finding minimal variance spherical clusters. Ward's method was used in this study to identify groups of specific areas that are morphologically similar. Once well-defined clusters are formed from a cluster analysis, it is possible to determine which variables contribute most to their separation. A suitable approach is to set up discriminate functions using a multiple-discriminant analysis. The weighting coefficients (standardized discriminant function coefficients) for each of the variables identify those which contribute most to the separation of the groups along each respective function (Klecka 1975). Numerical values give the percentage variances that are accounted for by each function. Signs for the coefficients indicate whether the variables are positively or negatively correlated. Multiple discriminant function analysis was used in this study to identify the most important variables for the discrimination of morphologically similar groups.

2.3 STRUCTURAL COMPONENT

While site-specific hydrologic and hydraulic indices are a rational approach to defining representativeness in terms of instream hydraulics, the structural component is needed to consider the variation in aquatic habitat quality that results from differences in nonhydraulic attributes between specific areas. This component is defined as the physical formation of the channel bed, which includes vegetation, debris, deadfall, sediments, etc. The evaluation of structural cover is an important habitat component influencing the distribution of juvenile salmon (Reiser and Bjornn 1979), and therefore is a prerequisite to the development of habitat assessments.

In the IFIM, the structural component is typically described and incorporated into the analysis using a number of substrate and cover codes depending on the species/life stage and river system under study. In the middle Susitna River, cover codes developed by ADF&G (Suchanek et al. 1984) were used to describe structural cover at study areas. Cover suitability data for juvenile chinook salmon were then used to develop weighting factors for the evaluation of the relative contribution to overall habitat quality of the various cover types. By combining structural habitat weighting factors with hydrologic and hydraulic input, a comprehensive physical habitat simulation model was developed for each study area.

Structural variables such as debris, deadfall, boulder, and vegetative cover are frequently the result of localized conditions within a river corridor, such as those of topography, soils, geology, or channel morphology. Bed material size may also vary from one reach to another, even within areas of relatively uniform channel gradient (de Leeuw 1981). In a multiple-thread river system such as the Susitna, structural diversity is increased because of differences between channel branches. Braided river channel branches are of variable size and habitat character depending on local conditions and their relative position in the river's geomorphic regime. Where a single-thread river will often show characteristics of increased geographic maturity as one moves from the headwaters to its mouth (Lane 1955), a braided river will display longitudinal *and* lateral variation in age characteristics as channel migration leaves a history of remnant, peripheral, and mainstem channels along the same cross section.

2.3.1 STRUCTURAL HABITAT INDEX

To extrapolate habitat modeling results from study areas, the association of channel branches of a common geomorphic regime into representative groups significantly reduces the hydrologic, hydraulic, and morphologic disparity between portions of the river. However, field observations substantiate the expectation that, due to spatial variation, similar channel branches display a certain amount of structural diversity within the same representative group according to local conditions (e.g., topographic, geologic, morphologic, etc.). Consequently, a means was devised by use of a structural habitat index (SHI) to comparatively evaluate and weight the structural habitat quality of each specific area within each representative group. With this index, extrapolation of modeling results can be done within representative groups from modeled specific areas to nonmodeled specific areas with an adjustment for differences in structural habitat quality.

The basic premise behind the concept of the structural habitat index is simple. If two channels have comparable hydraulics and hydrology and different habitat values, the difference in habitat value must be attributed to differences in channel structure. Outwardly, this is a simplistic conclusion which does not address the possible effects of differences in water quality, nutrient loading, site location, and other environmental variables. However, when a judicious evaluation is made between sites within the same stream subsegment, many of these variables can be considered constant, or of secondary, or even minor, importance.

Methods

Structural habitat indices (SHI) represent the synthesis of six structural habitat variables into a single value: dominant cover; percent cover; substrate size; substrate embeddedness; channel cross-sectional geometry; and streamside vegetation. The procedure to derive structural habitat indices involves three steps: (1) rating the affect of each variable on juvenile chinook salmon habitat quality for each specific area; (2) ranking the relative importance of each variable to juvenile chinook salmon habitat quality; and (3) combining rating and weighting factors into a structural habitat index for each specific area. An explanation of each step follows.

Information obtained from habitat inventory and aerial photo procedures was the basis for rating each structural habitat variable. The precision of this information permitted the rating of each variable into the following categories: excellent, good, fair, poor, and nonexistent. These rating categories were assigned numerical values of 1.0, 0.75, 0.50, 0.25, and 0.0, respectively.

Dominant cover and percent cover were rated as a variable combination to allow for the use of ADF&G clearwater cover suitability criteria for juvenile chinook salmon in the rating process (Table 5). Clearwater criteria were selected rather than turbid water criteria because of their independence from the influence of turbidity as a cover variable. The clearwater criteria were thus assumed to be more directly related to structural cover as described by dominant cover and percent cover codes (see Appendix 2). Juvenile chinook salmon criteria were used because they are a primary evaluation species in middle Susitna River instream flow studies (E. Woody Trihey & Associates and Woodward-Clyde Consultants, 1985).

Table 5. Cover suitability criteria recommended for use in modeling juvenile chinook habitat under clearwater conditions in the Susitna River (Schmidt et al. 1984).

	COVER TYPE								
Percent Cover	No Cover	Emergent Veg.	Aquatic Veg.	Large Gravel	Rubble 3"-5"	Cobble or Boulders 5"	Debris & Deadfall	Overhanging Riparian	Undercut Banks
Clear Water (ADF&G)									
0-5%	0.01	0.01	0.07	0.07	0.09	0.09	0.11	0.06	0.10
6-25%	0.01	0.04	0.22	0.21	0.27	0.29	0.33	0.20	0.32
26-50%	0.01	0.07	0.38	0.35	0.45	0.49	0.56	0.34	0.54
51-75%	0.01	0.09	0.53	0.49	0.63	0.69	0.78	0.47	0.75
76-100%	0.01	0.12	0.68	0.63	0.81	0.89	1.00	0.61	0.97

The suitability criteria for cover were rated by dividing the range of suitability index values into discrete intervals, each corresponding to a rating factor, as follows: 0.0 (nonexistent), 0.01-0.10 (poor), 0.11-0.30 (fair), 0.31-0.50 (good), and 0.51-1.0 (excellent). The professional judgement of EWT&A and AEIDC staff biologists was used to establish these intervals. The rating factors for dominant cover and percent cover codes for each specific area were obtained by classifying the corresponding suitability index into one of the above intervals. A matrix of dominant cover and percent cover rating factors appears as Table 6.

Table 6. Dominant cover/percent cover rating factors.

Percent Cover Code	Dominant Cover Code								
	1	2	3	4	5	6	7	8	9
1	0.25	0.25	0.25	0.25	0.25	0.25	0.50	0.25	0.25
2	0.25	0.25	0.50	0.50	0.50	0.50	0.75	0.50	0.75
3	0.25	0.25	0.75	0.75	0.75	0.75	1.00	0.75	1.00
4	0.25	0.25	1.00	0.75	1.00	1.00	1.00	0.75	1.00
5	0.25	0.25	1.00	1.00	1.00	1.00	1.00	1.00	1.00
6	0.25	0.50	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Channel cross-sectional geometry was evaluated as a structural habitat variable on the basis of the approximate proportions in which three general types of channel cross-sectional geometry were represented at each specific area. The three cross-sectional types are as follows: (1) broad cross sections with gentle-sloping banks; (2) cross sections with one gentle-sloping bank and one steep bank; and (3) cross sections that are incised with two steep banks. The first cross-sectional geometry type has a positive correlation with habitat availability for juvenile chinook salmon by providing proportionately larger areas along channel margins where edge effects retard velocities to suitable levels. Velocity suitability criteria for juvenile chinook indicate that suitability decreases as velocities become greater than 0.35 fps for turbid conditions and 0.65 fps for clearwater conditions (Suchanek et al. 1984). Cross-sectional geometry with one gentle-sloping bank was rated half as valuable as cross-sectional geometry with two gentle-sloping banks. Incised cross-sectional geometry with steep banks received a zero rating factor. Streambank slope codes (see Appendix 2) and aerial photo interpretation were used to evaluate the cross-sectional geometry of each specific area. Proportions for the three types of channel cross-sectional geometry were allocated into the following categories with the sum for a given specific area to equal 1.0: 0, 0.25, 0.50, 0.75, and 1.00. Table 7 lists rating factors for the various combinations of cross-sectional geometry types that could be represented at a specific area.

Table 7. Channel cross-sectional geometry rating factors for the various combinations of cross-sectional geometry types that could be represented at a specific area.

Channel Cross-sectional Geometry Type	Proportion of Cross-sectional Geometry Type													
2 gentle-sloping sides	1.00	0.75	0.75	0.50	0.50	0.25	0.00	0.50	0.25	0.25	0.00	0.25	0.00	0.00
1 gentle-sloping side	0.00	0.25	0.00	0.50	0.25	0.75	1.00	0.00	0.50	0.25	0.75	0.00	0.25	0.00
2 steep sides	0.00	0.00	0.25	0.00	0.25	0.00	0.00	0.50	0.25	0.50	0.25	0.75	0.75	1.00
Rating Factor	1.00	1.00	0.75	0.75	0.75	0.75	0.50	0.50	0.50	0.50	0.50	0.25	0.25	0.00

The channel cross-sectional geometry rating factors assume that velocities prohibitive to juvenile chinook salmon occur in the primary flow corridor of each specific area. While this is true for the preponderance of side channel habitats during breached conditions in the middle Susitna River, it is not true for upland sloughs and side channel habitats that are nonbreached. For this reason, upland slough habitats, which seldom have velocities that are prohibitive to juvenile chinook, were all rated as excellent for channel cross-sectional geometry. This eliminated cross-sectional geometry as a discriminating factor of structural habitat quality between upland sloughs. Side channel habitats were evaluated for breached conditions only, when it could be assumed that cross-sectional geometry was correlated with the availability of channel margin habitats possessing suitable velocity for juvenile chinook salmon. The nonbreached phase of side channel habitats (side slough habitat) is less heavily utilized by juvenile chinook salmon (Schmidt et al. 1984).

Substrate size and substrate embeddedness are important descriptors of the predominant constituent of a channel's bed material. Suitability criteria indicate that increased substrate size increases cover value for juvenile chinook (Steward 1985) by providing larger velocity breaks and more interstitial space for refuge. Substrate embeddedness, which implies a large streambed element partially buried in a finer substrate material, has an inverse relationship to structural habitat quality. In the middle Susitna River, sand and silt are widely distributed and frequently fill a portion of the interstitial space between coarse substrate size classes. This reduces the interstitial space available for occupancy by juvenile chinook and, in heavily embedded areas, smooths the streambed, eliminating velocity breaks and increasing flow velocity.

Substrate size and embeddedness were coded in the field (see Appendix 2) and rated as a variable combination. Rating values similar to suitability factors for the cover variable combination of substrate size/percent cover reported by Steward (1985) were incorporated into a rating table (see Table 8). Differences between the rating table for substrate size/embeddedness and substrate size/percent cover include the incorporation of more substrate size classes into the former. Bed material in side channels of the middle Susitna River varies in size from silt to boulders and it was essential to describe substrate character as accurately as possible. Suitability factors for substrate size/percent cover include only three size classes: large gravel (1-3"), rubble (3-5"), and cobble/boulder (>5"). Rating factors for substrate size classes finer than large gravel were derived based on field experience, professional judgement, and interpretation of the trends of coarser substrate size suitability factors.

Table 8. Substrate size/substrate embeddedness rating factors.

Substrate Embeddedness Code	Substrate Size Code												
	1	2	3	4	5	6	7	8	9	10	11	12	13
1	0.00	0.00	0.00	0.00	0.00	0.25	0.25	0.25	0.50	0.50	0.50	0.50	0.50
2	0.00	0.00	0.00	0.00	0.25	0.25	0.25	0.50	0.50	0.75	0.75	1.00	1.00
3	0.00	0.00	0.00	0.25	0.25	0.50	0.75	0.75	1.00	1.00	1.00	1.00	1.00

Streamside vegetation codes (see Appendix 2) and aerial photography were used to evaluate the extensiveness of streamside vegetation for each specific area. Channel width was also considered in the evaluation of rating factors because the relative effect of streamside vegetation on overall channel habitat quality is a function of width. Streamside vegetation as a structural habitat variable affects shading, terrestrial insect import, and bank stability. Vegetation as a cover parameter is included in the dominant cover coding discussed earlier. The rationale behind the assignment of rating factors is reflected in Table 9. Actual ratings of streamside vegetation were assessed for each specific area based on professional judgement.

Table 9. Streamside vegetation rating factor.

	Rating Factor
Narrow Channel/Extensive Vegetation	1.00
Moderate Channel Width/Extensive Vegetation	0.75
Moderate Channel Width/Moderate Vegetation	0.50
Wide Channel/Extensive Vegetation	0.25
Wide Channel/Moderate Vegetation	0.00

After each structural habitat variable/variable combination was rated, it was necessary to weight the relative importance of each variable/variable combination to overall structural habitat quality. As there is a negligible amount of information in the literature pertaining to weighting schemes of habitat variables, development of the criteria to accomplish this task was not straightforward. Hynes (1970) notes that it is generally recognized that temperature, water quality, water depth and velocity, cover or shelter, and streambed material are the most important physical variables affecting the amount or quality of riverine fish habitat. Gorman and Karr (1978) suggest that three physical habitat variables are important in the microhabitat specialization of stream fishes; these are substrate, depth, and current. Binns and Eiserman (1979) included cover, stream width, bank stability, and substrate among nine habitat attributes used in a regression model developed to predict trout standing crop in Wyoming streams. In the final analysis, the criterion used to weight the relative importance of the habitat variable/variable combinations on overall structural habitat quality for juvenile chinook salmon was that of corroboration between resulting structural habitat indices and subjective habitat quality evaluations recorded on habitat inventory field forms. This corroboration was satisfied by the following weighting scheme for the respective variable/variable combinations: (1) dominant cover/percent cover (0.45); (2) channel cross-sectional geometry (0.30); (3) dominant substrate size/substrate embeddedness (0.20); and (4) streamside vegetation (0.05). A summary of the weighting factors for each variable/variable combination appears as Table 10.

Table 10. Structural habitat variables and their corresponding weighting factors and order of importance.

Habitat Variable	Weighting Factor
Dominant Cover/Percent Cover	0.45
Channel Cross-Sectional Geometry	0.30
Substrate Size/Substrate Embeddedness	0.20
Streamside Vegetation	0.05

Rating and weighting factors were combined in a matrix that provided a convenient form for evaluating structural habitat indices. For example, consider specific area 136.0L. This specific area is a small side channel with a dominant cover code of 7, percent cover code of 2, cross-sectional geometry described as 75 percent 2 steep sides, 25 percent 1 steep side, substrate size code of 8, and a substrate embeddedness code of 2. Streamside vegetation was judged to be fair. From Table 6, dominant cover/percent cover receives a rating of good. Channel cross-sectional geometry is rated as poor (Table 7) and substrate size/substrate embeddedness is rated fair (Table 8). Figure 9 demonstrates the use of the structural habitat index form to combine rating and weighting factors into a SHI value for specific area 136.0L. This process was repeated for all 172 specific areas inventoried in the middle Susitna River.

Affect on Habitat Quality (Rating Factor)		Habitat Variable/Variable Combination (Weighting Factor): Dominant Cover/Percent Cover (0.45)	Channel Geometry (0.30)	Substrate Size/ Substrate Embeddedness (0.20)	Streamside Vegetation (0.05)
Excellent	(1.00)	.45	.30	.20	.05
Good	(0.75)	.34	.23	.15	.04
Fair	(0.50)	.23	.15	.10	.03
Poor	(0.25)	.11	.08	.05	.01
Nonexistent	(0.0)	.0	.0	.0	.0
Product of rating and weighting factors		.34	.08	.10	.03

SHI = .55

Figure 9. Structural habitat index form for specific area 136.0L.

3. RESULTS AND DISCUSSION

Results and discussion pertaining to the characterization of each aquatic habitat component is presented in this section in the order of their development: hydrologic, hydraulic, and structural. The application of these habitat characterizations to the development of structural habitat indices and representative groups will follow.

3.1 HYDROLOGIC COMPONENT

Of the five indices used to describe the hydrology of specific areas (Section 2.1), habitat transformation, breaching flow, and upwelling were the most useful for characterizing aquatic habitat.

3.1.1 HABITAT TRANSFORMATION TRACKING

The results from the habitat transformation monitoring methodology appear in Appendix 3 where habitat transformation categories for each specific area between the reference flow of 23000 cfs and all lower flow aerial photography are listed. From the results, the number of specific areas in each habitat transformation category was tabulated for each evaluation flow (Table 11). Table 11 and Figure 10 illustrate how the quantity of riverine habitats in the middle Susitna River change significantly as mainstem discharge decreases. For a discussion of the qualitative aspects of the change in habitats, see Section 3.2.1, Mean Reach Velocity. The number of clearwater habitats with breaching flows greater than 35000 cfs (Category 1) is relatively stable throughout the flow range. There is a substantial increase in the number of side channels that transform to sloughs as mainstem discharge decreases (Category 2) and a corresponding decrease in the number of side channels (Category 4). As can be expected, the number of indistinct areas (Category 6) and mainstem areas (Category 10) also decrease. The number of areas that dewater (Category 9) showed the most dramatic change, with a fivefold increase between the highest and lowest flows. The number of areas described by the remaining categories (Categories 3, 5, 7, and 8) fluctuate over the flow range considered, but collectively account for only 10 to 20 percent of the 172 specific areas evaluated.

Table 11. Number of specific areas in each habitat transformation category by evaluation mainstem flow, referenced to 23000 cfs.

	Evaluation Mainstem Q (cfs)						
	18000	16000	12500	10600	9000	7400	5100
Category	Number of Specific Areas						
1	35	34	33	33	33	32	32
2	12	14	19	24	27	30	30
3	7	6	8	8	11	10	13
4	48	46	40	35	26	24	24
5	5	6	8	11	13	11	11
6	33	32	28	22	18	18	15
7	3	3	3	3	3	4	5
8	3	3	5	7	8	5	4
9	6	8	13	14	20	27	30
10	20	20	15	15	13	11	8

It is interesting to note that the number of dewatered specific areas remains relatively stable between mainstem discharges of 12500 and 10600 cfs (13 and 14, respectively), but then almost doubles with a reduction in discharge to 7400 cfs (27). An accelerated change in overall riverine habitat character appears to occur between 10600 and 7400 cfs.

