ALASKA DEPARTMENT OF FISH AND GAME
SUSITNA HYDRO AQUATIC STUDIES

REPORT NO. 3

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

CHAPTER 7 REVIEW DRAFT

Edited by:

Christopher C. Estes
and
Douglas S. Vincent-Lang

Prepared for:

ALASKA POWER AUTHORITY
334 W. FIFTH AVE.
ANCHORAGE, ALASKA 99501

PREFACE

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

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

TITLES IN THE 1983 SERIES

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

This report, "Aquatic Habitat and Instream Flow Investigations" is divided into two parts. Part I, the "Hydrologic and Water Quality Investigations", is a compilation of the physical and chemical data collected by th ADF&G Su Hydro Aquatic Studies team during 1983. These data are arranged by individual variables and geographic location for ease of access to user agencies. The combined data set represents the available physical habitat of the study area within the Cook Inlet to Oshetna River reach of the Susitna River. Part II, the "Adult Anadromous Fish Habitat Investigations", describes the subset of available habitat compiled in Part 1 that is utilized by adult anadromous fish studied in the middle and lower Susitna River (Cook Inlet to Devil Canyon) study area. The studies primarily emphasize the utilization of side slough and side channel habitats of the middle reach of the Susitna River for spawning (Figure A). It represents the first stage of development for an instream flow relationships analysis report which will be prepared by E.W. Trihey and Associates.

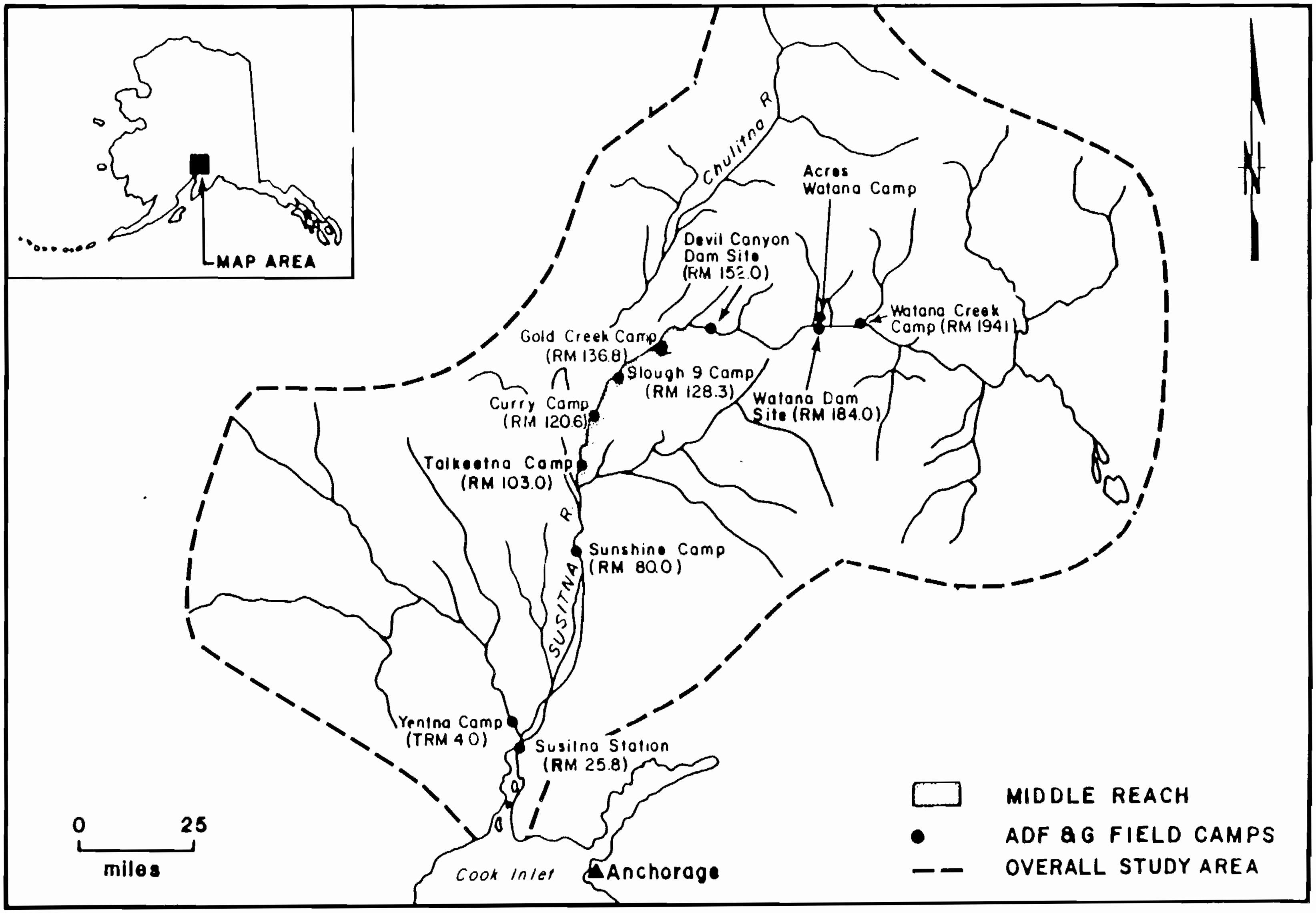

Figure A. Susitna River drainage basin.

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Part One

Part Two

Questions concerning this and prior reports should be directed to:

Alaska Power Authority
334 W. 5th Avenue
Anchorage, Alaska 99501
Telephone (907) 276-0001

AN EVALUATION OF CHUM AND SOCKEYE SALMON SPAWNING HABITAT IN SLOUGHS AND SIDE CHANNELS OF THE MIDDLE SUSITNA RIVER

1984 Report No. 3, Chapter 7

By: Andrew Hoffmann, Doug Vincent-Lang, Allen Bingham, Diane Hillard, Christopher Estes, and E. Woody Trihey

Alaska Department of Fish and Game
Susitna Hydro Aquatic Studies
2207 Spendard Road
Anchorage, Alaska 99503

ABSTRACT

(TO BE WRITTEN IN FINAL)

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This chapter presents an evaluation of the suitability of selected side channel and side slough habitats in the middle reach of the Susitna River for spawning by chum and sockeye salmon as a function of flow variation. It is divided into six sections as described below:

Section 1.0: General Introduction - The rationale, objectives, and study approach utilized in the evaluation are presented in this section.

Section 2.0: Study Site Selection - This section presents a discussion of the concepts and rationale used in the selection of study sites. Additionally, generally descriptions of selected study sites are presented in this section.

Section 3.0: Physical Availability Modelling* - The development and use of hydraulic availability models to forecast the range of water depths, velocities, substrates, and upwelling conditions important for chum and sockeye salmon spawning as a function of flow variation in side slough and side channel study sites is discussed in this section.

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* The physical availability models discussed in Section 3.0 were also developed to support modelling of juvenile salmon and resident fish utilization of these habitats. The juvenile salmon and resident fish habitat modelling is reported in Schmidt et al. (1984). A discussion of the cover component of the models, which is specific to that analysis, is not included in this report.

Section 4.0: Fish Habitat Criteria Analysis - This section discusses the behavioral responses of spawning fish to various levels of several habitat variables, including depth, velocity, substrate, and upwelling and the corresponding development of weighted behavioral response curves (i.e., suitability criteria).

Section 5.0: Spawning Habitat Area Projections - The process of linking site-specific hydraulic availability data with suitability criteria using a habitat simulation model to calculate projections of Weighted Usable Area (WUA) of salmon spawning habitat within study sites as a function of flow variation in presented in this section.

Section 6.0: Summary and Conclusions - A summary and the conclusions of these investigations are presented in this section.

1.0 GENERAL INTRODUCTION

1.1 Background and Objectives

This chapter presents the results of an investigation the ADF&G Su Hydro Aquatic Studies Team has conducted since 1981 to evaluate the effects of flow fluctuations on spawning habitat availability within selected side channel and side slough habitats in the Talkeetna to Devil Canyon reach of the Susitna River (middle river reach). Of the six major habitat types identified for the Susitna River* side channel and side sloughs were chosen for study since hydraulic conditions within these areas are most likely to be significantly altered by changes in the flow regime which will result from the filling and operation of the proposed hydroelectric facility. The persistence of spawning habitat within these areas will largely depend on the availability of suitable water depths and velocities under with-project flow conditions. Chum and sockeye salmon were chosen for evaluation because they are the dominant species which presently spawn in side channel and side slough areas of the Susitna River.

The overall objective of the investigation has been to evaluate the suitability of selected side channel and side slough habitats in the middle reach as a function of flow variation for chum and sockeye salmon spawning. This objective was evaluated using the instream flow

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* The six major habitat types present in middle reach of the Susitna River are: mainstem channel, side channel, side slough, upland slough, tributary, and tributary mouth (Figure 7-1-1).

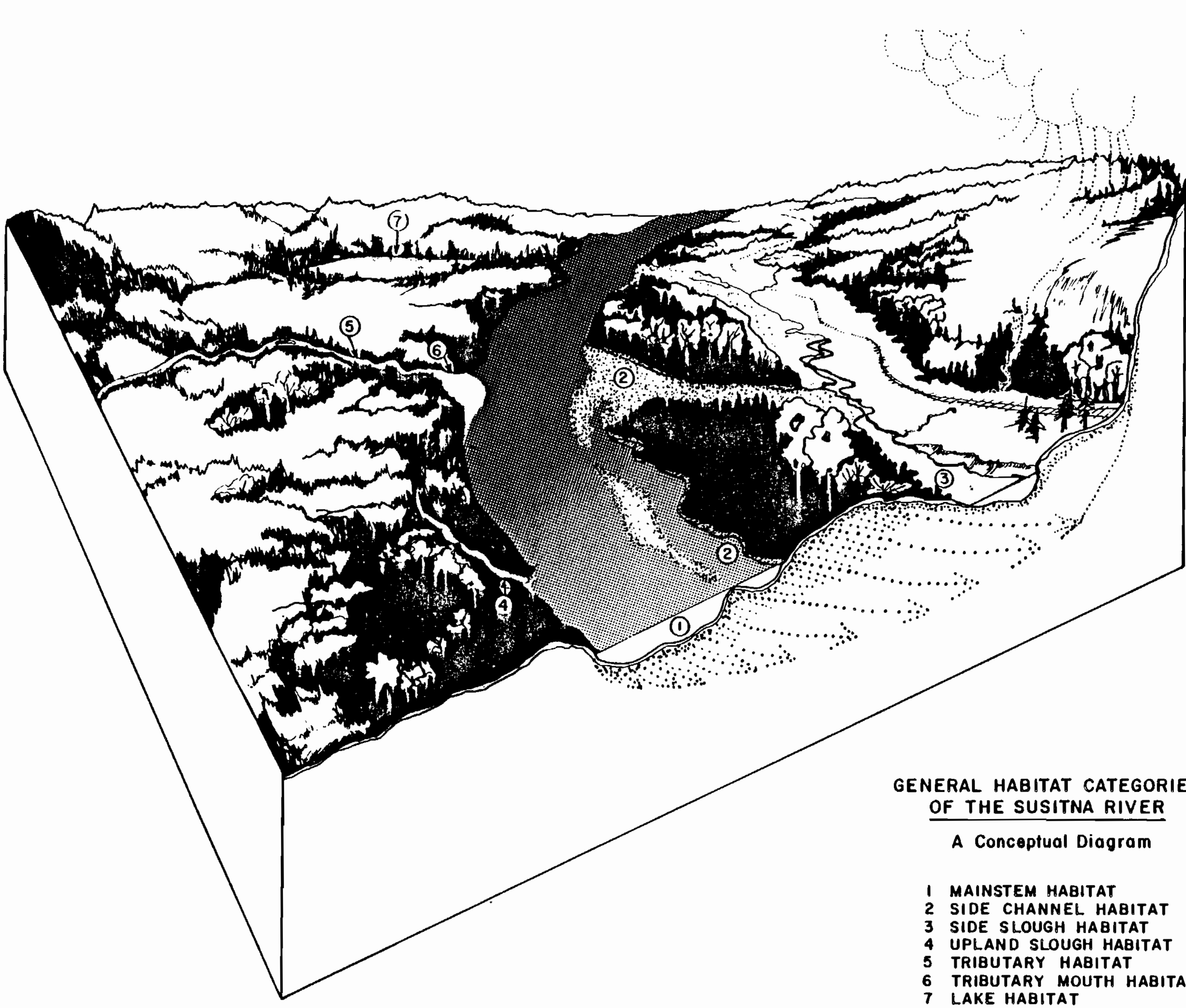

Figure 7-1-1. General habitat categories of the middle Susitna River – a conceptual diagram (ADF&G 1983).

incremental methodology (IFIM) physical habitat simulation (PHABSIM) modelling system developed by the US Fish and Wildlife Service Instream Flow Group (IFG) (IFG 1980; Bovee 1982).

Within the overall objective of this investigation, three specific tasks were addressed:

1. To collect field data to forecast, through the use of hydraulic availability models, the values of selected hydraulically controlled variables (i.e., water depth and velocity) important for chum and sockeye salmon spawning as a function of flow variation. Additionally, data on streambed composition and groundwater upwelling, which are considered important to spawning yet assumed to be independent of flow levels, were also collected.

2. To collect field data to determine the behavioral responses of spawning chum and sockeye salmon to variations in habitat variables (i.e., depth, velocity, substrate, and upwelling) to be used in the development of weighted behavioral response criteria for each variable. The resulting suitability criteria, derived from habitat utilization and availability data, describe the relative probability that a spawning fish will utilize some increment of a physical habitat variable within a preferred range of that variable.

3. To calculate, using a habitat simulation model, the weighted usable area (WUA) of chum and sockeye salmon spawning habitat as function of flow variation for selected study sites.

1.2 Study Approach

The quantity and quality of chum and sockeye salmon spawning habitat in side sloughs and side channels is dependent on a multitude of interrelated environmental factors, including water depth and velocity, which are intimately related to discharge levels, and streambed composition and upwelling, which are less directly affected by streamflows. Significant temporal and spatial differences in these variables are expected to affect habitat suitability for spawning by salmon in sloughs and side channels.

The response of habitat variables to naturally occurring changes in flow could not be cost-effectively evaluated by monitoring a natural system of this magnitude on a continual basis. For this reason, the instream flow incremental methodology (IFIM) physical habitat simulation (PHABSIM) modelling system of the U.S. Fish and Wildlife Service Instream Flow Group (IFG) (IFG 1980; Bovee 1982) was selected in 1982 (ADF&G 1983a, b: Appendix D) as a means of quantifying the probable effects of unobserved flow patterns on existing spawning habitat in side slough and side channel habitats.

The PHABSIM system is a collection of computer programs used to simulate both the available hydraulic conditions and usable habitat at a study site for a particular species/life phase as a function of flow variation. The PHABISM modelling system is based on the theory that changes in riverine habitat conditions can be estimated from a sufficient hydraulic and biologic field data base. The system is based on a three step approach. The first step uses field data to calibrate hydraulic simulation models to forecast anticipated changes in physical variables important for the species/life phase in question as a function of flow variation. The second step involves the collection and analysis of biological data to determine the behavioral responses of a particular species/life phase to selected physical variables important for the species/life phase under study. This information is used to develop weighted behavioral response criteria curves (e.g., utilization curves, best utilization curves, and suitability criteria curves). The third step combines information gained in the first two steps to calculate weighted usable area (WUA) indices of habitat availability as a function of flow for the selected species/life phase.

PHABSIM is intended for use in those situations where the flow regime and channel structure are the major factors influencing riverine habitat conditions. Furthermore, the physical and biological aspects of field conditions must be compatible with the underlying theories and assumptions of the models being applied. Specific assumptions required in the application of these models and the resulting limitations of the simulated data are discussed in the Sections 3.0, 4.0, and 5.0.

1.3 Previous Studies

Background studies to assist in selection of study sites for evaluation using the PHABSIM modelling approach were initiated in 1981. Based on these studies, three side slough habitats (Sloughs 8A, 9, and 21) in the Talkeetna to Devil Canyon reach were selected for evaluation (ADF&G 1982).

Spawning habitat assessment using the PHABSIM modelling approach was initiated in Sloughs 8A, 9, and 21 in 1982 (ADF&G 1983B, Appendix D). However, lower than average discharge conditions in 1982 prohibited the collection of hydraulic data necessary for calibration of the physical availability models for the study sites. These conditions also restricted access into sloughs by spawning salmon, which limited the quantity of fish utilization data available to develop weighted behavioral response criteria curves.

In 1983, the additional data necessary for completing the PHABSIM analysis were collected at each of the three side slough study sites. In addition, data necessary for completing a PHABSIM analysis at four side channel study sites (Side Channels 10, Lower and Upper 11, and 21) were collected in 1983. These results are presented in this chapter.

2.0 STUDY SITE SELECTION

This section presents the concepts and rationale used in the selection of study sites. In addition, general descriptions of sites selected for evaluation are presented.

2.1 Study Site Selection Concepts

Two basic approaches exist for selecting study sites to be evaluated using the PHABSIM modelling system which is part of the Instream Flow Incremental Methodology (IFIM) study approach: the critical reach and representative reach concepts (Bovee and Milhous 1978; Trihey 1979; Bovee 1982). Application of the critical reach concept requires knowledge of a stream's hydrology, water chemistry, and channel geometry in addition to rather extensive knowledge of fish distribution, relative abundance, and species-specific life history requirements. Criteria for application of the representative reach concept are less restrictive, enabling this approach to be used when only limited biological information is available or when critical habitat conditions cannot be identified with any degree of certainty.

Using the critical reach concept, a study reach is selected because one or more of the physical or chemical attributes of the habitat are of critical importance to the fish resource. Recognizable physical or chemical characteristics of the watershed hydrology, instream hydraulics, or water quality must be known to control species distribution or relative abundance within the study area. An evaluation of project effects on critical reach areas will provide a meaningful index of species response to with-project conditions in those areas.

The representative reach concept acknowledges the importance of physical habitat variables throughout the entire stream in sustaining fish populations. Thus, under the representative reach approach, study reaches are selected for the purpose of quantifying relationships between streamflow and physical habitat conditions at several locations (representative reaches) that collectively exemplify the general habitat characteristics of the entire river segment inhabited by the species of interest.

2.2 Study Site Selection

2.2.1 Slough Study Sites

Preliminary studies of the Susitna River (ADF&G 1974, 1976, 1977, 1978) indicated that slough habitats in the middle reach of the Susitna River are utilized for spawning and rearing by chum and sockeye salmon. Because this type of habitat is located along the lateral margins of the river flood plain, it will be subject to dewatering during the open water field season if naturally occurring summer streamflows are significantly reduced by the proposed Susitna Hydroelectric Project. For these reasons, slough habitats in the Talkeetna-to-Devil Canyon river segment were initially selected in 1981 for study using the PHABSIM modelling approach (ADF&G 1981a, b, 1982). It was not possible, however, due to resource and manpower limitations, to cost-effectively evaluate all slough habitats in the middle river reach. For this reason, baseline studies were conducted during 1981 to assist in selection of specific slough habitats to be evaluated using the PHABSIM modelling approach.

Based on a review of baseline fishery, water quality, and channel morphology data from previous ADF&G investigations (ADF&G 1974, 1976, 1977, 1978); discussions with personnel familiar with the middle river habitat conditions from Acres American, Inc., E.W. Trihey and Associates, and R&M Consultants Inc.; and, results of a reconnaissance trip to the middle river reach in June 1981 by ADF&G Su Hydro and U.S. Geological Survey (USGS) personnel, six slough habitats were selected for further baseline evaluation to select specific sites for study using the PHABSIM modelling approach. These six sloughs (Sloughs 8A, 9, 11, 16B, 19, and 21) were thought to represent a cross section of the biological, physical, and chemical characteristics typical of slough habitats in the middle reach of the Susitna River (Table 7-2-1).

On the basis of additional field investigations conducted during the fall of 1981 (ADF&G 1982a b), Sloughs 8A, 9, and 21 were selected for evaluation using the PHABSIM modelling approach. These sloughs were selected based primarily on their relatively high utilization by spawning chum and sockeye salmon and their amenability to habitat modelling using the PHABSIM modelling system (Table 7-2-2). Although Slough 11 is also heavily utilized by spawners, the relatively low frequency of overtopping at this slough would have made it difficult to evaluate using the IFIM approach. Additionally, it was felt that it was

Table 7-2-1. Matrix of information from previous studies (ADF&G 1977, 1978) used as criteria to initially select slough sites to be evaluated during 1981 for study using the IFIM modelling approach.

HABITAT		BIOLOGICAL DATA					PHYSICAL DATA	WATER QUALITY DATA			
		Spawning		Rearing							
Slough	River Mile	Chum	Sockeye	Coho	Chinook	Sockeye	Streambed Morphology	pH	Alkalimily (mg/l)	Hardness (mg/l)	Specific Conductance (umho/cm)
8A	125.3	++	++	-	-	-	Beaver Dam Backwater	5.6-7.6	-	-	45-175
9	128.3	++	+	-	-	-	Open Channel	5.4-8.0	-	-	100-190
10	133.8	0	0	P	0	0	Open Channel	7.3-7.5	50-65	60-75	150-230
11	135.7	++	+++	0	0	0	Open Channel	7.4-7.6	70-105	85-95	55-230
13	135.7	0	0	P	0	P	Open Channel	6.7-7.6	60-70	80-90	170-200
14	136.7	0	0	P	0	0	Open Channel	6.8-6.9	15-40	35-45	85-95
15	137.2	0	+	P	P	P	Open Channel	6.7-6.8	10-30	25-30	68-72
16	137.8	0	0	P	P	0	Open Channel	6.2-7.2	20-35	20-45	60-85
17	138.9	0	0	P	0	0	Open Channel	6.7-7.0	20-35	25-30	66-80
18	139.1	0	0	P	0	0	Open Channel	7.0-8.0	45-50	40-60	105-135
19	140.0	0	+	P	0	P	Backwater	7.1-7.8	40-60	60-70	140-150
20	140.1	++	0	P	0	0	Open Channel	7.6-7.7	35-40	35-55	95-110
21	141.8	+++	++	P	P	P	Open Channel	5.0-8.0	-	-	135-200

Key:
P = Present
0 = Absent
+ = Less than 10 fish
++ = 10-100 fish
+++ = More than 100 fish
- = Data not available

Table 7-2-2. Baseline biological, physical, and water quality characteristics of sloughs evaluated for study sites using the PHABSIM aproach during 1981 (ADF&G 1981a, b, c).

HABITAT		BIOLOGICAL DATA				PHYSICAL DATA	WATER QUALITY DATA			
		Spawning		Rearing						
Slough	River Mile	Chum	Sockeye	Chum	Sockeye	Streambed Morphology	Dissolved Oxygen (mg/l)	pH	Specific Conductance (umho/cm)	Turbidity (NTU)
8A	125.3	+++	++	0	0	Beaver Dam Backwater	8.8-10.5	6.8-7.6	108-160	1-205
9	128.3	++	++	0	+	Open Channel	10.6-11.4	6.8-7.4	113-145	1-130
11	135.7	+++	+++	+++	0	Open Channel	9.3-10.7	6.8-7.1	144-222	2-98
16B	137.8	+	+	-	-	Open Channel	10.8-11.7	6.4-7.1	64-72	1-43
19	140.0	+	+	-	-	Backwater	9.4-10.4	6.5-7.3	127-150	1-3
21	141.8	++	++	-	-	Open Channel	10.3-11.3	7.0-7.7	103-226	1-150

Key: +++ high utilization
++ moderate utilization
\+ low utilization
0 absent
\- unknown, data not available

unlikely that spawning habitat in Slough 11 would be significantly affected by further reductions in mainstem discharge due to its relatively low frequency of overtopping. Sloughs 16B and 19 were not selected for habitat modelling because of their comparatively low utilization by spawning chum and sockeye salmon. Additionally, it was felt that backwater effects at Slough 19 would significantly complicate the modelling process.*

2.2.2 Side Channel Study Sites

Prior to the onset of the 1983 field season it was decided that side channel habitats should also be evaluated using the PHABSIM modelling approach since the physical characteristics of this type of habitat may also change considerably if naturally occurring summer discharges are reduced as a result of the Susitna Hydroelectric Project. Although limited spawning currently occurs in side channels under pre-project conditions, their utilization may increase if with-project flows reduce available habitat in sloughs and provide more favorable spawning habitat conditions in side channels. Additionally, these habitats are a significant chinook salmon rearing area.

In contrast to slough habitat study sites, only a limited amount of baseline biological, physical, and water quality data was available for selecting representative side channel habitats in the middle reach of

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* For further discussion of this site selection process refer to ADF&G (1982a, b).

the Susitna River to be evaluated using the PHABSIM modelling approach. Based on preliminary field observations and consensus among personnel familiar with middle rive habitats from ADF&G Su Hydro and E. Woody Trihey and Associates, four side channel sites (Side Channel 10, Lower and Upper Side Channel 11, and Side Channel 21) were selected for study using the PHABSIM modelling approach. These side channels are assumed to be capable of supporting either spawning or rearing salmon under appropriate flow conditions.

Upper Side Channel 11 and Side Channel 21 were selected for evaluation because these side channels are known to support limited chum/sockeye spawning. Additionally, these two side channels provide significant chinook salmon rearing habitat. Lower Side Channel 11 and Side Channel 10 were selected primarily because these side channels provide significant rearing habitat for chinook salmon juveniles. A further reason for selecting Side Channel 21 and Lower Side Channel 11 was due to their proximity to Sloughs 21 and 11, areas which currently are utilized by spawning chum and sockeye salmon. If with-project conditions caused access problems into these adjacent sloughs, increased spawning may take place in their respective side channels if suitable spawning habitat were present.

Hydraulic availability models were calibrated for each of these four side channel study sites. Projections of weighted useable area of spawning habitat calculated for the Upper Side Channel 11 and Side Channel 21 study sites were used as an index of available spawning habitat as a function of flow variation. Since no chum or sockeye spawning is known to occur in Side Channel 10 or Lower Side Channel 11 projections of weighted useable area at these sites were not used as an index of available spawning habitat. The WUA projections for these sites were only used for comparative purposes to verify model validity.

2.3 Representativeness of Sites Selected for Study

As discussed previously, two concepts exist in selecting study sites for evaluation using the PHABSIM modelling approach: the representative and critical concepts. An adaptation of these two concepts was applied in this study. The critical habitat concept was used initially to select slough and side channel habitats for investigation since these two habitat types (of the six major habitat types which have been identified in the middle river reach) are most likely to be significantly affected by changes in flow regime that will result from the filling and operation of the proposed hydroelectric facility. Furthermore, these two habitat types support a majority of the salmon spawning habitat occurring in the middle reach mainstem affected areas. Within the critical slough and side channel habitat areas, specific slough and side channels were selected as critical representative habitats of the habitat types within the middle reach. The selected sites were then investigated using the PHABSIM modelling system.

2.3.1 Slough Habitats

Only slough habitats in which chum and sockeye salmon spawning has been documented were considered for study using the PHABSIM modelling approach. The three side sloughs selected for modelling were thought to be representative of remaining slough habitats in the middle reach that currently support chum and sockeye salmon spawning.

To establish the representativeness of Slough 8A, 9, and 21, available baseline data on the biological and physical characteristics of these sloughs were compared with similar information obtained for selected non-modelled slough habitats in the middle reach which are known to support chum and sockeye salmon spawning. It appears from a consideration of the information presented in Table 7-2-3 that Sloughs 8A, 9, and 21 are generally representative of other selected non-modelled slough habitats. Collectively, these non-modelled sloughs support 81% of the known chum salmon and 92% of the known sockeye salmon spawning observed in sloughs in the middle reach of the Susitna River. However, it may not be appropriate to extrapolate the results of these studies to non-modelled slough habitats. A prerequisite to such extrapolation is that the flow-related variables on which the model are based are the habitat variables that limit chum and sockeye salmon spawning. If it is established that other variables limit spawning in non-modelled sloughs, then extrapolations of the modelling results are not warranted, regardless of the availability of suitable depth, velocity, substrate, and upwelling conditions. Accordingly, we do not recommend the transferral of modelling results to sloughs which do not currently support chum and sockeye salmon spawning.

2.3.2 Side Channel ~~Habitats~~

Since baseline data on side channel habitats in the middle reach of the Susitna River are limited, the representativeness of the modelled study

Table 7-2-3. Comparison of biological and physical characteristics at major chum and sockeye salmon slough spawning habitats in the middle river reach.

HABITAT		BIOLOGICAL		PHYSICAL						
		Percent Distribution in Sloughs above RM 99								
Slough	River Mile	Chum	Sockeye	Channel Morphology	Breaching Mainstem Q	Controlling Mainstem Q	Gradient (ft/mile)	Substrate	Upwelling	Turbidity (NTU)
8	113.6	4.6	0.0	OC	24,000	24,000	Unknown	SI/SD, RU/CO	Present	Unknown
8A	125.3	15.1	13.0	BW, OC	33,000	33,000	12.5	GR/RU, SI/SD	Present	1-205
9	128.3	11.1	0.7	OC	16,000	19,000	13.8	GR/RU, SI/SD	Present	15-130
9A	133.2	6.2	0.1	OC	19,600*	19,600*	16.1	RU/CO	Present	Unknown
11	135.3	16.9	66.3	OC	42,000	42,000	19.8	CO/RU	Present	2-98
20	140.1	1.7	0.1	OC	22,000	27,000	13.5	RU/GR	Present	4-50
21	141.8	20.2	12.0	OC	18,000	24,000	22.9	CO/RU, SI/SD	Present	2-180
22	144.2	5.2	0.0	OC	20,000	23,000	15.2	CO/RU, SI/SD	Present	8-84
	Totals	81.0	92.2							
References		A	A	B	C	C	B	B	D	D

* Estimated

Key:
OC - Open Channel
BW - Backwater
CO - Cobble
RU - Rubble
SI - Silt
SD - Sand

References:
A Barrett, et al., 1984
B Estes and Vincent-Lang, 1984 - Chapter 2
C Estes and Vincent-Lang, 1984 - Chapter 3
D ADF&G, 1983 - Volume 4

sites is not well documented. Chum and sockeye salmon have been observed at only two (Upper Side Channel 11 and Side Channel 21) of the four side channel sites evaluated. For this reason, projections of weighted usable area of spawning habitat at these two sites can be used as an index to available spawning habitat as a function of flow variation. No chum or sockeye salmon spawning was observed in Side Channel 10 or Lower Channel 11, therefore projections of weighted usable areas of spawning habitat at these two sites were made solely for comparative purposes to verify model accuracy. Unless utilization is documented at these two sites, we do not recommend the use of modelling results as a index of available habitat at these sites. Furthermore, we feel it is inappropriate to extrapolate the results of the modelling process to non-modelled side channels unless utilization of these sites is verified by field observations.

2.4 Study Site Descriptions

A description of the general physical characteristics and utilization by spawning salmon of each of the side slough and side channel sites selected for evaluation using the PHABSIM modelling system is presented below by site. Information pertaining to juvenile fish utilization within the study sites is presented in Schmidt et al., (1984).

Side Slough 8A

Side Slough 8A is located on the east bank of the Susitna River at river mile 125.3 (Figure 7-2-1). It is approximately two miles in length and

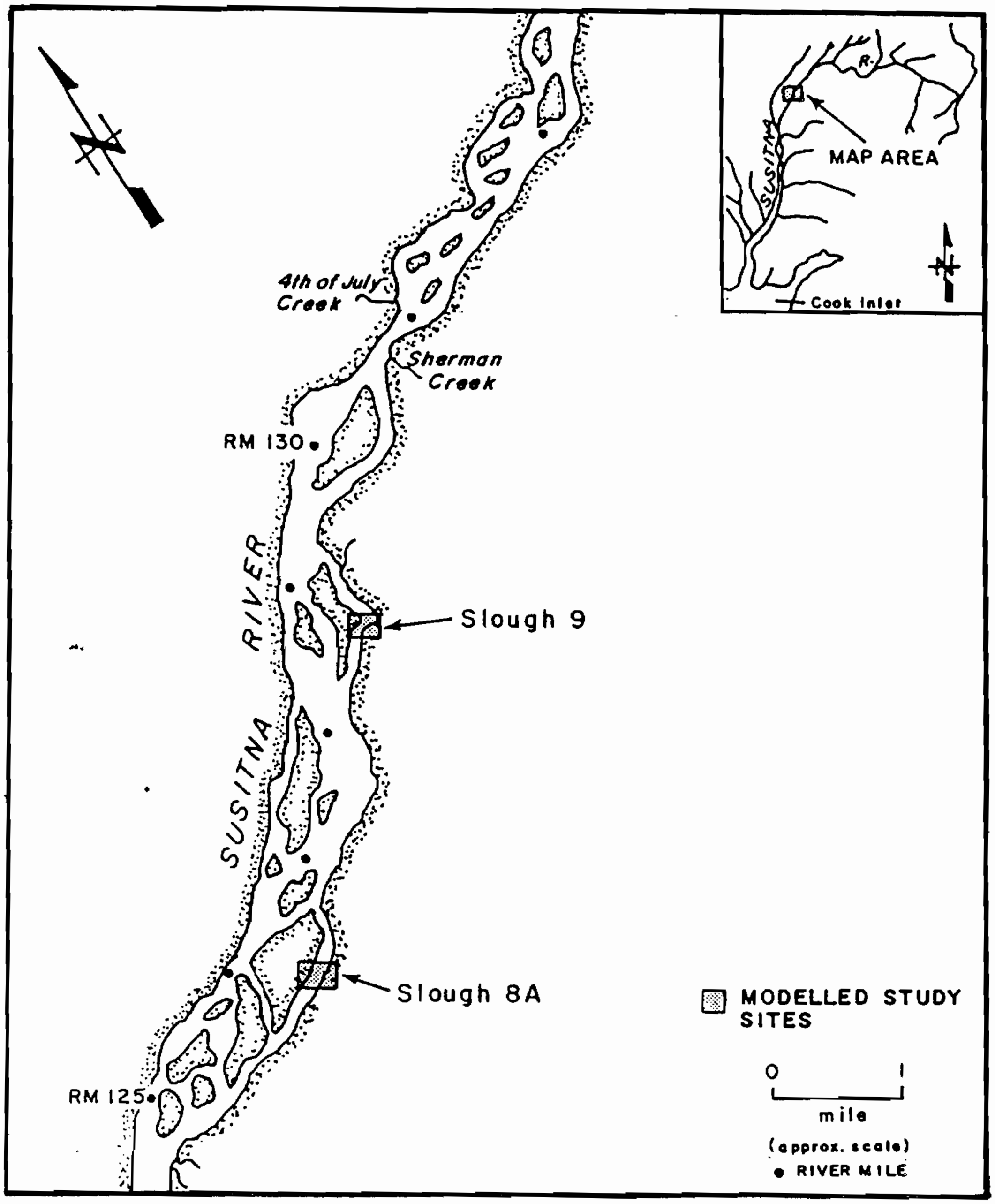

Figure 7-2-1. Middle river study sites evaluated using the IFIM modelling system

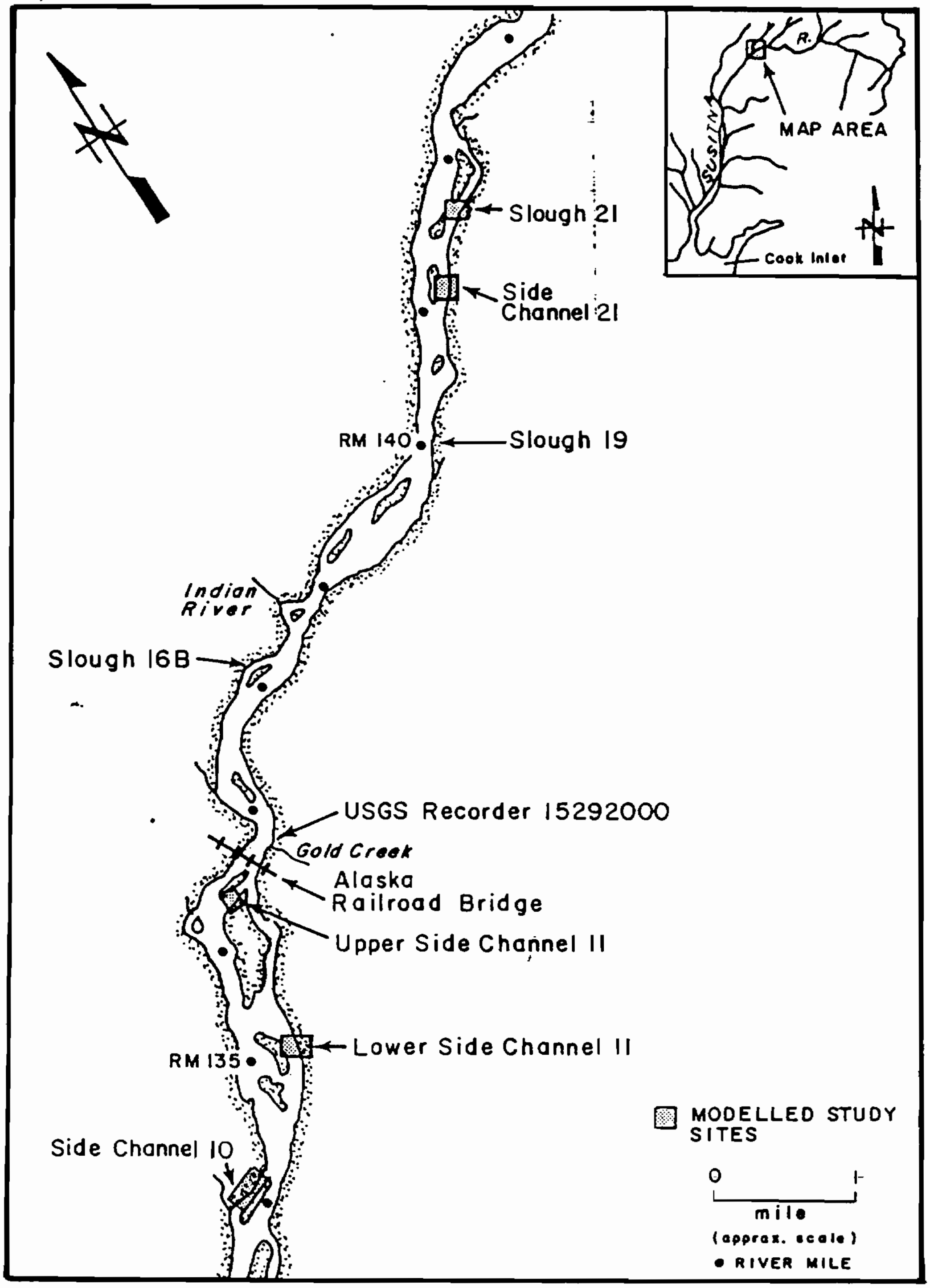

Figure 7-2-1. continued

is separated from the mainstem by two relatively large vegetated island (Plate 7-2-1). The channel is relatively straight with a gentle bend near the head of the slough. Approximately 2,000 feet upstream of the mouth, a series of beaver dams are located across the braided channel which, depending on flow conditions, may block upstream migration of salmon. Approximately 2,500 feet upstream of the mouth, the channel divides into two forks, a NW fork and NE fork. The study site is located in the NE fork.

An area of backwater occurs at the mouth of this side slough during periods of moderate and high mainstem discharge which, depending on discharge, extends up to 1,000 feet into the slough. Above the backwater area is a 100-300 foot long riffle followed by a beaver dam. A large pool occurs behind the beaver dam into which the NW fork discharges. Another dam 1,200 feet further upstream impounds the discharge from the NE fork.

The overall gradient of the slough is 10.5 feet/mile as compared to the overall gradient of the adjacent mainstem of 9.3 feet/mile. Substrate composition in the slough varies depending on location. Cobble/boulder substrates predominate in the upper half of the slough while gravel/rubble substrates are characteristic of in the lower half of the slough. Deposits of silt/sand are found in the backwater area at the slough mouth and in the pools formed by the beaver dams.

Prior to overtopping by the mainstem, a base flow ranging from 1-20 cfs in the NE slough fork is maintained by surface runoff, groundwater

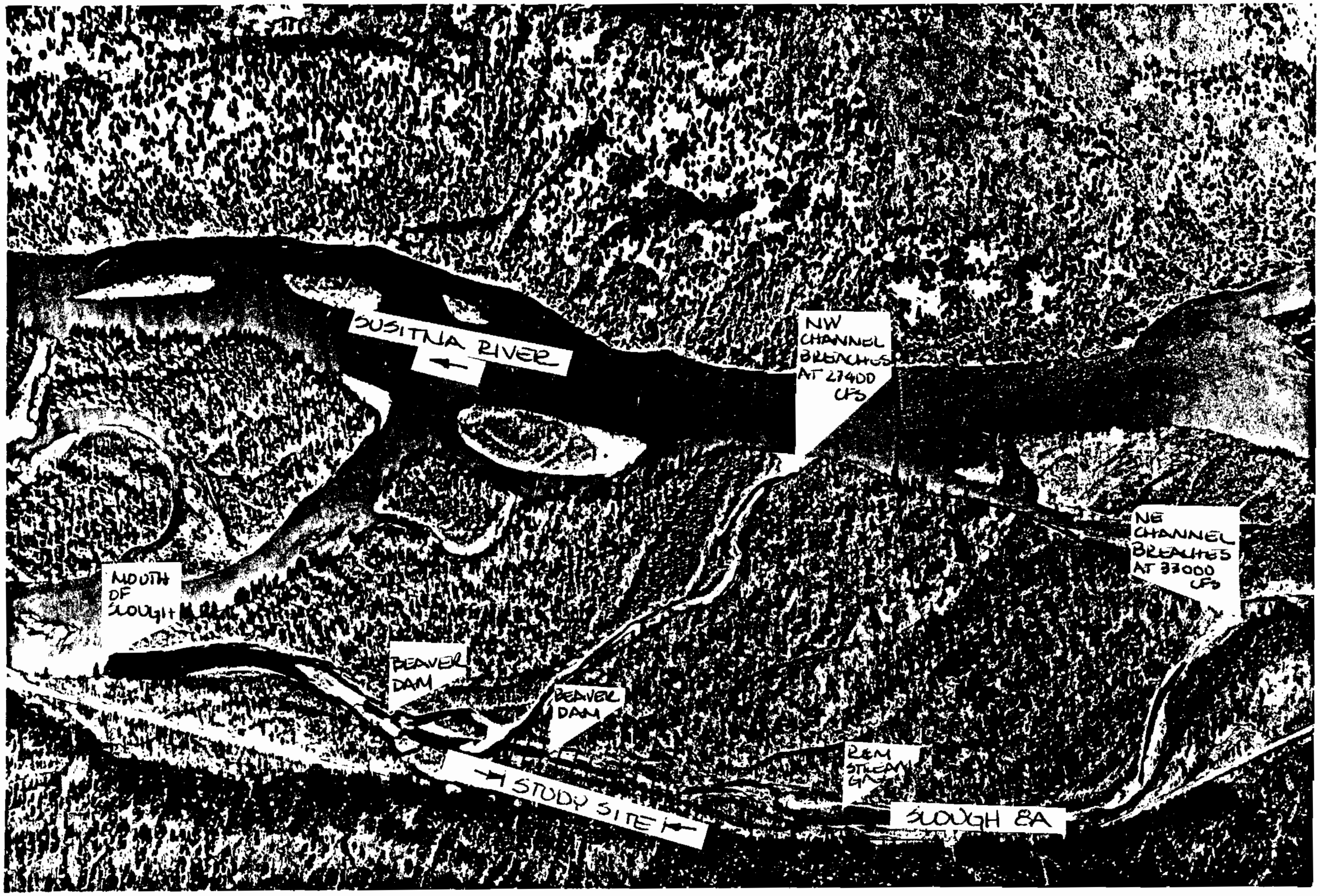

Plate 7-2-1. Slough 8A modelling site.

seepage, and upwelling. Subsequent to overtopping, flows up to 70 cfs which are controlled by mainstem discharge have been observed in the NE fork. The lowest observed initial breaching discharge (see glossary) and controlling breaching discharge of the NE channel are estimated to be 33,000 cfs. Based on the 30 year historical flow record, this level of discharge, however rarely occurs during the months of August and September, the primary months of peak chum and sockeye salmon spawning in sloughs (Figure 7-2-2).

Chum and sockeye salmon, and to lesser extent, pink and coho salmon utilize this side slough for spawning. Observed areas of spawning of chum and sockeye salmon in this side slough are presented in Figures 7-2-3 and 7-2-4.

Side Slough 9

Side Slough 9 is located on the east bank of the Susitna River at river mile 128.3 (Figure 7-2-1). It is approximately 1.2 miles in length and is separated from the mainstem by a large vegetated island (Plate 7-2-2). The channel is S-shaped and is composed of an alternating series of pools and riffles. Two small unnammed tributaries and Slough 9B empty into the slough. The banks generally have a moderate to steep slope and are 3 to 4 feet high.

The overall gradient of the slough is 13.7 feet/mile as compared to the overall gradient of the adjacent mainstem of 8.7 feet/mile. Generally,

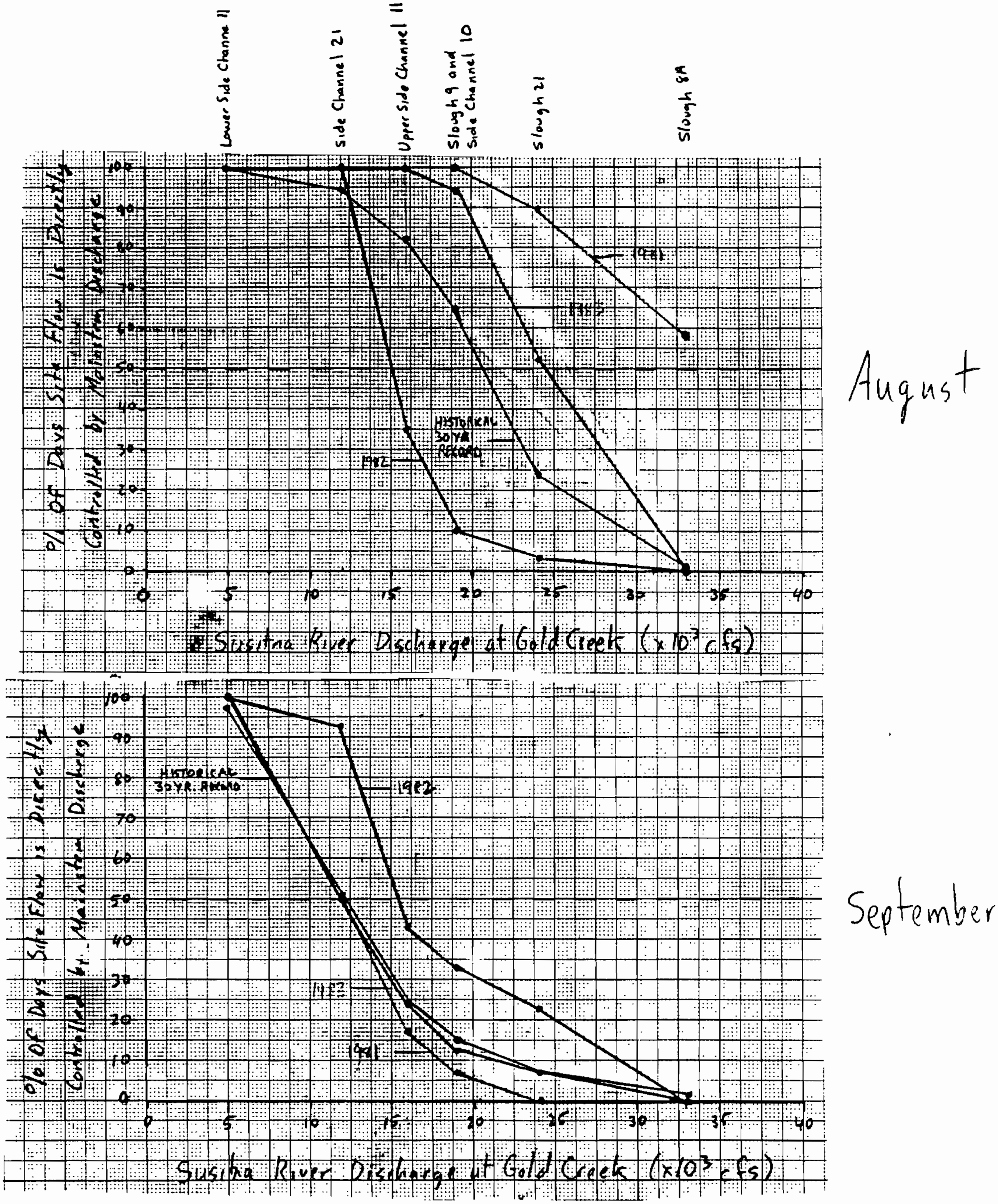

Figure 7-2-2. Flow duration curves for the months of August and September for the years 1981, 1982 and 1983 and the 30 year historical composite record depicting the % of days the site flow is controlled by mainstem discharge for the modelled study sites.

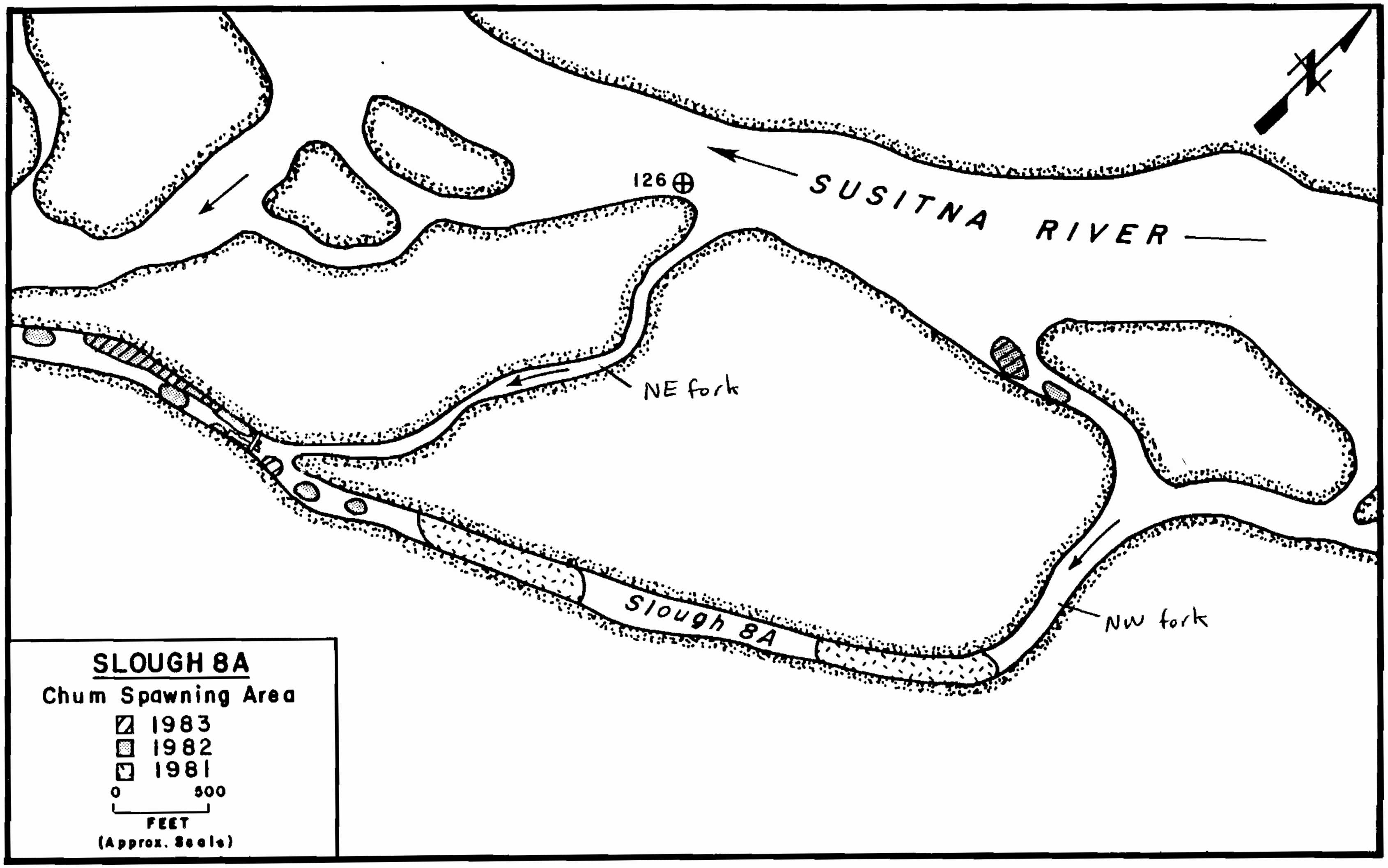

Figure 7-2-3. Chum salmon spawning areas, Slough 8A, 1981, 1982, 1983.

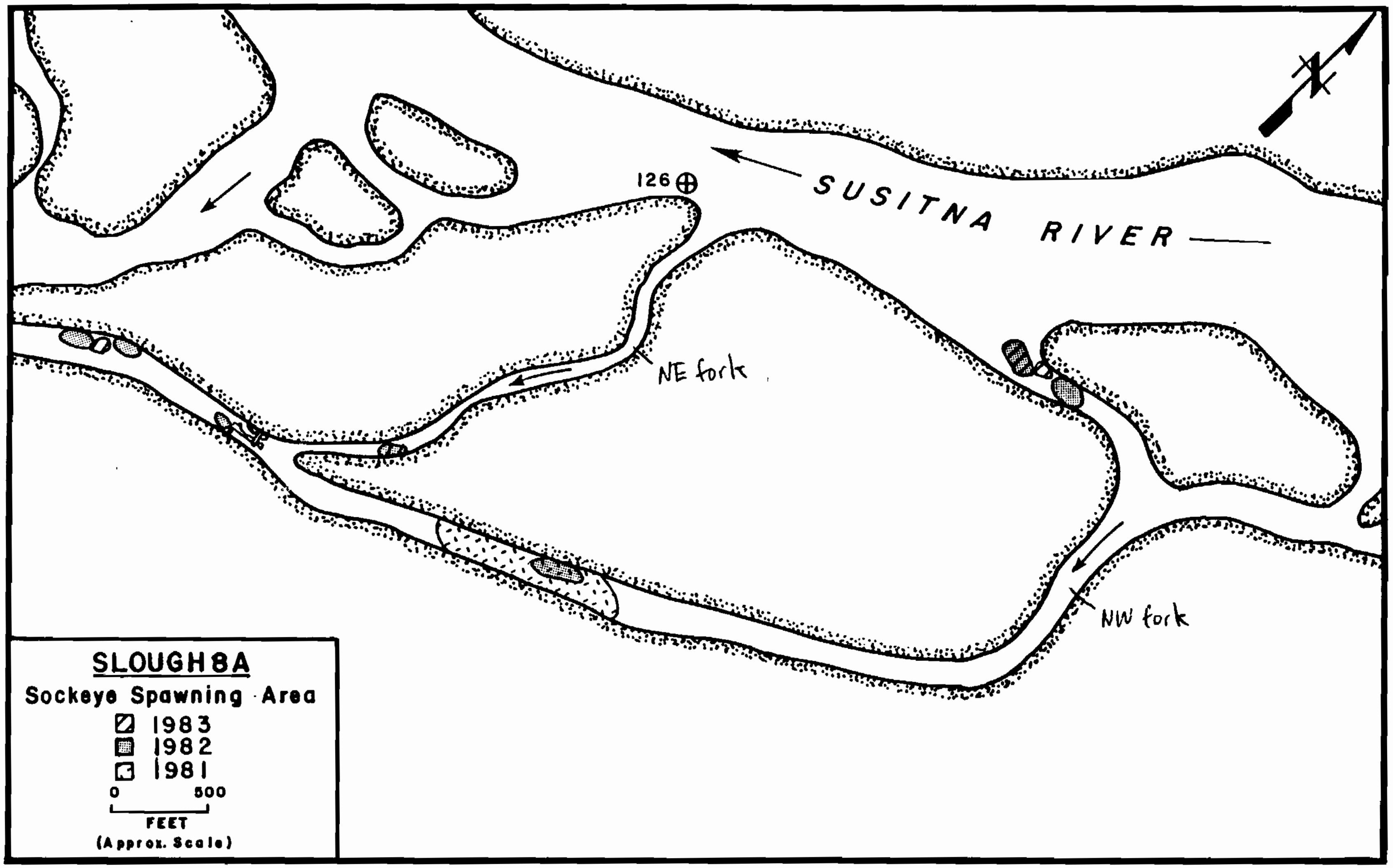

Figure 7-2-4. Sockeye salmon spawning areas, Slough 8A, 1981, 1982, 1983.

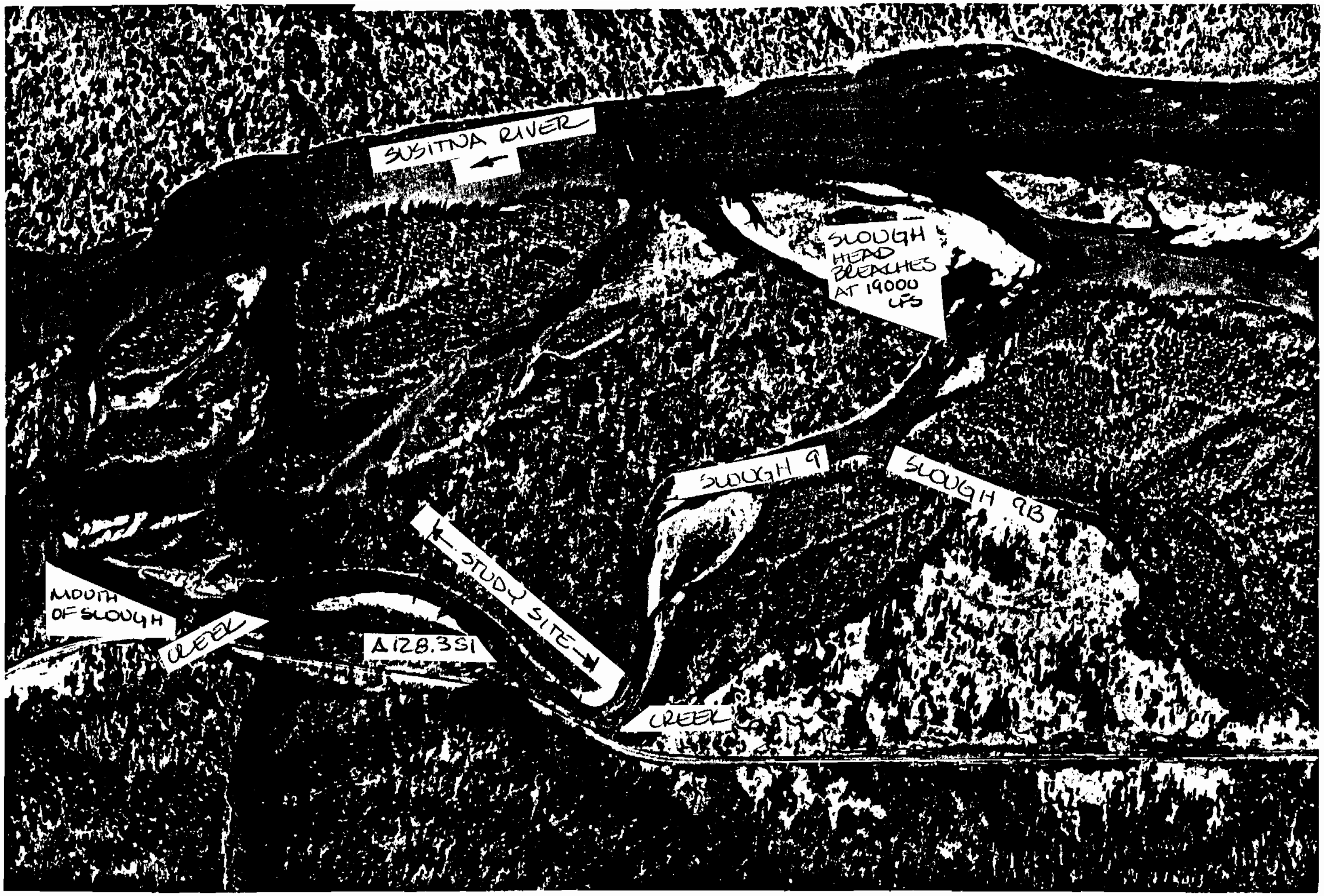

Plate 7-2-2. Slough 9 modelling site.

the lower half of the slough has a relatively shallower gradient than the upper half.

Substrate composition in the slough varies depending on location. Cobble/boulder substrates predominate in the upper half of the slough while gravel/rubble substrates predominate in the lower half. Deposits of silt and sand are found in the backwater and pool areas.

An area of backwater occurs at the mouth of this side slough during periods of moderate and high mainstem discharges. During periods of moderate mainstem discharges, the backwater area extends approximately 500 feet upstream to the base of the first riffle. During periods of high mainstem discharge, backwater inundates these first riffles and the lower half of the slough becomes one long backwater pool.

Prior to overtopping by the mainstem, a base flow ranging from 1-5 cfs in the slough is maintained by two small tributaries, Slough 9B, groundwater seepage, and upwelling. During these periods, the upper half of the slough is dry with flow occurring intragravelly. Subsequent to overtopping, slough flows ranging up to 500 cfs have been observed which are controlled by mainstem discharge. The initial and controlling breaching discharges of this side slough are 16,000 and 19,000 cfs, respectively. Based on the 30 year historical flow record, this level of discharge is typically exceeded more than 65 per cent of the time in August but only 30 per cent of the time in September, the month of peak spawning activity in sloughs.

Chum salmon and to a lesser extent pink and sockeye salmon utilize this side slough for spawning (Table 7-5-3). Observed areas of spawning of chum and sockeye salmon in this side slough are presented in Figures 7-2-5 and 7-2-6.

Side Slough 21

Side Slough 21 is located on the east bank of the Susitna River at river mile 141.8 (Figure 7-2-1). It is approximately 0.5 miles in length and is separated from the mainstem by a large vegetated island (Plate 7-2-3). Approximately half way up the slough, the channel divides into two forks, a NW and NE fork. The banks are generally steep and undercut and are approximately 5 feet high. Immediately downstream of the mouth of the slough proper is an area that exhibits slough characteristics during unbreached conditions and becomes essentially an extension of the slough during these periods. During 1982, which was a low flow year, this area was slough like during the majority of the spawning period and the majority of the spawning occurred here rather than in the slough due to access problems at the mouth resulting from the low flow.

The overall gradient of the slough is 22.9 feet/mile as compared to the overall gradient of the adjacent mainstem of 12.2 feet/mile. Generally, the channel cross-section is flat with a relatively deep narrow channel running along the east bank.

The predominant substrate in the slough is cobble/boulder. However, silt/sand deposits are found in backwater and pool areas.