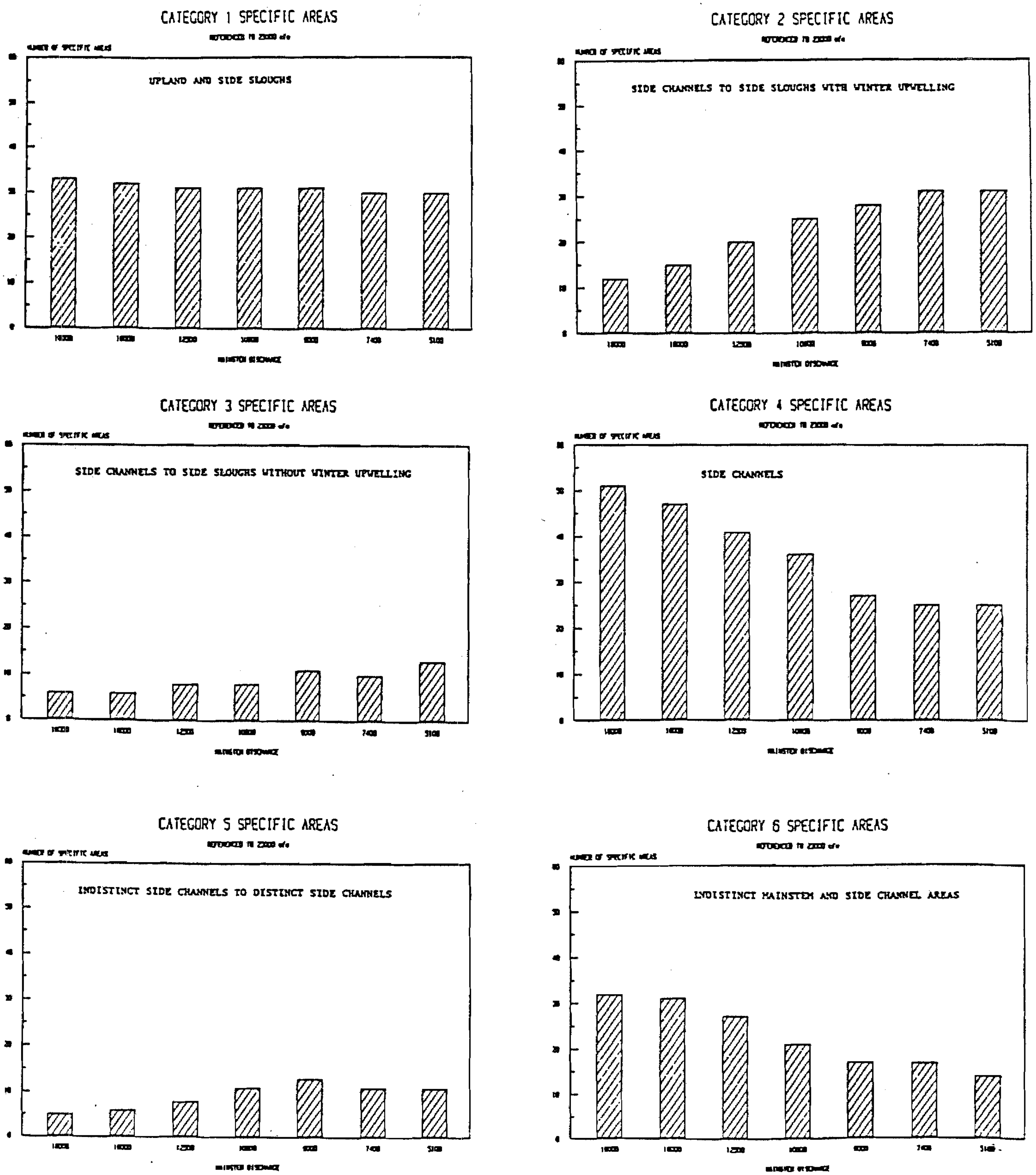


Figure 10. Number of specific areas in each habitat transformation category at various mainstem flows.

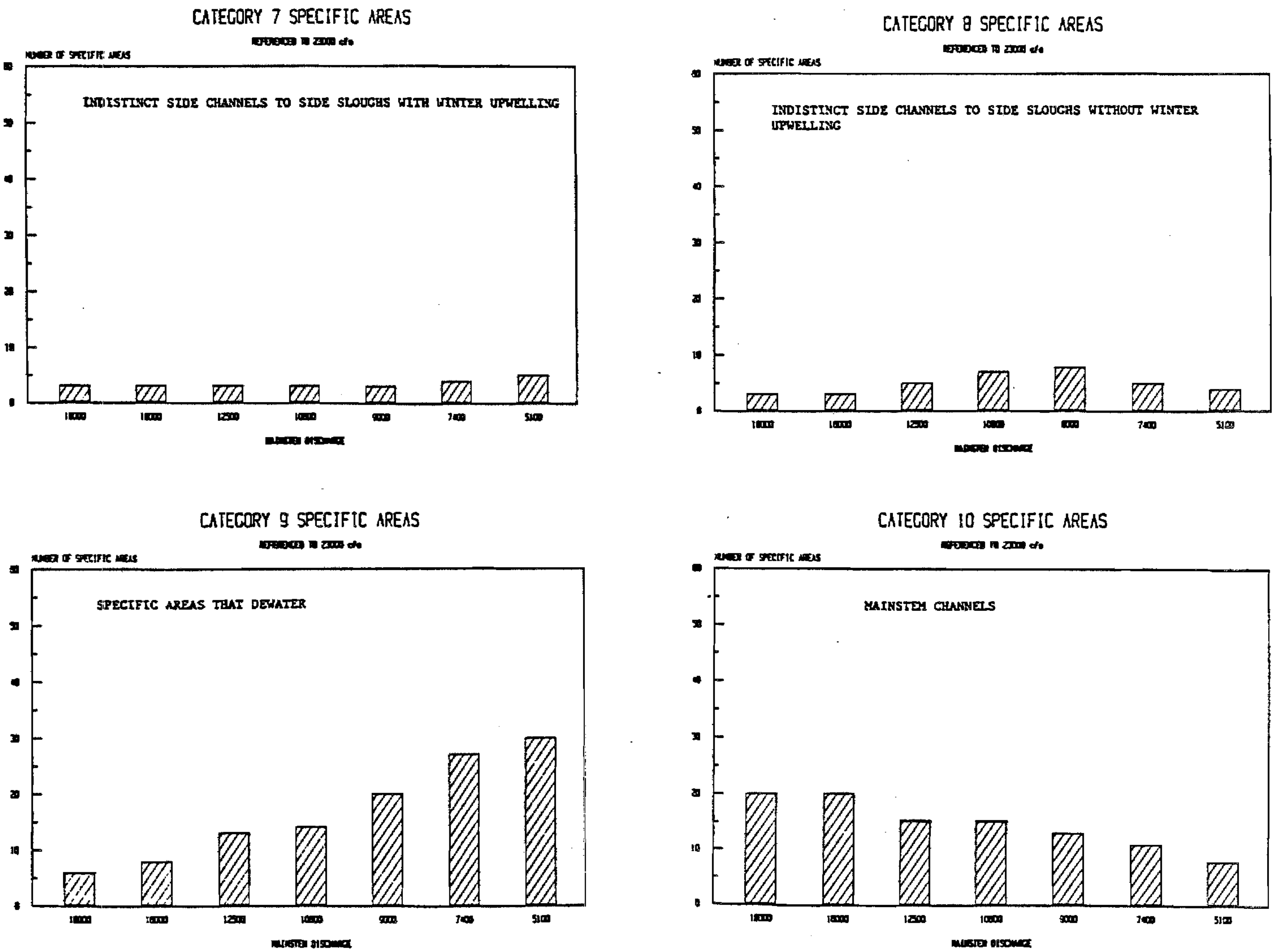


Figure 10 (Continued).

Klinger and Trihey (1984) observed similar trends in the overall habitat character as flows decrease. They used wetted surface area as an index of habitat quantity and determined that as mainstem discharge decreases from 23000 to 9000 cfs, there was an associated decrease in mainstem habitat (from 3737 to 2399 acres) and side channel habitat (from 1241 to 762 acres) and an increase in side slough habitat (from 53 to 156 acres). The wetted surface area of upland slough habitat was relatively stable within this flow range.

3.1.2 BREACHING FLOW

Breaching flows were determined with a precision of approximately ±1500 cfs within the flow range from 5100 to 18000 cfs, and ±2500 cfs above 18000 cfs and below 5100 cfs. Breaching flows for each specific area are listed in Appendix 4.

3.1.3 CROSS-SECTIONAL GEOMETRY OF SIDE CHANNEL HEAD BERMS

Plots of wetted top width at the head berm versus mainstem discharge were developed for 46 specific area channels that had low breaching flows and readily identifiable head berms. These were classified by curve slope into four categories: (1) steep; (2) moderate; (3) flat; and (4) irregular (Figure 11). The interpretation of each category of curve slope is as follows:

(1) steep slopes are indicative of broad channel sections with relatively gentle-sloped sides at the head berm;

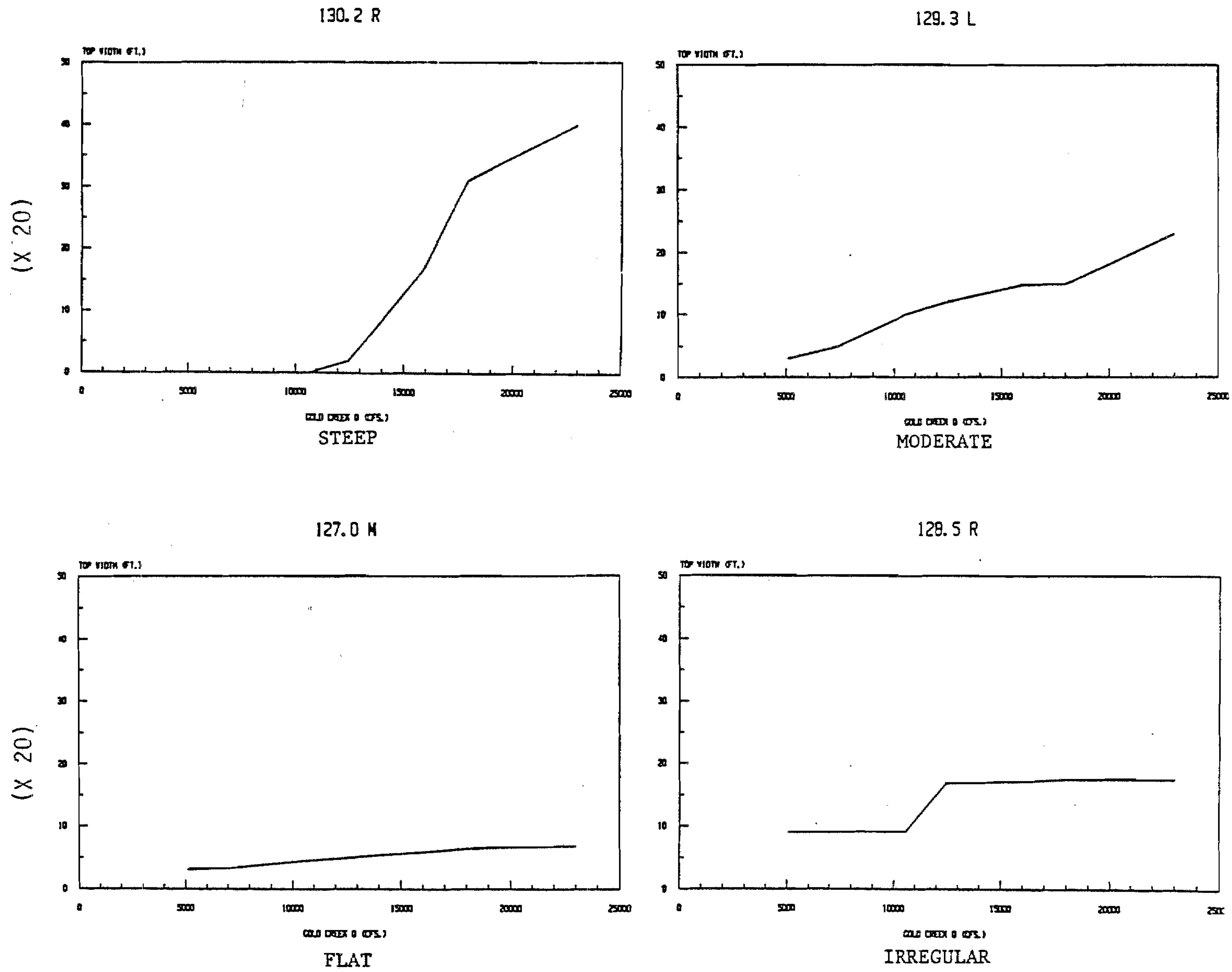


Figure 11. Representative wetted top width versus discharge plots for each category of curve slope.

(2) moderate slopes are indicative of channels with cross-sectional geometry at the head berm that is gentle-sloped on one side and steep on the other;

(3) flat slopes are indicative of channels where cross-sectional geometry at the head berm has steep-sloping sides; and

(4) irregular or stepped curves are indicative of channels with irregular cross-sectional geometry at the head berm.

Of the 46 side channels studied in this section, 21 (46%) had curve slopes that were flat, 11 (24%) moderate, 8 (17%) irregular, and 6 (13%) steep (Table 12). Generally, mainstem and large side channels had flat curve slopes characteristic of steep-sided channels. There was also a tendency for the large channels with breaching flows between 8000 and 16000 cfs to be broad with gentle-sloping sides.

From Table 12, it is apparent that each curve slope class is distributed throughout the middle Susitna River. No longitudinal trends were observed for consideration in grouping specific areas. Although no consistent trends were identified from the data, the study provided insights useful in the subjective consideration of cross-sectional geometry as a criterion for the development of representative groups.

Table 12. Curve slope classes of plots of wetted top width versus discharge from measurements made at channel head berms at 46 specific areas in the Talkeetna-to-Devil Canyon segment of the Susitna River.

Specific Area	Curve Slope Class	Specific Area	Curve Slope Class
100.6L	3	123.0L	3
100.7R	2	124.1L	3
101.2R	2	125.2R	3
101.5L	2	125.6L	2
102.6L	4	127.0M	3
105.7R	4	127.1M	4
106.3R	4	127.4L	2
108.7L	3	128.5R	4
108.9L	2	129.3L	2
109.4M	3	130.2R	1
110.8M	3	130.2L	3
111.0R	3	131.7L	4
111.5R	3	132.6L	3
112.6L	1	134.9R	3
114.0R	3	135.0L	3
115.0R	1	136.0L	3
116.8R	4	137.2R	1
117.7L	3	138.0L	1
117.8L	2	138.8R	1
119.2R	2	139.4L	4
119.6L	3	139.6L	3
121.1L	2	144.2L	3
121.7R	3	145.3R	2

Curve slope classes: 1 = steep, 2 = moderate, 3 = flat, 4 = irregular

3.1.4 CROSS-SECTIONAL GEOMETRY OF MAINSTEM

The increase in mainstem stage due to an increase in mainstem discharge varies between mainstem reaches of the middle Susitna River (Table 13). The responsiveness of mainstem stage to discharge in a reach has a direct influence on the hydrologic regimen of adjacent side channels. In reaches where mainstem stage is relatively responsive to changing discharge, the volume of flow entering adjacent side channels will be relatively unstable. The opposite is true in reaches where mainstem stage responds less dynamically to changing discharge. From the information in Table 13, it would be expected that side channel habitats within the continuous reach from river miles 131 to 137 would have less stable flow regimes than other channels in the middle Susitna River.

Characteristic mainstem stage fluctuations may prove useful in subsequent analyses, especially in the interpretation of WUA curves. For example, a steep and laterally compressed WUA curve could be explained by the relatively large response of mainstem stage to discharge at a mainstem reach.

Table 13. Stage increase at selected cross sections in the Talkeetna-to-Devil Canyon segment of the Susitna River as mainstem discharge increases from 9700 to 23400 cfs.

Cross Section No.	River Mile	Stage Increase (Ft.)
7	101.5	1.9
11	106.7	2.6
25	121.6	2.2
29	126.1	2.0
36	131.2	3.5
44	136.4	3.3
49	138.2	2.8
54	140.8	2.7
55	141.5	2.4

Source: R&M Consultants 1982

3.1.5 EVALUATION OF UPWELLING

Table 14 lists the specific areas that were determined to possess upwelling. Of 59 specific areas that had open leads in the March 1983 photography, 40

Table 14. Summary of the specific areas where upwelling is present in the Talkeetna-to-Devil Canyon segment of the Susitna River.

Specific Areas with Upwelling					
River Mile	Open Leads	Spawning Activity*	River Mile	Open Leads	Spawning Activity*
100.60R	X	X	129.40R	X	X
100.60L			130.20R	X	X
101.20R	X	X	130.20L		X
101.40L	X	X	131.30L	X	X
101.60L	X	X	131.70L		X
101.71L	X		131.80L		X
101.80L	X	X	132.60L		
102.20L	X	X	132.80R	X	X
107.60L			133.70R	X	X
110.40L	X		133.80L	X	
111.60R			133.90R	X	X
112.50L	X		133.90L	X	X
112.60L			134.00L	X	
113.70R	X	X	134.90R		X
115.00R	X	X	135.10R		
115.60R	X	X	135.30L		
116.30R			135.60R	X	X
117.80L	X		135.70R	X	
117.90L	X	X	136.30R	X	X
118.00L			136.90R	X	
118.60M			137.20R	X	X
118.91L	X	X	137.50R	X	
119.11L	X	X	137.50L		
119.30L	X	X	137.80L	X	
119.70L	X		137.90L	X	
120.00R	X	X	138.00L	X	
121.10L		X	138.71L		
122.40R	X	X	139.00L	X	X
122.50R	X	X	139.01L		X
123.20R			139.50R	X	
123.60R	X	X	139.70R	X	
124.00M	X		139.90R	X	X
125.10R	X		140.20R	X	X
125.90R	X	X	140.60R		X
126.00R	X	X	141.40R	X	X
126.30R	X	X	141.60R	X	X
127.00L			142.10R	X	X
127.20M	X		143.00L	X	X
127.40L			143.40L		X
128.50R	X		144.20L		
128.70R	X	X	144.40L	X	X
128.80R	X	X	145.60R		
129.30L					

*Spawning activity observed as indicated by the presence of redds or spawning behavior.

(68%) were observed to have chum salmon spawning activity during the 1984 habitat reconnaissance surveys. There was also a strong correlation between the presence of chum salmon spawners and those specific areas where upwelling was observed in the field but did not necessarily have open leads in the winter photography. Of these 85 sites, 48 (56%) were observed to have chum salmon spawning activity.

More indicative of the importance of upwelling to spawning chum salmon is the percentage of specific areas where spawning activity was observed that also had upwelling. Of the 53 specific areas where spawning activity was observed, 48 (91%) were observed to have upwelling. ADF&G maps of chum salmon spawning areas were thus used to corroborate upwelling. A summary of fish observations appears in Appendix 5.

Although field observations of upwelling are highly reliable, upwelling may have gone unobserved in some areas due to specific conditions. For instance, turbid water conditions make it difficult to detect upwelling directly. Also, the absence of open leads in the winter ice cover does not rule out the presence of upwelling. It is possible that the thermal quality of upwelling that occurs in relatively deep or swift and turbulent currents will become sufficiently diffused by mixing to preclude the formation of a thermal lead in the winter ice cover.

The presence of upwelling is incorporated directly into the habitat transformation categories defined in Table 3. Upwelling is thus included implicitly in the development of representative groups via the sequence of habitat transformation categories that occur at a specific area.

3.2 HYDRAULIC COMPONENT

Analysis of the hydraulic component of specific area habitats was focused on: 1) estimated or measured mean reach velocity during breached conditions, 2) substrate size, and 3) channel morphology. Of these three variables, mean reach velocity was the best and most direct index of channel hydraulics for use in the characterization of habitat.