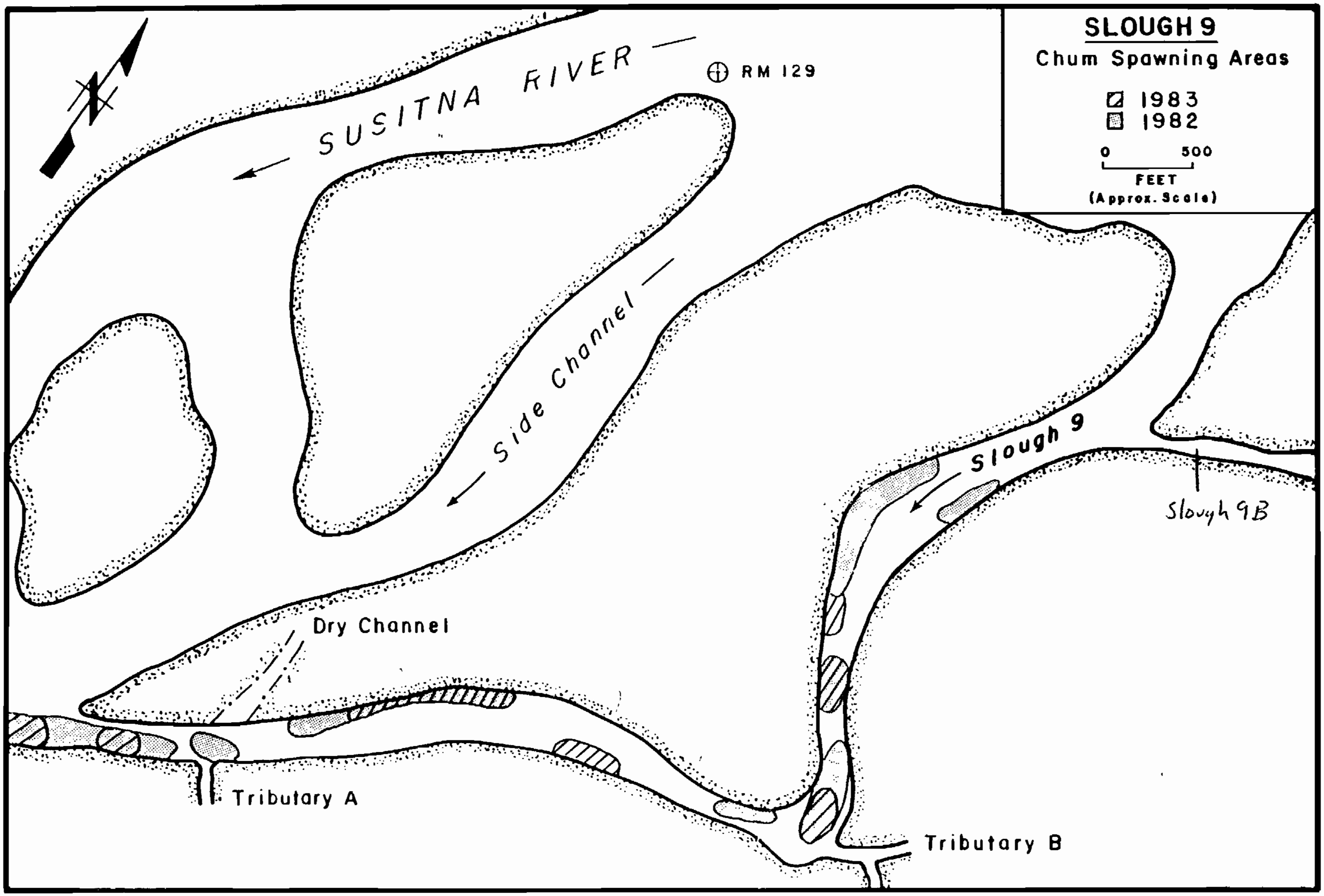

Figure 7-2-5 Chum salmon spawning areas, Slough 9, 1982
1983

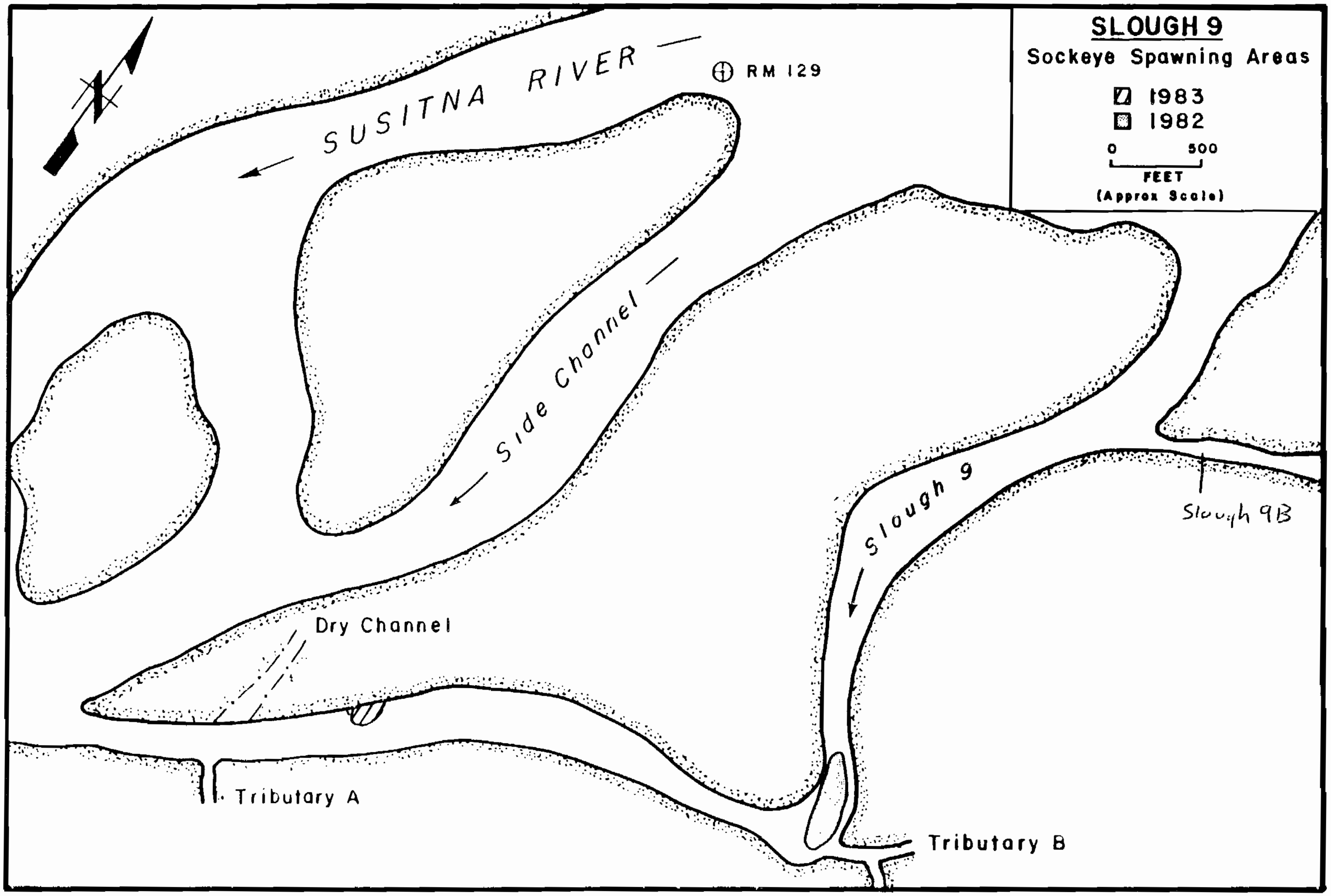

Figure 7-2-6. Sockeye salmon spawning areas, Slough 9, 1982, 1983

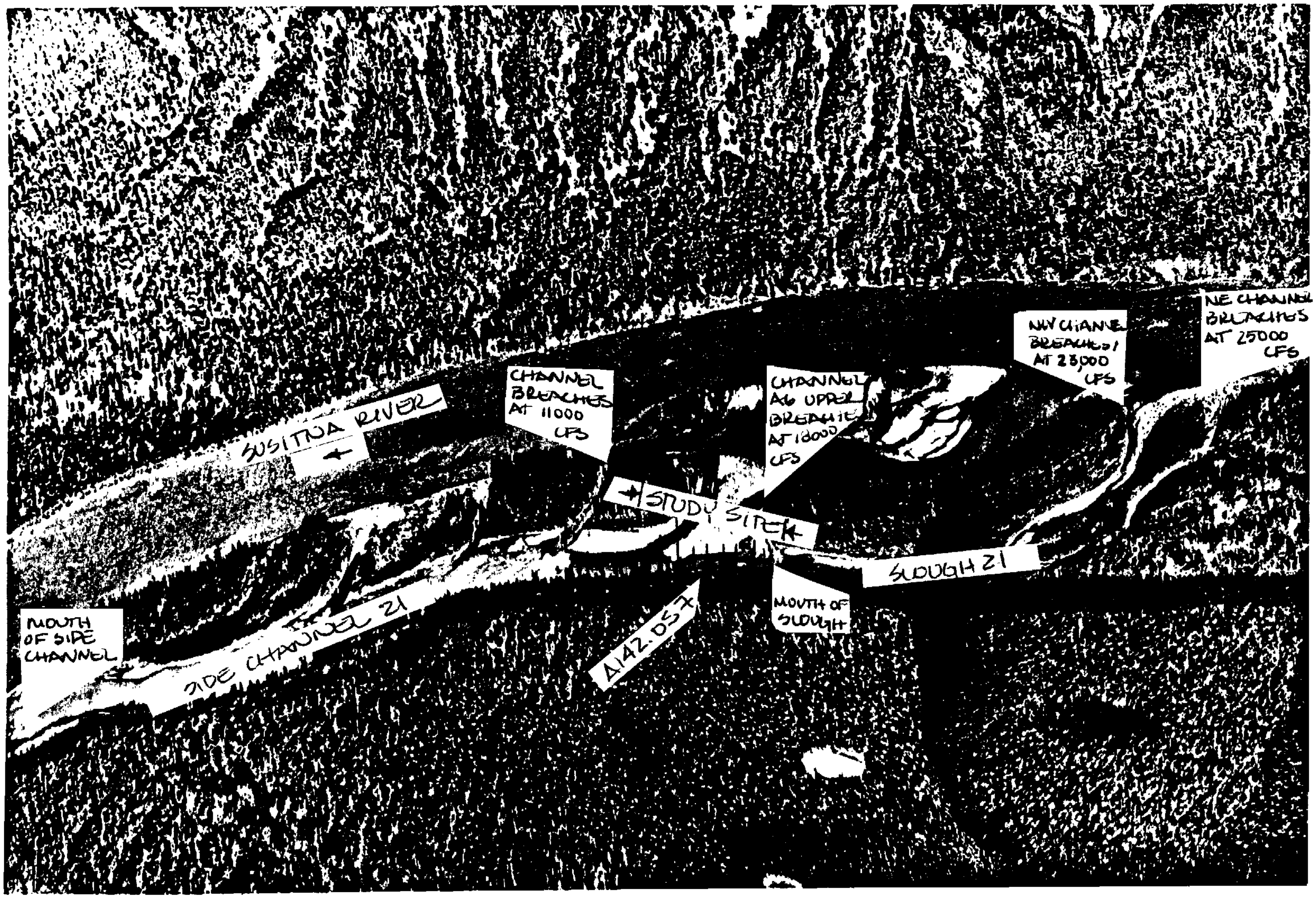

Plate 7-2-3. Slough 21 modelling site.

Only a small area of backwater occurs at the mouth of this side slough during periods of high mainstem discharge.

Prior to overtopping by the mainstem, a base flow up to 5 cfs in the side slough is maintained by a small unnammed tributary, local runoff, groundwater seepage, and upwelling. During these periods, the upper half of the slough is dewatered with isolated pools. Subsequent to overtopping, the flow in the slough has been observed up to 350 cfs and is controlled by mainstem discharge. The lowest observed initial breaching discharge that influences the study site at this side slough is 18,000 cfs, which compares to a controlling breaching discharge of 24,000 cfs. Based on the 30 year historical flow record, this controlling breaching discharge, however is exceeded less than 30 per cent of the time in either August or September, the months of peak spawning activity in sloughs.

Chum salmon and to a lesser extent sockeye and pink salmon utilize this side slough for spawning. Observed areas of spawning of chum and sockeye salmon in this side slough are presented in Figures 7-2-7 and 7-2-8.

Side Channel 10

Side Channel 10 is located on the west bank of the Susitna River at river mile 133.8 (Figure 7-2-1). It is approximately 0.4 miles in length and is separated from the mainstem by a large gravel bar (Plate 7-2-4). It joins with Slough 10 forty feet upstream of the mouth of the

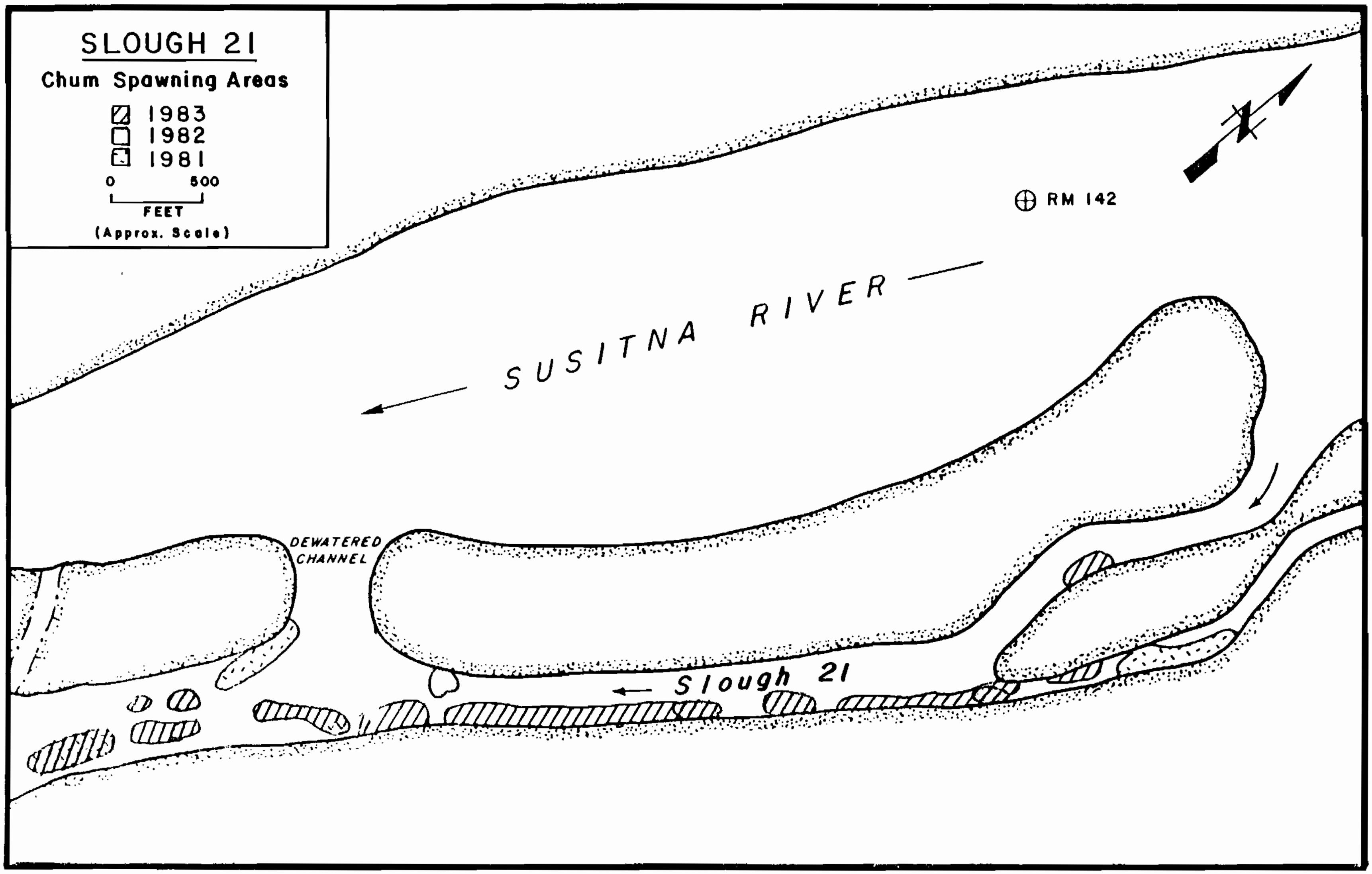

Figure 7-2-7 Chum salmon spawning area, Slough 21, 1981, 1982, 1983

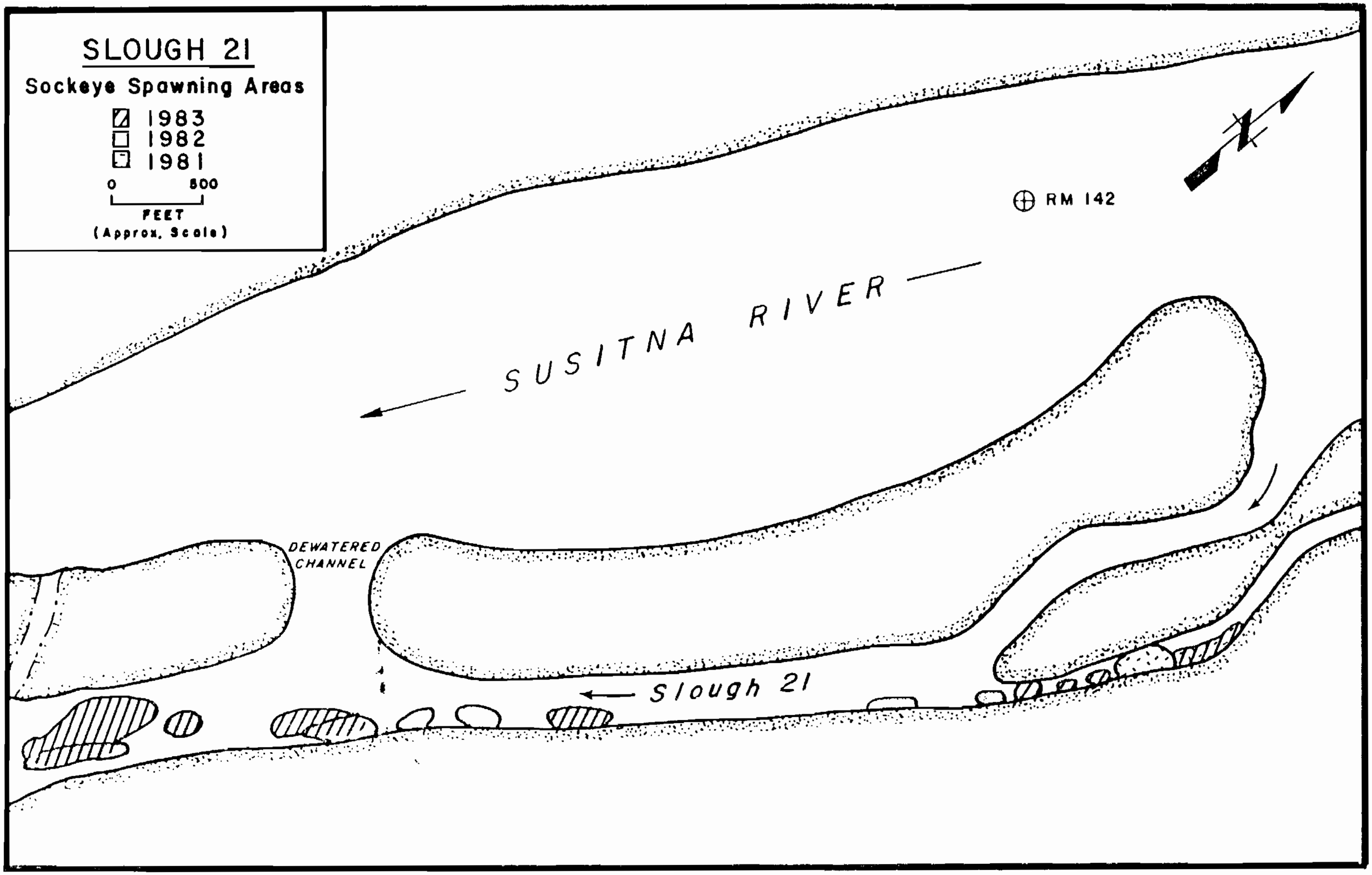

Figure 7-2-8. Sockeye salmon spawning area, Slough 21, 1981, 1982, 1983

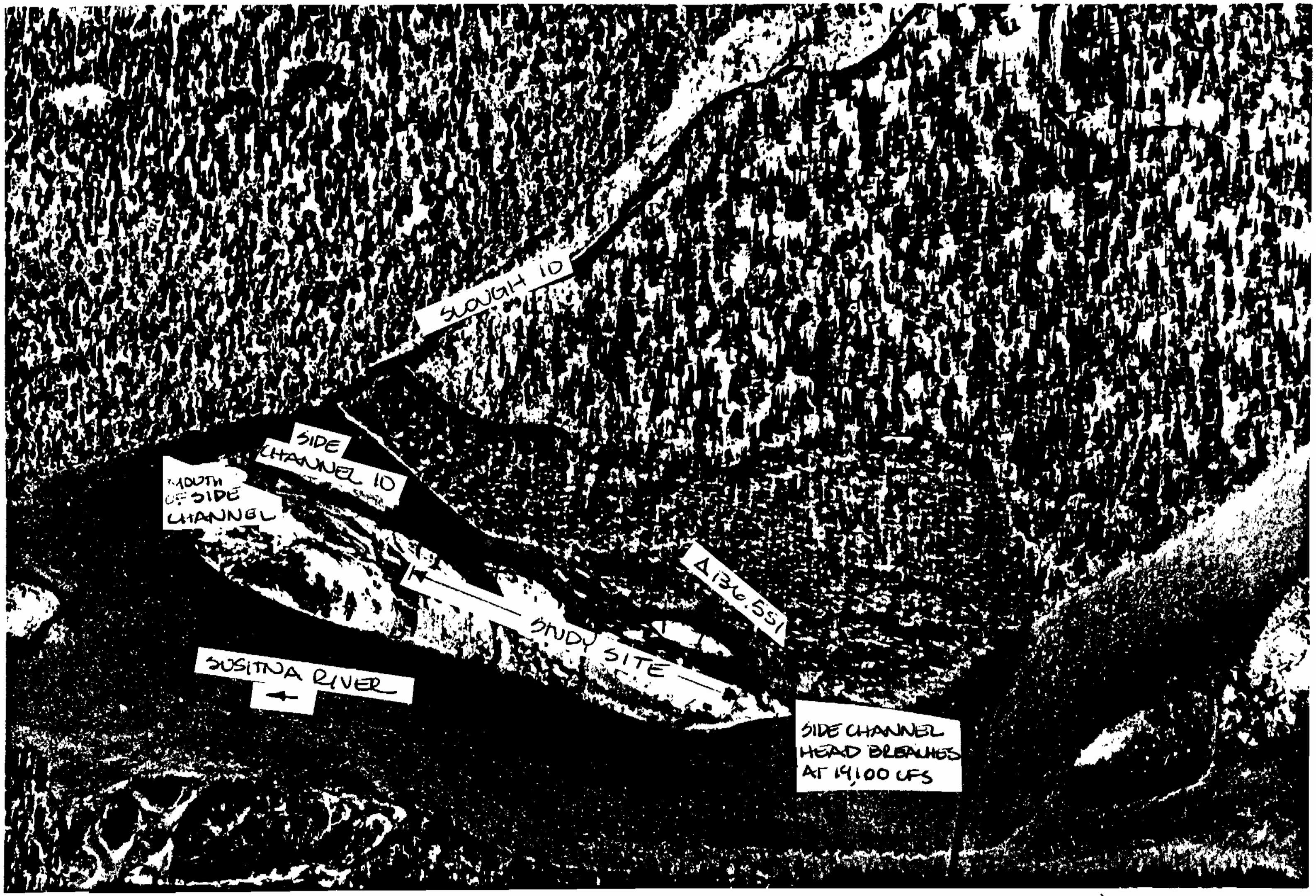

Plate 7-2-4. Side Channel 10 modelling site.

slough. The east bank along the gravel bar is gently sloping as compared to the west bank which is high, steep, and undercut. A pool/riffle sequence predominates throughout the side channel along with a backwater pool at the mouth. During periods of moderate to high mainstem discharge, the backwater area extends up to 1,000 feet upstream of the side channel mouth.

The overall gradient of the side channel is 20.5 feet/mile as compared an overall gradient of the adjacent mainstem of 8.9 feet/mile. Generally, the channel cross section is relatively flat with a deep narrow channel running along the west bank.

Substrate composition in the slough varies depending on location. The upper half of the slough is generally characterized by cobble/boulder substrates while the lower half is characterized by gravel/rubble substrates. Silt/sand deposits are found in pool areas and the backwater zone near the mouth.

Prior to overtopping by the mainstem, a base flow up to 10 cfs in the side channel is provided by local runoff and groundwater seepage. Subsequent to overtopping, flows up to 260 cfs in side channel have been observed. Under these condition the flow becomes turbid and controlled by the mainstem. The initial and controlling breaching discharges for this side channel are the same being 19,000 cfs. Based on the 30 year historical flow record, this controlling breaching discharge is typically exceeded more than 65 per cent of the time in August but only

30 per cent of the time in September, the months of peak spawning activity in side channels.

No salmon species have been observed to utilize this side channel for spawning. For this reason, projections of weighted useable area of spawning habitat at this site were only made for comparative purposes to verify model accuracy.

Lower Side Channel 11

Lower Side Channel 11 is located on the east bank of the Susitna River at river mile 134.6 (Figure 7-2-1). It is approximately 0.7 miles in length and is separated from the mainstem by a large well-vegetated island (Plate 7-2-5). Just upstream of the confluence of Slough 11, the channel divides into two forks, a NE and NW fork. Substrate in the side channel predominantly consists of cobble and rubble interspersed with large gravel and sand. Only a small backwater area has been observed at the mouth of this side channel.

This side channel has been observed to be controlled by the mainstem at discharges as low as 5,000 cfs. Flows in the side channel under these conditions have ranged from 800 to 4,800 cfs. The initial and controlling breaching discharges for this side channel are the same being 5,000 cfs. Based on the 30 year historical flow record, the flow in this side channel is controlled by the mainstem more than 99 per cent of the time during the months of August and September.

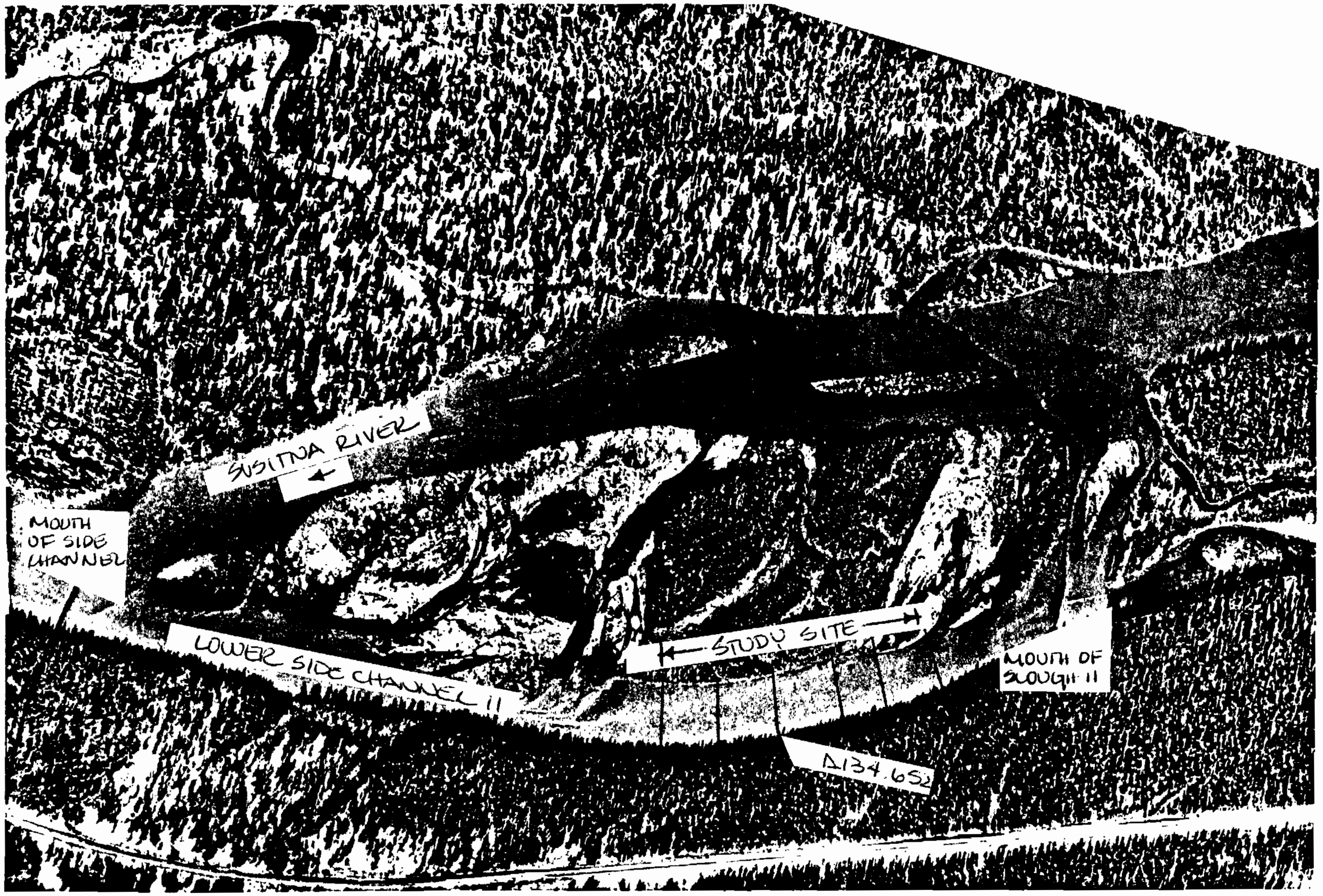

Plate 7-2-5. Lower Side Channel 11 modelling site.

Chum and sockeye salmon have been observed in this side channel during migration into Slough 11, however no spawning has been documented at the site. For this reason, projections of weighted useable area of spawning habitat at this site were only made for comparative purposes to verify model accuracy.

Upper Side Channel 11

Upper Side Channel 11 is located on the east bank of the Susitna River at river mile 136.2 (Figure 7-2-1). It is approximately 0.4 miles in length and is separated from the mainstem by a large vegetated island (Plate 7-2-6). The head of Slough 11 is located on the east side this side channel, just below its upper confluence with the mainstem. The west bank of the side channel is a low lying, gently sloping, sparsely vegetated gravel bar, as compared to the east bank which is high, steep, and vegetated. A pool/riffle sequence predominates in the side channel except for the lower 500 feet of the side channel where a backwater area predominates. The backwater area extends roughly 500 feet into the mouth of this side channel during periods of moderate mainstem discharges. As mainstem discharges increases, the area of backwater increases, inundating the first riffle.

The overall gradient of the side channel is 23.6 feet/mile as compared to the overall gradient of the adjacent mainstem of 17.5 feet/mile. Generally, the gradient is lower in the first 500 feet of the side channel (11.0 feet/mile) than it is in the remainder of the side channel (21.9 feet/mile). The predominant substrate in the side channel is

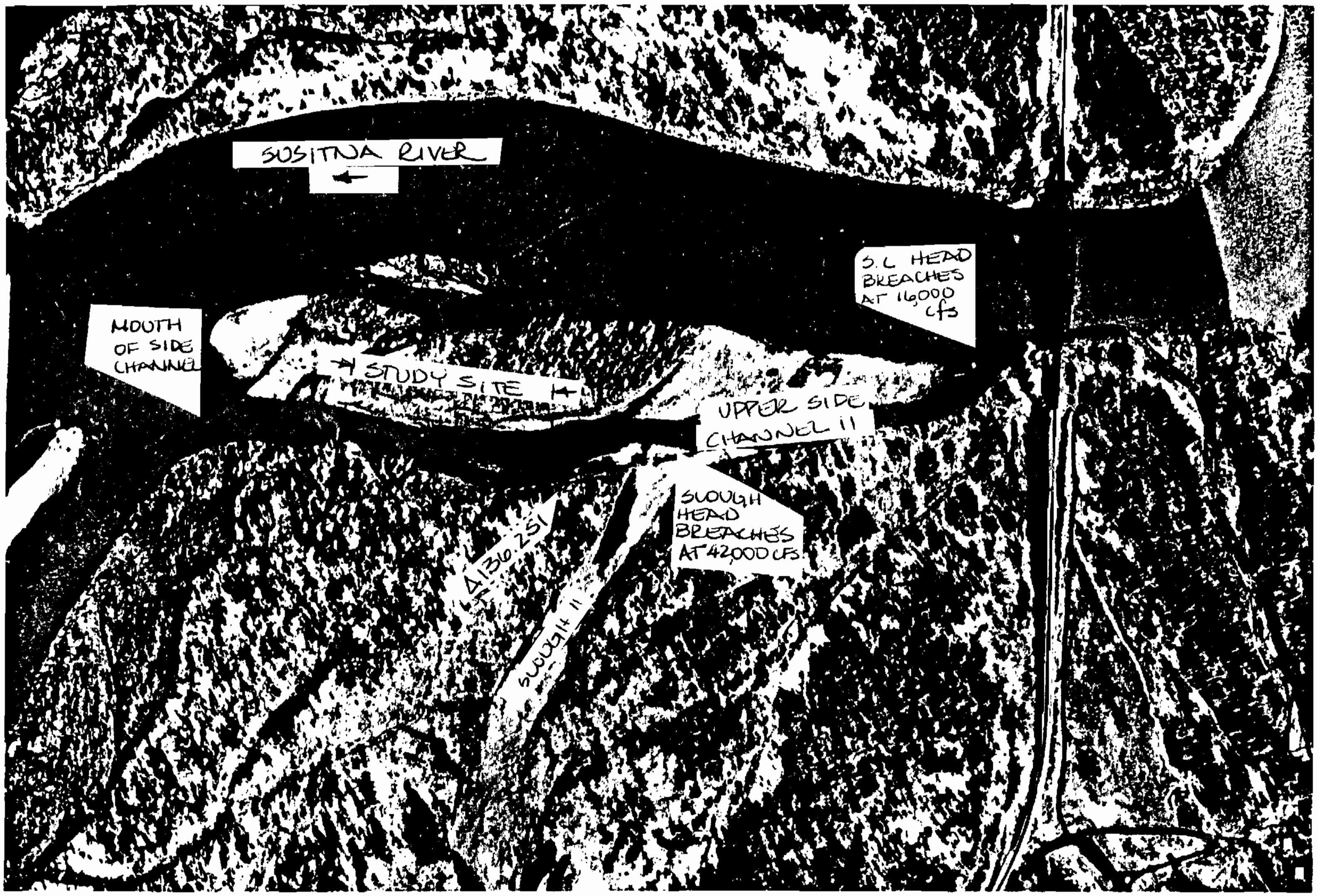

Plate 7-2-6. Upper Side Channel 11 modelling site.

cobble/boulder interspersed with silt/sand deposits in pool and backwater areas.

Prior to overtopping by the mainstem, a base flow up to 25 cfs in the side channel is provided by local runoff, groundwater seepage, and upwelling. During unbreached periods, a normal pool/riffle sequence exists. Subsequent to overtopping by the mainstem, flows up to 350 cfs have been observed in the side channel. During this period, the flows in the side channel become controlled by the mainstem and the side channel becomes a long run. The initial and controlling breaching discharges for this side channel are 13,000 and 16,000 cfs, respectively. Based on the 30 year historical flow record, this controlling breaching discharge is exceeded more than 80 per cent of the time in August and 20 per cent of the time in September, the months of peak spawning activity in side channels.

Chum salmon utilize this side channel for spawning. Observed areas of chum salmon spawning in this side channel are presented in Figure 7-2-9.

Side Channel 21

Side Channel 21 is located on the east bank of the Susitna River at river mile 141.2 (Figure 7-2-1). It is approximately 0.9 miles in length and is separated from the mainstem by a series of well-vegetated islands and gravel bars (Plate 7-2-7). Approximately 500 feet downstream of the head, Slough 21 enters the side channel. Additionally, a small unnammed tributary enters approximately 1,500 feet

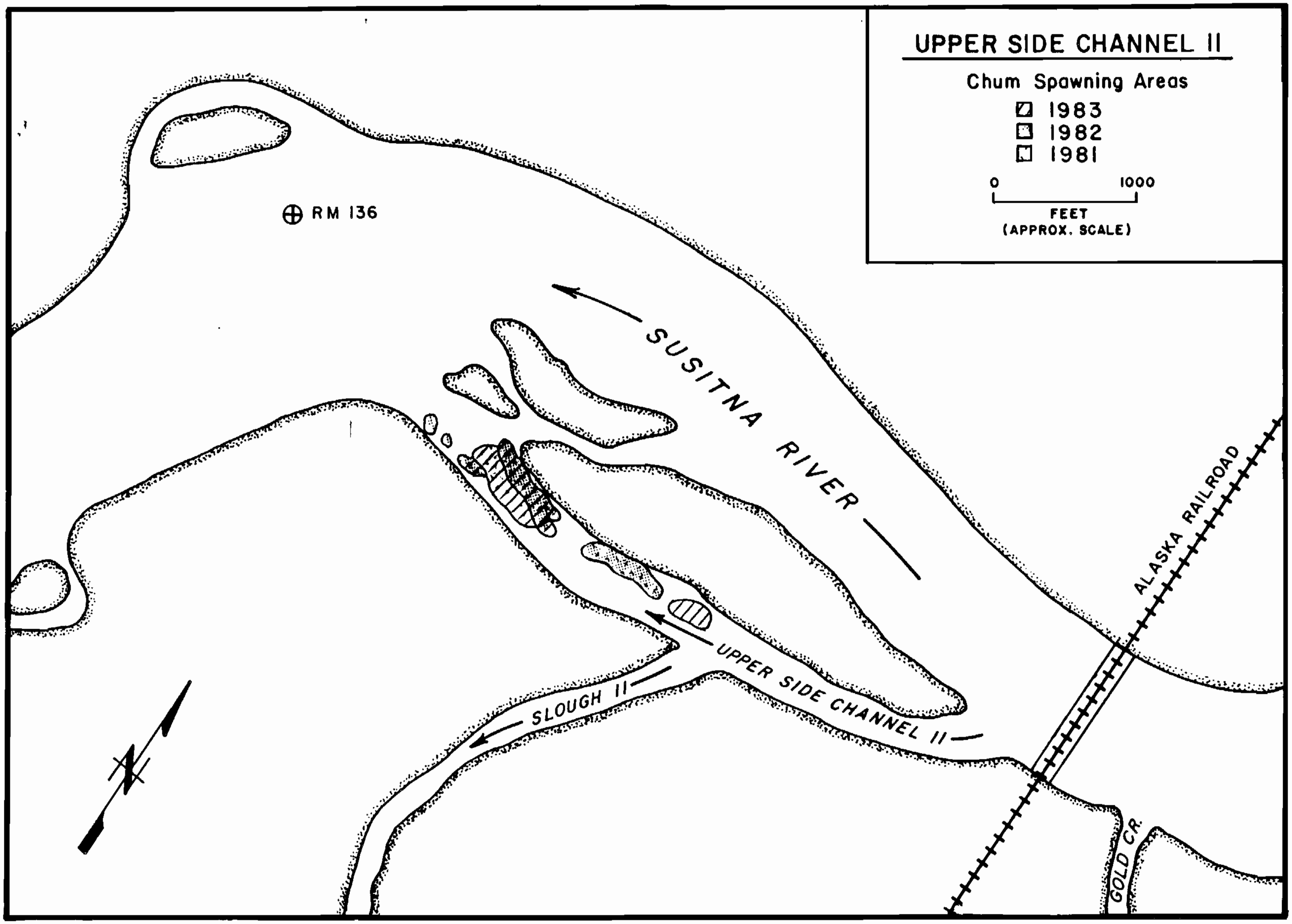

Figure 7-2-9. Chum salmon spawning areas, Upper Side Channel II; 1981, 1982, and 1983.

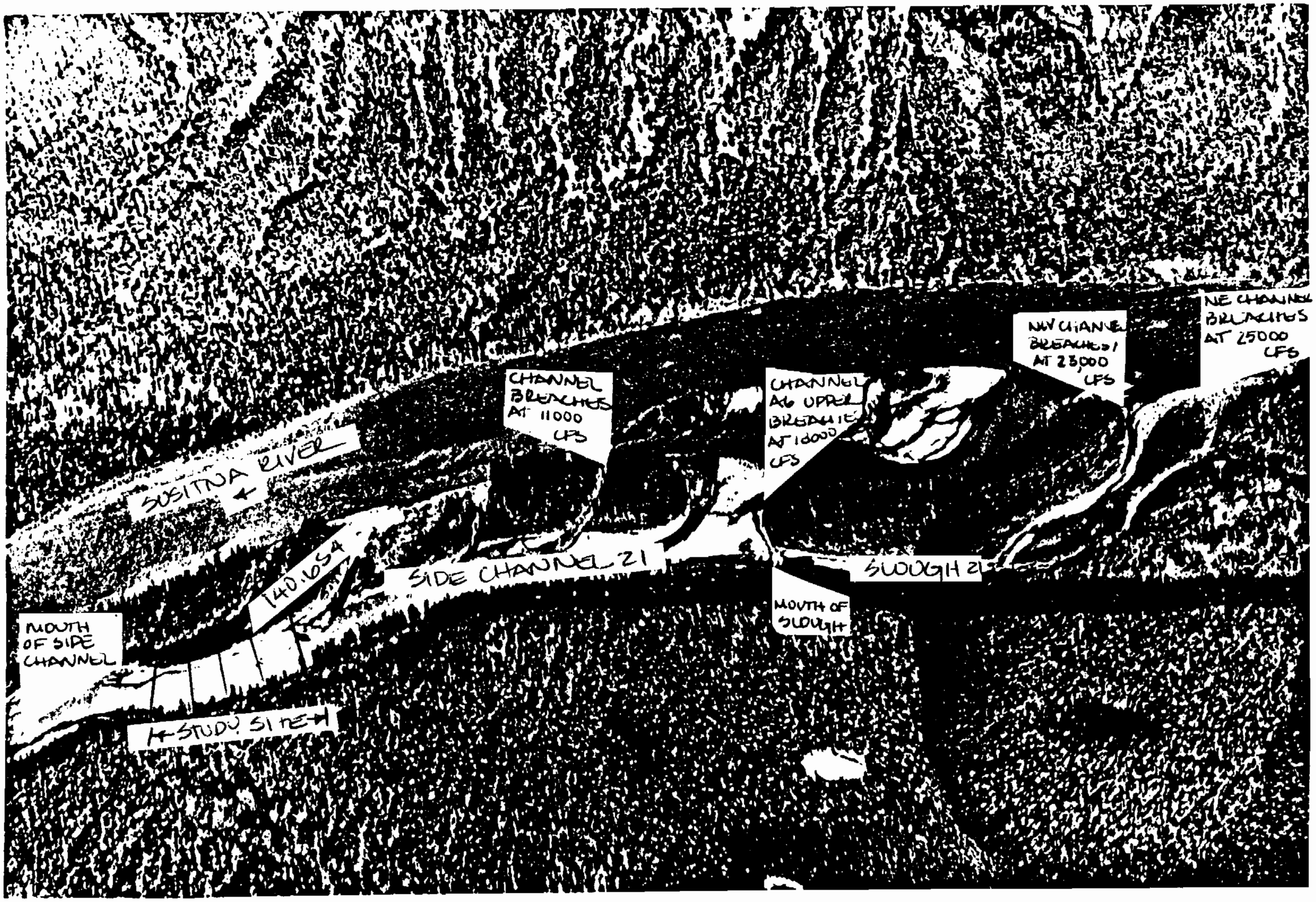

Plate 7-2-7. Side Channel 21 modelling site.

upstream of the mouth. The west bank of the side channel consists of a vegetated, low-lying gravel bar with gently sloping banks. Several overflow channels from the mainstem enter the side channel through this gravel bar. In comparison, the east bank is high, steep and vegetated. A pool/riffle sequence predominates in the side channel except for the lower reach where a backwater area predominates. During periods of high mainstem discharge, the backwater extends approximately 1,300 feet upstream from the mouth.

The overall gradient of the side channel is 15.8 feet/mile as compared to a gradient of the adjacent mainstem of 13.9 feet/mile.

Generally, the middle portion of the side channel has a steeper gradient (18.7 feet/mile) than either the head (3.2 feet/mile) or mouth (9.4 feet/mile) areas. Cobble/boulder substrates predominate throughout the side channel with silt/sand deposits occurring in pool and backwater areas.

Prior to overtopping by the mainstem, a base flow up to 70 cfs in the side channel is maintained by Slough 21, local runoff, groundwater seepage, and upwelling. Subsequent to overtopping, the mainstem enters via an overflow channel below the month of the Slough 21. Under these condition the side channel flows up to 1,200 cfs which are controlled by the mainstem have been observed int his side channel. Breaching flows are difficult to assess because of the numerous intermittent overflow channels which connect the side channel with the mainstem. One or more of these overflow channels are breached in the range of mainstem discharges from 9,200 to 26,000 cfs. The controlling breaching discharge that influences the study area is 12,000 cfs. Based on the 30 year historical flow record, the flow in this side channel is controlled by the mainstem more than 90 per cent of the time in August but only 50 per cent of the time in September, the period of peak spawning activity in side channels.

Chum and to a lesser extent sockeye salmon utilize this channel for spawning. Observed areas of spawning of these species in this side channel are presented in Figures 7-2-10 and 7-2-11.

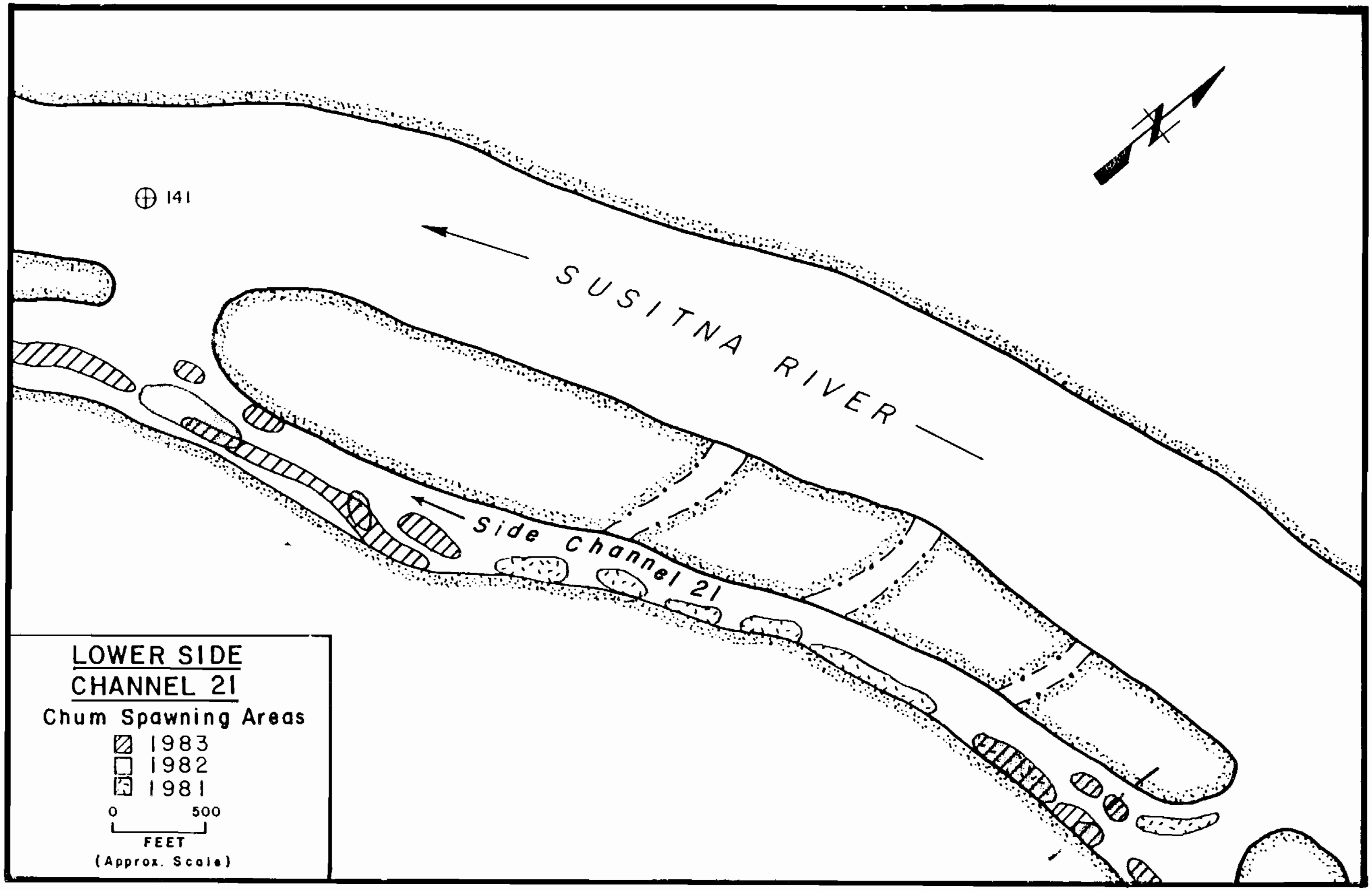

Figure 7-2-10 Chum salmon spawning area, Side Channel 21, 1981, 1982, 1983.

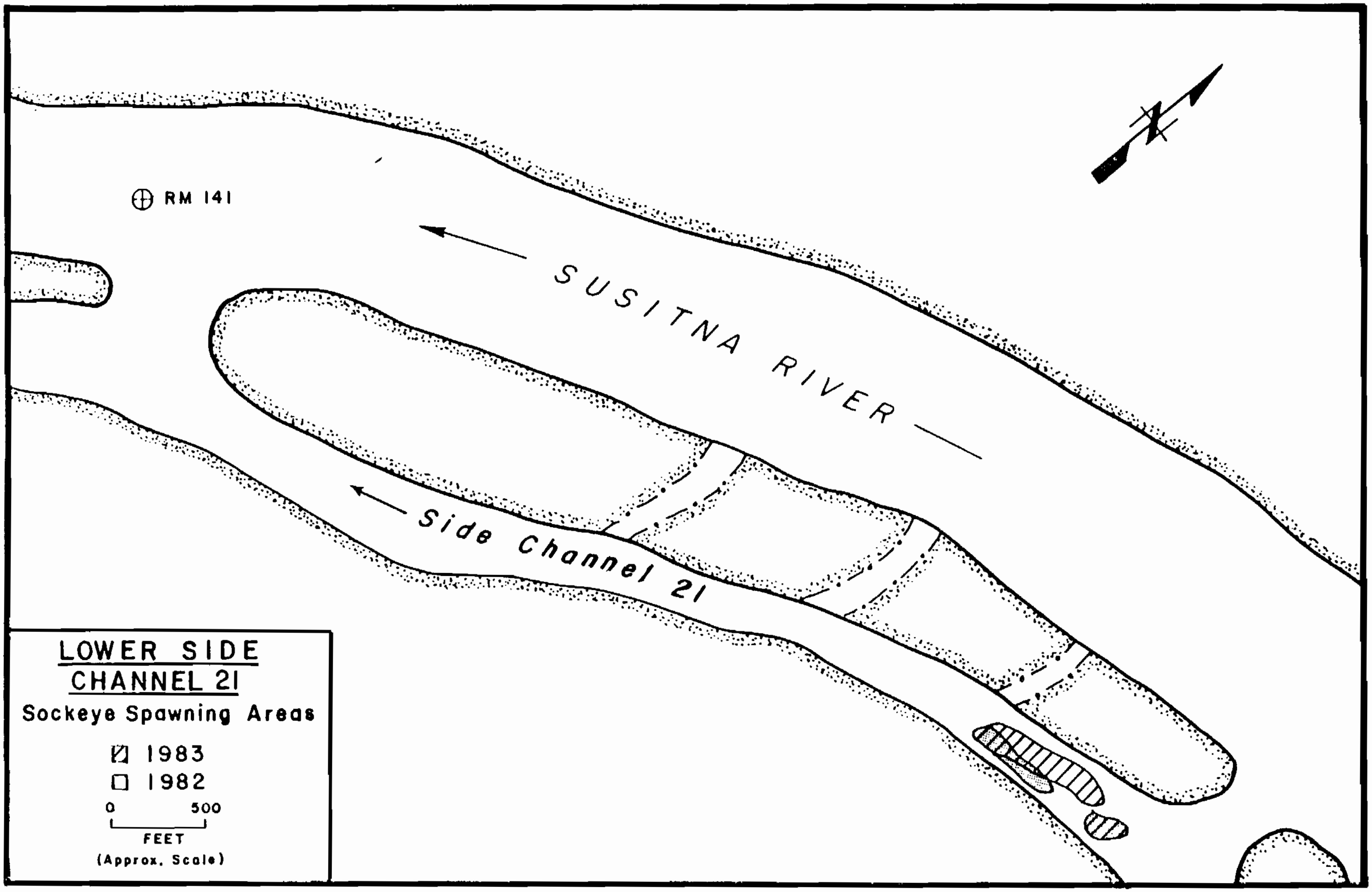

Figure 7-2-11. Sockeye salmon spawning area, Side Channel 21, 1982, 1983.

3.0 HYDRAULIC SIMULATION MODELS

3.1 Introduction

This section describes the data collection and analysis required in the development of hydraulic simulation models for selected side sloughs and side channels of the Talkeetna-to-Devil Canyon reach of the Susitna River. The models represent the first step of the PHABSIM modelling process and are used to predict the spatial distribution of depths and velocities within the study sites over a range of discharges. In later stages of the analysis, the predicted values are combined with chum and sockeye salmon suitability criteria to calculate a spawning WUA value for each species and discharge of interest. These steps will be discussed in detail in Sections 4.0 and 5.0.

Hydraulic modelling studies were initiated in 1982 as part of the PHABSIM modelling effort. Study sites were located in three side sloughs (8A, 9, and 21) and four side channels (10, Lower 11, Upper 11, and 21) that collectively represent a broad spectrum of physical attributes of aquatic habitat present in the Talkeetna-to-Devil Canyon segment of the Susitna River. Hydraulic data were collected for each study site over a range of mainstem discharge and local flow conditions. Ten hydraulic simulation models (Table 7-3-1) were calibrated to forecast depths and velocities associated with a range of site-specific flows at the seven study sites. These models will be combined with the weighted behavioral response criteria developed in the following section to calculate weighted usable area of spawning habitat at selected study sites.

Table 7-3-1. IFG-2 and IFG-4 modelling sites.

SITE	RIVER MILE	TYPE OF HYDRAULIC MODEL	NUMBER OF MODELS
Sloughs			
Slough 8A	125.3	IFG-4	2
Slough 9	128.3	IFG-4	1
Slough 21	141.8	IFG-4	2
Side Channels			
Side Channel 10	133.8	IFG-4	1
Lower Side Channel 11	135.0	IFG-2	1
Upper Side Channel 11	136.2	IFG-4	1
Side Channel 21	140.6	IFG-4	2

3.2 Methods

3.2.1 Analytical Approach

Hydraulic modeling is of central importance to the PHABSIM system. The primary purpose of incorporating hydraulic modeling into this analytical approach is to make the most efficient use of limited field observations to forecast hydraulic attributes of riverine habitat (depths and velocities) under a broad range of unobserved streamflow conditions. The IFG specifically developed two hydraulic models (IFG-2 and IFG-4) during the late 1970's to assist fisheries biologists in making quantitative evaluations of effects of streamflow alterations on fish habitat.

The IFG-2 hydraulic model is a water surface profile program that is based on hydraulic theory and formulae. The IFG-2 model can be used to predict the horizontal distribution of depths and mean column velocities at 100 points along a cross section for a range of streamflows with only one set of field data. The IFG-4 model provides the same type of hydraulic predictions as the IFG-2 model, but it is more strongly based on field observations and empiricism than hydraulic theory and formulae. Although a minimum of two data sets are required for calibrating the IFG-4 model, three are recommended. Both hydraulic models are based on regression analysis. Either model will forecast depths and velocities occurring in a stream channel over a broad range of streamflow conditions. In general, the extrapolation range for either hydraulic model (properly calibrated) ranges from 40 percent of the lowest calibration flow up to 250 percent of the highest calibration flow (Bovee and Milhous 1978).

Both models are most applicable to streams of moderate size. They are based on the assumption that steady flow conditions exist within a rigid stream channel. Streamflow is defined as "steady" if the depth of flow at a given location in the channel remains constant during the time interval under consideration. This does not necessarily mean that the flow rate (discharge) must remain consistent through a stream reach. If the flow rate is constant through a stream reach then the flow is said to be "continuous". Where a steady flow condition exists, but the discharge is not constant (water runs into or is diverted from a stream within the study reach), the flow is called spatially varied or "discontinuous". Both continuous and discontinuous flow are commonly encountered steady flow conditions in natural channels.

The definition of "rigid" does not mean that the stream channel cannot change over time or as a result of conveying peak flows. A stream channel is rigid if it meets the following two criteria: (1) it must not change shape during the period of time over which the calibration data are collected, and (2) it must not change shape while conveying streamflows within the range of those that are to be simulated. Thus a channel may be "rigid" by the above definition, even though it periodically (perhaps seasonally) changes course (Bovee and Milhous 1978; Trihey 1980).

In this analysis, all streamflow rates were referenced to the average daily discharge of the Susitna River at the U.S. Geological Survey (USGS) stream gage at Gold Creek, Alaska (Station number 15292000). This location was selected as the index station for several reasons: a long-term streamflow record exists, the gage is located near the center of the river segment that is of greatest interest in this particular analysis, and tributary inflow in the Susitna River between this stream gage and the proposed dam sites is relatively small (estimated as being less than 5 percent of the total flow between the Devil Canyon damsite and the Gold Creek gage, and from 15 to 20 percent of the total flow between Watana and Gold Creek).

Site specific streamflow data collected during 1982 and 1983 provided the basis for correlating flow rates through the various study sites to the average daily streamflow of the Susitna River at the Gold Creek gage. Detailed site specific channel geometry and hydraulic measurements provided the necessary data base to calibrate hydraulic models for each study site. Variables dependent upon local hydraulic condition such as substrate, upwelling, and cover were also collected for input into the models. These data and hydraulic models make up the hydraulic component of the physical habitat analysis. For a given discharge of the Susitna River at Gold Creek, the flow through each study site can be determined then site specific hydraulic (velocity and depth) and related (substrate, upwelling, and cover) conditions can be predicted. These results may be used to forecast the effects of mainstem discharge on the availability and quality of aquatic habitats in the Talkeetna-to-Devil Canyon river segment.

3.2.2 General Techniques for Data Collection

A reach in each of the three study sloughs was selected for detailed evaluation. Each reach included a minimum of 10 percent of the total length of the slough with the intent of modelling it to represent the free-flowing water portion within that slough (ADF&G 1983: Volume 4).* The surface area of the free flowing portion of water in each slough when unbreached is governed by a combination of local flow and mainstem discharge conditions.

Cross sections were located within each study reach following field methods described in Bovee and Milhous (1978) and Trihey and Wegner (1981). Each cross section was located to facilitate collection of hydraulic and channel geometry measurements of importance in evaluating flow effects on salmon spawning and rearing habitats. The slough study sites were established in 1982 and the side channel study sites in 1983. Field data were obtained in 1982 and 1983 to describe a representative spectrum of water depth and velocity patterns, cover, substrate composition and presence of upwelling at each slough study reach and in 1983 for each side channel reach.

The number of cross sections established at the study reaches varied from four to eleven. The end points of each cross sections were marked with 30-inch steel rods (headpins) driven approximately 28 inches into the ground. The elevation of each headpin was determined by differential leveling using benchmarks previously surveyed to the project datum by R&M Consultants, Inc. (1982). Cross section profiles were measured with a self-leveling level, survey rod, and fiberglass tape. Horizontal distances were recorded to the nearest 1.0 foot and streambed elevations

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* Modelling of the spawning habitat availability in the backwater areas of the sloughs was also planned but not funded.

to the nearest 0.1 foot. Water surface elevations at each cross section in the study site were determined to the nearest 0.01 feet by differential leveling or reading staff gages located on the cross section.

Streambed elevations used in the hydraulic models were determined by making a comparison between the surveyed cross section profile and the cross section profiles derived by subtracting the flow depth measurements at each cross section from the surveyed water surface elevation at each calibration flow following the analytical procedure described in Trihey (1980). At the onset of the 1983 field season, discharge data were collected at cross sections established in 1982. Depth profiles indicated that the channel geometry did not change significantly from 1982. Therefore, the cross sections determined in 1982 were not resurveyed in 1983.

A longitudinal streambed profile (thalweg profile) was surveyed and plotted to scale for each modeling site (Part One, Chapter 2: Figures 2-5, 2-7, 2-9, 2-14, 2-16). The water surface elevation at which no flow occurs (stage of zero flow) at each cross section in the study site was determined from the streambed profile. If the cross section was not located on a hydraulic control, then the stage of zero flow was assumed equal to that of the control immediately downstream of the cross section.

Discharge measurements were made using a Marsh-McBirney or Price AA velocity meter, topsetting wading rod and fiberglass tape. Discharge measurements were made using standard field techniques (Buchanan and

Somers 1973; Bovee and Milhous 1978; Trihey and Wegner 1981). Depth and velocity measurements at each calibration flow were recorded for the same respective points along the cross sections by referencing all horizontal measurements from the left bank headpin, and zeroing the fiberglass tape over the headpin for each calibration flow regardless of where the water's edge occurred.

Substrate categories for each cell along modelling transects were classified by visual observation. The distribution of various substrate types was indicated on field maps. Substrates were classified by one or a combination of two of the following codes, with the first of the two codes being the most predominant (i.e., 70% rubble - 30% cobble = RU/CU). The substrate classifications used in this study are listed in Table 7-3-2.

Table 7-3-2. Substrate classifications.

Classification	Code	Size (inches)
Silt	SI	--
Sand	SA	--
Small Gravel	SG	1/8-1
Large Gravel	LG	1 - 3
Rubble	RU	3 - 5
Cobble	CO	5 - 10
Boulder	BO	>10

Presence of upwelling was determined along transects by examining maps of obvious upwelling locations compiled by the ADF&G during the summer of 1982 and maps of open leads completed during winter flights in 1982-83 (ADF&G 1983a, b: Appendix C). Cells were assigned a value of one in areas where upwelling and bank seepage were observed. Cells in areas showing no open leads or definite upwelling were considered "unknown" and assigned an absent upwelling code. The code for absent upwelling was also applied to areas on banks where there was no observed seepage.

3.2.3 General Techniques for Calibration

The calibration procedure for the hydraulic models at each individual study site consisted of field data collection, data reduction and refining the input data. The field data collection entailed establishing cross sections along which hydraulic data (water surface elevations, depths, and velocities) were measured and quantifying the hydraulic data at different channel flows. The data reduction entails determining the streambed elevations and stage of zero flow for each cross section and determining a mean discharge for all the cross sections in the study site. Refining the input data entailed adjusting the water surface elevations and velocities so that the forecasted data agreed more closely to the observed. A model was considered calibrated when (1) the predicted water surface profiles were reliable (the profiles decrease as flow moved downstream) and were within ±0.05 ft of the observed elevations and (2) the predicted velocity profiles were nearly the same as the observed profiles. A calibrated IFG-4 model gives velocity adjustment factors in the range of 0.9 to 1.1, and relatively few velocity prediction errors. The velocity adjustment factor is the ratio of the computed (observed) discharge to the predicted discharge. An

IFG-2 model does not have velocity adjustment factors and must be reviewed with the observed data before its considered calibrated.

3.2.4 General Techniques for Verification

The IFG recommends an extrapolation range of 0.7 times the low flow to 1.3 times the high flow for a two-flow IFG-4 hydraulic model (Milhous et al. 1981). For a three-flow IFG-4 hydraulic model, an extrapolation range of 0.4 times the low flow to 2.5 times the high flow is recommended. The extrapolation range for an IFG-2 hydraulic model, is from 0.4 to 2.5 times the calibration flow.

In addition to the IFG guidelines for model calibration, one other technique was used to evaluate how well the calibrated models could forecast observed relationships or measurements. The technique, diagrammed in Figure 7-3-1, involved a comparison of observed and predicted water surface elevations for a single cross section in each study reach. As part of an investigation of the relationship between mainstem discharge and site specific flows (see Chapter 1 of this report), periodic discharge and water surface elevation measurements were obtained at cross sections located within each study reach in order to develop empirical rating curves.

The regression lines developed independently from rating curve and modelling data were statistically tested for coincidence, that is, their slopes and intercepts were tested for equality. A small sample t test for parallelism and common intercept was performed using the pooled variances of both regression lines (Kleinbaum and Kupper 1978). In

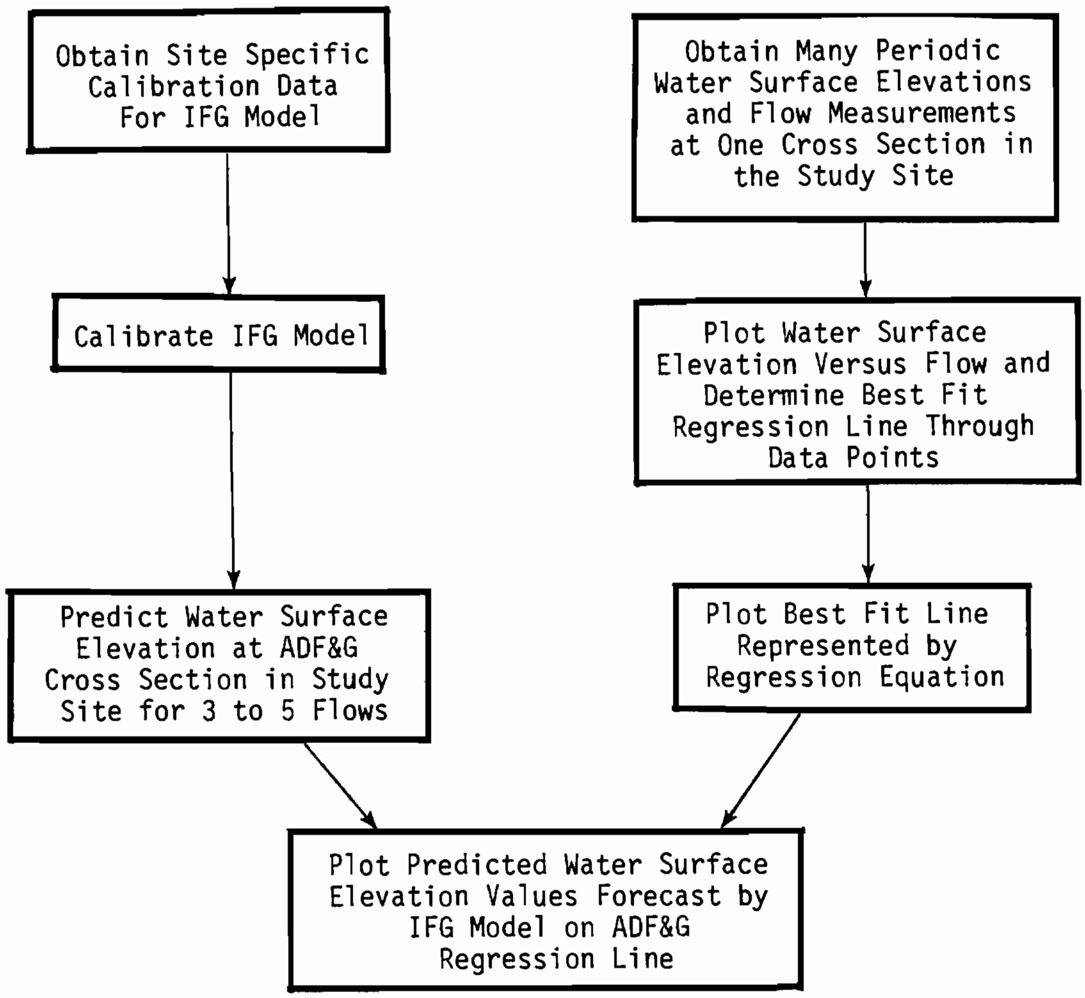

Figure 7-3-1. Flow chart for comparing model predicted water surface elevations with site specific water surface elevations-versus-discharge curves developed by ADF&G.

cases where the hypotheses of equal slopes and intercepts were not rejected (= 0.05), it may be assumed the two sets of data represent the same water surface elevation versus discharge relationship. In those cases where the two lines were not coincident, the difference between stages predicted from each equation was determined for the extreme calibration flows.

3.3 Results

3.3.1 Slough 8A (River Mile 125.3)

3.3.1.1 Site Description

A 1,000 foot long multiple cross section study site was established in Slough 8A in July 1982 (Plate 7-2-1). The study site represents typical pool/run habitat in Slough 8A that continues from the study site upstream to the head of the slough. The study site is not representative of the beaver pond and backwater habitats found downstream of its location. Eleven cross sections were surveyed to define channel geometry for the use with the IFG-4 hydraulic simulation model (Figure 7-3-2). Cross sections 1, 3, and 7 are located in transition areas between adjacent pools and riffles. Cross sections 2, 5, 8, 9, 10, and 11 define pool areas and cross sections 4 and 6 describe riffles. A beaver dam constructed between cross sections 3 and 4 during the later portion of 1983 field season has considerably altered the slough hydraulics. The dam did not adversely effect the hydraulic data used to calibrate the IFG-4 model because it was constructed after the last data set was obtained.

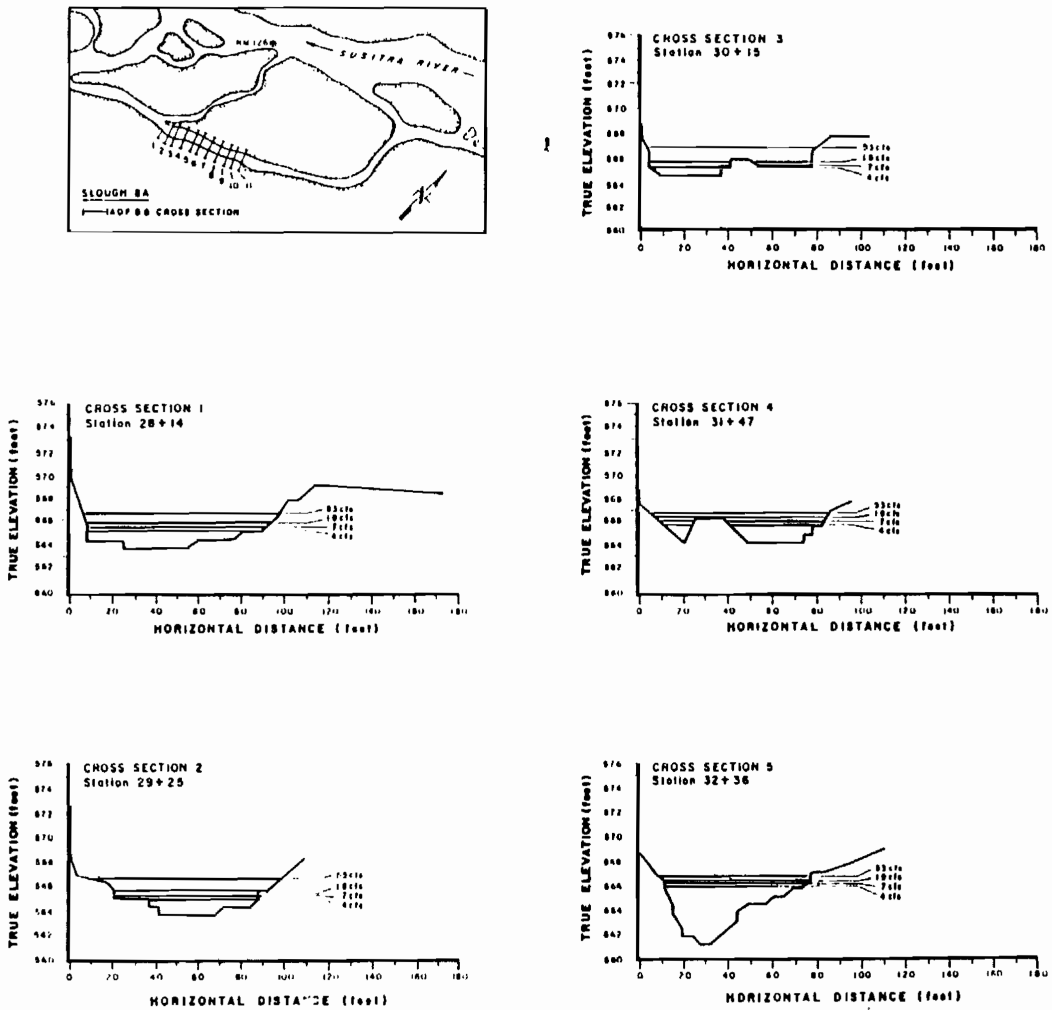

Figure 7-3-2 Cross sections for Slough 8A study site depicting water surface elevations at calibration discharges of 4, 7, 19, and 53 cfs.