3.2.1 MEAN REACH VELOCITY

The side channels of the middle Susitna River constitute a complex flow delivery system with individual side channels beginning to flow at various mainstem discharges according to their breaching flows. A comparison of mean reach velocities between side channels for any given mainstem stage would yield a range of values depending on whether the channels were nonbreached, barely breached, or flowing full. Mean reach velocity is thus a stage-dependent variable whose use as a comparative index of side channel hydraulics is complicated by a dependence on breaching flow.

Mean reach velocities were measured or estimated in this study at mainstem discharges ranging from approximately 8000 to 11000 cfs. In a few cases, estimates were made at 18000 cfs. Because of the relatively low flows that were coincident with the field trips, channels where velocities were measured for breached conditions had relatively low breaching flows. This reduced the need to consider the variability of breaching flows between channels in the interpretation of mean reach velocity data. Although it is possible to normalize mean reach velocity measurements at different side channels on the basis of breaching flow, it was not considered necessary in this study. Mean reach velocities are presented in Tables 17-26.

The incomplete data set that was obtained due to consistent low flows during reconnaissance restricted the use of mean reach velocities for the comparative evaluation of hydraulics to specific areas with low breaching flows. Mean reach velocities were obtained during breached conditions for 63 of the 172 specific areas delineated in the middle Susitna River.

The velocity data collected was also useful in describing the hydraulic characteristics of each habitat transformation category. The following generalizations are provided for each category to develop a qualitative appreciation of the trends depicted in Figure 10.

Category 0 - Tributary mouth habitat. These habitats exist as clear water plumes at the confluence of tributaries to the middle Susitna River. This category has not been directly addressed within the extrapolation methodology because of the comparatively small amount of surface area associated with this habitat type.

Category 1 - Upland slough and side slough habitats that do not transform within the flow range of interest. These areas offer low velocities, frequently near-zero, with the greatest hydraulic disparity being depth.

Category 2 - Side slough habitats that have transformed from side channel habitats and which possess winter upwelling. These areas are typified as a series of clearwater pools connected by short, shallow riffles. Riffle velocities are frequently less than 1 fps and 0.5 feet or less in depth. Pool velocities are near zero and depths are generally less than 3 feet.

Category 3 - Side slough habitats that have transformed from side channel habitats. These are distinguished from Category 2 areas only by the lack of an upwelling groundwater source that persists throughout winter. The hydraulic characterization is the same as that of Category 2.

Category 4 - Side channel habitat that has transformed from mainstem habitat or has remained as side channel habitat at the evaluation flow. These areas display greater hydraulic diversity than the previous categories. Velocities range from approximately 2-5 fps (10000 cfs mainstem) between specific areas.

Category 5 - Side channel habitat that has transformed from indistinct channels (Category 6). These are distinguished from Category 4 areas primarily by the presence of one gravel bar bank which becomes inundated at high mainstem discharges, causing the channel to appear less visible (indistinct) in the aerial photography. These channels typically have higher velocities, often greater than 5 fps (10000 cfs mainstem), than Category 4 channels.

Category 6 - Indistinct areas that remain indistinct through the flow range of interest. This category includes those riverine areas termed shoals. By definition, they are shallow water areas, typically marginal to a mainstem channel. Depths are generally under 4 feet and velocities are reduced compared to mean mainstem velocities as a result of channel edge effects.

Category 7 - Side slough habitats that have transformed from turbid indistinct channels and which possess winter upwelling. These areas are distinguished from Category 2 areas primarily by their origin from indistinct rather than distinct channels. The hydraulic characterization is the same as that for Category 2.

Category 8 - Side slough habitats that have transformed from turbid indistinct areas. These areas are distinguished from Category 3 areas primarily by their origin from indistinct rather than distinct channels. The hydraulic characterization remains the same as that for Category 3.

Category 9 - Specific areas that become dewatered. This is a terminal category that requires no hydraulic characterization. These areas may contain isolated pools that, by definition, have no habitat value.

Category 10 - Mainstem habitats that do not transform within the flow range of interest. These channels are typically deeper and swifter than any other habitat category. Mean velocities are frequently 5 fps (10000 cfs mainstem) or greater.

3.2.2 SUBSTRATE SIZE

In the evaluation of substrate size, dominant substrate codes were used (see Appendix 2). Frequently more than one code was selected because of the evenly balanced mixture of fine and coarse substrate size classes present at many specific areas. Sands were distributed throughout the middle Susitna River segment and were considered to be less indicative of specific area hydraulics. For this reason, when more than one dominant substrate size code was selected, the coarser size class was used as the index of channel hydraulics.

Substrate size was found to be a less valuable index of channel hydraulics than mean reach velocity. Although it was evident during the habitat reconnaissance work that mainstem channels had recognizably coarser substrate and swifter velocities than other habitats, it was more difficult to generalize substrate size and the hydraulic characteristics of side channels. Substrate size in side channels is less directly correlated with channel slope and more strongly influenced by factors relating to sediment supply. These factors are: channel head berm geometry and elevation with respect to the mainstem, channel orientation to the mainstem, and influences from localized sediment sources. Although not a primary criterion in the development of representative groups, dominant substrate sizes are presented in Tables 17-26 to aid the reader in developing a qualitative appreciation of channel characteristics.

3.2.3 CHANNEL MORPHOLOGY

Channel morphology was the most indirect index of specific area hydraulics used to characterize habitat. During the course of the habitat reconnaissance field work, considerable evidence of repetitive form was observed throughout the middle Susitna River. Sometimes a distinct plan form was recognized from the air in transit to a specific area. Other times a distinctive riffle/pool pattern was recognized while on the ground. Similarities between specific areas were recorded on the habitat inventory data form for consideration in the development of representative groups. Careful inspection of aerial photography also revealed similarities in plan form between individual side channels.

The middle Susitna River has been divided into six discrete reaches by R&M Consultants (1982) based on characteristic mainstem channel patterns (Table 15). Dividing the mainstem in this manner provides the basis for evaluating long term trends in main channel morphology. More applicable to the study of juvenile chinook salmon habitat, which is concentrated in the peripheral areas of the river, is the identification of side channel complexes. Complexes are systems of adjacent, often interconnected, side channels which convey mainstem water. Major side channel complexes of the middle Susitna River identified in this study are listed in Table 16 and are easily discernible in the aerial photography in Appendix 1.

Although channels within a complex are sometimes hydraulically, hydrologically, and morphologically similar since they are influenced by the same mainstem conditions, such as slope, stage response to discharge, and sediment load, more than one habitat type is generally represented in a complex. Habitat type is thus sporadically represented in different side channel complexes throughout the middle Susitna River.

A statistical approach was taken to study the similarities between side channel areas in the middle Susitna River based on plan form. Through a cluster analysis of several side channel variables, including length, width, length-to-width ratio, channel sinuosity, and the number of bends, six

Table 15. Definition of reaches within the Talkeetna-to-Devil Canyon segment of the Susitna River.

River Mile	Average Slope	Description
RM 149 to 144	0.00195	Single channel confined by valley walls. Frequent bedrock control points.
RM 144 to 139	0.00260	Split channel confined by valley walls and terraces.
RM 139 to 129.5	0.00210	Split channel confined occasionally by terraces and valley walls. Main channels, side channels, and sloughs occupy valley bottom.
RM 129.5 to 119	0.00173	Split channel with occasional tendency to braid. Main channel frequently flows against west valley wall. Subchannels and sloughs occupy east flood plain.
RM 119 to 104	0.00153	Single channel frequently incised, and occasional islands.
RM 104 to 95	0.00147	Transition from split channel to braided, occasionally bounded by terraces. Braided through the confluence with Chulitna and Talkeetna Rivers.

Source: R&M Consultants 1982.

Table 16. Major side channel complexes of the Talkeetna-to-Devil Canyon segment of the Susitna River.

Reference Name	Location (RM)
Whiskers Creek	100-102
Bushrod Slough	117-118
Oxbow II	119-120
Slough 8B	121-123
Skull Creek	125-126
Fourth of July	131-132
Slough 21	141-142

distinct cluster groupings were identified. The findings corroborated subjective evaluations of morphologic similarities between side channels.

A discriminant function multivariate analysis was performed using the six cluster groupings to determine the relative importance of variables in defining morphologic groups. The length-to-width ratio was the most important variable with channel width second, followed by channel length. A limitation of the multivariate analysis was that it could be applied only for distinct side channels where it was possible to evaluate each of the previously mentioned variables. This limited the analysis to 70 specific areas. Subjective evaluation of channel morphology was the primary criterion in the development of three representative groups (Tables 21, 22, and 26).

3.3 STRUCTURAL COMPONENT

3.3.1 STRUCTURAL HABITAT INDICES

The structural habitat index is used in the extrapolation methodology to adjust the amplitude of the habitat availability curve of a modeled specific area to more accurately represent an associated nonmodeled specific area within the same representative group. The importance of the index is as a species-specific, Susitna-specific, relative index to be applied within representative groups and not as an absolute index of structural habitat quality. It was not intended that the SHI be used as a comparative index of habitat quality between representative groups. The criteria for developing the SHI for Representative Group I were slightly different than for the other representative groups. Structural habitat quality should not be confused with overall habitat quality. Note that although a representative group may appear to offer higher quality habitat than another representative group by virtue of higher mean SHI values, when other (e.g., hydraulic) criteria are considered this may not be true. Comparative statistical treatments of SHI values for representative groups are considered inappropriate and are not presented. The structural habitat index for each specific area appears in Tables 17-26.

In viewing the range of SHI values within representative groups, two trends are apparent: (1) many specific areas have comparable SHI values; and (2) some specific areas are rated more than twice as valuable as others. The first trend can be expected and explained as resulting from the occurrence of similar river processes within each representative group. The second trend emphasizes the variability of structural habitat attributes that may occur within representative groups as accorded by local conditions. The range of SHI values in these areas is reasonable and reflects the importance of structural cover to juvenile chinook habitat quality. In a previous study of instream enhancement structures by Ward and Slaney (1979), the standing crop of steelhead parr and coho fingerlings increased threefold in a boulder-enhanced reach of stream over preplacement values.

3.4 DEVELOPMENT OF REPRESENTATIVE GROUPS

Representative groups are composed of specific areas that are hydrologically, hydraulically, and morphologically similar. Variables that were used in the development of representative groups are: breaching flow, habitat transformation category sequence, mean reach velocity, flow pattern, and channel morphology. Field notes provided core groupings of specific areas that were observed to be similar. Field experience, coupled with professional judgement, provided the balance of the matrix needed to discern representative groups.

Although variables describing each of the components of aquatic habitat character were considered in the development of representative groups, frequently one or two components dominated the distinction of a group. The character of Representative Group I (Table 17), for example, is dominated by its relative isolation from a mainstem water source (hydrologic component). This group includes upland sloughs and side sloughs with breaching flows greater than 35000 cfs. Principal water sources are groundwater and surface runoff, with several of these specific areas receiving inflow from small tributaries. In the geomorphic regime of the middle Susitna River, these specific areas are remnant channels following events from ice processes and/or channel migration.

The character of Representative Group II (Table 18) is dominated by relatively high breaching flows (20000 to 33000 cfs) and the presence of upwelling groundwater sources. These specific areas are commonly called side sloughs. Morphologically, these channels tend to be more sinuous than those of other representative groups. Geomorphically, several of these specific areas have succeeded from side channels since 1949 as their head berms have emerged relative to the mainstem (LaBelle et al. 1985). Several others that were side sloughs in 1949 have emerged to become upland sloughs (Representative Group I) today.

The character of Representative Group III (Table 19) is dominated by breaching flows (8200 to 16000 cfs) intermediate to those of most side channels and side sloughs. Although the channel morphology is more characteristic of side channels than side sloughs, portions of these channels commonly contain clear groundwater from upwelling sources in their nonbreached phase. Transformation from side channel to side slough habitat is thus characteristic of this group as evidenced by the habitat transformation category sequence.

The character of Representative Group IV (Table 20) is dominated by low breaching flows (<5100 cfs) and mean reach velocities between 2 fps and 5 fps (10000 cfs mainstem). This group includes specific areas commonly called side channels. The distinction between side channel and mainstem habitat is primarily one of size. Generally, side channels convey less than approximately 10% of the total flow in the river. In addition, side channels tend to have lower flow velocities and less coarse bed material than mainstem channels on the average.

The character of Representative Group V (Table 21) is dominated by channel morphology. This group includes shoal areas, many of which transform to slough habitats as mainstem discharge decreases. Shoal areas are described as shallow water areas bordering deeper mainstem channels. Velocities in these areas are generally less than mean mainstem velocity and flow characteristics can be described as riffle or run. Shoals frequently form as a point bar on the inside bend of a meander, as an alternate bar, or at the downstream end of an island where the mainstem has aggraded.

The character of Representative Group VI (Table 22) is dominated by channel morphology. This group includes overflow channels that parallel the adjacent mainstem, usually separated by a sparsely vegetated gravel bar. These specific areas may or may not possess an upwelling groundwater source. It is likely that many of these channels have formed as a result of ice jams routing mainstem water around the primary flow corridor.

The character of Representative Group VII (Table 23) is dominated by a characteristic riffle/pool sequence. These specific areas would otherwise be included in Representative Group IV or Group III except for a characteristic large backwater that forms near the channel mouth and a riffle upstream of it. Mean reach velocities are between 2.0 fps and 4.0 fps (10000 cfs mainstem).

The character of Representative Group VIII (Table 24) is dominated by a tendency of these channels to dewater at relatively high mainstem flows. Dewatering frequently occurs soon after the channel becomes nonbreached and is reflected by a 9 in the habitat transformation category sequence. Channels in this group are frequently oriented with a 30+ angle to the mainstem flowline at their heads and contain finer substrate than most groups. Large sand deposits are common in the channels of this group.

Representative Group IX (Table 25) consists of mainstem habitats. The character of this group is dominated by low breaching flows (<5100 cfs) and mean reach velocities frequently greater than 5 fps. These specific areas generally convey more than approximately 10% of the total discharge and have coarser bed material on the average compared to other groups. Geomorphically, these specific areas are currently the primary flow conveying channels in the middle Susitna River.

The character of Representative Group X (Table 26) is dominated by channel morphology and local hydrology. This group includes large mainstem shoals and mainstem margin areas that had open leads in the March 1983 aerial photography. Mainstem shoals are large expanses of shallow water adjoining a primary mainstem channel and they typically occur on the inside of a bend, as an alternate bar, or at the downstream side of an island as the result of aggradation in the mainstem. This group is distinguished from Representative Group V primarily by size and typically coarser bed material. This group also includes mainstem margin areas that were suspected of having an upwelling groundwater source as evidenced by open (possibly thermal) leads in the aerial photography. Other than the possible presence of upwelling, nothing remarkable distinguishes these specific areas from other mainstem channel margins in the middle Susitna River.

Although of less importance in the development of representative groups, dominant substrate size codes and channel length-to-width ratios were included in Tables 17-26 where data was available. These were included to aid the reader in gaining an appreciation of the habitat characteristics of the various specific areas.

Table 17. Representative Group I

Description: Habitat character is dominated by high breaching flow. This group includes all upland sloughs and Slough 11 (RM 135.6R). Specific area hydraulics are characterized by pooled clear water with velocities frequently near-zero and depths greater than 1 ft. Pooled areas are commonly connected by short riffles where velocities are less than 1 fps and depths are less than 0.5 ft.

Specific Area	Breaching Flow (cfs)	Habitat Transformation Category Sequence	Mean[1] Reach Velocity (fps)	Dominant Substrate Code	Channel Length-to-Width Ratio	Structural Habitat Index	Model
102.2L	>35000	1	0+	1	--	0.83	--
105.2R	>35000	1	1.0	1	--	0.69	--
107.6L	>35000	1	0+	2	--	0.44	RJHAB
108.3L	>35000	1	1.0	1	--	0.70	--
112.5L	>35000	1	0	1	--	0.68	RJHAB
119.4L	>35000	1-9	0	1	--	0.45	--
120.0R	>35000	1	0+	1	--	0.50	--
121.9R	>35000	1	<1.0	9	--	0.72	--
123.1R	>35000	1	0+	1	--	0.45	--
123.3R	>35000	1	0	2	--	0.67	--
127.2M	>35000	1	0+	2	--	0.58	--
129.4R	>35000	1	0+	1	--	0.44	--
133.9L	>35000	1	<0.5	9	--	0.67	--
134.0L	>35000	1	0+	1	--	0.89	--
135.5R	>35000	9	0+	1	--	0.32	--
135.6R	>35000	1	0+	6	--	0.54	--
136.9R	>35000	1	0+	2	--	0.69	--
139.0L	>35000	1	0	2	--	0.45	--
139.9R	>35000	1	0+	1	--	0.74	--

[1]Mean reach velocities for nonbreached conditions

RJHAB = ADF&G Habitat Model
-- = Data Not Available

Table 18. Representative Group II

Description: Habitat character is dominated by relatively high breaching flows and the presence of upwelling groundwater sources that persist throughout winter. This group includes the specific areas that are commonly called sloughs. These specific areas typically have relatively large channel length-to-width ratios.

Specific Area	Breaching Flow (cfs)	Habitat Transformation Category Sequence	Mean Reach Velocity (fps)	Dominant Substrate Code	Channel Length-to-Width Ratio	Structural Habitat Index	Model
100.6R	33000	1	--	9	--	0.60	--
101.4L	22000	2	--	10	38.4	0.54	RJHAB
101.8L	22000	2	--	10	77.8	0.65	--
113.1R	26000	1	--	6	--	0.31	--
113.7R	24000	1	--	6	100.0	0.51	RJHAB
115.6R	23000	4-2	--	9	21.2	0.54	--
117.9L	22000	2	--	9	29.3	0.62	--
118.0L	22000	3	--	9	12.8	0.39	--
121.8R	22000	3	--	2	20.9	0.27	--
122.4R	26000	1	--	1	23.1	0.29	--
122.5R	20000	2	--	8	104.5	0.51	--
123.6R	25500	1	--	2	--	0.43	--
125.1R	20000	2	--	3	25.5	0.48	--
125.9R	26000	1	--	12	74.7	0.56	--
126.0R	33000	1	--	9	71.8	0.51	IFG
126.3R	27000	4-2	--	9	39.6	0.59	--
131.8L	26900	1	--	8	--	0.45	--
133.9R	30000	1	--	7	--	0.50	--
135.3L	23000	3	--	12	19.1	0.30	--
137.5R	22000	2	--	12	--	0.44	DIHAB
137.5L	29000	1	--	1	--	0.61	--
137.8L	20000	2	--	11	15.0	0.54	--
137.9L	21000	2	--	11	76.0	0.50	--
140.2R	26500	1	--	11	73.3	0.50	--
142.1R	23000	1	--	11	--	0.60	--
142.2R	26000	1	--	9	--	0.52	--
143.4L	23000	1	--	13	60.0	0.55	--
144.4L	21000	2	--	13	91.5	0.60	RJHAB

IFG = Instream Flow Group Habitat Model
DIHAB = Direct Input Habitat Model developed by EWT&A
RJHAB = ADF&G Habitat Model
-- = Data Not Available

Table 19. Representative Group III

Description: Habitat character is dominated by intermediate breaching flows and relatively broad channel sections. This group includes side channels which become nonbreached at intermediate mainstem discharge levels and transform into slough habitat at lower discharges. Breaching flows are typically lower than for Group II, upwelling is present, and the length-to-width ratios of the channels are generally less than ratios for Group II.

Specific Area	Breaching Flow (cfs)	Habitat Transformation Category Sequence	Mean Reach Velocity (fps)	Dominant Substrate Code	Channel Length-to-Width Ratio	Structural Habitat Index	Model
100.4R	12500	4-2	--	8	22.5	0.51	--
100.6L	9200	4-3	--	11	12.0	0.42	--
101.2R	9200	4-2	--	8	8.1	0.56	IFG
101.6L	14000	4-2	--	10	14.8	0.56	--
101.7L	9600	4-3	--	10	10.5	0.46	--
110.4L	12000	4-2	--	11	37.6	0.67	--
115.0R	12000	4-2	--	10	15.3	0.55	DIHAB
117.8L	8000	4-2	--	9	19.2	0.48	--
119.3L	16000	4-2	--	10	25.8	0.56	--
128.5R	10400	4-2	--	8	--	0.48	--
128.7R	15000	4-2	--	6	20.8	0.49	--
128.8R	16000	4-2	--	3	39.1	0.46	IFG
130.2R	12000	4-2	--	9	15.9	0.64	DIHAB
130.2L	8200	4-3	--	11	33.5	0.60	--
132.6L	10500	4-3	--	10	65.2	0.49	IFG/ RJHAB
133.7R	11500	4-2	3.5	10	71.4	0.44	--
137.2R	10400	4-2	2.5	12	8.6	0.49	--
141.4R	11500	4-2	--	12	--	0.56	IFG

IFG = Instream Flow Group Habitat Model
DIHAB = Direct Input Habitat Model developed by EWT&A
RJHAB = ADF&G Habitat Model
-- = No Data Available

Table 20. Representative Group IV

Description: Habitat character is dominated by low breaching flows and intermediate mean reach velocities. This group includes the specific areas that are commonly called side channels. These specific areas possess mean reach velocities ranging from 2-5 fps at a mainstem discharge of approximately 10000 cfs.

Specific Area	Breaching Flow (cfs)	Habitat Transformation Category Sequence	Mean Reach Velocity (fps)	Dominant Substrate Code	Channel Length-to-Width Ratio	Structural Habitat Index	Model
100.7R	<5100	10-4	3.8	8	14.5	0.49	--
108.7L	<5100	10-4	3.0	11	6.9	0.53	--
110.8M	<5100	4	3.5	6	5.9	0.48	--
111.5R	5100	10-4	2.5	9	13.8	0.48	--
112.6L	<5100	4	3.0	10	10.0	0.60	IFG
114.0R	<5100	4	3.0	9	--	0.43	--
116.8R	<5100	10-4	4.5	9	10.6	0.48	--
119.5L	5000	4	2.5	8	20.9	0.54	--
119.6L	<5100	4	3.0	10	54.6	0.53	--
121.7R	<5100	10-4	4.0	8	24.7	0.48	--
124.1L	<5100	10-4	3.5	11	17.0	0.46	--
125.2R	<5100	4	4.5	10	37.8	0.56	DIHAB
127.0M	<5100	4	2.5	7	10.1	0.65	--
127.4L	<5100	10-4	4.0	9	36.4	0.46	--
129.5R	<5100	6-5	3.0	8	13.5	0.56	--
131.7L	5000	4	2.6	10	48.6	0.47	IFG
134.9R	<5100	4	4.0	8	22.3	0.56	IFG
136.0L	<5100	4	2.0	5	24.0	0.55	IFG
139.4L	<5100	4	2.0	8	3.6	0.61	--
139.6L	<5100	10-4	3.2	13	14.9	0.51	--
140.4R	<5100	6	3.0	10	7.7	0.48	--
145.3R	<5100	10-4	4.5	12	11.8	0.53	--

IFG = Instream Flow Group Habitat Model
DIHAB = Direct Input Habitat Model developed by EWT&A
-- = No Data Available

Table 21. Representative Group V

Description: Habitat character is dominated by channel morphology. This group includes shoal areas which transform to slough or clearwater habitats as mainstem discharge decreases.

Specific Area	Breaching Flow (cfs)	Habitat Transformation Category Sequence	Mean Reach Velocity (fps)	Dominant Substrate Code	Channel Length-to-Width Ratio	Structural Habitat Index	Model
101.71L	MSS	7-9	--	9	--	0.48	DIHAB
117.0M	15500	6-7-9	--	3	--	0.31	--
118.91L	MSS	6	--	9	--	0.48	DIHAB
124.0M	23000	7	--	6	--	0.51	--
132.8R	19500	7	--	8	36.0	0.57	--
139.01L	MSS	6	--	6	--	0.37	DIHAB
139.7R	22000	2	--	3	--	0.51	--
141.6R	21000	7	--	3	--	0.56	IFG
143.0L	7000	6-7	--	5	--	0.31	--

MSS = Mainstem Shoal
IFG = Instream Flow Group Habitat Model
DIHAB = Direct Input Habitat Model developed by EWT&A
-- = No Data Available

Table 22. Representative Group VI

Description: Habitat character is dominated by channel morphology. This group includes overflow channels that parallel the adjacent mainstem, usually separated by a sparsely vegetated gravel bar. These specific areas may or may not possess an upwelling groundwater source.

Specific Area	Breaching Flow (cfs)	Habitat Transformation Category Sequence	Mean Reach Velocity (fps)	Dominant Substrate Code	Channel Length-to-Width Ratio	Structural Habitat Index	Model
102.6L	6500	4-3	2.0	12	14.2	0.69	--
106.3R	4800	4	2.5	11	17.4	0.53	--
107.1L	9600	4-3-9	--	12	--	0.69	--
117.9R	7300	4-3	2.0	12	24.7	0.49	--
119.7L	23000	2	--	9	--	0.51	--
133.8L	17500	4-2	--	9	24.0	0.49	IFG
135.7R	27500	1	--	3	26.0	0.32	--
136.3R	13000	4-2	--	11	14.4	0.54	IFG
138.0L	8000	4-2	--	11	--	0.53	--
138.8R	6000	6-5-9	3.0	9	15.0	0.31	--
139.5R	8900	6-5-7	2.5	12	--	0.31	--
140.6R	12000	6-5-8-9	--	10	--	0.61	--
142.0R	10500	5-8	--	12	--	0.53	--

IFG = Instream Flow Group Habitat Model
-- = No Data Available

Table 23. Representative Group VII

Description: Habitat character is dominated by a characteristic riffle/pool sequence. The Little Rock IFG modeling site (RM 119.2R) is typical, with a riffle just downstream of the side channel head that flows into a large backwater pool near the mouth.

Specific Area	Breaching Flow (cfs)	Habitat Transformation Category Sequence	Mean Reach Velocity (fps)	Dominant Substrate Code	Channel Length-to-Width Ratio	Structural Habitat Index	Model
114.1R	<5100	5	2.5	8	22.8	0.31	DIHAB
119.2R	10000	4-3	3.6	10	15.1	0.41	IFG
121.1L	7400	4-3	3.0	6	41.2	0.43	--
123.0L	<5100	4	2.0	7	17.4	0.39	--
125.6L	<5100	6-5	3.5	12	9.5	0.52	--
127.5M	<5100	6-5	3.5	6	24.2	0.31	--
131.3L	9000	4-2	4.0	7	18.2	0.31	DIHAB

IFG = Instream Flow Group Habitat Model
DIHAB = Direct Input Habitat Model developed by EWT&A
-- = No Data Available

Table 24. Representative Group VIII

Description: Habitat character is dominated by the tendency of these channels to dewater at a relatively high mainstem discharge. Channels in this group are frequently oriented with a 30°+ angle to the mainstem flowline at their heads.

Specific Area	Breaching Flow (cfs)	Habitat Transformation Category Sequence	Mean Reach Velocity (fps)	Dominant Substrate Code	Channel Length-to-Width Ratio	Structural Habitat Index	Model
101.3M	9200	4-9	--	11	9.3	0.57	--
102.0L	10000	4-9	--	5	2.4	0.43	--
104.3M	21000	4-3-9	--	9	4.3	0.48	--
109.5M	16000	4-9	--	9	8.7	0.49	--
112.4L	22000	9	--	11	18.4	0.27	--
117.1M	15500	4-3	--	3	16.0	0.32	--
117.2M	20000	3-9	--	3	9.8	0.32	--
118.6M	14000	5-8	--	3	--	0.36	--
119.8L	15500	4-9	--	9	7.8	0.51	--
120.0L	12500	4-3-9	--	10	20.3	0.32	--
121.5R	19500	3-9	--	6	--	0.32	--
121.6R	15500	4-3-9	--	9	--	0.60	--
123.2R	23000	8-9	--	3	--	0.26	--
124.8R	19500	8-9	--	2	3.9	0.46	--
125.6R	26000	9	--	8	12.7	0.44	--
128.4R	9000	6-5-9	--	8	--	0.56	--
132.5L	14500	4-9	--	11	10.0	0.57	--
135.0R	21500	9	--	6	11.2	0.44	--
135.1R	20000	3	--	6	18.9	0.44	--
144.0M	22000	9	--	12	9.0	0.31	--
145.6R	22000	9	--	8	56.3	0.62	--
146.6L	26500	1-9	--	12	--	0.48	--

-- = No Data Available

Table 25. Representative Group IX

Description: Habitat character is dominated by low breaching flows and relatively swift velocities. This group includes specific areas that were categorized as mainstem at 5100 cfs, as well as side channels (Category 5) and indistinct side channels (Category 6) with mean reach velocities greater than 5 fps at 10000 cfs mainstem.

Specific Area	Breaching Flow (cfs)	Habitat Transformation Category Sequence	Mean Reach Velocity (fps)	Dominant Substrate Code	Channel Length-to-Width Ratio	Structural Habitat Index	Model
101.5L	<5100	10	3.0	12	12.7	0.45	IFG
104.0R	<5100	6	5.5	8	9.4	0.48	--
105.7R	<5100	10	3.0	11	8.6	0.53	--
108.9L	<5100	10	5.0	11	9.0	0.58	--
109.4R	<5100	10	>4.0	12	18.2	0.45	--
111.0R	<5100	10	3.5	6	12.3	0.35	--
113.8R	<5100	6	6.0	12	7.2	0.53	--
117.7L	<5100	6-5	5.5	8	8.5	0.41	--
127.1M	<5100	6-5	5.0	10	13.9	0.53	--
128.3R	<5100	6	>5.0	12	--	0.63	--
129.3L	<5100	10-5	>6.0	12	12.2	0.62	--
129.8R	<5100	10	>4.0	12	9.7	0.56	--
131.2R	<5100	5	>5.0	8	13.6	0.48	--
135.0L	<5100	10	4.5	12	6.1	0.48	--
139.2R	<5100	6	>5.0	10	10.7	0.61	--
141.2R	<5100	6-5	>5.0	13	--	0.69	--
141.3R	<5100	5	>5.0	12	--	0.69	--
142.8R	<5100	6	>5.0	12	--	0.56	--
144.0R	<5100	10	>5.0	11	15.1	0.53	--
144.2L	<5100	10	3.5	12	21.0	0.53	--
147.1L	<5100	10	5.0	12	10.8	0.57	IFG

IFG = Instream Flow Group Habitat Model
-- = No Data Available

Table 26. Representative Group X

Description: Habitat character is dominated by channel morphology. This group includes large mainstem shoals and mainstem margin areas that had open leads in the March 1983 photography.

Specific Area	Breaching Flow (cfs)	Habitat Transformation Category Sequence	Mean Reach Velocity (fps)	Dominant Substrate Code	Channel Length-to-Width Ratio	Structural Habitat Index	Model
105.81L	MSS	6	--	12	--	0.57	DIHAB
109.3M	MSS	6-9	--	8	--	0.48	--
111.6R	11500	6-8-9	--	10	--	0.49	--
113.6R	10500	6-8	--	8	--	0.55	--
113.9R	7000	6	--	8	--	0.48	--
119.11L	MSS	6	2.0	8	--	0.41	DIHAB
121.1R	MSS	6-5	3.5	10	--	0.47	--
133.81R	MSS	6	2.0	12	--	0.48	DIHAB
138.71L	MSS	6	3.0	12	--	0.57	DIHAB
139.3L	MSS	6	--	10	--	0.56	--
139.41L	MSS	6	3.5	11	--	0.41	DIHAB
142.8L	MSS	6	1.5	9	--	0.36	--
148.2R	MSS	6-9	--	12	--	0.48	--

MSS = Mainstem Shoal
DIHAB = Direct Input Habitat Model developed by EWT&A
-- = No Data Available

4. FUNCTION OF RESULTS IN EXTRAPOLATION

This section introduces the methodology used to extrapolate results from modeled sites to nonmodeled areas of the middle Susitna River. As stated in the introduction, this methodology consists of three parallel pathways of analysis: 1) quantification, 2) stratification, and 3) simulation. The function of each of these pathways is described below.

The quantification pathway, used to develop relationships between wetted surface area (WSA) and discharge for each specific area, provides the basis for determining habitat quantities. The response to discharge relationships are developed by digitizing areas delineated on aerial photo reproductions at several mainstem flows. For a detailed discussion of the relationships of the response of wetted surface area to discharge in the middle Susitna River see Klinger-Kingsley (1985).

The stratification pathway, used to group individual channels based on common characteristics, assesses the representativeness of modeled sites to non-modeled areas of the river and provides an index of site-specific structural habitat quality for use in the derivation of habitat response to mainstem discharge relationships at nonmodeled areas. Representativeness between modeled and nonmodeled specific areas is evaluated using hydrologic, hydraulic, and morphologic indices derived from aerial photo and habitat inventory data bases. Structural habitat indices are developed using habitat inventory data and ADF&G suitability criteria for juvenile chinook salmon.

The simulation pathway, using habitat models to develop relationships between habitat availability and discharge at a spectrum of habitat types, identifies the characteristic habitat response for a given type of habitat. The modeling techniques used in this study are: 1) the Instream Flow Group[1] (IFG) habitat model (Milhous et al. 1984); 2) a habitat model (RJHAB) developed by ADF&G (Schmidt et al. 1984); and 3) a direct input variation of the IFG habitat model (DIHAB) developed by EWT&A (Hilliard et al. 1985). Tributary habitats were not evaluated because they would not be affected by an altered mainstem flow regime. Neither were tributary mouth habitats evaluated, because they constitute a small portion of the middle Susitna River habitat and would not be affected significantly.

The basic unit generated by the habitat models is weighted usable area (WUA). Weighted usable area is a quantitative index of juvenile chinook salmon habitat availability at a given streamflow. It is a product of wetted surface area (WSA) and suitability factors for pertinent habitat variables (i.e., flow velocity, depth, and cover) (Suchanek et al. 1984). Pertinent to extrapolation in the simulation analysis is the concept of the habitat availability index (HAI). Defined as WUA/WSA, the HAI provides a unitless measure of the overall habitat suitability of a study site at a given streamflow. When the HAI versus discharge is plotted, the resulting curve represents a characteristic habitat response for a given type of habitat. This relationship is used to derive habitat response to discharge relationships at nonmodeled areas.

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1 Now known as the Instream Flow and Aquatic Systems Group.

To derive HAI versus discharge relationships for nonmodeled areas, products from the stratification and simulation pathways of analysis must be integrated. These products are: (1) HAI versus discharge curves for each modeled specific area; (2) representative groups; (3) breaching flows for modeled and nonmodeled specific areas; and (4) structural habitat indices (SHI) for modeled and nonmodeled specific areas. Three assumptions for these relationships are also required: (1) the HAI versus discharge curve of modeled specific areas is characteristic of nonmodeled specific areas within the same representative group; (2) breaching flows for modeled and nonmodeled specific areas occur at the same relative position in the respective HAI versus discharge curves; and (3) the amplitude of HAI versus discharge curves derived for nonmodeled specific areas can be adjusted linearly using the ratio of SHI's for nonmodeled and modeled specific areas. The procedures to derive HAI versus discharge curves for nonmodeled specific areas are illustrated in Figure 12 and described as follows: (1) the characteristic curve of the representative modeled specific area (MS) is assumed and shifted along the X-axis to correspond with the breaching flow of the nonmodeled specific area (SA); and (2) the amplitude of the curve is adjusted using the formula $HAI_{(SA)} = HAI_{(MS)} \times (SHI_{(SA)} / SHI_{(MS)})$. This procedure is repeated for each nonmodeled specific area in the middle Susitna River.

To calculate WUA at nonmodeled specific areas, HAI versus discharge curves from the foregoing analysis are combined with results from the quantification pathway. As defined earlier, HAI's are unitless suitability factors calculated as WUA/WSA. From this definition it follows that WUA can be calculated as HAI times WSA. By combining WSA relationships developed for each specific area via the quantification pathway with HAI versus discharge relationships,

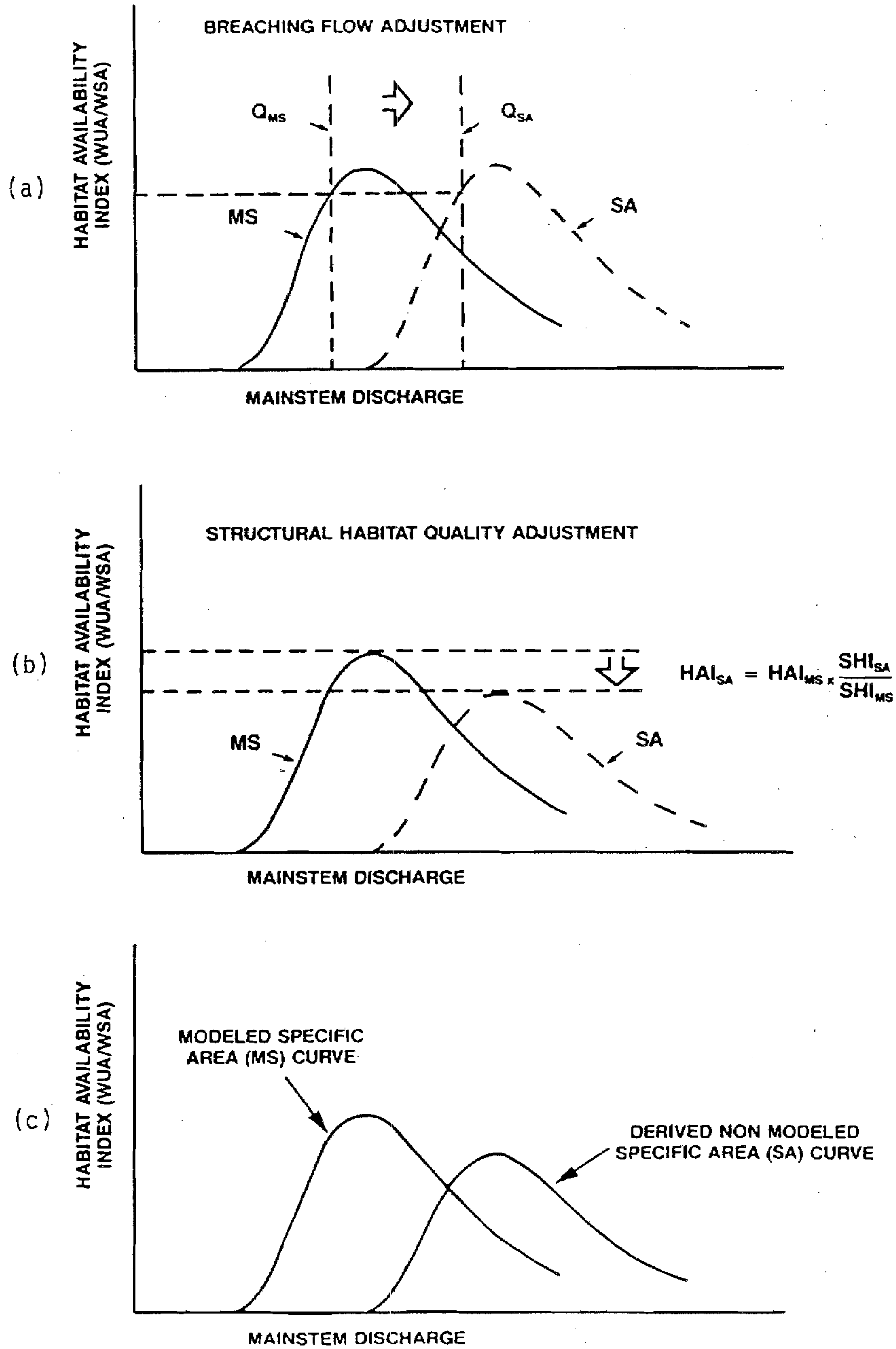

Figure 12. Derivation of a HAI versus discharge curve for a nonmodeled specific area (SA) from the representative curve of a modeled specific area (MS) showing: (a) breaching flow adjustment; (b) structural habitat quality adjustment; and (c) the derived curve.