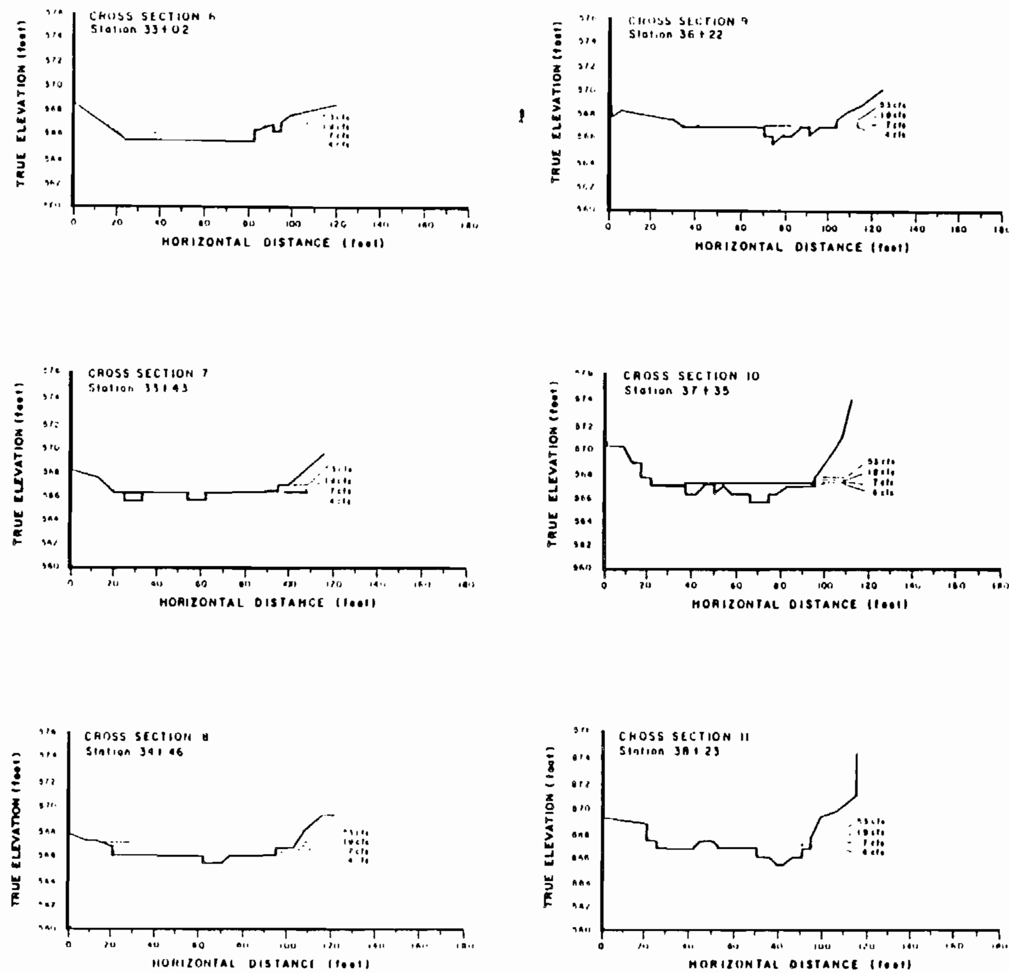

Figure 7-3-2 continued

3.3.1.2 Data Collected

Mean daily discharges for the Susitna River on the dates that calibration data were collected at the Slough 8A study site were determined from provisional USGS streamflow data for the Gold Creek Station recorder (Table 7-3-3).

Table 7-3-3. Calibration data collected at Slough 8A study site.

Date	Site Specific Flow (cfs)	Susitna River Discharge (cfs)
820822	4	12,200
820907	7	11,700
820917	19	24,100
830604	53	36,000

3.3.1.3 Calibration

Calibration data were available at the close of the 1982 field season for slough flows of 4, 7, and 19 cfs. An IFG-4 model was used to forecast instream hydraulics based on these calibration flows. The water surface profile at a slough flow of 50 cfs was selected as the upper limit of the extrapolation range for this particular model using the criteria suggested by the IFG (Bovee and Milhous 1978). The streambed profile, stages of zero flow, and observed and predicted water surface elevations for the study reach are plotted to scale in Figure 7-3-3. Because the 19 cfs data set was collected when the slough was not breached by the mainstem, an additional data set was needed to explain

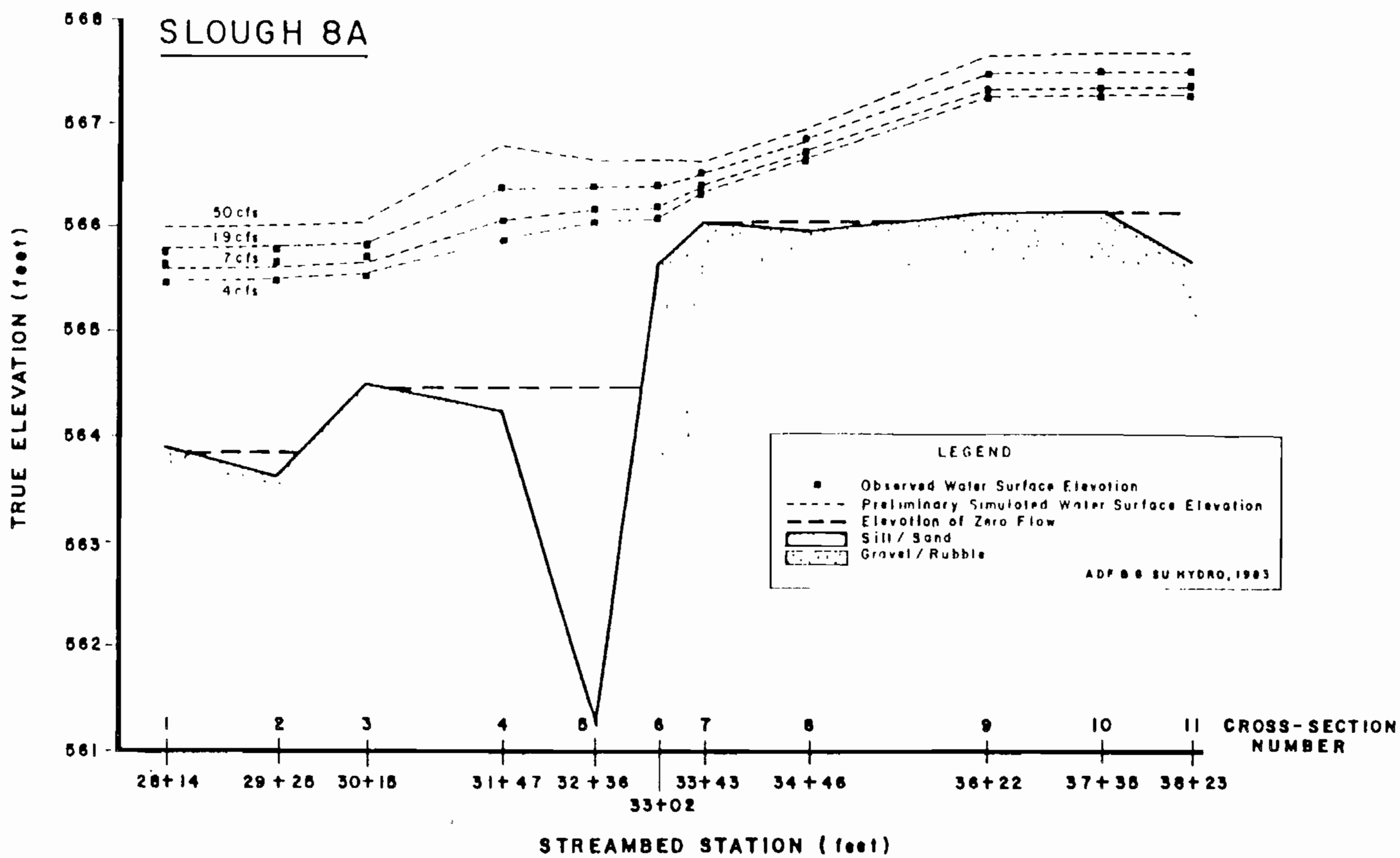

Figure 7-3-3 Comparison of observed and predicted water surface profiles from non-calibrated model at Slough 8A study site.

the channel hydraulics during breached conditions. A fourth data set was collected during the 1983 field season at a slough flow of 53 cfs.

All four data sets were used to predict water surface profiles for slough flows between 4 and 125 cfs. These forecasts are compared to observed water surface profiles and are plotted to scale in Figure 7-3-4. The predicted profile for 125 cfs is unreasonable because the water surface profile flows uphill from cross section 7 to 4. A significant difference was observed between the observed and predicted water surface elevations occurs for each calibration flow at the first seven cross sections. This discrepancy is due to backwater effects occurring at the site when the northeast channel is breached. This situation was modeled by using two IFG-4 hydraulic models; one with backwater effects in the lower half of the study area and the other without backwater effects. The 4, 7, and 19 cfs data sets were used to calibrate a hydraulic model capable of simulating flow conditions without backwater effects (Figure 7-3-5) and the 19 and 53 cfs data sets were used to calibrate a model for use when backwater effects are present (Figure 7-3-6).

To evaluate the performance of the calibrated IFG-4 hydraulic models, observed and predicted water surface elevations, discharges, and velocities were compared (Appendix Tables 7-A-1 and 7-A-2). The maximum difference in water surface elevations for each calibration flow was 0.02 ft at the 11 cross sections. The mean calibration discharges predicted by the low flow models were 4, 7, and 20 cfs, respectively, and the mean calibration discharges predicted by the high flow models

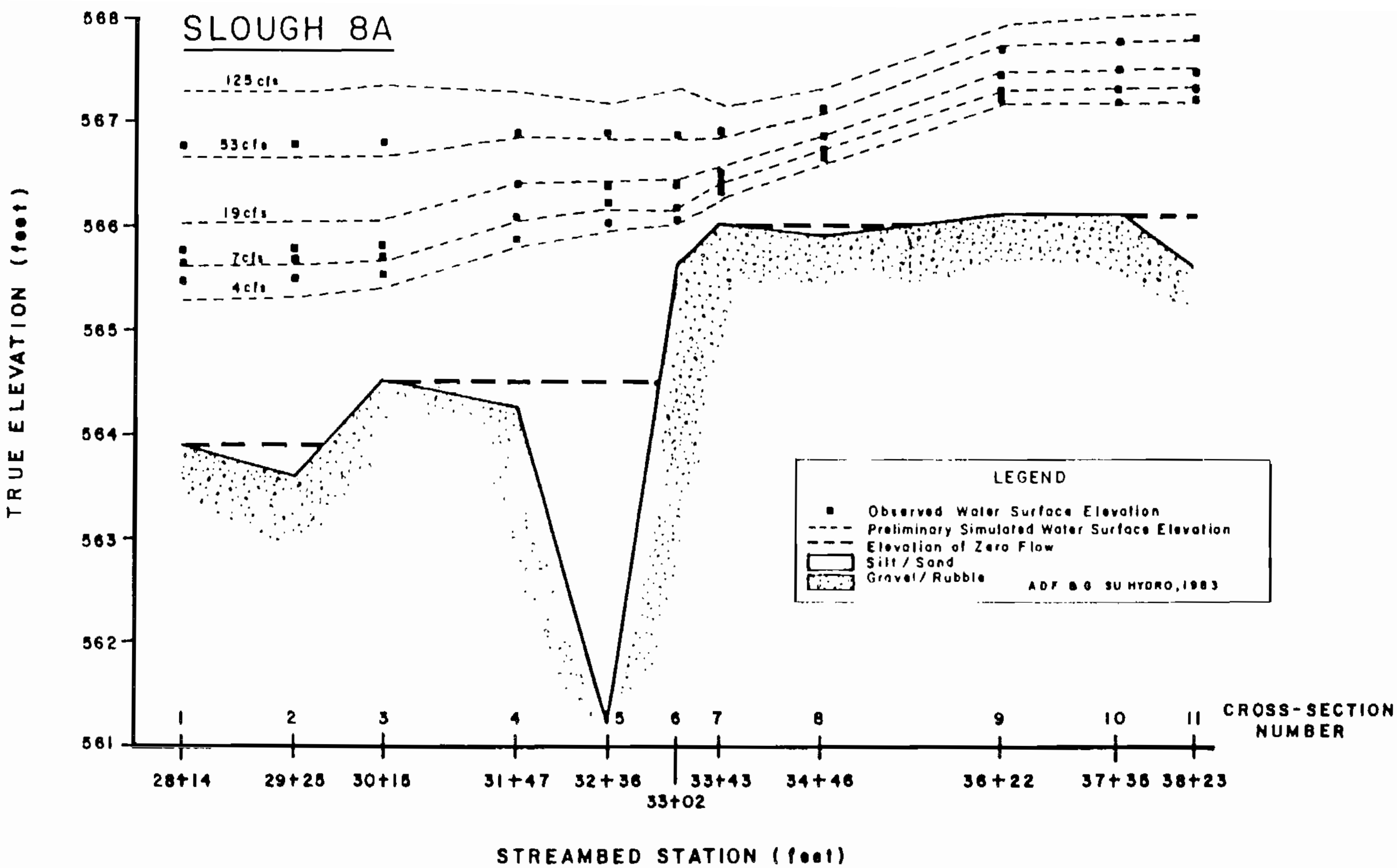

Figure 7-3-4 Comparison of observed and predicted water surface profiles from non-calibrated model at Slough 8A study site.

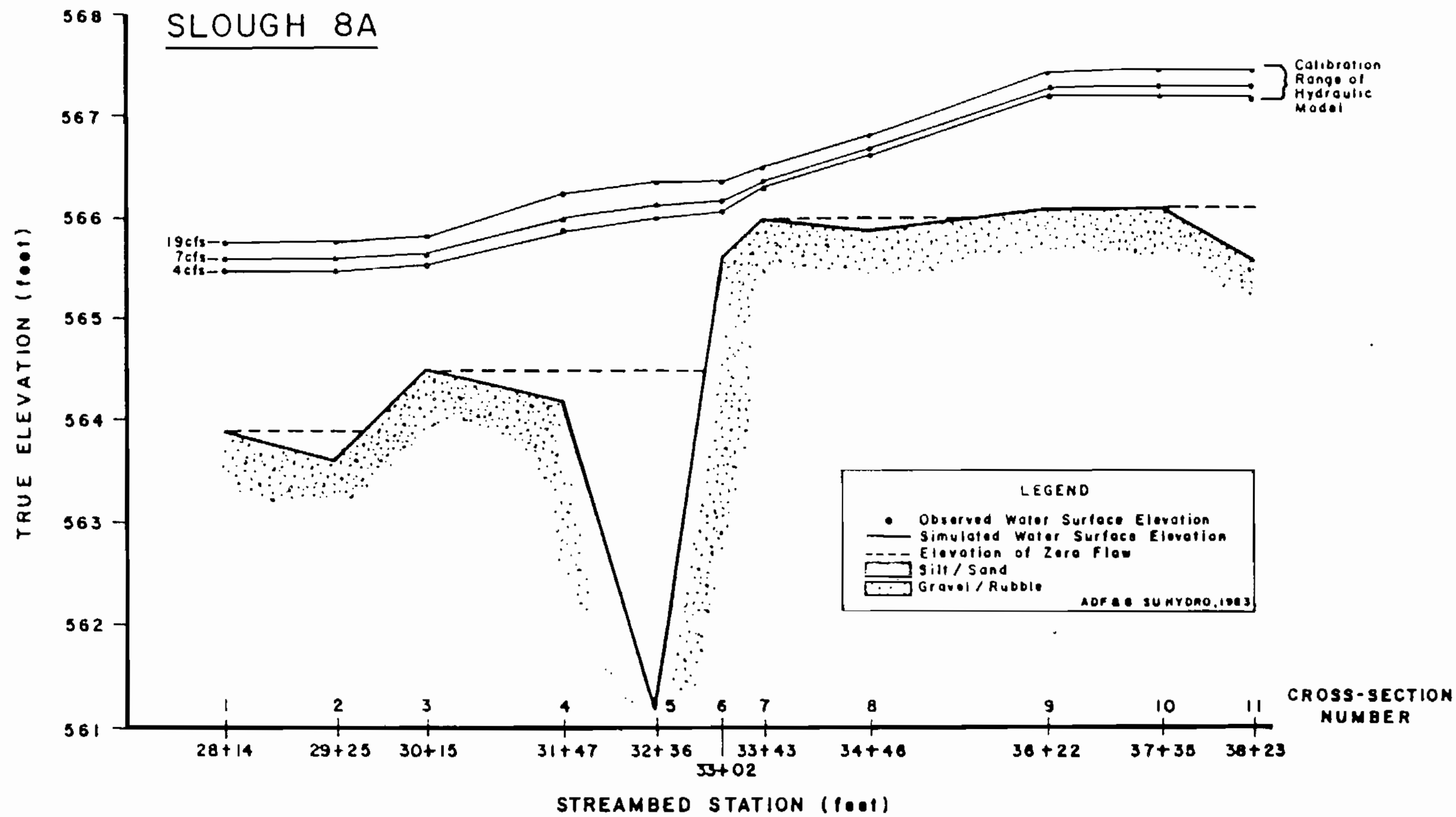

Figure 7-3-5. Comparison of observed and predicted water surface profiles from calibrated model at Slough 8A study site for low flow regime.

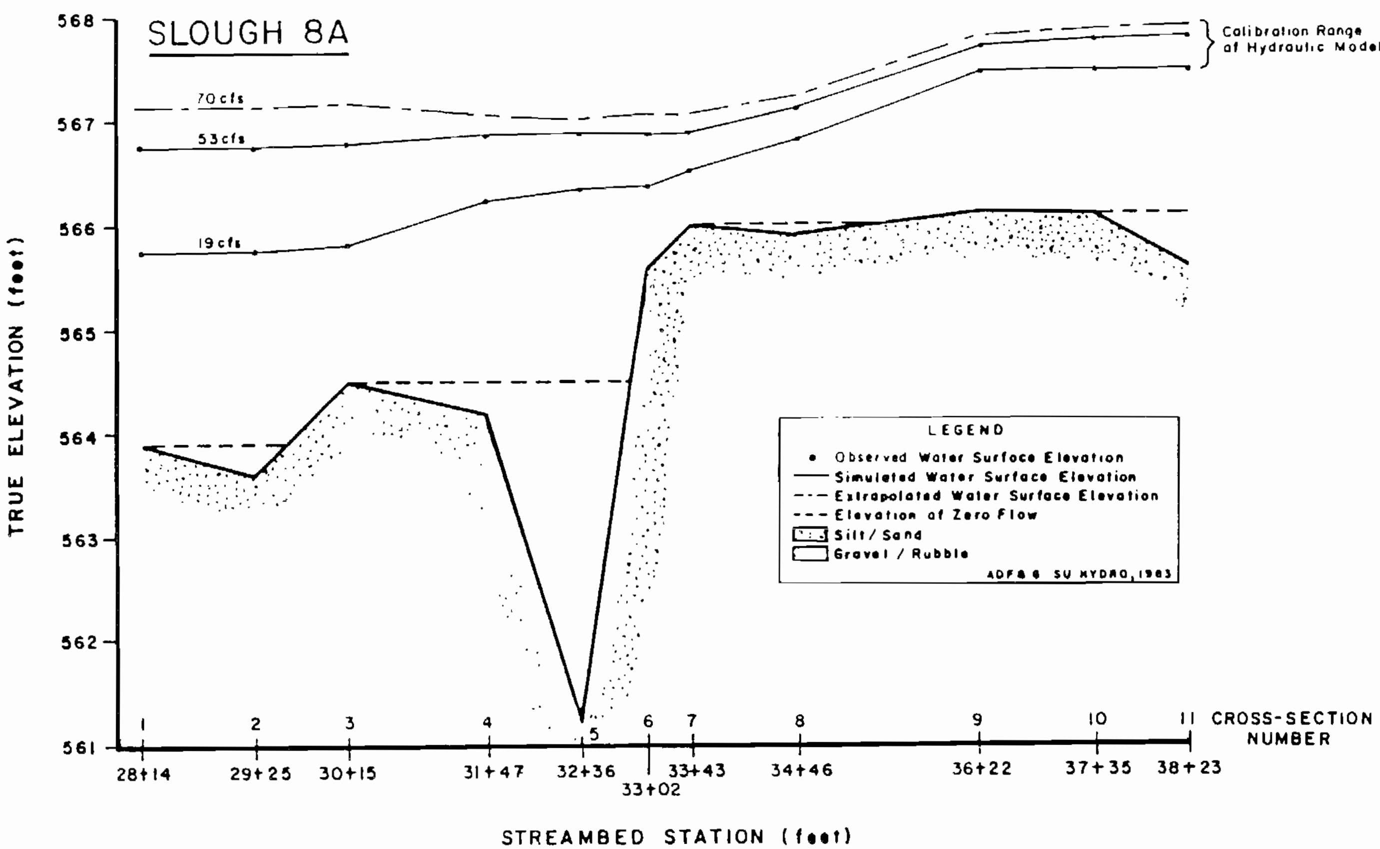

Figure 7-3-6. Comparison of observed and predicted water surface profiles from calibrated model at Slough 8A study site for high flow regime.

were 19 and 53 cfs, respectively. The velocity adjustment factors for both models range from 0.95 to 1.03, indicating the models are suitably calibrated (Milhous et al. 1981).

3.3.1.4 Verification

For Slough 8A, the three-flow model (4, 7, and 19 cfs) describing the hydraulic conditions without backwater effects has an extrapolation range of 4 to 20 cfs. At slough flows below 4 cfs, the depths become so shallow in the wide rectangular-shaped cross sections that accurate velocity readings are difficult to make. Therefore, the hydraulic model was not extrapolated below the measured 4 cfs slough flow. Backwater effects become present in the study site when the northeast channel is breached at slough flows of 20 to 30 cfs. Accordingly, the upper extrapolation limit of the low flow hydraulic model is 20 cfs. This corresponds to Susitna River discharges at Gold Creek of less than 33,000 cfs. The two-flow model (19 and 53 cfs) describing the backwater effects has an extrapolation range from 20 to 70 cfs. Insufficient data were available to define a relationship between slough flow and mainstem discharge when the northeast channel was breached. Therefore, corresponding mainstem discharges are not defined for slough flows greater 20 cfs.

A comparison was made between water surface elevations predicted by the IFG-4 hydraulic models for selected flows at cross section 11 and the empirical rating curve developed by ADF&G at the R&M stream gage upstream from the study site (Figure 7-3-7). The stream gage is located

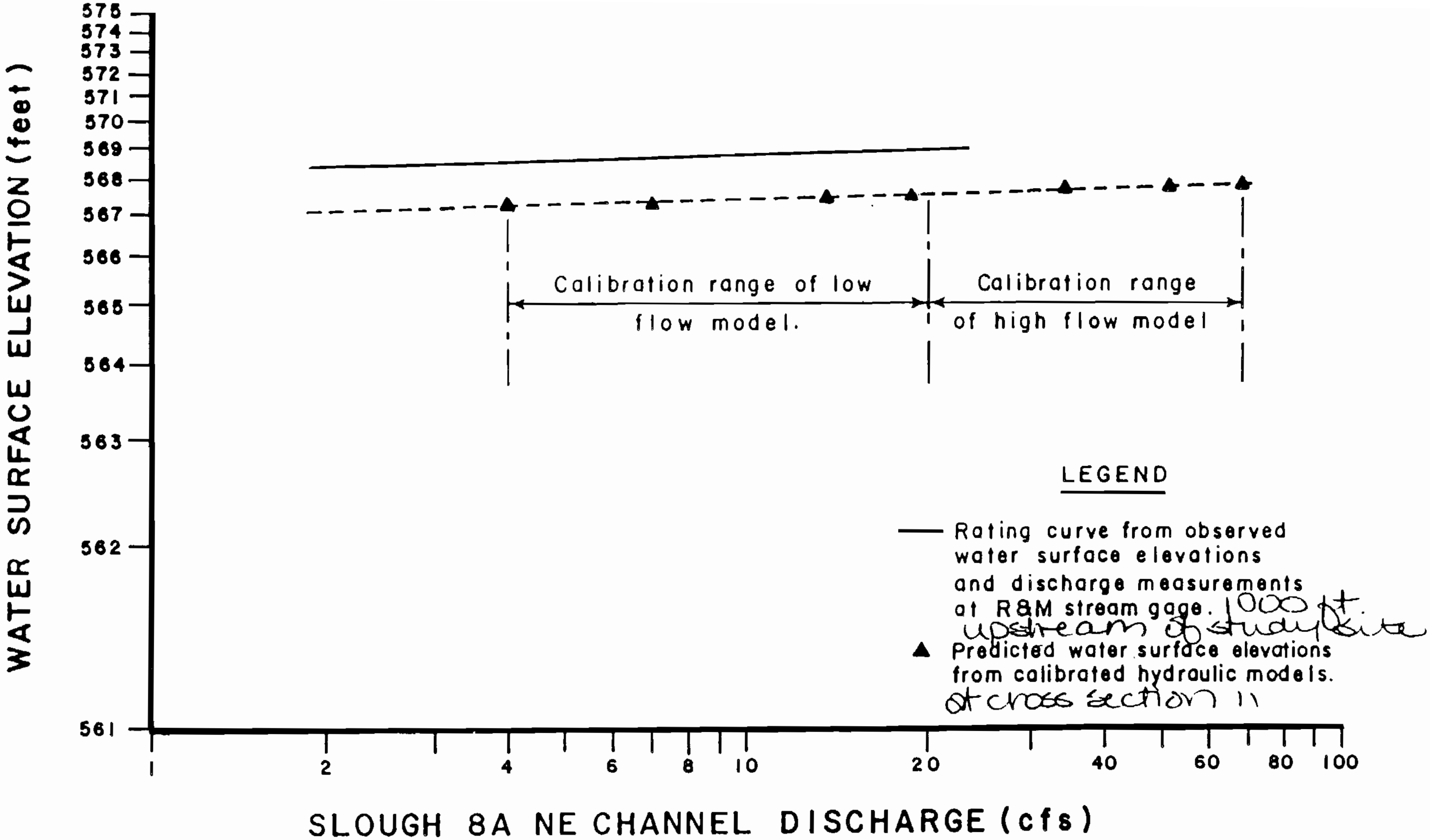

Figure 7-3-7 Comparison between ADF&G rating curve and model predicted water surface elevations.

1000 ft upstream from Slough 8A study site at a higher bed elevation than cross section 11 (is 1.4 ft higher). Therefore, the curve for the stream gage is plotted on the graph higher than the curve for cross section 11. The regression lines were statisticly tested for parallelism (the curves were developed at different cross sections and can not be coincident) and the hypotheses that both lines had the same slope was rejected. A comparison in water surface elevations for the extreme extrapolated flows are listed in Table 7-3-4.

Table 7-3-4. Comparisons between water surface elevations predicted by the IFG-4 model and the ADF&G rating curve for the extreme calibration flows at the Slough 8A study site.

Flow (cfs)	Water Surface Elev. (ft) Model	Water Surface Elev. (ft) Rating	Diff. in Streambed Elev.	Actual Diff.	Adjusted Diff.
4	567.20	568.62	1.4	1.42	0.02
20	567.46	568.92	1.4	1.46	0.06

Because the difference is minimal, the model was considered to be adequately calibrated. There was insufficient data available to develop an empirical rating curve above 19 cfs slough flow. Therefore, the two point high flow model for Slough 8A could not be statistically tested.

3.3.1.5 Application

The study site in Slough 8A was chosen to represent typical spawning and rearing habitat in the free-flowing portion of this slough (Part 1, Section 2, Figure 2-14). The study site is located approximately 900 ft upstream from a large beaver dam that existed prior to the 1982 field season. Because of the pronounced effect of backwater from the beaver dam associated with breaching flows at the study site, high and low flow hydraulic models were calibrated to represent the hydraulic conditions with and without backwater effects.

The high flow model was based on calibration flows of 19 and 53 cfs. This model was well calibrated, but should be applied with caution. Due to the lack of data to verify the predictive capabilities of the model at high slough flows, it is recommended that the model not be used for slough flows greater than 70 cfs. The most appropriate use for this model is to forecast depth and velocities occurring between streambed stations 27+00 and 40+00 when slough flows are between 19 and 70 cfs. Slough flows occur in this range when the northeast channel is breached which corresponds to mainstem discharges greater than 33,000 cfs.

The low flow model was based on calibration flows of 4, 7, and 19 cfs. It is capable of providing reliable estimates of depths and velocities for slough flows between 4 and 50 cfs provided that no backwater effects exist. This model is most suitable for forecasting hydraulic conditions for non-breached conditions throughout the free flowing portion of the slough or for breached conditions between streambed stations 27+00 and 40+00. The low flow model could also be used to simulate depths and velocities for breached conditions between streambed stations 15+00 and 70+00 if the large beaver dam downstream from the study site is removed.

At flows of less than 4 cfs, significant differences were noted between forecasted and observed depths and velocities, indicating that the predictive capability of the hydraulic model is diminished at extremely low flows. This result is due primarily to modelling limitations along the channel margins and low velocity areas. A roughness coefficient, n, is assigned and Manning's equation used to predict velocity in these areas. The n value is assumed to be constant throughout the extrapolation range of the model which causes a higher predicted velocity value at extreme low depths (less than 0.10 ft).

3.3.2 Slough 9 (River Mile 128.3)

3.3.2.1 Site Description

The multiple cross section study site in Slough 9 was established in July 1982 (Plate 7-2-2). Ten cross sections were initially surveyed to define the channel geometry for the 1,160 ft study reach (Figure 7-3-8). The streambed elevations for cross section 7 were not measured by ADF&G but were obtained from R&M Consultants, Inc., who had previously established a discharge site at the same location. Cross sections 1, 7, 8, 9, and 10 describe pool areas. Cross sections 2 and 6 define transition areas between adjacent pools and riffles. Cross sections 3, 4, and 5 cross a riffle and are similar in shape. Cross sections 3 and 5 were not used in the hydraulic model but were surveyed to evaluate passage conditions for adult salmon. Cross section 4, located across the middle of the riffle, was used to define hydraulic conditions in the riffle for the entire flow range being simulated.

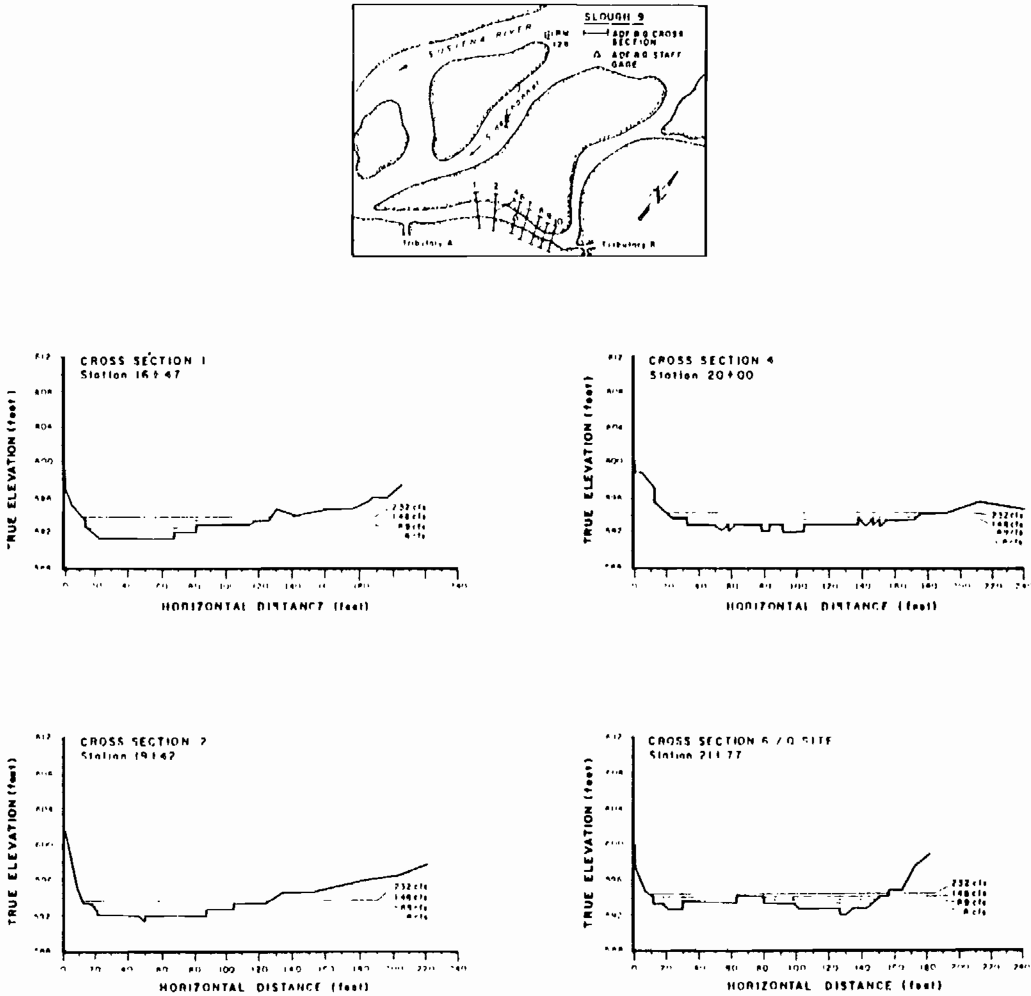

Figure 7-3-8 Cross sections for Slough 9 study site depicting water surface elevations at calibration discharges of 8, 89, 148, and 232 cfs.

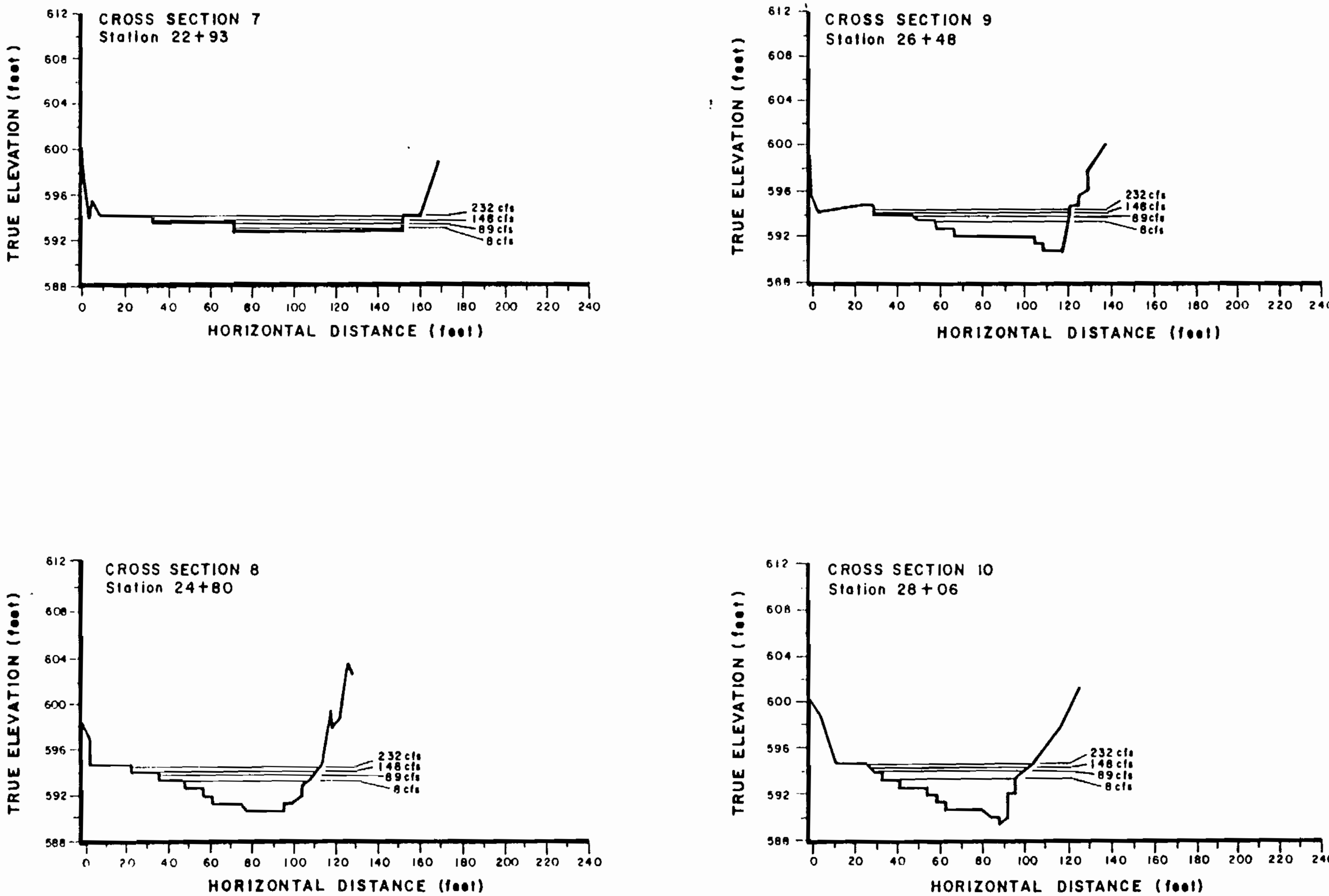

Figure 7-3-8. continued.