WUA versus discharge curves are derived for each specific area. By summing the WUA versus discharge curves for each specific area within a representative group, habitat response to discharge relationships are developed at the habitat type level. Systemwide habitat response to discharge relationships can be developed subsequently by summing the relationships determined for each representative group. For a detailed discussion of the development and presentation of habitat response relationships at middle Susitna River study sites see Steward et al. (1985). Figure 13 shows a flow chart for the stratification and integration pathways of the extrapolation methodology.

Stratification Pathway of the Extrapolation Methodology

Stratification Pathway

- Delineate specific areas of homogeneous aquatic habitat type on aerial photo plates.
- Conduct reconnaissance-level survey of aquatic habitat at each specific area.
- Analyze aerial photography and habitat reconnaissance data base to describe hydrologic, hydraulic, and structural components of each specific area.
- Stratify specific areas into Representative Groups using available hydrologic and hydraulic information.
- Develop Structural Habitat Indices for each specific area including modeled sites using the habitat reconnaissance data base.

Quantification Pathway **Integration** **Simulation Pathway**

The following steps are completed for each evaluation species/life stage.

- Use the habitat availability index (HAI) versus discharge curve of a modeled specific area to synthesize the HAI versus discharge curve for a nonmodeled specific area within the same Representative Group. Shift the curve laterally to compensate for differences in breaching flow between a modeled and nonmodeled specific area. Adjust the HAI curve vertically using the ratio of structural habitat indices to account for differences in structural habitat quality between modeled and nonmodeled specific areas.
- Calculate the weighted usable area (WUA) present within each specific area using surface area and habitat availability indices for each mainstem evaluation flow.
- Sum the WUA calculated for all specific areas within each Representative Group for each mainstem evaluation flow.
- Sum the WUA calculated for all Representative Groups for each mainstem evaluation flow to forecast Middle Susitna River habitat response to flow variations.

Figure 13. Flow chart for the stratification and pathway of the extrapolation methodology.

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LITERATURE CITED

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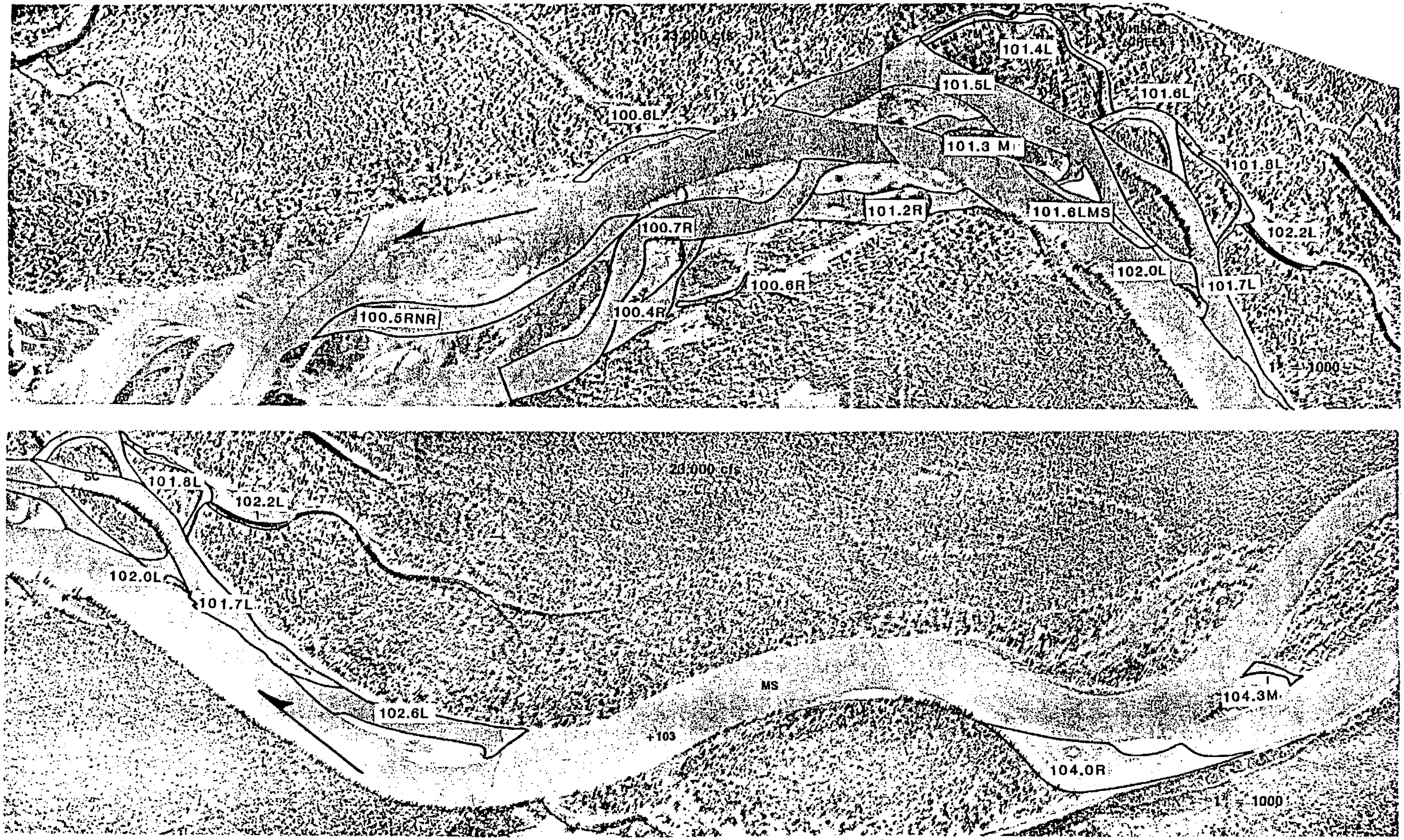
APPENDIX 1

SPECIFIC AREAS DELINEATED ON THE 23000 CFS AERIAL PHOTOGRAPHY



Specific areas from river mile 100 to 104 at a mainstem discharge of 23000 cfs.

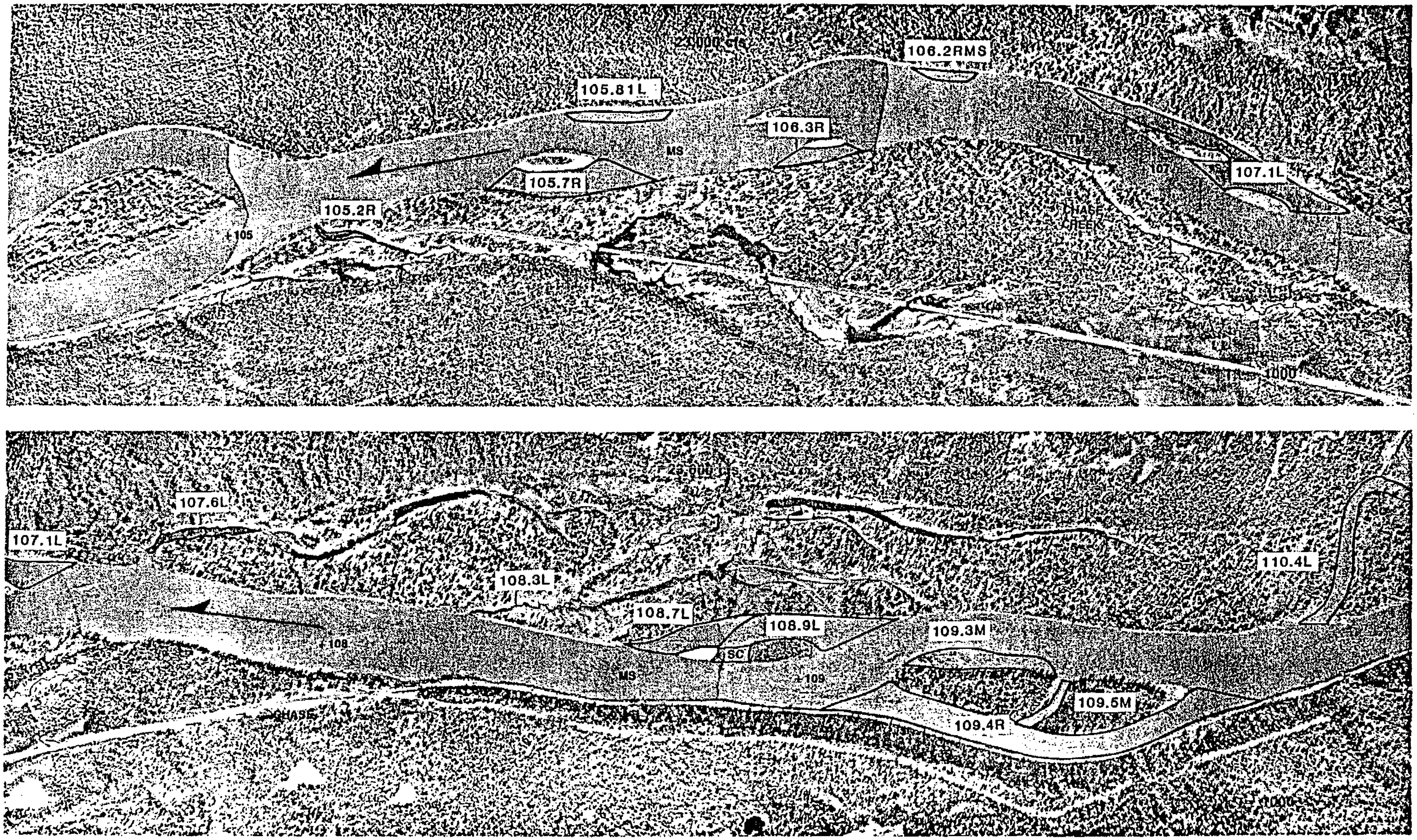
LEGEND:

L = Left
R = Right
M = Middle

RNR = Right Not Reconned
LNR = Left Not Reconned
LMS = Left Mainstem Spawning

RMS = Right Mainstem Spawning
MMS = Middle Mainstem Spawning

T = Tributary
+ = River Mile
← = Flow Direction



Specific areas from river mile 104 to 110 at a mainstem discharge of 23000 cfs.

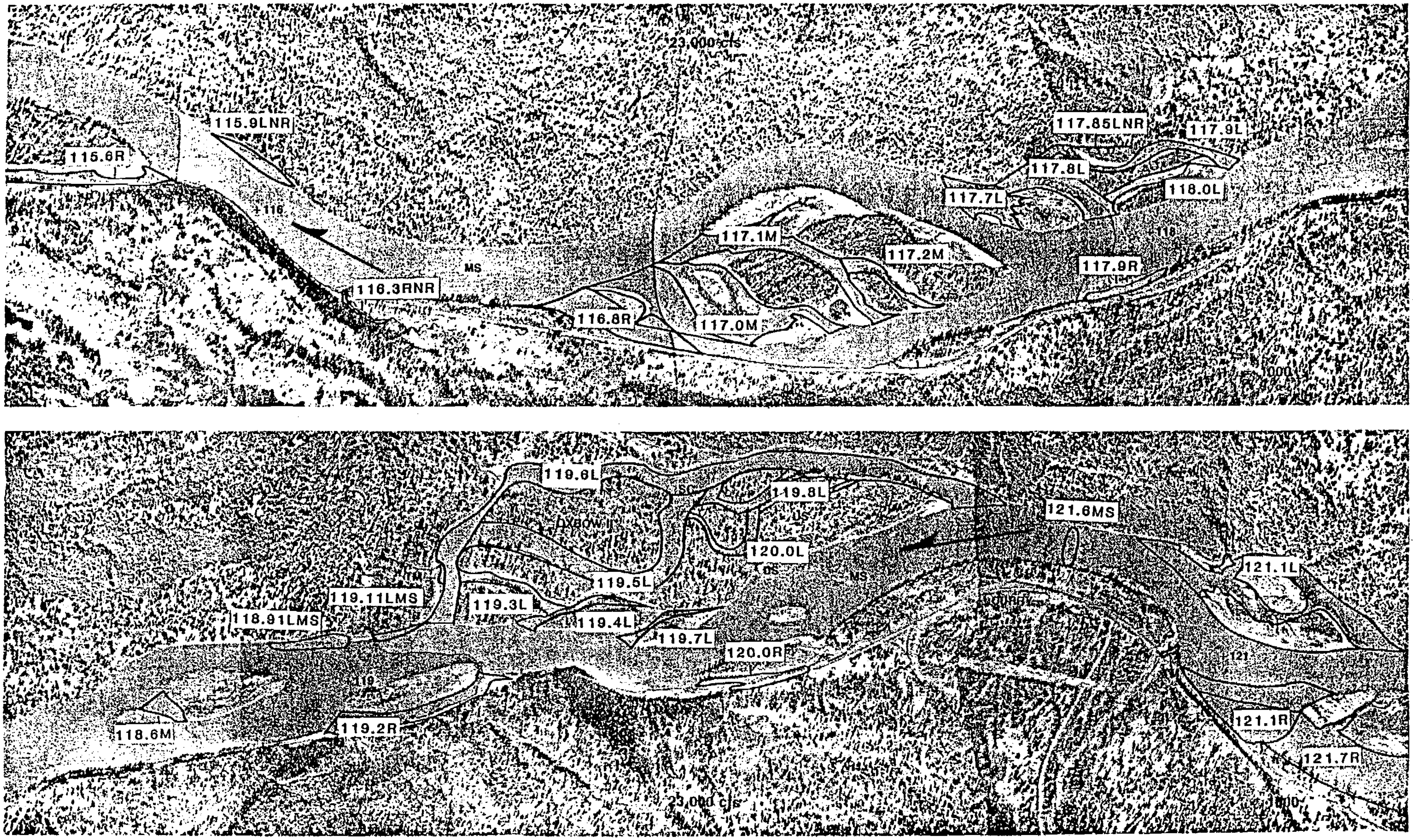
LEGEND:

L = Left	RNR = Right Not Reconned	RMS = Right Mainstem Spawning	T = Tributary
R = Right	LNR = Left Not Reconned	MMS = Middle Mainstem Spawning	+ = River Mile
M = Middle	LMS = Left Mainstem Spawning		◄ = Flow Direction

Specific areas from river mile 110 to 115 at a mainstem discharge of 23000 cfs.

LEGEND:

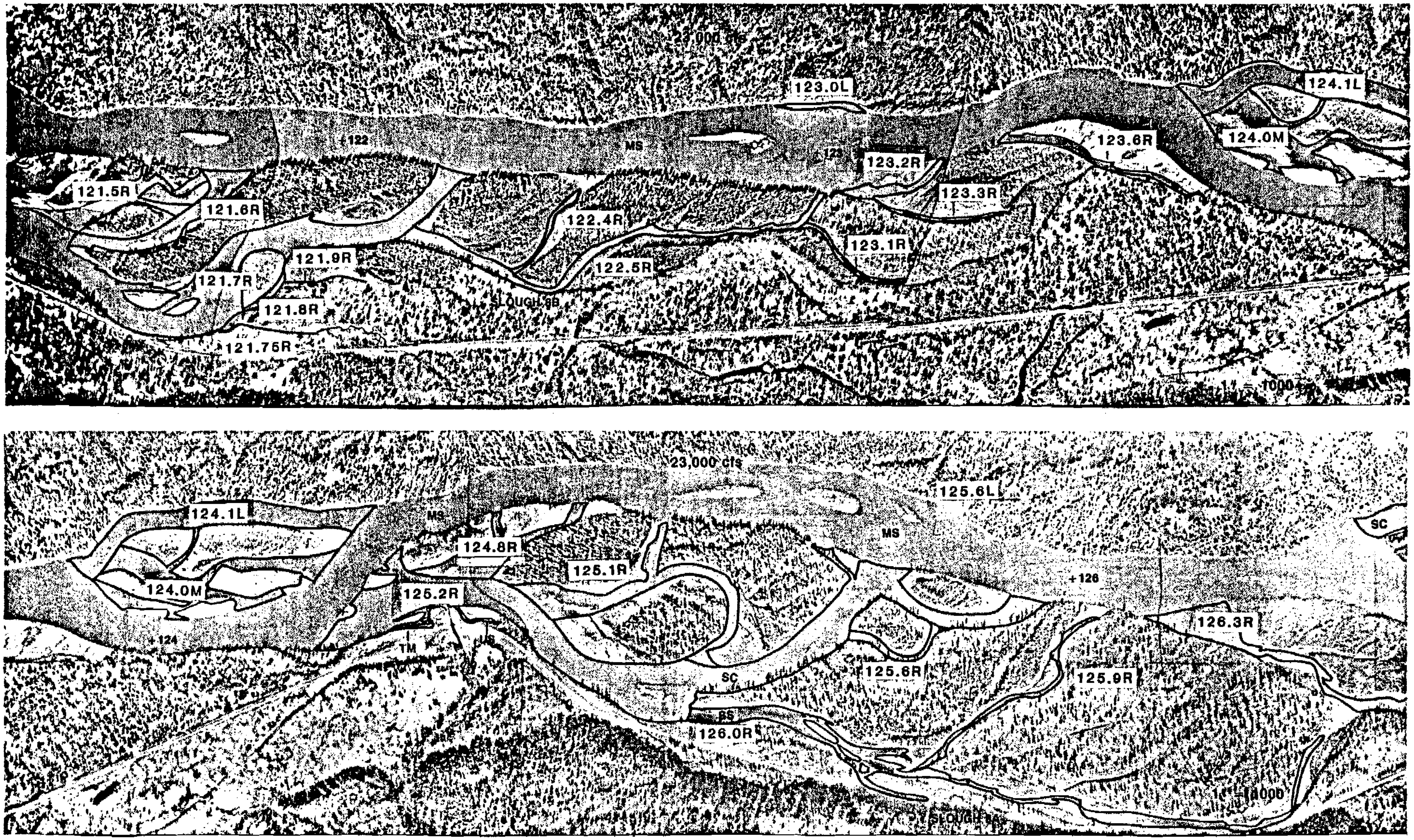
L = Left
R = Right
M = Middle
RNR = Right Not Reconned
LNR = Left Not Reconned
LMS = Left Mainstem Spawning
RMS = Right Mainstem Spawning
MMS = Middle Mainstem Spawning
T = Tributary
+ = River Mile
= Flow Direction



Specific areas from river mile 115 to 121 at a mainstem discharge of 23000 cfs.