3.3.2.2 Data Collected

On the dates that calibration data were collected at the Slough 9 study site, corresponding mean daily discharges were determined for the Susitna River at Gold Creek. The discharge data collected is listed in Table 7-3-5..

Table 7-3-5. Calibration data collected at Slough 9 study site.

Date	Site Specific Flow (cfs)	Susitna River Discharge (cfs)
820904	8	14,400
830818	30	21,000
830607	89	23,000
820920	148	24,000
820918	232	27,500

3.3.2.3 Calibration

Calibration data were available at the close of the 1982 field season for slough flows of 8, 148, and 232 cfs. An IFG-4 model was used to forecast hydraulic conditions present at these flows. The water surface profile for a slough flow of 600 cfs was also forecast to evaluate the predictive capability of the model at the upper limit of the extrapolation range. The streambed profile, stage of zero flow and observed and predicted water surface elevations for the study reach using the 1982 data are plotted to scale in Figure 7-3-9.

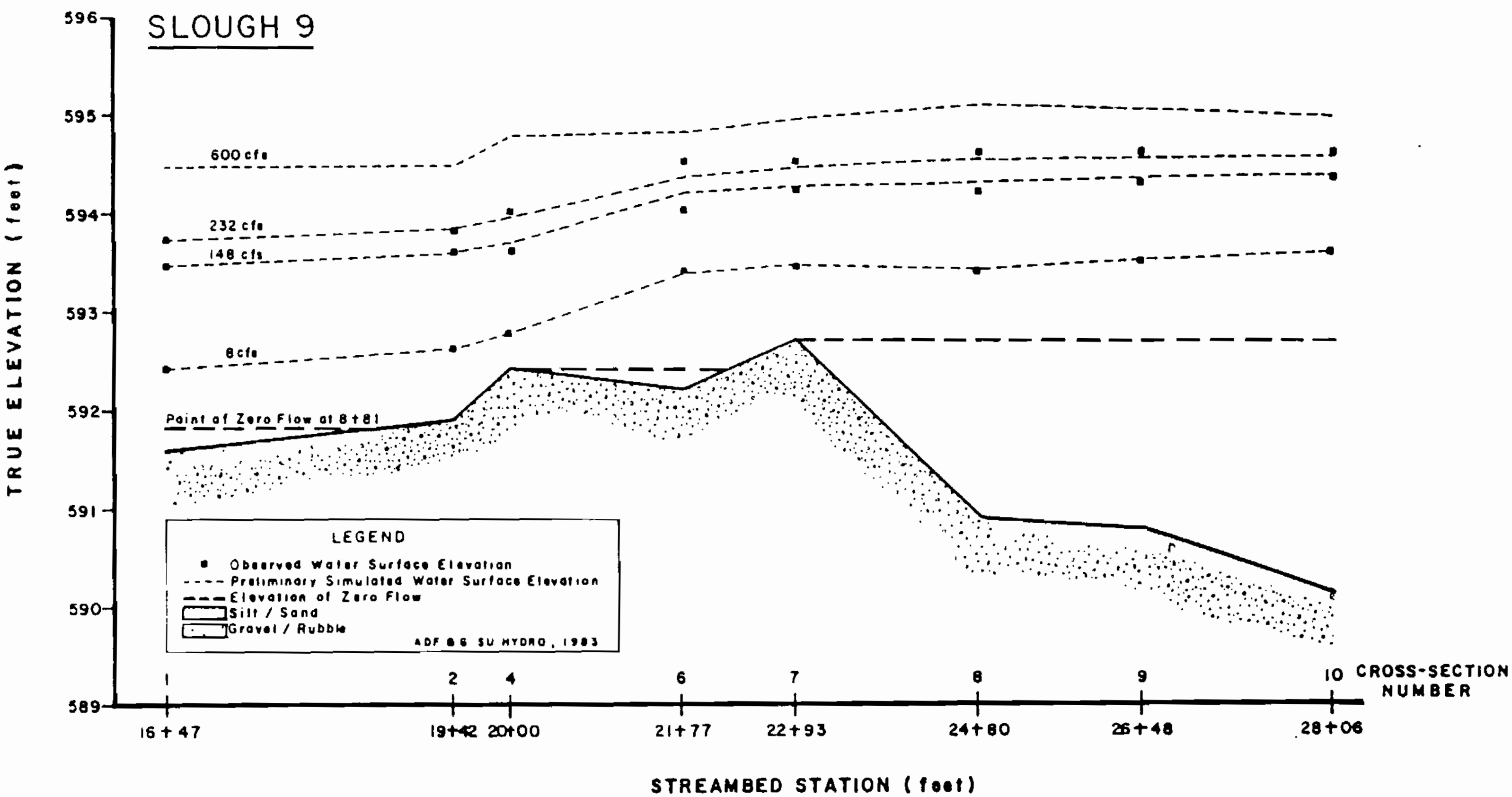

Figure 7-3-9. Comparison of observed and predicted water surface profiles from non-calibrated model at Slough 9 study site.

An IFG-4 model developed from data collected at 8, 148 and 232 cfs did not provide an accurate description of the hydraulic conditions observed at this study reach. Representative velocity data were needed for slough flows between 8 and 148 cfs. Due to the large difference in wetted channel that exists between these flows, data were collected at 30 and 89 cfs during the 1983 field season. However, the 30 cfs data were found to be in error and were not used in the hydraulic model*.

During the 1982 field season, a large sand berm present near the head of the slough was breached by a high flow event that occurred in mid-September. A layer of sand was deposited throughout the slough which caused the water surface profile at 89 cfs to be nearly identical to that which existed in 1982 for a slough flow of 148 cfs (Figure 7-3-10). The three-flow model was used to forecast a slough flow of 90 cfs and a comparison was made between the observed depths of flow at 89 cfs (1983 data) and the predicted depths of flow for 90 cfs. These flow depths were found to be quite similar even though the predicted water surface profile for 90 cfs was lower than that measured for a slough flow of 89 cfs. It was also noted that the sand deposition had not drastically altered the cross sectional shape of the study site. Because the cross sectional shape of the channel and the depths of flow were similar, it was assumed that the velocities measured in 1983 at a slough flow of 89 cfs were of the same magnitude as velocities that

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* A review of the data collected for the 30 cfs measurement revealed differences in discharge estimates between cross sections which exceeded 200%. The velocity measurements obtained in the lower half of the study site were believed to be in error due to equipment failure. Therefore, the 30 cfs calibration data set was not used in the hydraulic model.

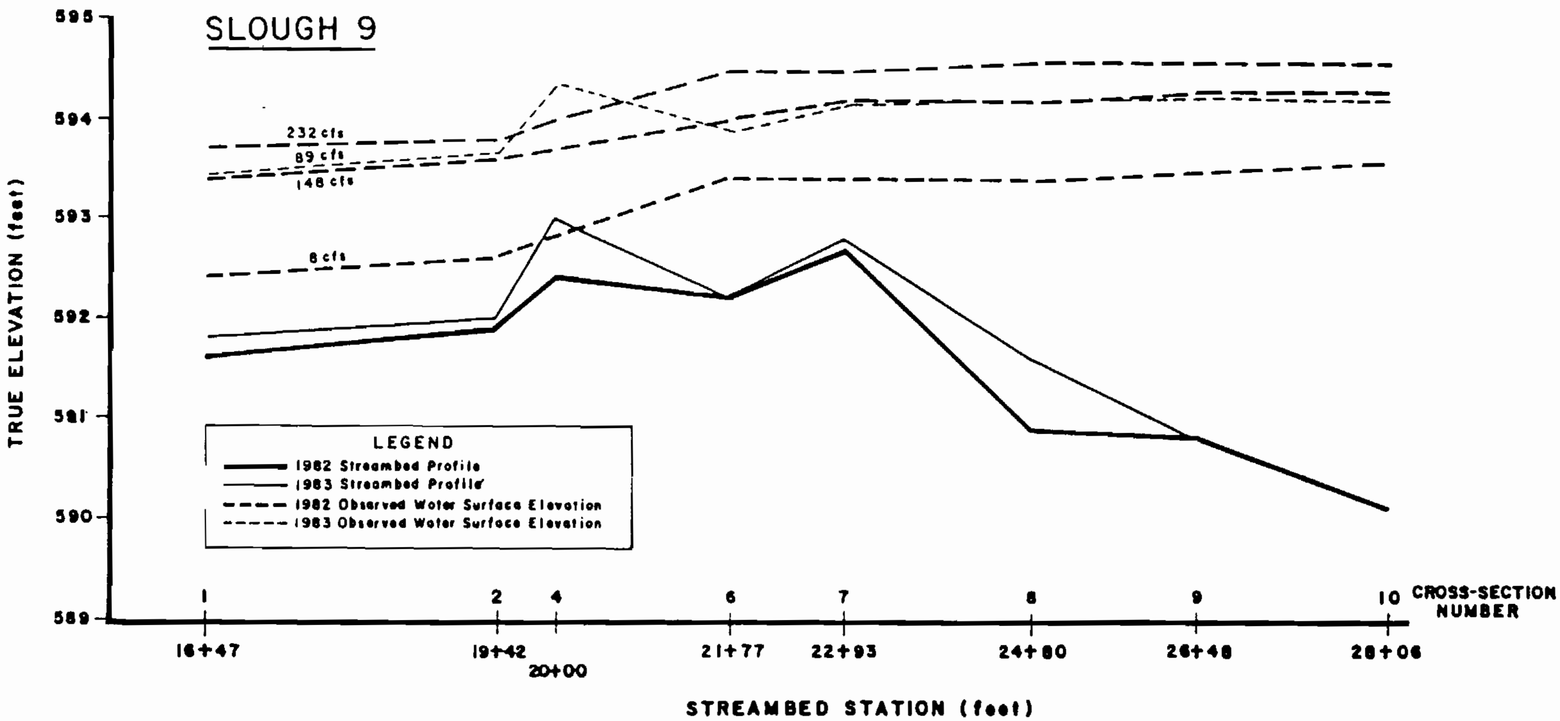


Figure 7-3-10. Comparison between 1982 and 1983 streambed and water surface profiles at Slough 9 study site.

would have been measured at a slough flow of 89 cfs in 1982 had such a slough flow occurred that year.

The 90 cfs predicted water surface profile was then used with the 1982 depth and velocity data collected at a slough flow of 89 cfs and combined with the three data sets to form a four-flow model. The water surface elevations predicted by the hydraulic model are plotted to scale in Figure 7-3-11.

To evaluate the reliability of the calibrated IFG-4 hydraulic model for Slough 9, observed and predicted water surface elevations, discharges and velocities were compared (Appendix Table 7-A-3). The maximum difference in water surface elevations for each calibration flow was 0.06 ft at the eight cross sections. The means of the calibration discharges predicted at each cross section by the IFG-4 hydraulic model were 8, 89, 148, and 232 cfs, as compared to means of 8, 88, 148, and 234 for observed values. The velocity adjustment factors range from 0.96 to 1.04, indicating an acceptably calibrated model.

3.3.2.4 Verification

For Slough 9, the four-flow model (8, 89, 148, and 232 cfs) describing the hydraulic conditions has an extrapolation range from 5 to 600 cfs. At slough flows below 5 cfs, the depths become so shallow in the wide rectangular cross sections that accurate velocity readings are difficult to make. Therefore, the hydraulic model was not extrapolated below 5 cfs. Slough 9 is mainstem controlled at Susitna River discharges near

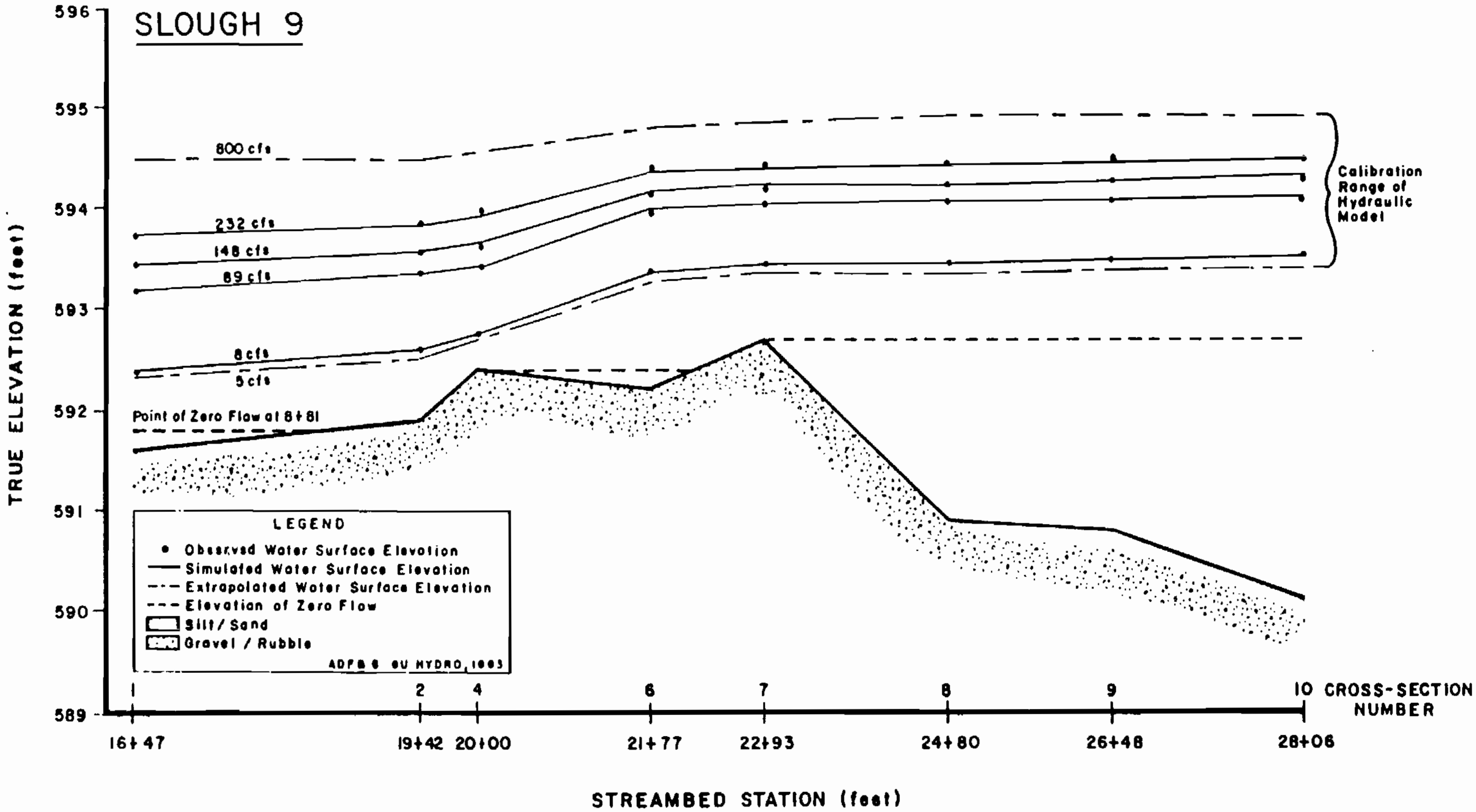


Figure 7-3-11 Comparison of observed and predicted water surface profiles from calibrated model at Slough 9 study site.

19,000 cfs. Thus the Slough 9 model can forecast hydraulic conditions in the study site for Susitna River discharges at Gold Creek up to 31,000 cfs (Figure 7-3-12).

A comparison was made between water surface elevations predicted by the IFG-4 hydraulic model for selected flows at the discharge cross section and the empirical rating curve developed by ADF&G for the same cross section (Figure 7-3-13). The statistical test for coincidence between the two regression lines indicated the hypothesis (both lines the same) was rejected. Water surface elevations at the extreme extrapolation flows were compared for the model and rating curve in Table 7-3-6.

Table 7-3-6. Comparisons between water surface elevations predicted by the IFG-4 model and the ADF&G rating curve for the extreme calibration flows at the Slough 9 study sites.

Flow (cfs)	Water Surface Elevation (ft) Model	Rating	Actual Diff.
5	593.23	593.22	0.01
600	594.65	594.89	0.24

3.3.2.5 Application

The study site in Slough 9 was chosen to represent typical spawning and rearing habitat in the free flowing portion of the slough (Part 1: Chapter 2, Figure 2-16). In general, the free flowing portion of Slough 9 extends from streambed station 6+00 to 35+00 for unbreached conditions and 8+00 to 60+00 when breached. Downstream of streambed station 6+00,

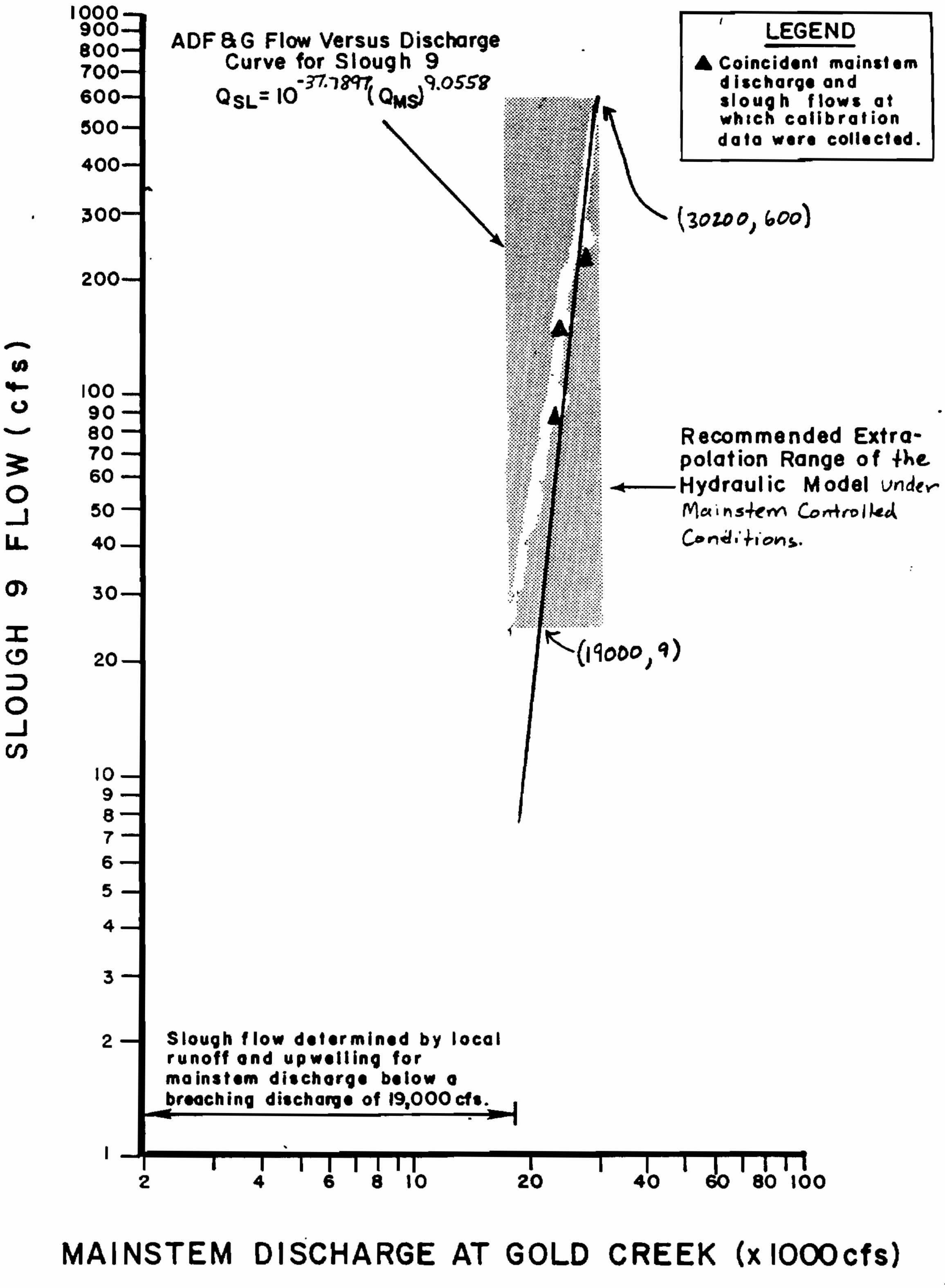


Figure 7-3-12. Relationship between extrapolation range of the Slough 9 model and ADF&G flow-versus-discharge curve.

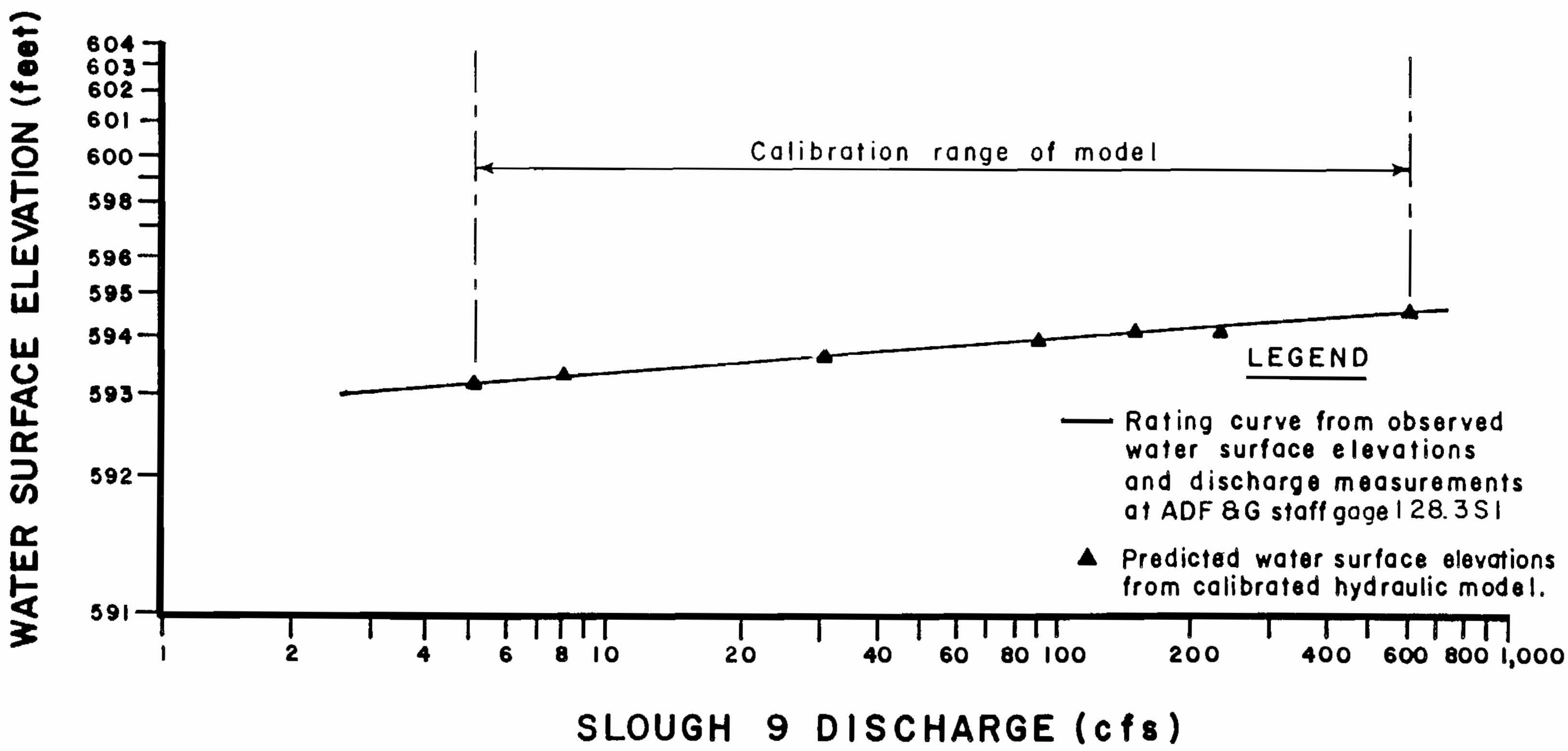


Figure 7-3-13 Comparison between ADF&G rating curve and model predicted water surface elevations.

depths and velocities within the slough are more significantly influenced by mainstem backwater effects than by slough flow. Hence, the Slough 9 hydraulic model should not be applied to this portion of the slough.

The Slough 9 hydraulic model will forecast depths and velocities for slough flows between 30 and 600 cfs which correspond to a range of mainstem discharge between 19,000 and 31,000 cfs. Below 19,000 cfs, the slough flow ranges from 3 to 30 cfs. Strict application of IFG guidelines for the recommended extrapolation range would indicate the model is applicable to a range of slough flows between 3 and 580 cfs. A comparison was made between depths and velocities forecast by the model for a slough flow of 3 cfs and a data set collected August 25, 1982 by ADF&G when the measured slough flow was 3 cfs. As with the Slough 8A low flow model, the reliability of the hydraulic model rapidly deteriorates when simulating extremely low slough flows. Therefore, a lower extrapolation limit of 5 cfs is recommended.

3.3.3 Slough 21 (River Mile 141.8)

3.3.3.1 Site Description

Initially, eight cross sections were established in July 1982 to define the physical habitat conditions present at Slough 21 (Plate 7-2-3, Figure 7-3-14). Cross section 3 defines the transition area between an adjacent pool and riffle. Cross sections 4, 5, 6, and 7 describe pool areas. Cross sections 1 and 2 were located below the confluence of

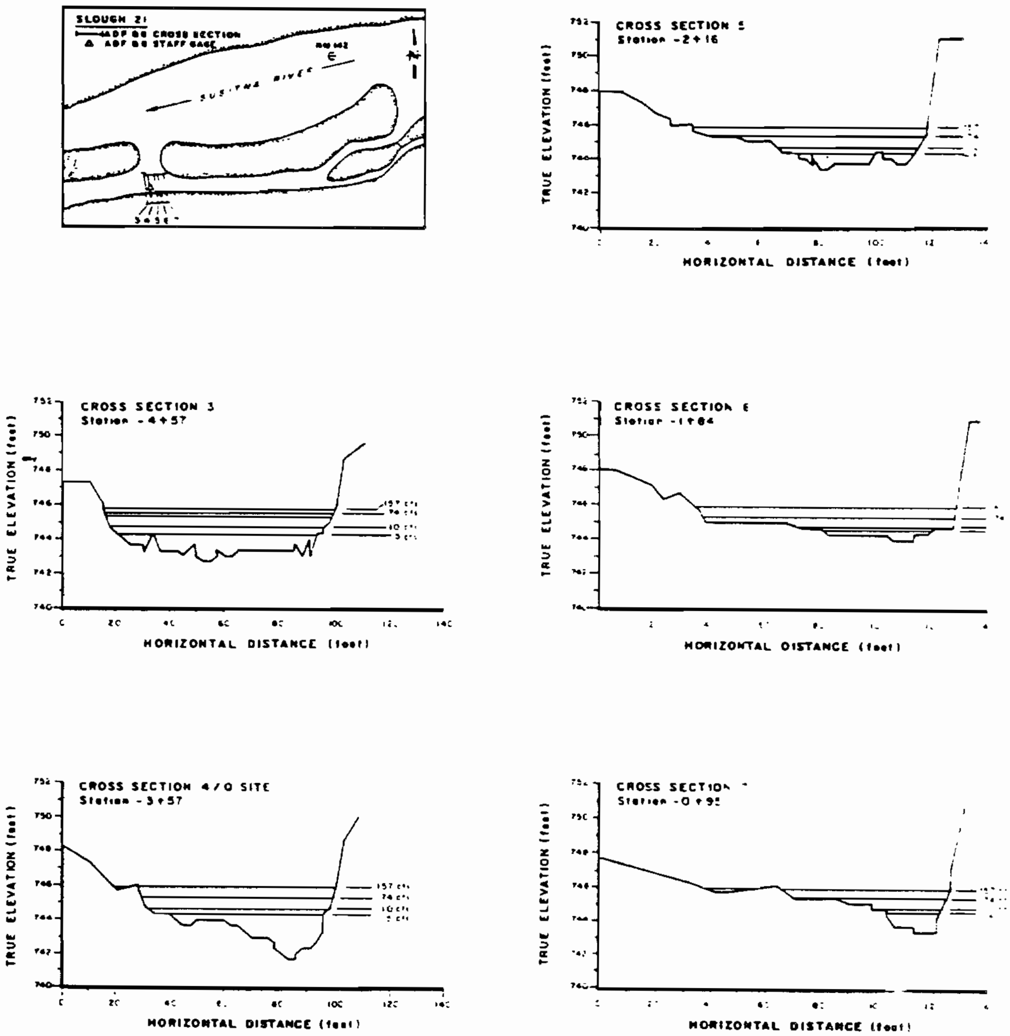


Figure 7-3-14. Cross sections for Slough 21 study site depicting water surface elevations at calibration discharges of 5, 10, 74, and 157 cfs.

Channel A6 Lower. The increased flow in cross sections 1 and 2 compared to the other cross sections in the study site violate the steady flow assumption of the IFG-4 hydraulic simulation model (Bovee and Milhous 1978; Trihey 1980). Therefore, cross sections 1 and 2 were not included in the hydraulic model. Cross section 8 was located at the slough mouth immediately upstream of the confluence with Channel A6 Upper. When this channel is breached, the direction of flow in the slough mouth is altered and a large backwater eddy area occurs at the cross section. Insufficient data were available to accurately model the negative velocities which occur in the backwater eddy. Therefore, this cross section was also excluded from the IFG-4 hydraulic model leaving a total of 5 cross sections (3 through 7).

A streambed profile was surveyed for the "Slough 21 Complex" that extended from the mouth of the side channel (River Mile 140.6), through the study site and Slough 21 to the junctures of the northwest and northeast heads of Slough 21 with the mainstem (River Mile 142.2). However, the streambed stationing was referenced to the mouth of the slough, not the mouth of the side channel. Therefore, the streambed stations of the cross sections at this study site are shown as negative stations and represent the distance downstream from the slough mouth.

3.3.3.2 Data Collected

Calibration data were collected at the Slough 21 study site and compared to the mean daily discharge at Gold Creek Station. The calibration and discharge data is listed in Table 7-3-7.

Table 7-3-7. Calibration data collected at Slough 21 study site.

Date	Site Specific Flow (cfs)	Susitna River Discharge (cfs)
820902	5	16,000
820919	10	24,100
830605	73	30,000
820917	157	32,000

3.3.3.3 Calibration

Calibration data were available at the close of the 1982 field season for slough flows of 5, 10, and 157 cfs. An IFG-4 model was used to forecast depths and velocities at these calibration flows. The water surface profile associated with a slough flow of 400 cfs was also forecast to evaluate the model's predictive capability near the upper limit of its extrapolation range. The streambed profile, stage of zero flow, and observed and predicted water surface elevations using only 1982 data were then plotted to scale (Figure 7-3-15).

The 1982 calibration data were widespread and did not provide an accurate description of the water surface profile at 400 cfs. Therefore, a fourth data set (73 cfs) was collected during the 1983 field season to better calibrate the IFG-4 hydraulic model. The streambed profile, elevation of zero flow, and observed and predicted water surface elevations for the 1983 model are plotted to scale in Figure 7-3-16. The water surface profile at 400 cfs does not appear to be correct, and the

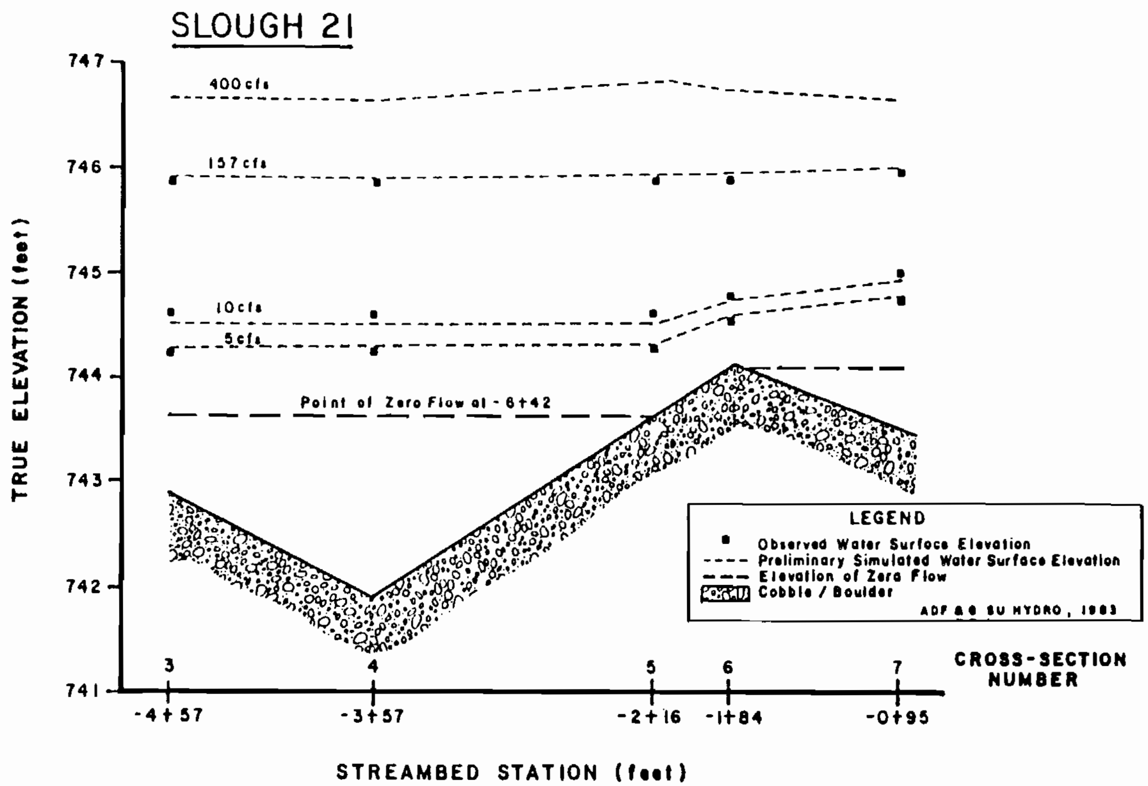


Figure 7-3-15 Comparison of observed and predicted water surface profiles from non-calibrated model at Slough 21 study site.