LEGEND:

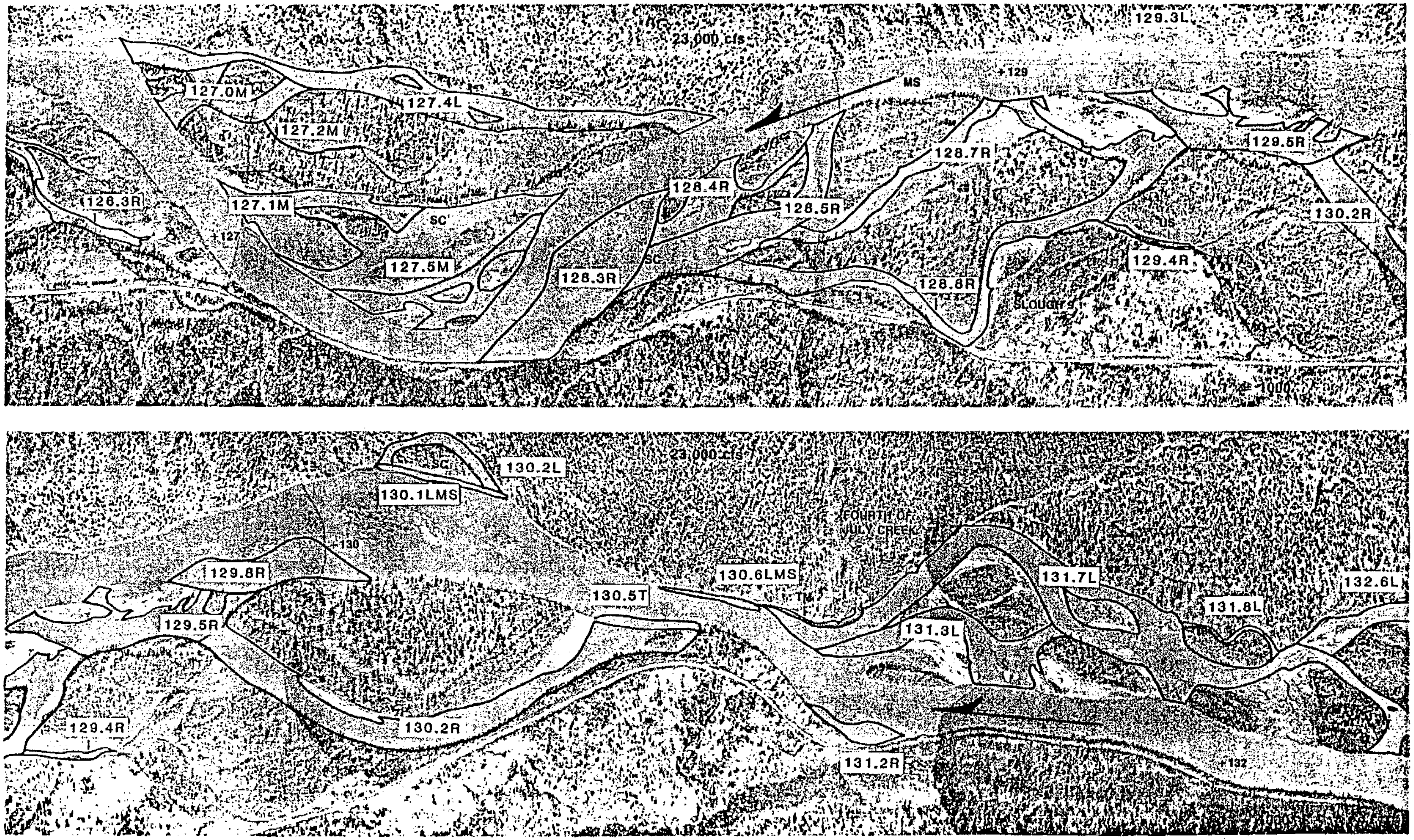
L = Left
R = Right
M = Middle
RNR = Right Not Reconned
LNR = Left Not Reconned
LMS = Left Mainstem Spawning
RMS = Right Mainstem Spawning
MMS = Middle Mainstem Spawning
T = Tributary
+ = River Mile
⟵ = Flow Direction



Specific areas from river mile 121 to 126 at a mainstem discharge of 23000 cfs.

LEGEND:

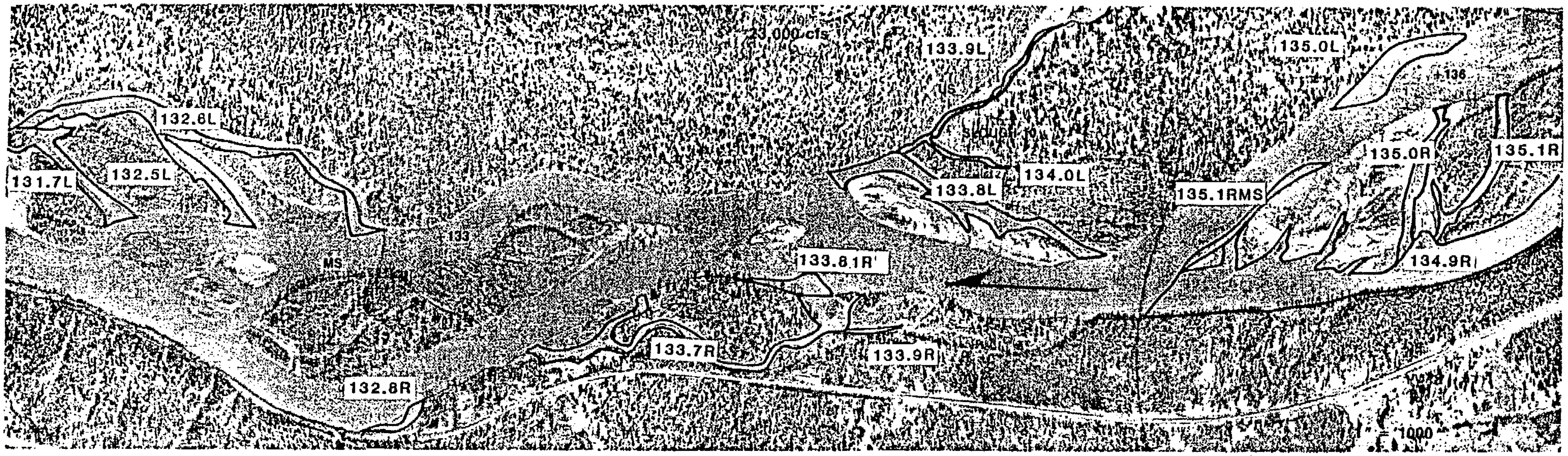
L = Left	RNR = Right Not Reconned	RMS = Right Mainstem Spawning	T = Tributary
R = Right	LNR = Left Not Reconned	MMS = Middle Mainstem Spawning	+ = River Mile
M = Middle	LMS = Left Mainstem Spawning		← = Flow Direction

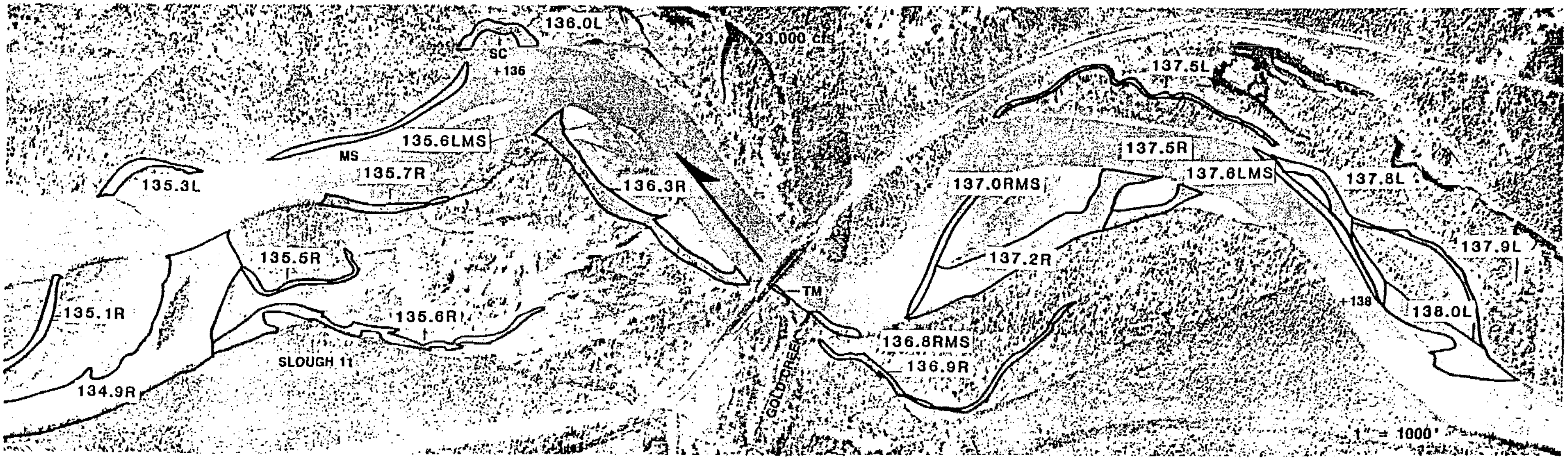


Specific areas from river mile 126 to 132 at a mainstem discharge of 23000 cfs.

LEGEND:

L = Left
R = Right
M = Middle
RNR = Right Not Reconned
LNR = Left Not Reconned
LMS = Left Mainstem Spawning
RMS = Right Mainstem Spawning
MMS = Middle Mainstem Spawning
T = Tributary
+ = River Mile
= Flow Direction

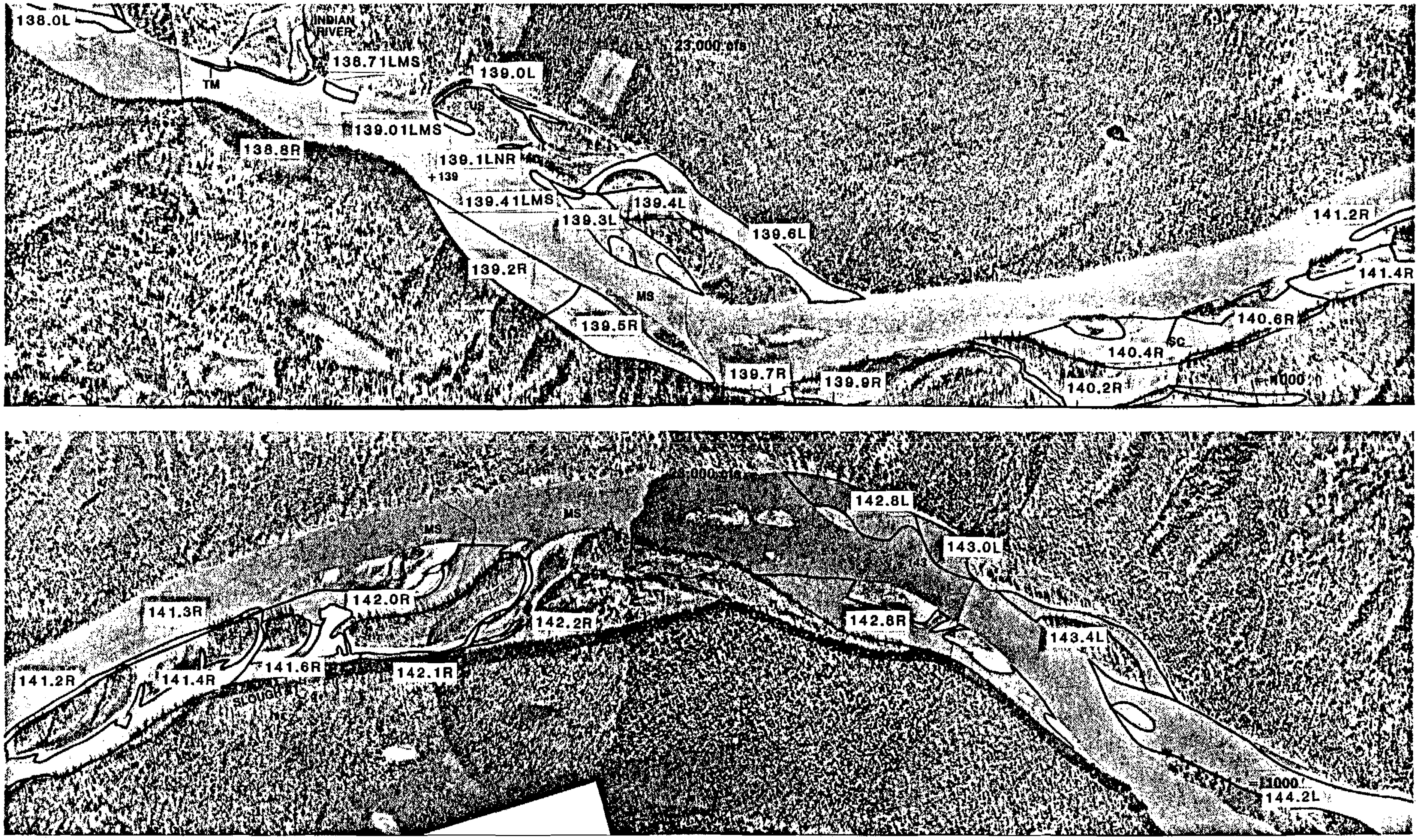




Specific areas from river mile 132 to 138 at a mainstem discharge of 23000 cfs.

LEGEND:

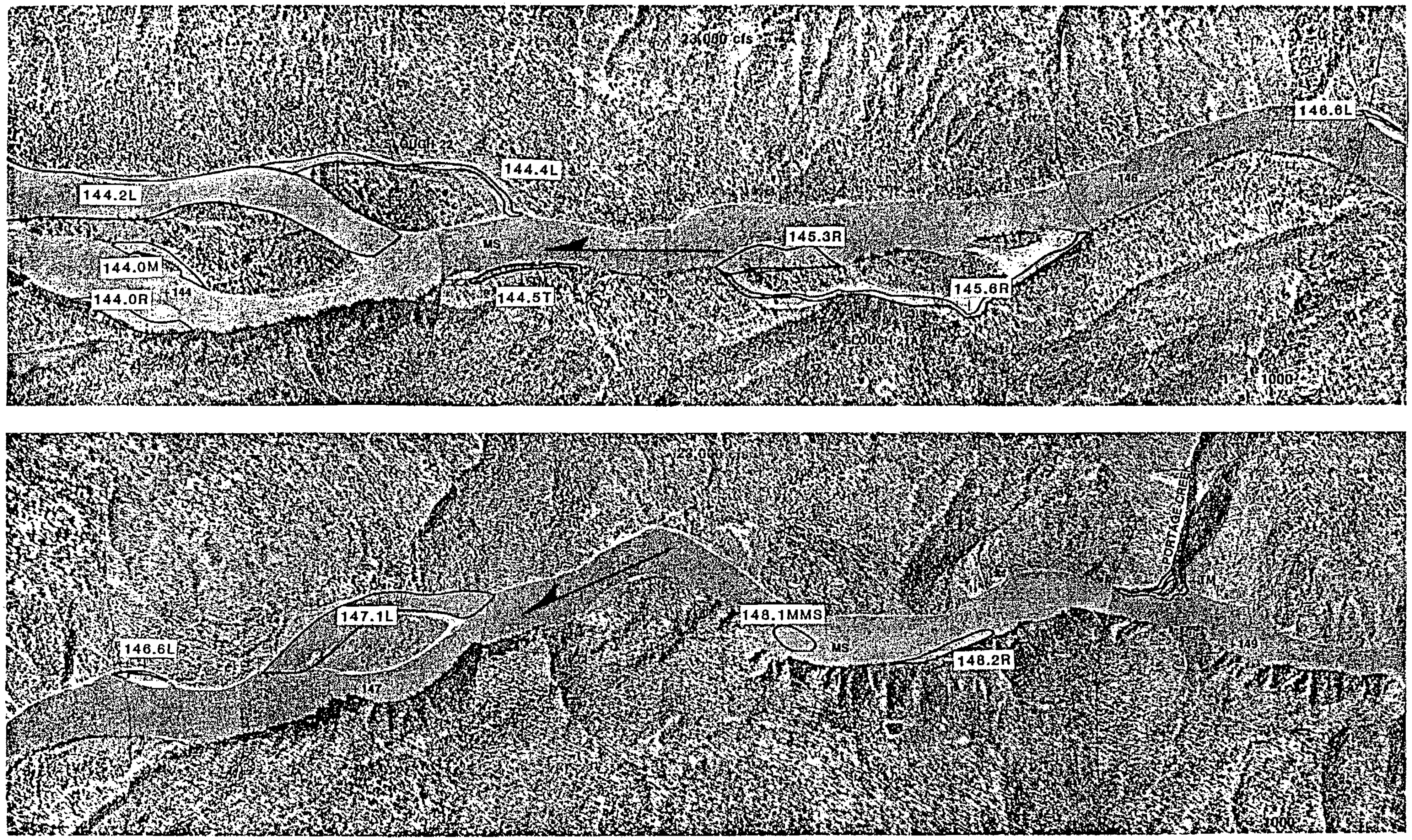
L = Left	RNR = Right Not Reconned	RMS = Right Mainstem Spawning	T = Tributary
R = Right	LNR = Left Not Reconned	MMS = Middle Mainstem Spawning	+ = River Mile
M = Middle	LMS = Left Mainstem Spawning		➔ = Flow Direction



Specific areas from river mile 138 to 144 at a mainstem discharge of 23000 cfs.

LEGEND:

L = Left	RNR = Right Not Reconned	RMS = Right Mainstem Spawning	T = Tributary
R = Right	LNR = Left Not Reconned	MMS = Middle Mainstem Spawning	+ = River Mile
M = Middle	LMS = Left Mainstem Spawning		= Flow Direction



Specific areas from river mile 144 to 148 at a mainstem discharge of 23000 cfs.