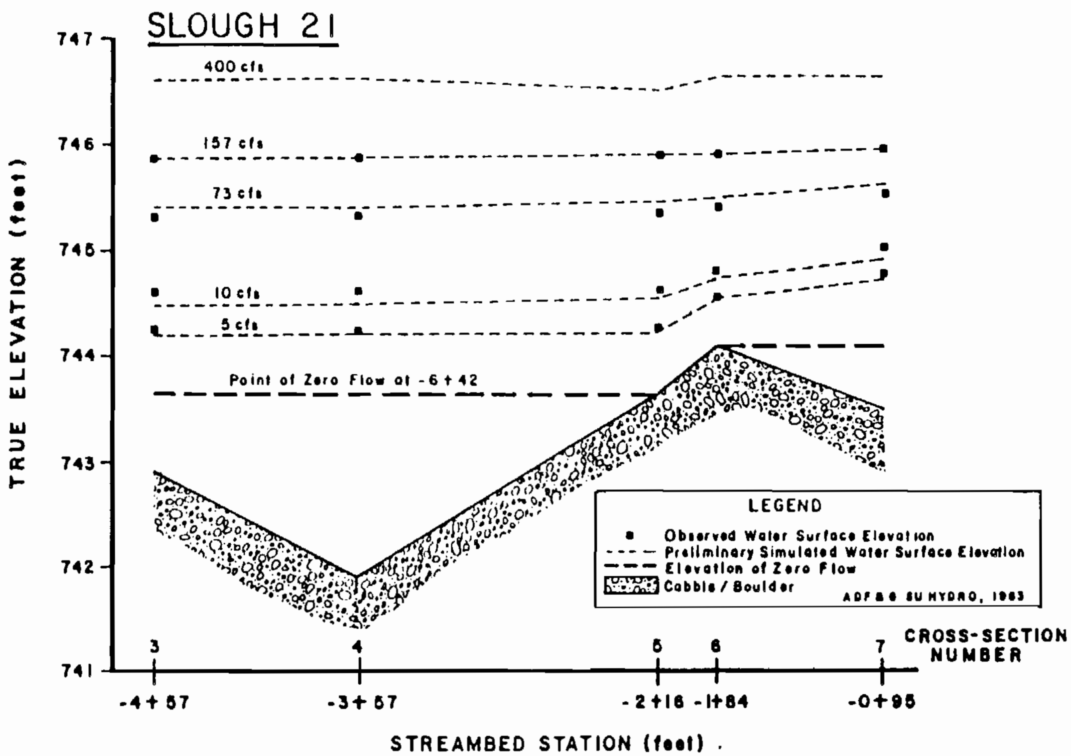


Figure 7-3-16. Comparison of observed and predicted water surface profiles from non-calibrated model at Slough 21 study site.

simulated profiles depart from observed values at the 5, 10, and 73 cfs flows at cross sections 3, 4 and 5.

Because of the differences between observed and predicted water surface profiles, it was decided to separate the data sets and calibrate two IFG-4 hydraulic models; one for low flow conditions using only the 5 and 10 cfs data sets (Figure 7-3-17) and one for high flow conditions using the 10, 73, and 157 cfs data sets (Figure 7-3-18) which correspond to mainstem discharges sufficient to breach Channel A6 Upper and the head of Slough 21.

To evaluate how well the IFG-4 hydraulic models were calibrated, observed and predicted water surface elevations, discharges, and velocities were compared (Appendix Tables 7-A-4 and 7-A-5). The maximum difference in water surface elevation for each calibration flow was 0.03 ft at the five cross sections. The means of the discharges predicted by the IFG-4 hydraulic models were 5, 10, 74, and 157 cfs which agree well with the observed values. The velocity adjustment factors for both models are within acceptable limits, ranging from 0.96 to 1.03.

3.3.2.4 Verification

For Slough 21, the two-flow model (5 and 10 cfs) describing unbreached conditions has an extrapolation range from 4 to 10 cfs. Backwater effects from Channel A6 Upper below cross section 3 were observed above slough flows of 10 cfs. Therefore, the upper extrapolation limit for the two-flow model and the lower extrapolation limit for the three-flow

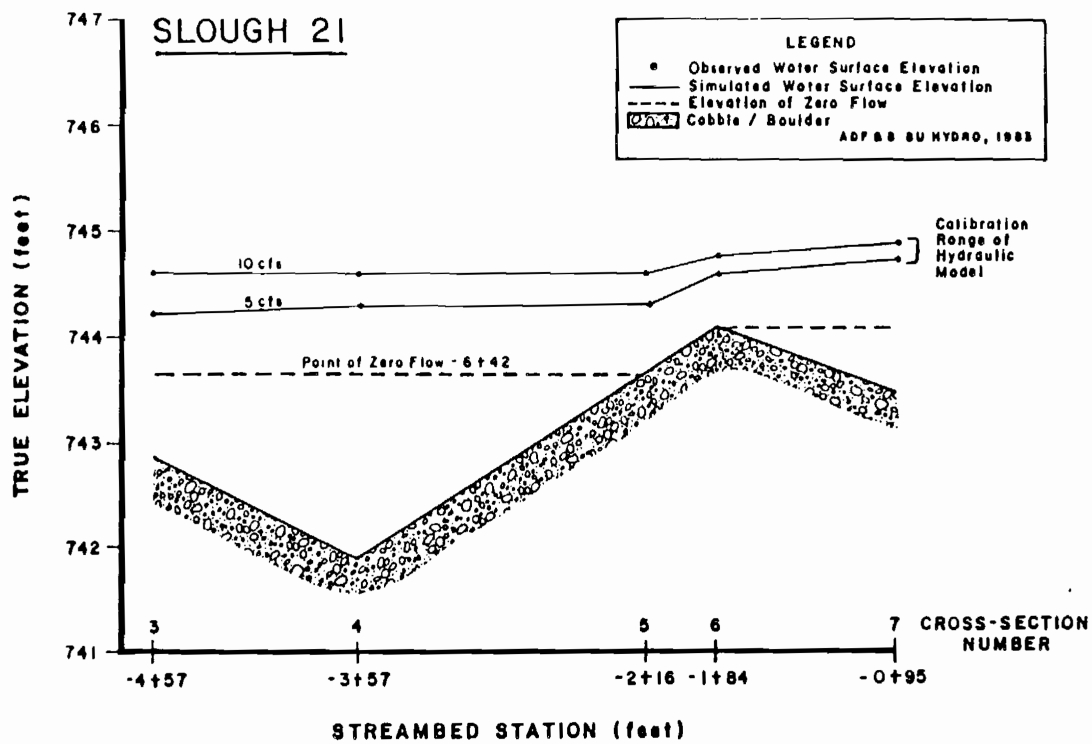


Figure 7-3-17. Comparison of observed and predicted water surface profiles from calibrated model at Slough 21 study site for low flow regime.

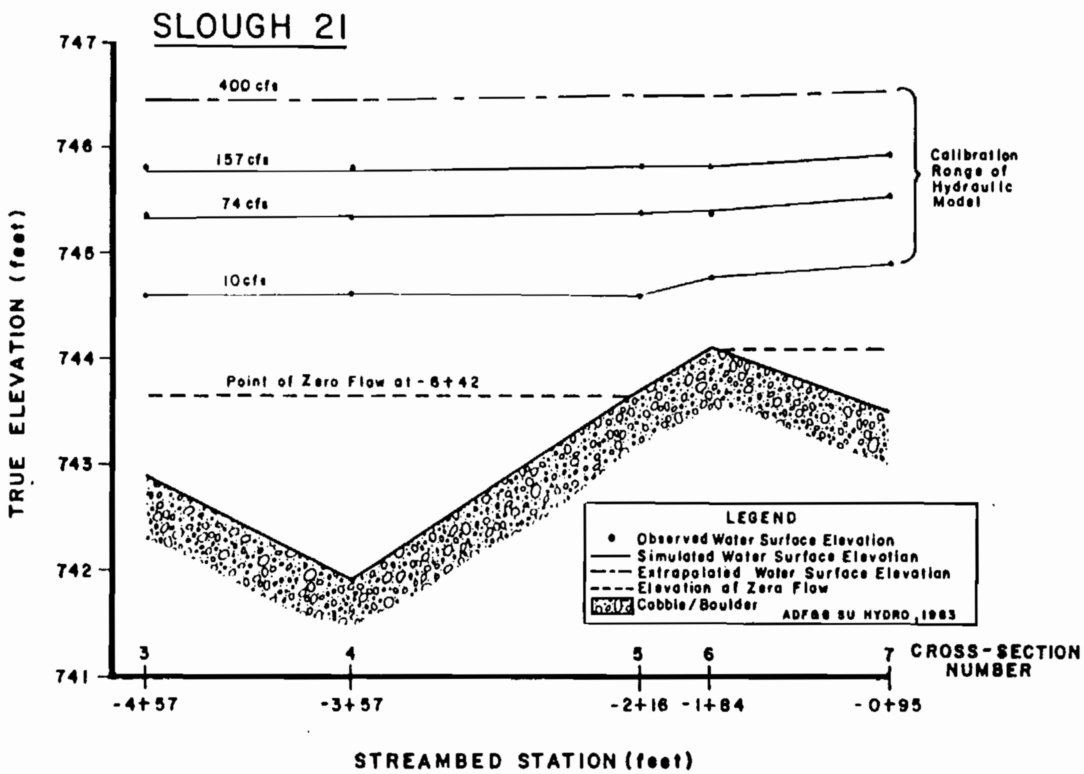


Figure 7-3-18. Comparison of observed and predicted water surface profiles from calibrated model at Slough 21 study site for high flow regime.

model is 10 cfs. The three-flow model (10, 74, and 157 cfs) describing mainstem controlled conditions in Channel A6 Upper and the head of the slough has an extrapolation range from 10 to 400 cfs. This corresponds to Susitna River discharges at Gold Creek of 24,000 to 33,500 cfs (Figure 7-3-19).

A comparison was made between water surface elevations predicted by the IFG-4 hydraulic models for selected flows at the discharge cross section and the empirical rating curve developed by ADF&G (Figure 7-3-20). The regression lines were statistically tested for coincidence and the hypothesis that both lines were the same was not rejected. The Slough 21 high flow model predicts the same relationship at cross section 4 as the empirical curve for the site. The low flow model was also tested for coincidence and the hypothesis was not rejected.

3.3.3.5 Application

The study site in Slough 21 was chosen to represent typical spawning and rearing habitat known to be utilized by salmon (Part 1, Section 2, Figure 2-9). The study site is located 457 ft downstream of the mouth of the slough and should be considered representative of the channel conditions between streambed station -4+57 and 0+00. Because of the pronounced influence of backwater effects associated with breaching flows in Channel A6 Lower, high and low flow hydraulic models were calibrated to represent the hydraulic conditions with and without backwater effects.

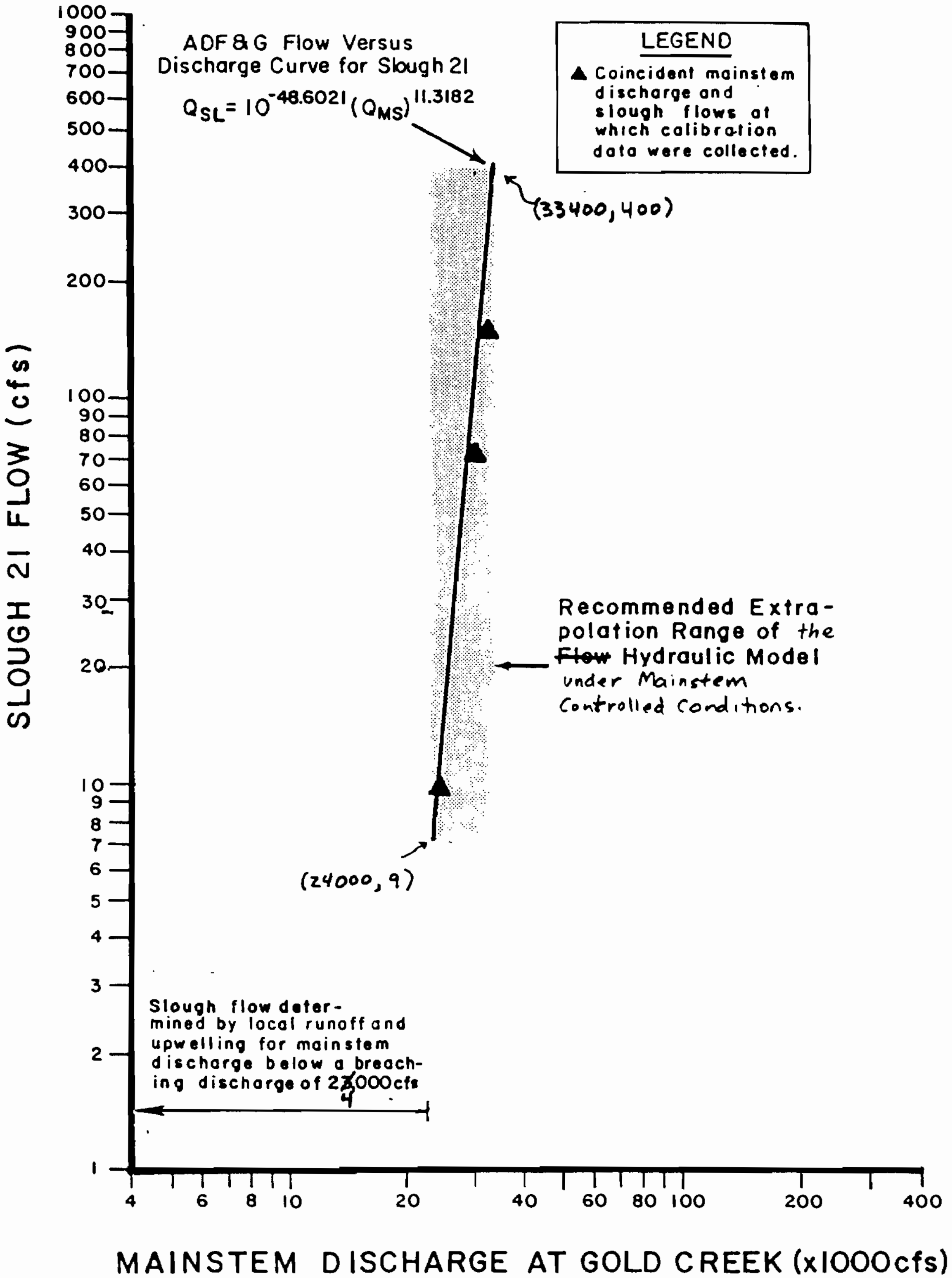


Figure 7-3-19. Relationship between extrapolation range of Slough 21 low and high flow models and ADF&G flow-versus-discharge curve.

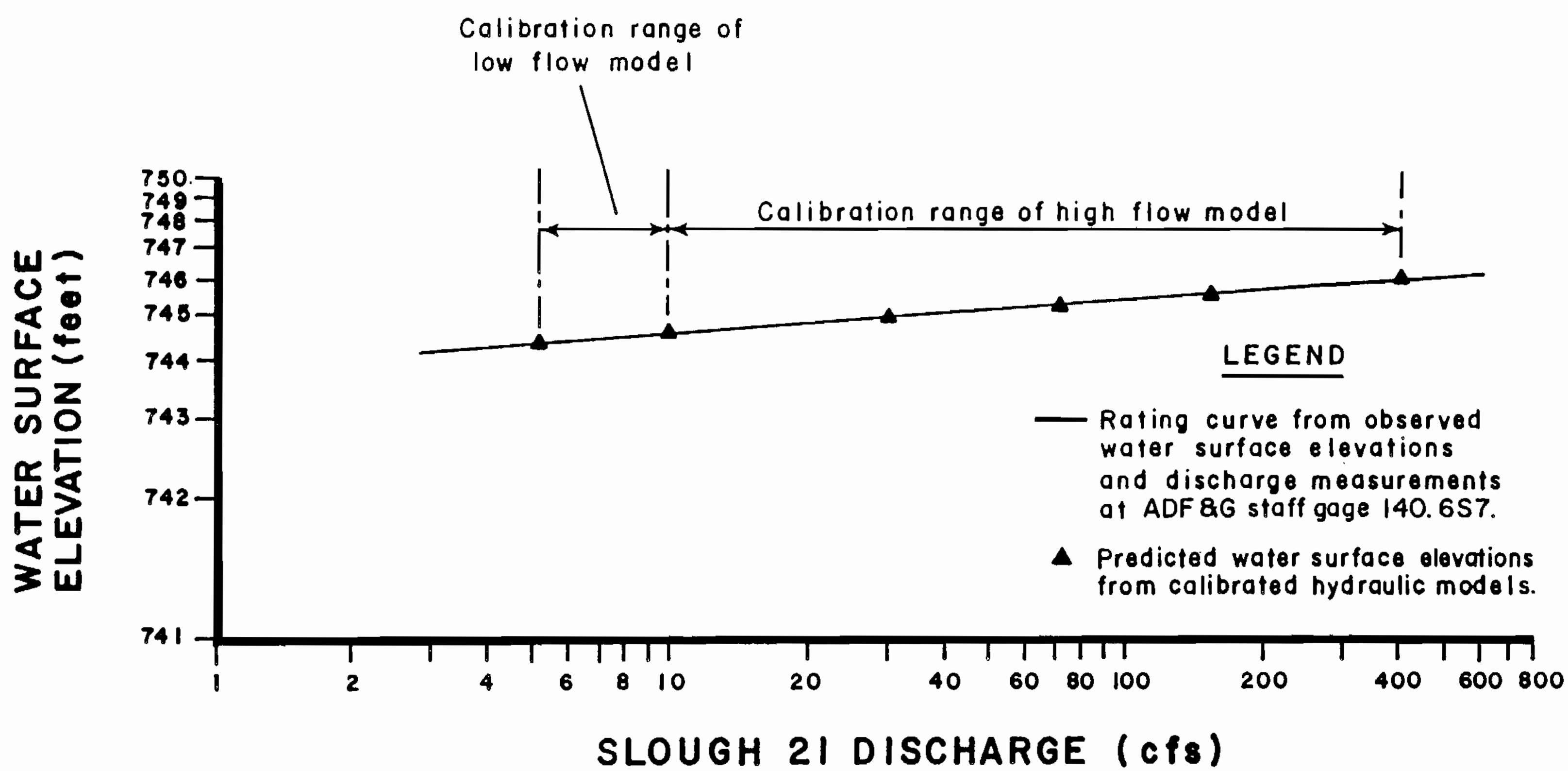


Figure 7-3-20. Comparison between ADF&G rating curve and model predicted water surface elevations.

The high flow model was based on calibration flows of 10, 74, and 157 cfs and is capable of providing reliable estimates of depths and velocities for slough flows between 10 and 400 cfs. Below a 10 cfs slough flow, Channel A6 Upper is breached and backwater effects extend up into the study site. Therefore, the lower limit for the high flow model and the upper limit for the low flow model is 10 cfs. The high flow model should be applied when the mainstem discharge is in the range of 24,000 to 33,500 cfs.

The low flow model was based on calibration flows of 5 and 10 cfs and is capable of providing reliable estimates of depths and velocities for slough flows between 4 and 10 cfs. This model is recommended for use when mainstem discharge is below 24,000 cfs.

3.3.4 Side Channel 10 (River Mile 133.8)

3.3.4.1 Site Description

Four cross sections which define channel geometry for the 1,200 ft study reach (Figure 7-3-21) were surveyed in 1983. A fifth cross section (cross section 4) was later synthesized and included in the study site to better define hydraulic conditions in the upper third of the side channel. Cross sections 1, 3, and 5 describe pool areas, cross sections 2 and 4 riffle areas.

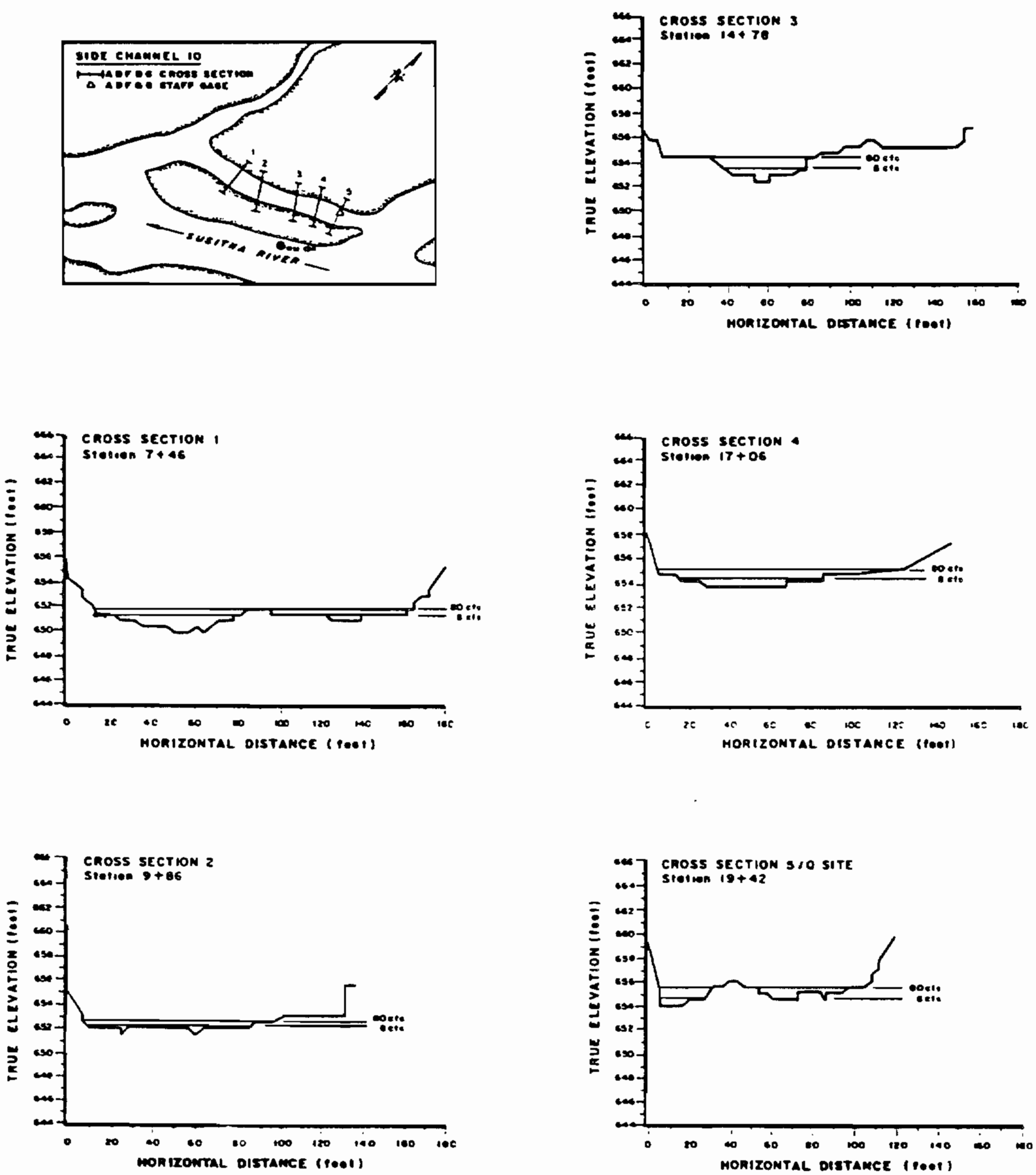


Figure 7-3-21. Cross sections for Side Channel 10 study site depicting water surface elevations at calibration discharges of 8 and 80 cfs.

3.3.4.2 Data Collected

Provisional USGS streamflow data for Gold Creek were used to determine the mean daily discharge on the dates that calibration data were collected at the Side Channel 10 study site (Table 7-3-8).

Table 7-3-8. Calibration data collected at Side Channel 10 study site.

Date	Site Specific Flow (cfs)	Susitna River Discharge (cfs)
830726	8	19,400
830724	78	22,700
830810	785	31,900

3.3.4.3 Calibration

Calibration data were collected at side channel flows of 8, 78, and 785 cfs during 1983. The water surface profile at a 1,500 cfs flow was forecasted to evaluate the predictive capability of the model at the upper limit of its extrapolation range.

The streambed profile, stage of zero flow, and observed and predicted water surface elevations for the study reach are plotted to scale in Figure 7-3-22. The available data were widespread and did not provide a reliable forecast of hydraulic conditions over the flow range being simulated. This was largely due to mainstem flow spilling over the gravel bar and entering the study site between cross sections 1 and 2

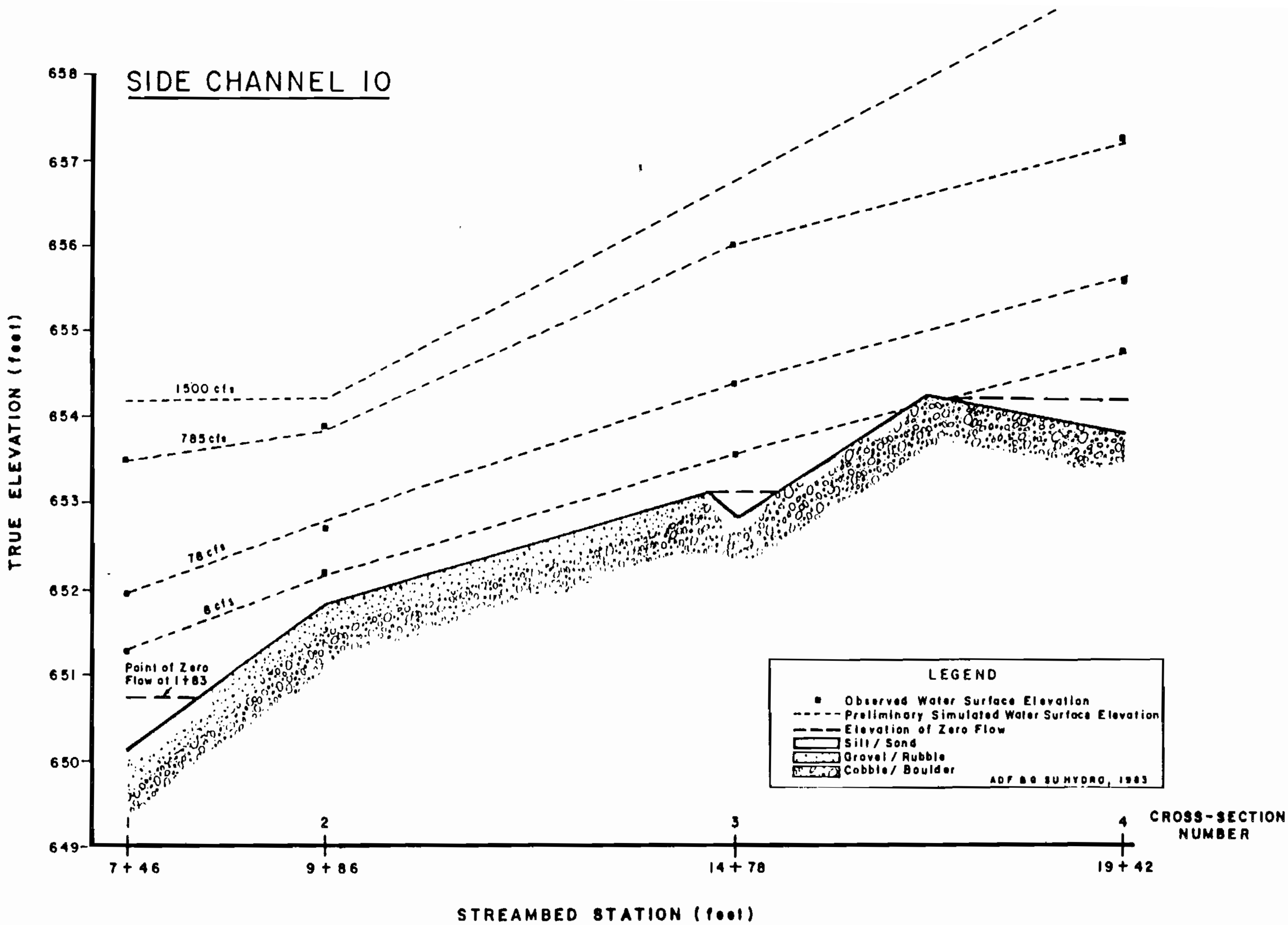


Figure 7-3-22. Comparison of observed and predicted water surface profiles from non-calibrated model at Side Channel 10 study site.

and 2 and 3 at the time the 785 cfs data set was obtained. Thus, the 785 cfs data set was not used in further refinement of the hydraulic model.

A two-flow IFG-4 model was calibrated using the 8 and 78 cfs data sets and a 100 cfs flow was selected as the upper limit of extrapolation. A fifth cross section was added to the original four at streambed station 17+06 using the streambed elevation and stage of zero flow from the surveyed streambed profile. The cross sectional shape was derived from aerial photography and by extrapolating between the cross sections at streambed stations 14+78 and 19+42. The IFG-4 model was calibrated and the resulting water surface profiles are plotted to scale in Figure 7-3-23.

To evaluate the performance of the IFG-4 hydraulic model for Side Channel 10, observed and predicted water surface elevations, discharges, and velocities were compared (Appendix Table 7-A-6). There was no difference in observed and predicted water surface elevations for both calibration flows at the five cross sections. Limited significance should be applied to the results because the data points are at the end of a two-point rating curve. Mean calibration discharges predicted by the two-point IFG-4 hydraulic model were 8 and 80 cfs, respectively. The velocity adjustment factors range from 0.87 to 1.01, which indicates that the models are suitably calibrated.

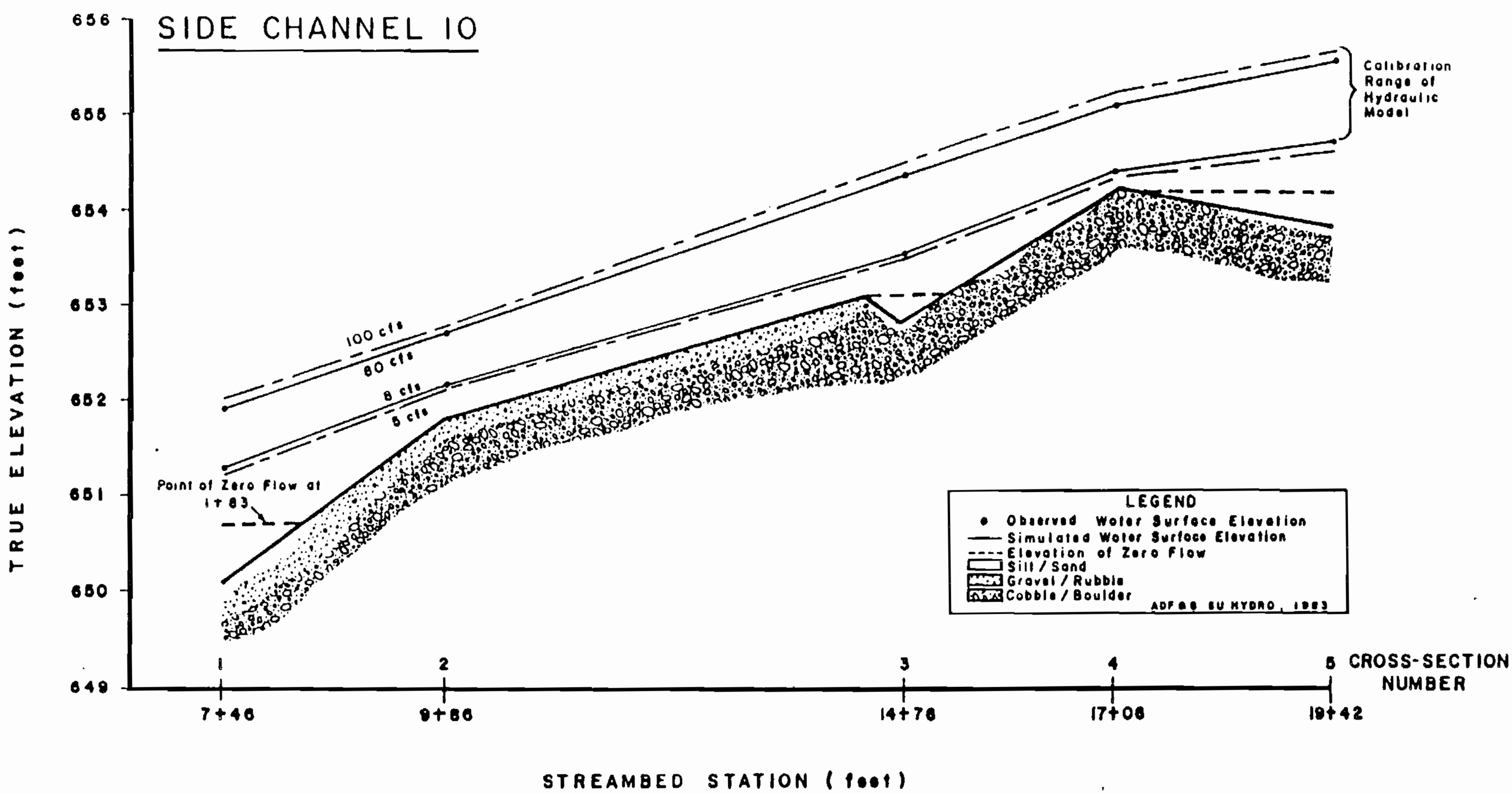


Figure 7-3-23. Comparison of observed and predicted water surface profiles from calibrated model at Side Channel 10 study site.

3.3.4.4 Verification

For the Side Channel 10 hydraulic model, the recommended extrapolation range is from 5 to 100 cfs. Side channel flow of 6 to 100 cfs correspond to Susitna River discharge at Gold Creek from 19,000 to 25,000 cfs (Figure 7-3-24). Below 19,000 cfs, side channel flows are in the area of 5 cfs.