LEGEND:

L = Left
R = Right
M = Middle
RNR = Right Not Reconned
LNR = Left Not Reconned
LMS = Left Mainstem Spawning
RMS = Right Mainstem Spawning
MMS = Middle Mainstem Spawning
T = Tributary
+ = River Mile
= Flow Direction

APPENDIX 2

HABITAT INVENTORY TECHNIQUES

HABITAT INVENTORY TECHNIQUES

The habitat reconnaissance work was based on the premise that the habitat characteristics of each specific area could be averaged in order to develop a reliable composite description of the entire area. The intent was to describe the habitat in general terms (for example, mean reach velocity) and not to map localized habitat features.

The habitat inventory forms (Figure 14) provided a framework for the field reconnaissance work. These forms were designed to facilitate a cost-effective means of gathering reliable field observations based on visual assessment and minimal field measurements.

Several factors were considered while developing the habitat inventory form. These included: (1) the total time allocated for the habitat inventory task (approximately one month); (2) the large number of specific areas to be surveyed; (3) a limitation of approximately one hour per specific area; (4) the use of minimal field gear (for ease in maneuvering at each specific area and during helicopter transport); (5) compatibility with ADF&G data; and (6) ease in computer data management. The methods and field techniques for completing the habitat inventory form are described below.

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): ______________________

____

____

____

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: LB 1 2 3 Stable/Unstable RB 1 2 3 Stable/Unstable

Streambank Vegetation: LB 1 2 3 4 RB 1 2 3 4

Representative Top Width: __________ Bankfull Top Width: __________

Representative Depth: __________ Bankfull Depth: __________

Water Clarity: Clear/Turbid __________ ft.

Length of Backwater: __________ Estimated/Measured

Were Fish Observed? Yes/No

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

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

Remarks:

Figure 14.

Habitat Inventory

Crew: ______________________________ Date: ____________

______________________________ Time: ____________

______________________________ R.M.: ____________

____

Site Sketch & Habitat Mapping

Flow Description & Remarks

Habitat Type Proportions: Pool ______ Riffle ______ Run ______

Habitat Quality Proportions: 1 ______ 2 ______ 3 ______ 4 ______ 5 ______

Figure 14 (cont)

Habitat Inventory

Crew: ______________________________ Date: ____________
______________________________ Time: ____________
______________________________ R.M.: ____________
______________________________ Film I.D. No.: ________

PHOTOGRAPHS

No.	Description

Figure 14 (cont)

Habitat Inventory

Crew: ______________________________

____

____

____

Date: ______________

Time: ______________

R.M.: ______________

DETAIL: Sketch and Description

Figure 14 (cont)

Two field crews were in the helicopter for initial morning flights. Upon reaching a specific area, an overflight of the area provided an overview for determining features such as flow patterns, breached or nonbreached conditions, backwater influence, etc. Low altitude aerial photos were taken at this time. The helicopter would then land and drop off the first crew to complete the ground survey and fill in the habitat inventory form. A separate form for each specific area was completed. The remaining crew would then proceed to the next specific area downstream of the first crew and complete that area. This "leap-frogging" down the river was a fast and efficient way of covering many specific areas each day. On the average, 27 specific areas were visited per day. For a more detailed discussion of habitat reconnaissance methodologies see Chamberlin 1981, and Shera and Harding 1981.

DESCRIPTION AND USE OF THE HABITAT INVENTORY FORM

PAGE ONE

Crew: A minimum of two people were sent to evaluate each specific area. Two people were important because of the subjectivity of the work. The ability to discuss the habitat and work out perceived differences helped remove individual bias from the data.

R.M.: Each specific area was referenced to a river mile and with respect to the mainstem looking upriver: left (L), right (R), or middle (M) if between two mainstem forks.

Category: The perceived habitat transformation category of the specific area.

Location: Designations commonly used to reference the specific area, if applicable.

Mainstem Discharge: This data was obtained from USGS records for the Gold Creek gage.

Breached: Whether the channel was breached or nonbreached.

Mean Reach Velocity: Three methods were used to determine mean reach velocity. The first method involved estimating the surface velocity by recording the time it took a floating object to travel a known distance. The mean reach velocity was estimated as 85 percent of this surface velocity (Linsley and Franzini 1979). The second method involved measuring the height (h) that water "climbed" a survey rod held perpendicular to the flow (i.e., conversion of kinetic energy to potential energy). The relationship between h and mean reach velocity is depicted in Figure 13. Tabulated values of velocity corresponding with particular heights appear in Table 19. On rare occasions, a Marsh McBirney Type 201 portable current meter with wading rod was used to measure velocity. Velocity was measured at a point 0.6 times the depth from the water surface elevation for depths less than or equal to 2.5 ft. Velocity was determined as the average of measurements made at 0.2 and 0.8 times the depth from the water surface elevation for depths greater than 2.5 ft. The Marsh McBirney was used primarily to check the accuracy of the two approximate methods of estimating mean reach velocities.

Site Specific Discharge: The discharge was estimated using the equation $Q=V(W)(d)$, where V is estimated mean reach velocity (fps), W is the representative top width (ft), and d is the mean depth of the portion of the top width conveying most of the flow (ft).

Does Upwelling Occur?: Visual detection was recorded as positive if actual upwelling was observed as a volcano-like structure in fine sediments. If an area was breached, turbidity made it difficult to visually determine if upwelling occurred. A response of "cannot be detected visually" was then appropriate. A negative response was recorded only if a channel was dewatered or consisted of isolated pools.

Do Tributaries Enter the Slough or Side Channel?: If one or more tributaries entered the specific area, a brief description of each was recorded. Information included where it entered the specific area, its estimated discharge, and the effect this additional inflow had on fish habitat.

Head Gage, Mid-Reach Gage, Mouth Gage: One or more staff gages were occasionally in place within the specific area. If so, the water surface elevation and gage number was recorded, as well as any remarks about the condition of the gage (e.g., bent).

Substrate: The coding scheme and methods chosen for this habitat inventory parameter corresponded directly with ADF&G field methods (Estes and Vincent-Lang 1984). The substrate type and corresponding code numbers are:

Code	Type	Size (inches)
1	Silt	
2	Silt and Sand	
3	Sand	
4	Sand and Small Gravel	
5	Small Gravel	1/8 - 1
6	Small and Large Gravel	
7	Large Gravel	1 - 3
8	Large Gravel and Rubble	
9	Rubble	3 - 5
10	Rubble and Cobble	
11	Cobble	5 - 10
12	Cobble and Boulder	
13	Boulder	10+

This was one of the more difficult parameters to average for an entire specific area. For this reason, two codes indicating substrate size were often chosen and a map indicating substrate zones within the specific area was drawn on page two of the habitat inventory form.

Substrate Embeddedness: Substrate embeddedness descriptions and their code numbers are:

Code	Description
1	Embedded, consolidated, and cemented
2	Embedded but not cemented
3	Not embedded

Embeddedness implies a larger substrate material partially or fully buried in smaller material. If a substrate constituent was not embedded in smaller material it was coded 3. Substrate that was partially embedded but not consolidated was coded 2. The degree of consolidation was determined by trying to penetrate the upper substrate layer with a boot. If the upper layer was difficult to break through, then the substrate was considered cemented for a substrate embeddedness code of 1.

Dominant Cover Code: The codes used were developed by ADF&G (Schmidt et al. 1984):

Code	Type
1	No Cover
2	Emergent Vegetation
3	Aquatic Vegetation
4	Large Gravel
5	Rubble
6	Cobble/Boulder
7	Debris/Deadfall
8	Overhanging Riparian
9	Undercut Banks

More than one cover code was recorded if the available cover in a specific area was not dominated by one type.

Percent Cover: This code indicates the percent surface area available as cover to juvenile fish. These codes were developed by ADF&G (Schmidt et al. 1984):

Code	Percent Cover
1	0-5
2	6-25
3	26-50
4	51-75
5	76-95
6	96-100

Streambank Slope: Streambank slope and stability for both the left and right banks was recorded. The slope was determined to be steep if the horizontal to vertical ratio was greater than or equal to 1:1 (code number 1); moderate if the ratio was between 1:1 and 20:1 (code number 2); and flat if the ratio was greater than 20:1 (code number 3). The streambank stability was determined by observing the composition of each bank. Sandy banks and broad, flat gravel bars were considered the least stable, while rocky or heavily vegetated banks were considered stable.

Streambank Vegetation: The vegetation for each bank was described by the following codes:

Code	Description
1	Less than 50 percent of streambank vegetated
2	Dominant vegetation is grass
3	Dominant vegetation is shrub
4	Dominant vegetation is of tree form

Two or more codes were used if one code did not adequately describe the vegetation. The areas of differing vegetation were then noted on page two of the habitat inventory form.

Representative Top Width, Bankfull Top Width, Representative Depth, and Bankfull Depth: Depth was measured using a yardstick or surveyor rod and distances were determined using either a Ranging 600 range finder or fiberglass tape. Bankfull top widths and bankfull depths were sometimes impossible to measure. A shoal for example has only one bank and top widths and depths are therefore not applicable. Some difficulty in determining the water line for bankfull depths was encountered. This was overcome by observing indicators such as debris lines, water stained or dirty rocks, damage to streambank vegetation, or channel morphology.

Water Clarity: Water within each specific area was identified as clear or turbid. If turbid, the depth, in feet, of how far one could see into the water was determined by reading the lowest visible mark on a survey rod or yardstick.

Length of Backwater: The intrusion of backwater was either measured or estimated, in feet, from the point of the confluence with the mainstem.

Were Fish Observed?: Determination of fish presence was through visual observation. Information recorded included the presence or absence of fish, whether the fish was an adult or juvenile, the species, the abundance, and the activity (spawning adults for example). To ensure positive identification of juvenile fish, attempts were made to capture a sample using either a beach seine or a hand-held dip net. The beach seine, used primarily in turbid water, proved to be too time-consuming. The use of this form of capture was discontinued after the first field trip.

PAGE TWO

Site Sketch and Habitat Mapping: A sketch of each specific area was made. Additionally, any notes on plan form; habitat types; discharge; velocities; size of pools, riffles, runs, and their relative proportions; fish usage;

general slope or gradient of the streambed; substrate; vegetation; fish activities; or other information which would help characterize the habitat was recorded.

Habitat Type Proportions: After the first field trip this parameter was added. An estimate of the percentage of pool and/or riffle and/or run was recorded.

Habitat Quality Proportions: Habitat quality proportions were recorded for juvenile chinook salmon according to the following codes:

Code	Description
1	No habitat value
2	Habitat quality was poor
3	Habitat quality was fair
4	Habitat quality was good
5	Habitat quality was excellent

For example, a specific area could have been recorded as 20%, code 2, poor habitat; 30%, code 3, fair habitat; and 50%, code 4, good habitat. Habitat quality proportions were subjective evaluations based on knowledge of fishery habitats.

PAGE THREE

Photographs were described and recorded on this page. Photographs were taken to help describe the specific area in general, or a particular feature of the area (such as substrate).

PAGE FOUR

This page was used for additional notes or detailed drawings to further describe a specific area.

APPENDIX 3

AQUATIC HABITAT TRANSFORMATIONS OF SPECIFIC AREAS OF THE MIDDLE SUSITNA RIVER AT SEVERAL MAINSTEM DISCHARGES REFERENCED TO 23000 CFS

APPENDIX 3

Aquatic Habitat Transformations of Specific Areas
of the Middle Susitna River
at Several Mainstem Discharges
Referenced to 23000 cfs

Mainstem Q(cfs)

River Mile	23000	18000	16000	12500	10600	9000	7400	5100
100.40 R	SC	4	4	2	2	2	2	2
100.60 R	SS	1	1	1	1	1	1	1
100.60 L	SC	4	4	4	4	3	3	3
100.70 R	MS	10	10	4	4	4	4	4
101.20 R	SC	4	4	4	4	2	2	2
101.30 M	SC	4	4	4	4	9	9	9
101.40 L	SC	2	2	2	2	2	2	2
101.50 L	MS	10	10	10	10	4	4	4
101.60 L	SC	4	4	2	2	2	2	2
101.70 L	SC	4	4	4	4	3	3	3
101.71 L	MSS	8	8	8	8	9	9	9
101.80 L	SC	2	2	2	2	2	2	2
102.00 L	SC	4	4	4	4	9	9	9
102.20 L	US	1	1	1	1	1	1	1
102.60 L	SC	4	4	4	4	4	4	3
104.00 R	IMS	6	6	6	6	6	6	6
104.30 M	SC	3	3	9	9	9	9	9
105.20 R	US	1	1	1	1	1	1	1
105.70 R	MS	10	10	10	10	10	10	10
105.81 L	MSS	6	6	6	6	6	6	6
106.30 R	SC	4	4	4	4	4	4	4
107.10 L	SC	4	4	4	4	3	9	9
107.60 L	US	1	1	1	1	1	1	1
108.30 L	US	1	1	1	1	1	1	1
108.70 L	MS	10	10	4	4	4	4	4
108.90 L	MS	10	10	10	10	10	10	10
109.30 M	MSS	6	6	6	6	9	9	9
109.40 R	MS	10	10	10	10	10	10	10
109.50 M	SC	4	4	9	9	9	9	9
110.40 L	SC	4	4	4	2	2	2	2
110.80 M	SC	4	4	4	4	4	4	4
111.00 R	MS	10	10	10	10	10	10	10
111.50 R	MS	10	10	4	4	4	4	4
111.60 R	MSS	6	6	6	8	8	9	9
112.40 L	SC	9	9	9	9	9	9	9
112.50 L	US	1	1	1	1	1	1	1
112.60 L	MS	4	4	4	4	4	4	4

Habitat Type at Reference Flow
IMS = Indistinct Mainstem
MSS = Mainstem Shoal
ISC = Indistinct Side Channel

SC = Side Channel
SS = Side Slough
US = Upland Slough
MS = Mainstem

River Mile	23000	18000	16000	12500	10600	9000	7400	5100
113.10 R	SS	1	1	1	1	1	1	1
113.60 R	IMS	6	6	6	6	8	8	8
113.70 R	SS	1	1	1	1	1	1	1
113.80 R	IMS	6	6	6	6	6	6	6
113.90 R	IMS	6	6	6	6	6	6	8
114.00 R	MS	4	4	4	4	4	4	4
114.10 R	ISC	5	5	5	5	5	5	5
115.00 R	SC	4	4	4	2	2	2	2
115.60 R	SC	2	2	2	2	2	2	2
116.80 R	MS	10	10	4	4	4	4	4
117.00 M	ISC	6	6	8	8	8	9	9
117.10 M	SC	4	4	3	3	3	3	3
117.20 M	SC	3	9	9	9	9	9	9
117.70 L	IMS	6	6	5	5	5	5	5
117.80 L	SC	4	4	4	4	4	2	2
117.90 R	SC	4	4	4	4	4	4	3
117.90 L	SC	2	2	2	2	2	2	2
118.00 L	SC	3	3	3	3	3	3	3
118.60 M	ISC	5	5	8	8	8	8	8
118.91 L	MSS	6	6	6	6	6	6	6
119.11 L	MSS	6	6	6	6	6	6	6
119.20 R	SC	4	4	4	4	3	3	3
119.30 L	SC	4	4	2	2	2	2	2
119.40 L	US	1	1	9	9	9	9	9
119.50 L	SC	4	4	4	4	4	4	4
119.60 L	SC	4	4	4	4	4	4	4
119.70 L	SC	2	2	2	2	2	2	2
119.80 L	SC	4	4	9	9	9	9	9
120.00 R	US	1	1	1	1	1	1	1
120.00 L	SC	4	4	3	3	3	9	9
121.10 R	IMS	6	6	6	6	6	6	5
121.10 L	SC	4	4	4	4	4	4	3
121.50 R	SC	3	3	3	3	9	9	9
121.60 R	SC	4	4	3	3	9	9	9
121.70 R	MS	10	10	4	4	4	4	4
121.80 R	SC	3	3	3	3	3	3	3
121.90 R	US	1	1	1	1	1	1	1
122.40 R	SS	1	1	1	1	1	1	1
122.50 R	SC	2	2	2	2	2	2	2
123.00 L	SC	4	4	4	4	4	4	4
123.10 R	US	1	1	1	1	1	1	1
123.20 R	ISC	8	8	8	8	8	8	9
123.30 R	US	1	1	1	1	1	1	1
123.60 R	SS	1	1	1	1	1	1	1

Habitat Type at Reference Flow
IMS = Indistinct Mainstem
MSS = Mainstem Shoal
ISC = Indistinct Side Channel
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SS = Side Slough
US = Upland Slough
MS = Mainstem

River Mile	23000	18000	16000	12500	10600	9000	7400	5100
124.00 M	ISC	7	7	7	7	7	7	7
124.10 L	MS	10	10	10	10	10	10	4
124.80 R	ISC	8	8	8	8	8	8	9
125.10 R	SC	2	2	2	2	2	2	2
125.20 R	MS	4	4	4	4	4	4	4
125.60 L	MSS	6	6	6	6	5	5	5
125.60 R	SS	9	9	9	9	9	9	9
125.90 R	SS	1	1	1	1	1	1	1
126.00 R	SS	1	1	1	1	1	1	1
126.30 R	SS	1	1	1	1	1	1	1
127.00 M	SC	4	4	4	4	4	4	4
127.10 M	IMS	6	6	6	5	5	5	5
127.20 M	US	1	1	1	1	1	1	1
127.40 L	MS	10	10	10	10	10	4	4
127.50 M	ISC	6	6	6	6	5	5	5
128.30 R	IMS	6	6	6	6	6	6	6
128.40 R	MSS	6	6	6	5	5	9	9
128.50 R	SC	4	4	4	4	2	2	2
128.70 R	SC	4	4	2	2	2	2	2
128.80 R	SC	4	2	2	2	2	2	2
129.30 L	IMS	10	10	10	10	5	5	5
129.40 R	US	1	1	1	1	1	1	1
129.50 R	ISC	6	6	5	5	5	5	5
129.80 R	MS	10	10	10	10	10	10	10
130.20 R	SC	4	4	4	2	2	2	2
130.20 L	SC	4	4	4	4	4	3	3
131.20 R	IMS	5	5	5	5	5	5	5
131.30 L	SC	4	4	4	4	4	2	2
131.70 L	SC	4	4	4	4	4	4	4
131.80 L	SS	1	1	1	1	1	1	1
132.50 L	SC	4	4	9	9	9	9	9
132.60 L	SC	4	4	4	4	3	3	3
132.80 R	IMS	7	7	7	7	7	7	7
133.70 R	SC	4	4	4	2	2	2	2
133.80 L	SC	4	2	2	2	2	2	2
133.81 R	MSS	6	6	6	6	6	6	6
133.90 R	SS	1	1	1	1	1	1	1
133.90 L	US	1	1	1	1	1	1	1
134.00 L	US	1	1	1	1	1	1	1
134.90 R	SC	4	4	4	4	4	4	4
135.00 R	SC	9	9	9	9	9	9	9
135.00 L	MS	10	10	10	10	10	10	10
135.10 R	SC	3	3	3	3	3	3	3
135.30 L	SC	3	3	3	3	3	3	3
135.50 R	US	9	9	9	9	9	9	9

Habitat Type at Reference Flow
IMS = Indistinct Mainstem
MSS = Mainstem Shoal
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SC = Side Channel
SS = Side Slough
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River Mile		23000	18000	16000	12500	10600	9000	7400	5100
135.60	R	SS	1	1	1	1	1	1	1
135.70	R	SS	1	1	1	1	1	1	1
136.00	L	SC	4	4	4	4	4	4	4
136.30	R	SC	4	4	2	2	2	2	2
136.90	R	US	1	1	1	1	1	1	1
137.20	R	SC	4	4	4	4	2	2	2
137.50	R	SC	2	2	2	2	2	2	2
137.50	L	SS	1	1	1	1	1	1	1
137.80	L	SC	2	2	2	2	2	2	2
137.90	L	SC	2	2	2	2	2	2	2
138.00	L	SC	4	4	4	4	4	2	2
138.71	L	MSS	6	6	6	6	6	6	6
138.80	R	IMS	6	5	5	5	5	5	9
139.00	L	US	1	1	1	1	1	1	1
139.01	L	MSS	6	6	6	6	6	6	6
139.20	R	IMS	6	6	6	6	6	6	6
139.30	L	MSS	6	6	6	6	6	6	6
139.40	L	SC	4	4	4	4	4	4	4
139.41	L	MSS	6	6	6	6	6	6	6
139.50	R	IMS	6	6	6	5	5	7	7
139.60	L	MS	10	10	10	10	10	10	4
139.70	R	SC	2	2	2	2	2	2	2
139.90	R	US	1	1	1	1	1	1	1
140.20	R	SS	1	1	1	1	1	1	1
140.40	R	IMS	6	6	6	6	6	6	6
140.60	R	ISC	6	6	5	8	8	9	9
141.20	R	IMS	6	6	6	5	5	5	5
141.30	R	IMS	5	5	5	5	5	5	5
141.40	R	SC	4	4	4	2	2	2	2
141.60	R	ISC	7	7	7	7	7	7	7
142.00	R	ISC	5	5	5	5	8	8	8
142.10	R	SS	1	1	1	1	1	1	1
142.20	R	SS	1	1	1	1	1	1	1
142.80	R	IMS	6	6	6	6	6	6	6
142.80	L	MSS	6	6	6	6	6	6	6
143.00	L	MSS	6	6	6	6	6	6	7
143.40	L	SS	1	1	1	1	1	9	9
144.00	R	MS	10	10	10	10	10	10	10
144.00	M	SC	9	9	9	9	9	9	9
144.20	L	MS	10	10	10	10	10	10	10
144.40	L	SC	2	2	2	2	2	2	2
145.30	R	MS	10	10	10	10	10	10	4
145.60	R	SC	9	9	9	9	9	9	9
146.60	L	SS	1	9	9	9	9	9	9
147.10	L	MS	10	10	10	10	10	10	10
148.20	R	MSS	6	6	6	9	9	9	9

Habitat Type at Reference Flow
IMS = Indistinct Mainstem
MSS = Mainstem Shoal
ISC = Indistinct Side Channel

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SS = Side Slough
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MS = Mainstem

APPENDIX 4

APPROXIMATE BREACHING FLOWS

OF SPECIFIC AREAS OF THE MIDDLE SUSITNA RIVER

APPENDIX 4

Approximate Breaching Flows of Specific Areas of the Middle Susitna River

River Mile	Breaching Flow	Model Type	River Mile	Breaching Flow	Model Type
100.40 R	12500		113.80 R	<5100	
100.60 R	33000		113.90 R	7000	
100.60 L	9200		114.00 R	<5100	
100.70 R	<5100		114.10 R	<5100	DIHAB
101.20 R	9200	IFG	115.00 R	12000	DIHAB
101.30 M	9200		115.60 R	23000	
101.40 L	22000	RJHAB	116.80 R	<5100	
101.50 L	<5100	IFG	117.00 M	15500	
101.60 L	14000		117.10 M	15500	
101.70 L	9600		117.20 M	20000	
101.71 L	MSS	DIHAB	117.70 L	<5100	
101.80 L	22000		117.80 L	8000	
102.00 L	10000		117.90 R	7300	
102.20 L	>35000		117.90 L	22000	
102.60 L	6500		118.00 L	22000	
104.00 R	<5100		118.60 M	14000	
104.30 M	21000		118.91 L	MSS	DIHAB
105.20 R	>35000		119.11 L	MSS	DIHAB
105.70 R	<5100		119.20 R	10000	IFG
105.81 L	MSS	DIHAB	119.30 L	16000	
106.30 R	4800		119.40 L	>35000	
107.10 L	9600		119.50 L	5000	
107.60 L	>35000	RJHAB	119.60 L	<5100	
108.30 L	>35000		119.70 L	23000	
108.70 L	<5100		119.80 L	15500	
108.90 L	<5100		120.00 R	>35000	
109.30 M	MSS		120.00 L	12500	
109.40 R	<5100		121.10 R	<5100	
109.50 M	16000		121.10 L	7400	
110.40 L	12000		121.50 R	19500	
110.80 M	<5100		121.60 R	15500	
111.00 R	<5100		121.70 R	<5100	
111.50 R	<5100		121.80 R	22000	
111.60 R	11500		121.90 R	>35000	
112.40 L	22000		122.40 R	26000	
112.50 L	>35000	RJHAB	122.50 R	20000	
112.60 L	<5100	IFG	123.00 L	<5100	
113.10 R	26000		123.10 R	> 35000	
113.60 R	10500		123.20 R	23000	
113.70 R	24000	RJHAB	123.30 R	> 35000	

RJHAB = ADF&G Habitat Model

MSS = Mainstem Shoal
DIHAB = EWT&A Direct Input Habitat Model
IFG = Instream Flow Group

River Mile	Breaching Flow	Model Type	River Mile	Breaching Flow	Model Type
123.60 R	25500		135.60 R	>35000	
124.00 M	23000		135.70 R	27500	
124.10 L	<5100		136.00 L	<5100	IFG
124.80 R	19500		136.30 R	13000	IFG
125.10 R	20000		136.90 R	> 35000	
125.20 R	<5100	DIHAB	137.20 R	10400	
125.60 L	<5100		137.50 R	22000	DIHAB
125.60 R	26000		137.50 L	29000	
125.90 R	26000		137.80 L	20000	
126.00 R	33000	IFG	137.90 L	21000	
126.30 R	27000		138.00 L	8000	
127.00 M	<5100		138.71 L	MSS	DIHAB
127.10 M	<5100		138.80 R	6000	
127.20 M	> 35000		139.00 L	> 35000	
127.40 L	<5100		139.01 L	MSS	DIHAB
127.50 M	<5100		139.20 R	<5100	
128.30 R	<5100		139.30 L	MSS	
128.40 R	9000		139.40 L	<5100	
128.50 R	10400		139.41 L	MSS	DIHAB
128.70 R	15000		139.50 R	8900	
128.80 R	16000	IFG	139.60 L	<5100	
129.30 L	<5100		139.70 R	22000	
129.40 R	> 35000		139.90 R	> 35000	
129.50 R	<5100		140.20 R	26500	
129.80 R	<5100		140.40 R	<5100	
130.20 R	12000	DIHAB	140.60 R	12000	
130.20 L	8200		141.20 R	<5100	
131.20 R	<5100		141.30 R	<5100	
131.30 L	9000	DIHAB	141.40 R	11500	IFG
131.70 L	5000	IFG	141.60 R	21000	IFG
131.80 L	26900		142.00 R	10500	
132.50 L	14500		142.10 R	23000	
132.60 L	10500	IFG, RJHAB	142.20 R	26000	
132.80 R	19500		142.80 R	<5100	
133.70 R	11500		142.80 L	MSS	
133.80 L	17500	IFG	143.00 L	7000	
133.81 R	MSS	DIHAB	143.40 L	23000	
133.90 R	30000		144.00 R	<5100	
133.90 L	> 35000		144.00 M	22000	
134.00 L	> 35000		144.20 L	<5100	
134.90 R	<5100	IFG	144.40 L	21000	RJHAB
135.00 R	21500		145.30 R	<5100	
135.00 L	<5100		145.60 R	22000	
135.10 R	20000		146.60 L	26500	
135.30 L	23000		147.10 L	<5100	IFG
135.50 R	>35000		148.20 R	MSS	

RJHAB = ADF&G Habitat Model

MSS = Mainstem Shoal
DIHAB = EWT&A Direct Input Habitat Model
IFG = Instream Flow Group

APPENDIX 5

FISH OBSERVATIONS

APPENDIX 5

FISH OBSERVATIONS

All fish observations made during the field reconnaissance are presented below. Most observations were made late in the spawning season. Consequently, some of the specific areas may have had spawning activity before the field investigations took place. There were no fish observed in 58 (34%) of the 172 specific areas visited during the field work. Fish observations included an estimate of numbers, species, and life stage (i.e., adult or juvenile), as well as any spawning activity and the number of redds observed.

ADULT AND JUVENILE SALMON OBSERVATIONS
HABITAT INVENTORY 8-21-84 THROUGH 10-2-84

RM = River Mile
L = Left Bank Looking Upstream
R = Right Bank Looking Upstream
M = Middle of River (usually island)
* = Spawning Activity Observed As Indicated by the Presence of Redds or Spawning Behavior.

SPECIFIC AREA (RM)	DATE	OBSERVATIONS
100.4R	09-11-84	Lots of coho juveniles
100.4R	10-02-84	One unidentified juvenile in pool (dry channel)
100.5R	09-11-84	Chum salmon adults
100.6R*	08-22-84	Chum salmon adults, unidentified juveniles, redds
100.6R*	10-02-84	Unidentified juveniles, several redds, scattered salmon eggs
100.6L	09-11-84	Pink and chum adults, few unidentified juveniles
101.2R*	09-11-84	Twenty+ chum adults and several redds
101.3L	09-11-84	Two dead chum, 1 dead pink
101.4L*	09-10-84	Coho juvenile (dead), juvenile chinooks
101.4L*	08-22-84	Chum, pink adults, several unidentified juveniles
101.6L	08-22-84	About 10 chum adults
101.6L*	09-10-84	Spawning chum, adult sockeye, numerous unidentified juveniles
101.7L	09-10-84	One adult chum, 1 chum carcass
101.8L*	09-10-84	Hundreds of juvenile (coho), 3 adult sockeye, 3 adult chum
101.8L*	10-02-84	Lots of unidentified juvenile salmonids
102.0L	09-10-84	One unidentified juvenile salmonid, 2 unidentified carcasses
102.2L*	09-10-84	Thousands of salmonid juveniles (identified 2 coho and 1 sockeye
102.2L*	10-02-84	Hundreds of unidentified salmonid juveniles, 15 redds, 1 sockeye adult, 2 chum adults, 1 dead pink
105.2R	09-10-84	Few juveniles (chino, coho)
107.1L	09-10-84	Chum and pink carcasses
107.6L	09-10-84	One pink carcass, several juveniles (2 identified as coho)
109.3M	09-10-84	One chum carcass
109.5M	09-10-84	One chum carcass
110.4L	08-22-84	One chum adult, 1 chum carcass
111.5R	09-06-84	Several chum carcasses, couple of unidentified juveniles
111.5R	10-01-84	Several chum carcasses, lots of unidentified juveniles
111.6R	09-06-84	Three chum carcasses

SPECIFIC AREA (RM)	DATE	OBSERVATIONS
112.5L	09-06-84	Several unidentified juveniles
112.5L	09-06-84	Thousands of juveniles unidentified
112.5L	08-22-84	Unidentified juveniles
112.6L	09-06-84	Several juvenile chinook
112.6L	09-11-84	Juvenile salmonids - unidentified
113.6R	09-06-84	Chum and pink carcasses - 1 juvenile unidentified
113.7R*	09-06-84	About 40 adult chum, lots of juveniles (chinook and coho)
113.7R*	08-22-84	About 50 adult chum
113.7R*	09-11-84	Greater than 20 adult chum, redds, juvenile chinook, coho, sockeye
114.0R	09-06-84	Chum carcasses, 1 adult chum, chinook juvenile (1)
114.1R	09-06-84	One chum carcass
115.0R*	09-06-84	Fourteen+ adult chums, 1 sockeye adult, 1 unidentified juvenile
115.0R*	08-22-84	Several adult chums
115.0R*	09-06-84	Several chinook juveniles, 1 rainbow juvenile
115.6R*	09-06-84	Sixty+ adult chum, several chinook juveniles, 1 rainbow juvenile
116.3R	09-06-84	One chum carcass, several unidentified juveniles
117.0M	09-06-84	Several chum carcasses
117.1M	09-06-84	Chinook juveniles
117.1M	08-22-84	Several unidentified juveniles
117.2M	09-06-84	Scattered eggs
117.85L	10-01-84	Chinook and coho juveniles
117.9R	09-06-84	Adult coho (in tributary), chum carcass, unidentified juveniles
117.9L*	09-06-84	Two coho juveniles
118.91L*	09-07-84	About 16 chum adults
119.11L*	09-07-84	About 6 chum adults, 3 redds
119.2R	09-07-84	Several unidentified juveniles
119.3L*	09-07-84	Two chum adults, chinook and sockeye juveniles, 1 grayling
119.4L	09-07-84	A few unidentified juveniles
119.4L*	08-22-84	Redds
119.5L	09-07-84	Several chinook juveniles and unidentified
119.7L	09-07-84	Coho juveniles
120.0L	09-07-84	Unidentified juveniles
120.0R*	09-07-84	One redd observed
121.1L*	09-07-84	One chum adult, 2 unidentified juveniles
121.5R	09-07-84	Chinook juveniles
121.6R	09-07-84	Chinook juveniles
121.7R	09-07-84	Chum adults, chinook juveniles
121.8R*	08-22-84	Chum adults, unidentified juveniles
121.8R*	09-07-84	Greater than 40 chum adults
121.9R*	09-07-84	One chum carcass, chinook juvenile, obvious spawning activity

SPECIFIC AREA (RM)	DATE	OBSERVATIONS
122.4R*	09-07-84	Several chum adults, several redds, coho juvenile
122.5R*	09-07-84	About 150 chum adults, unidentified juveniles, chinook juvenile
122.5R*	08-21-84	Chum adults
123.1R	09-07-84	Several unidentified juveniles
123.1R	09-30-84	Many unidentified juveniles
123.2R	09-07-84	Several chinook and coho juveniles, 1 grayling juvenile
123.3R	09-30-84	One unidentified juvenile
123.6R*	08-21-84	Sockeye and chum adults
123.6R*	09-07-84	Chum adults, chinook and coho juveniles
124.0M	09-07-84	Several chinook juveniles
125.1R	09-05-84	Two chum carcasses
125.1R	09-05-84	Several unidentified juveniles
125.2R	09-05-84	One chum adult, few unidentified juveniles
125.9R*	08-21-84	Few sockeye adults, 75+ chum adults, school of unidentified juveniles
125.9R*	09-05-84	Sockeye and chum adults
126.0R*	09-05-84	Sockeye and chum adults, several unidentified juveniles
126.0R*	08-21-84	Some sockeye adults, few pink adults, hundreds of chum adults
126.3R*	08-05-84	Sockeye and chum adults
127.0L	09-05-84	One chum carcass, several unidentified juveniles
127.4M	09-05-84	Several unidentified juveniles
127.5M	09-05-84	One chum carcass
128.3R	09-05-84	One chum, chinook juveniles
128.5R	09-05-84	Chinook juveniles
128.7R*	09-05-84	Chum adults
128.8R*	08-21-84	Several adult chums
128.8R*	09-05-84	Several unidentified juveniles
129.4R*	09-05-84	Several chum adults, unidentified juveniles
129.5R	09-05-84	Chum adults
129.5R	09-30-84	One coho carcass
130.2R*	09-05-84	Chum adults, chinook juveniles
130.2L*	09-05-84	One chum carcass, unidentified juveniles (1 chinook identified)
131.3L*	09-05-84	Chum adults, redds
131.7L*	09-04-84	Lots of chum adults, few unidentified juveniles
131.8L*	09-04-84	About 20 chum adults, lots of redds, 1 unidentified juvenile
132.6L	09-05-84	Unidentified juveniles
132.8R*	09-05-84	Chum adults, 1 dead chinook juvenile
133.7R*	08-21-84	Some chum adults
133.7R*	09-04-84	Chum adults, few chinook juveniles
133.8R	09-04-84	Chum adults, 1 unidentified juvenile
133.8L	08-21-84	Chum adult
133.8L	09-05-84	Chinook juveniles
133.9R*	09-04-84	Chinook juveniles
133.9L*	09-04-84	Chum adults, chinook juveniles

SPECIFIC AREA (RM)	DATE	OBSERVATIONS
134.0L	09-04-84	One chum carcass, few unidentified juveniles
134.9R*	08-21-84	One chum adult, 1 chum carcass
134.9R*	09-04-84	Several chum adults, several unidentified juveniles
135.0L*	09-04-84	Chinook and unidentified juveniles
135.1R	09-04-84	Several unidentified juveniles
135.6R*	09-04-84	Hundreds of sockeye adults, thousands of chum adults, chinook juveniles
135.6R*	08-21-84	Sockeye, chum, pink adults greater than 400 fish
135.7R	08-21-84	Some chum adults, 2 pink carcasses, several unidentified juveniles (1 chinook)
136.0L	09-04-84	Two chum carcasses, unidentified adults
136.3R*	09-04-84	Chum adults, chinook juveniles
137.2R*	09-04-84	Chum adults, 2 unidentified juveniles
137.5R	09-04-84	Chum adults, 2 chum carcasses, chinook juveniles
137.5L	09-04-84	Chum carcasses, chinook juveniles
137.9L	08-21-84	Few unidentified juveniles
138.7L	09-04-84	One chum carcass, 1 unidentified adult
139.01L*	09-04-84	About 30 chum adults
139.0L*	08-21-84	Some sockeye adults, 50+ chum adults, 1 pink carcass
139.4L	09-03-84	Several chum carcasses, several unidentified juveniles (1 chinook identified)
139.5R	09-03-84	Sockeye and chum adults
139.6L	09-03-84	Several chum carcasses, several unidentified juveniles (1 chinook identified)
139.9R*	09-03-84	Sockeye and chum adults, chinook juveniles
140.2R*	08-21-84	Lots of chum adults, lots of unidentified juveniles
140.2R*	09-03-84	About 12 chum adults, lots of coho and chinook juveniles
140.6R*	09-03-84	Several chum carcasses, redds, few unidentified adults (1 chinook identified)
141.4R*	09-03-84	Hundreds to thousands of sockeye and chum adults, chinook juveniles
141.6R*	08-21-84	Some sockeye adults, hundreds of chum adults, 1 unidentified juvenile
142.0R	09-03-84	Chum adults, unidentified juveniles
142.0R	09-29-84	Fifteen+ unidentified juvenile fish
142.1R*	09-03-84	Sockeye and chum adults, greater than 500 chinook juveniles, several unidentified juveniles
142.8L*	09-03-84	Fifty+ chum adults
143.0L*	09-03-84	Twelve+ chum adults, unidentified juveniles
143.4L*	09-03-84	Thirty-two+ chum adults, unidentified juveniles (1 chinook identified)
144.2L	09-03-84	Chum carcass, chinook juveniles
144.4L*	08-21-84	Fifty+ chum adults
145.6R	08-21-84	One chinook juvenile