A comparison was made between water surface elevations predicted by the IFG-4 hydraulic model for selected flows at the discharge cross section and the empirical rating curve developed by ADF&G for cross section 5 (Figure 7-3-25). The statistical test for coincidence between both regression lines were made and the hypothesis that both lines were equal was rejected. The water surface elevations for the extrapolated flows were determined from both regression lines and their difference compared (Table 7-3-9). The difference is so slight that the model was considered adequate.

Table 7-3-9. Comparisons between water surface elevations predicted by the IFG-4 Model and the ADF&G rating curve for the extreme calibration flows at the Side Channel 10 study site.

Flow (cfs)	Water Surface Elevation (ft) Model	Rating	Actual Diff.
5	654.56	664.49	0.07
100	655.67	655.77	0.10

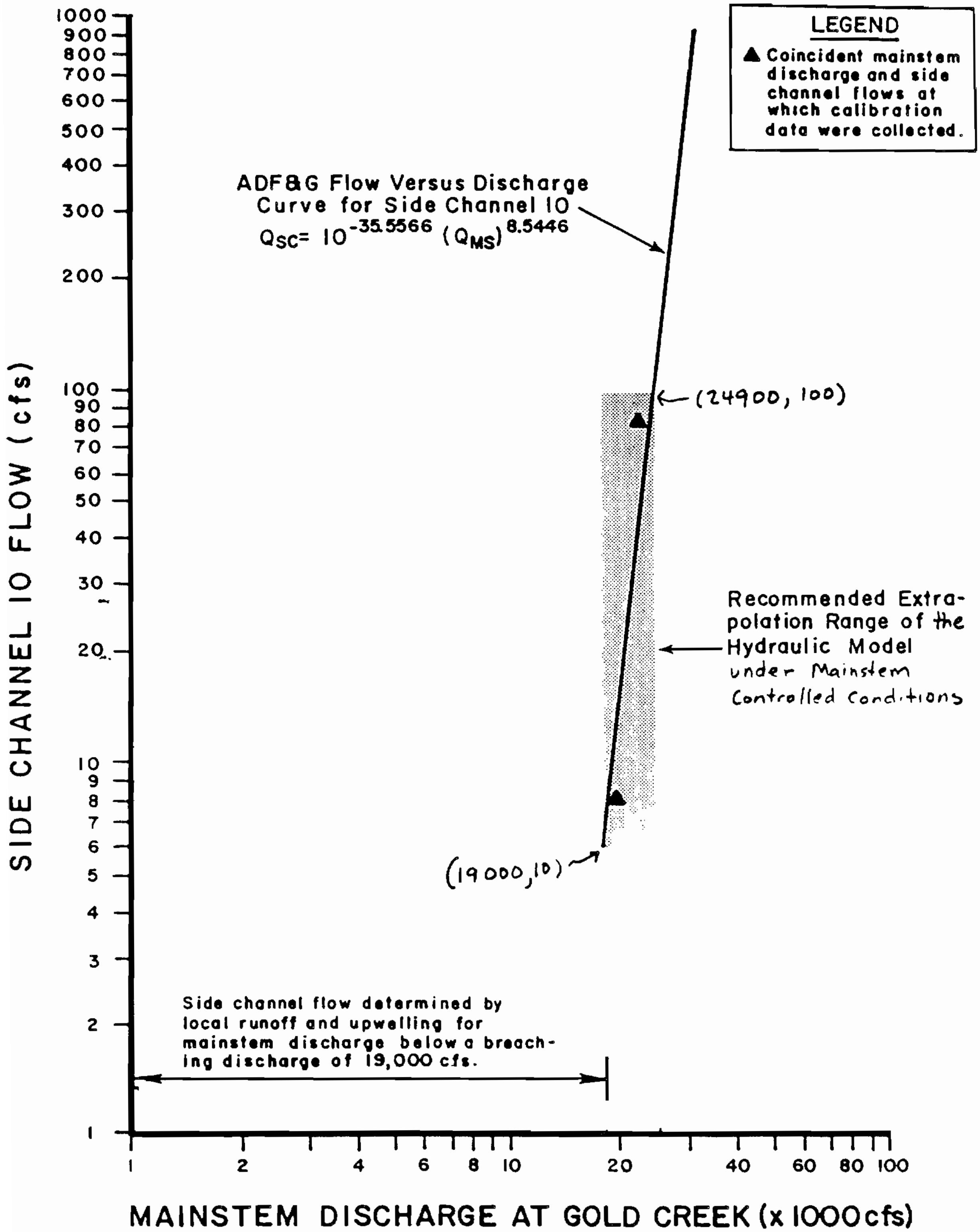


Figure 7-3-24. Relationship between extrapolation range of Side Channel 10 model and ADF&G flow-versus-discharge curve.

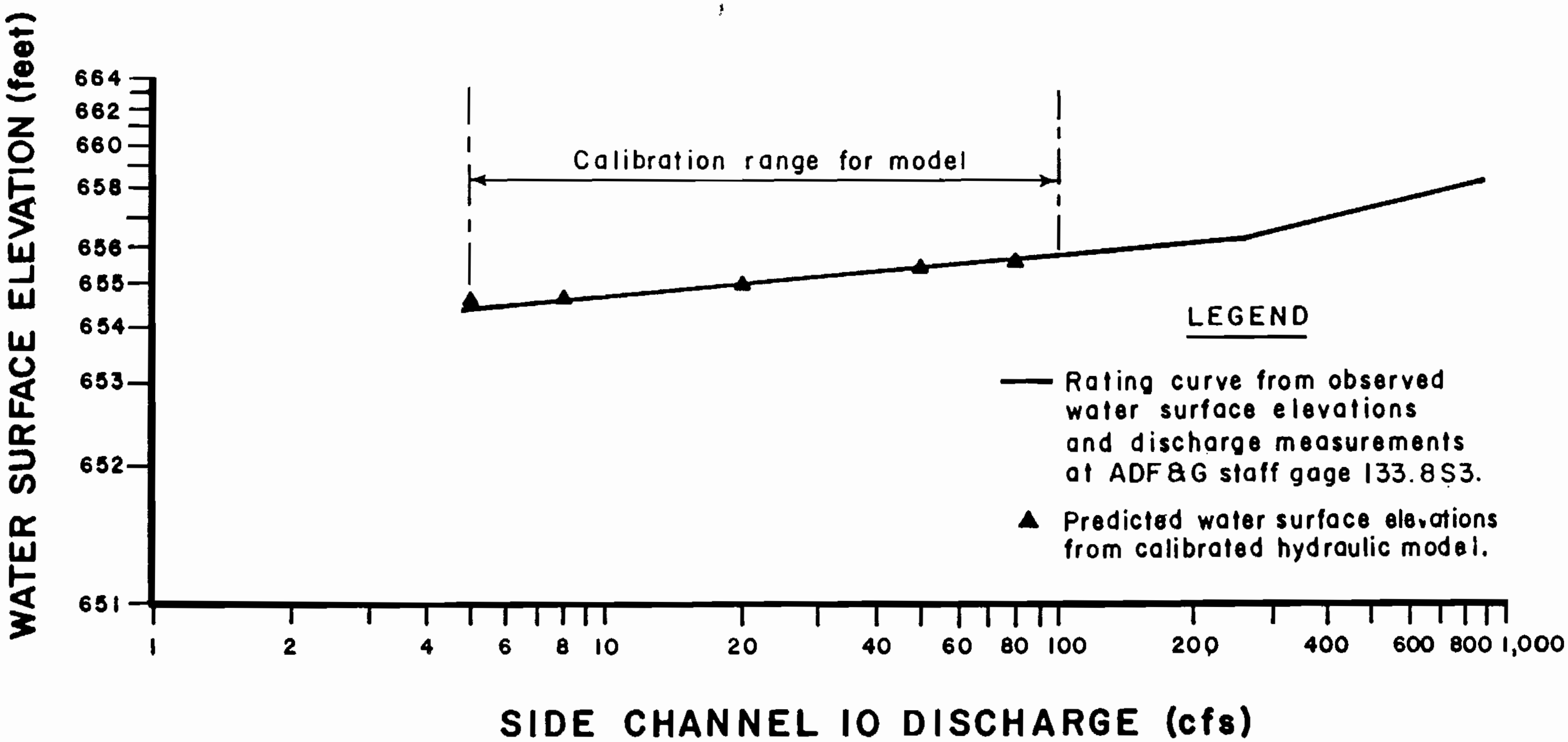


Figure 7-3-25. Comparison between ADF&G rating curve and model predicted water surface elevations.

3.3.4.5 Application

The study site in Side Channel 10 was chosen to represent possible spawning and rearing habitat in the free-flowing portion of the side channel from streambed station 5+00 to 23+00 (Part 1, Section 2, Figure 2-5). In effect, the study site includes the entire free-flowing portion of the side channel and is suitable for forecasting hydraulic conditions for both breached and non-breached conditions. The model is based upon calibration flows of 8 and 80 cfs. It is capable of providing reliable estimates of depths and velocities for side channel flows between and 6 and 100 cfs which correspond to a range of mainstem discharge from 19,000 to 25,000 cfs. However, field observations and supporting data indicate that the gravel bar which separates the side channel from the mainstem is overtopped in two locations at mainstem discharges greater than 30,000 cfs. Consequently, the model is not applicable for this range of mainstem discharges. Caution should be exercised when applying the model to mainstem flows between 25,000 and 30,000 cfs.

Field observations indicate that side channel flow is typically in the range of 3 to 5 cfs when the mainstem discharge is less than 19,000 cfs and not large enough to breach the head of the side channel. Hence, another undefined area exists at this end of the calibration range.

3.3.5 Lower Side Channel 11 (River Mile 134.6)

3.3.5.1 Site Description

The multiple cross section study site at Lower Side Channel 11 was established in June 1983 (Plate 7-2-5). The IFG-2 hydraulic model was selected for use of this site rather than the IFG-4 model because of the size of the channel, the uniform nature of hydraulic conditions at mainstem discharges of 9,000 to 30,000 cfs and its cost-effectiveness (only one data set was needed for model calibration). Five cross sections were surveyed to describe the 1,416 ft study reach (Figure 7-3-26). A sixth cross section at streambed station 3+34 was generated by extrapolation. Cross sections 2, 3, 4, 5, and 6 describe a long run upstream from the hydraulic control which is delimited by cross section 1.

3.3.5.2 Data Collected

On the dates that calibration data were collected at the Lower Side Channel 11 study site, mean daily discharges were determined for the Susitna River at Gold Creek. A site specific flow of 820 cfs with a corresponding Susitna River discharge of 9,400 cfs was collected and September 29, 1983.

3.3.5.3 Calibration

A large gravel bar originates at the left bank facing upstream near cross section 4 and extends diagonally 1,100 ft downstream. At

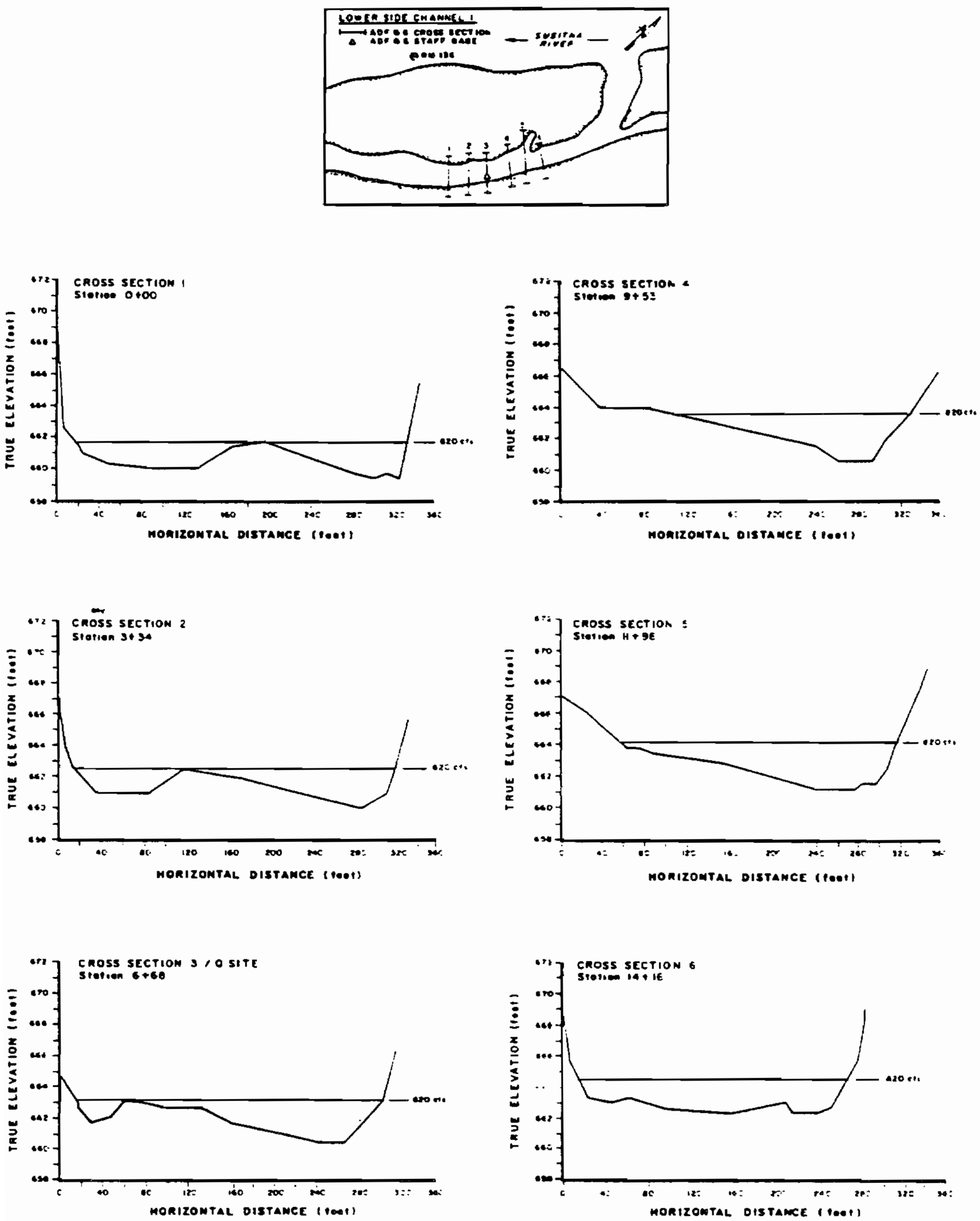


Figure 7-3-26. Cross sections for Lower Side Channel 11 study site depicting water surface elevations at calibration discharge of 820 cfs.

discharges below 16,000 cfs, the gravel bar parallels the direction of flow and extends from cross section 1 upstream through cross section 3. The gravel bar divides the flow into two parallel streams between cross sections 1 and 3, and caused differences of 0.56 ft and 0.85 ft in right and left bank water surface elevations at each cross section, respectively (Figure 7-3-27). Since the IFG-2 model required a horizontal water surface elevation at each cross section, the differences in left and right channel water surface elevations had to be adjusted. The largest portion of flow occurred to the right of the gravel bar. Therefore, the water surface elevations for the right channel (looking upstream) were used as the representative elevation for the entire cross section. However, the depth of flow in the left channel had to be maintained. The mean difference between the right and left channel water surface elevation at a cross section were added to the surveyed streambed coordinates for the left channel. This raised the streambed elevations for the left channel at the cross section so the measured depths in the left channel at the calibration flow would not change but a horizontal water surface was provided at the cross section. This procedure was repeated for cross sections two and three.

The distance between cross sections 1 and 3 appeared too large to adequately define the flow conditions between these sections. A sixth cross section was added at streambed station 3+34. A linear transition in channel geometry was assumed to occur between cross sections 1 and 3 since the instream hydraulic conditions appeared constant. The slope of the streambed was assumed to be approximately the same as that of water surface profile between cross sections 1 and 3.

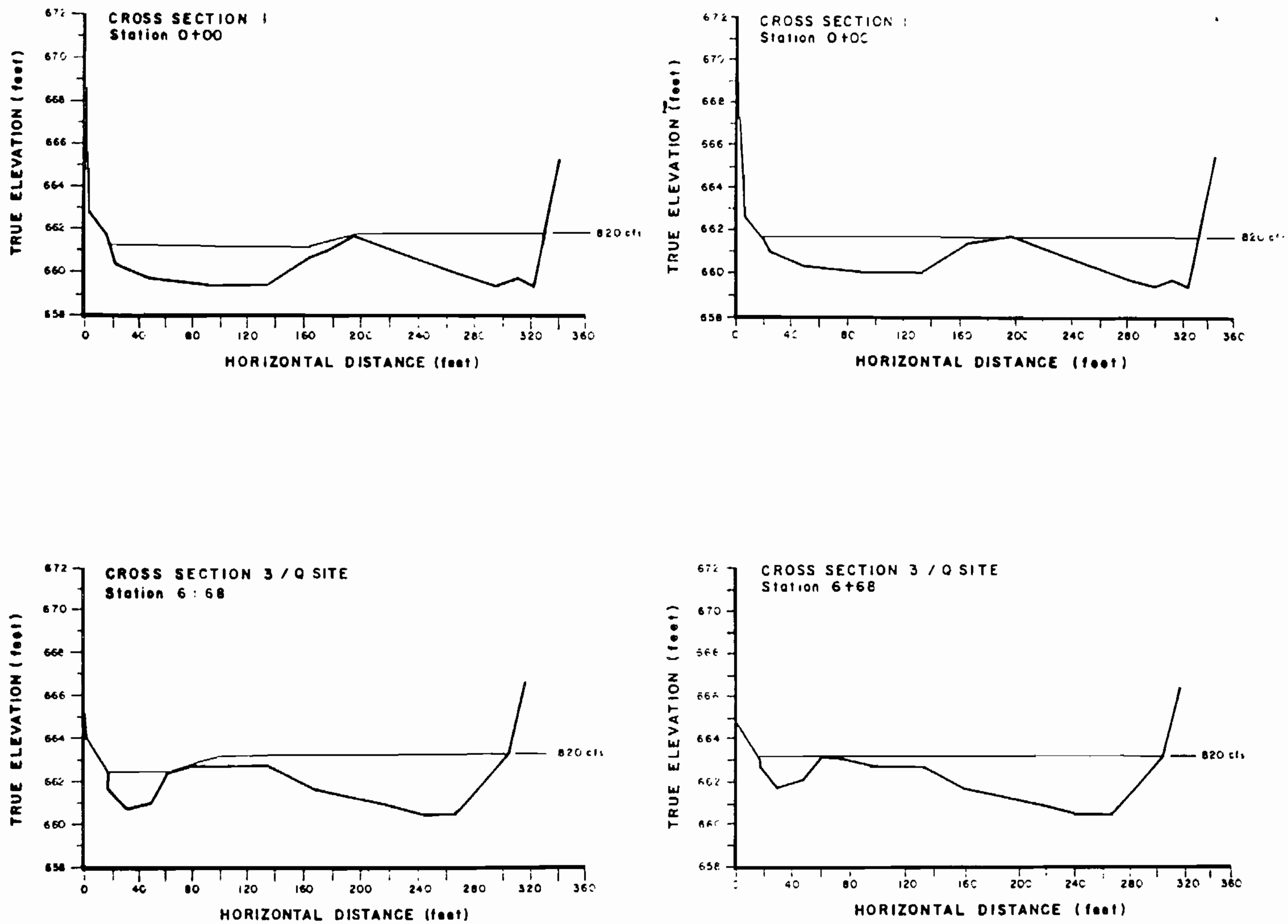


Figure 7-3-27. Comparison between measured and adjusted cross sections 1 and 3 for Lower Side Channel 11 study site.

A rating curve was developed for a staff gage located at cross section 3 and then used to determine the water surface elevations at cross section 1 to forecast a range of flows. The velocity values were assigned by constructing isopleths between cross sections 1 and 3. Water surface profile and depth-velocity data collected at cross sections 1, 3, and 6 were used as the basis for calibrating an IFG-2 model. The Manning's n values were adjusted for each cross segment using a modified version of Manning's equation for the study site:

$$n = C \frac{R^{2/3}}{V}$$

where:

n = roughness coefficient for the cell

C = 1.49 x (the slope of the energy line between adjacent cross sections) $^{1/2}$

R = hydraulic radii, ft

V = mean cell velocity, ft/sec

For a given flow, the slope of the energy line remains constant between adjacent cross sections. The "n" value for each segment of the cross section was adjusted until the predicted water surface elevation and the velocity distribution across the channel agreed with those observed at 820 cfs. Cell velocities were adjusted in a similar manner at those cross sections for which detailed depth and velocity data were not available until the water surface elevations agreed with the predicted value at 820 cfs and the "n" values were similar to those for the adjacent upstream and downstream cross sections. The final water surface profile was plotted to scale (Figure 7-3-28).

3.3.5.4 Verification

The hydraulic model for Lower Side Channel 11 has an extrapolation range from 400 to 2,000 cfs. This corresponds to Susitna River discharges at Gold Creek of 6,000 to 16,500 cfs (Figure 7-3-29).

A comparison was made between water surface elevations predicted by the IFG-2 hydraulic models for selected flows at the ADF&G discharge cross section and the empirical rating curve developed from ADF&G data. The data points from the model were found to be on the curve. This is indicative of a precise correspondence between the model and the rating curve (Figure 7-3-30).

3.3.5.5 Application

The study site in Lower Side Channel 11 was chosen to represent potential spawning and rearing habitat in that portion of the side channel which extends from cross section 1 upstream to the mouth of Slough 11; a distance of 1.1 miles. The model is based upon a calibration flow of 820 cfs and is capable of providing reliable estimates of depths and velocities for side channel flows between 400 and 2,000 cfs. This corresponds to mainstem discharge at Gold Creek ranging from 6,000 to 16,500 cfs.

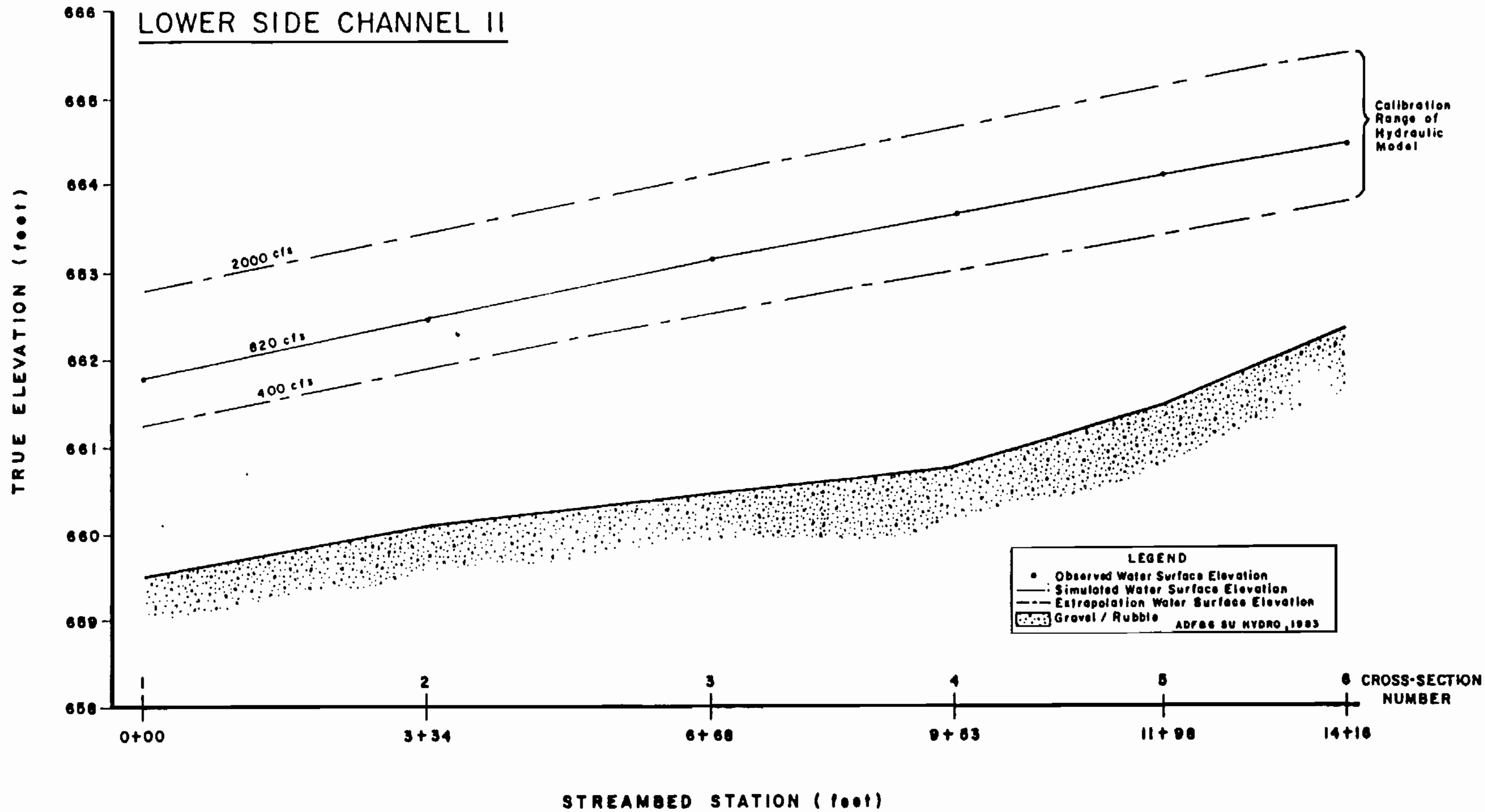


Figure 7-3-28. Comparison of observed and predicted water surface profiles from calibrated model at Lower Side Channel 11 study site.

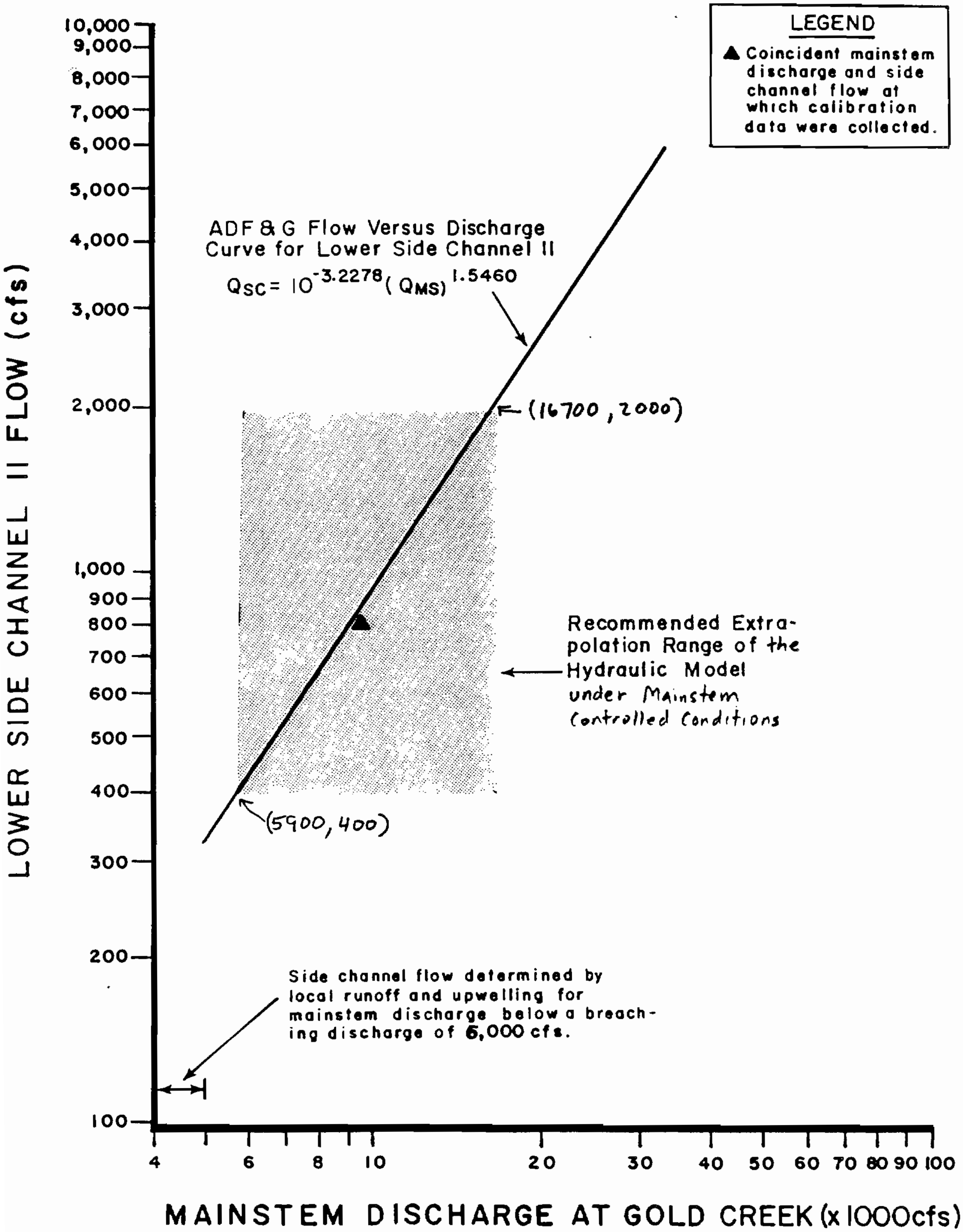


Figure 7-3-29. Relationship between extrapolation range of Lower Side Channel 11 model and ADF&G flow-versus-discharge curve.

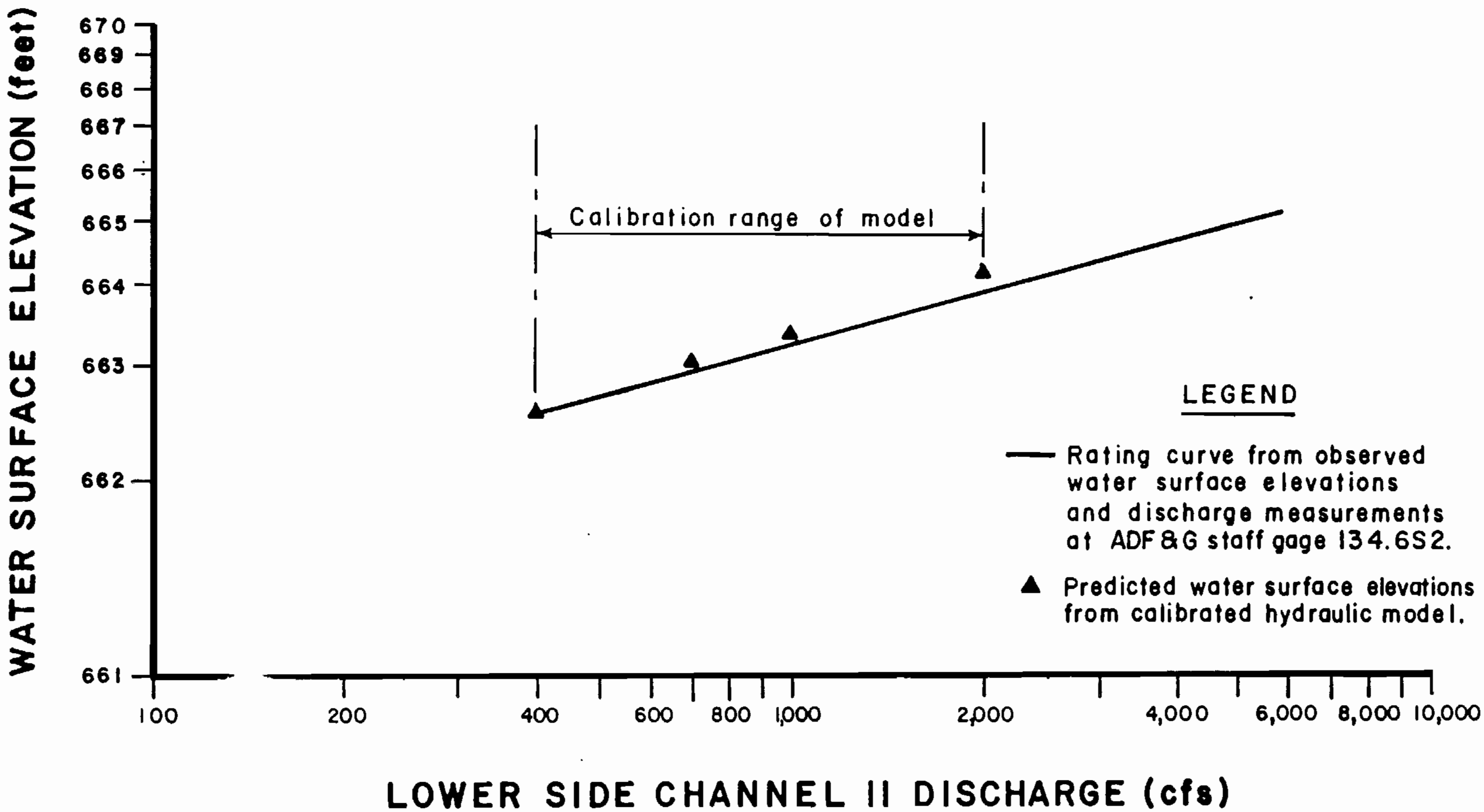


Figure 7-3-30. Comparison between ADF&G rating curve and model predicted water surface elevations.

To extrapolate beyond this range, small changes in the roughness coefficients can be made. Manning's n values could be adjusted in the model until the forecasted water surface elevations fit the water surface elevation-versus-discharge curve for the study site. Application of this procedure would give a reasonable approximation of depths and velocities within the study reach when mainstem discharges at Gold Creek were less than 6,000 or greater than 16,500.

3.3.6 Upper Side Channel 11 (River Mile 136.0)

3.3.6.1 Site Description

The study site at Upper Side Channel 11 was established in June 1983 to obtain the minimum field data necessary to calibrate an IFG-4 hydraulic simulation model (Plate 7-2-6). Four cross sections were located to define channel geometry for the 1,040 ft study reach (Figure 7-3-31). Cross sections 1 and 2 describe the upper extent of the backwater zone; cross section 3 the transition area between the backwater zone and a long riffle; and cross section 4 the riffle.

3.3.6.2 Data Collected

Mean daily discharge at Gold Creek on the dates calibration data were collected at the Upper Side Channel 11 study site were determined from provisional USGS streamflow data (Table 7-3-10).

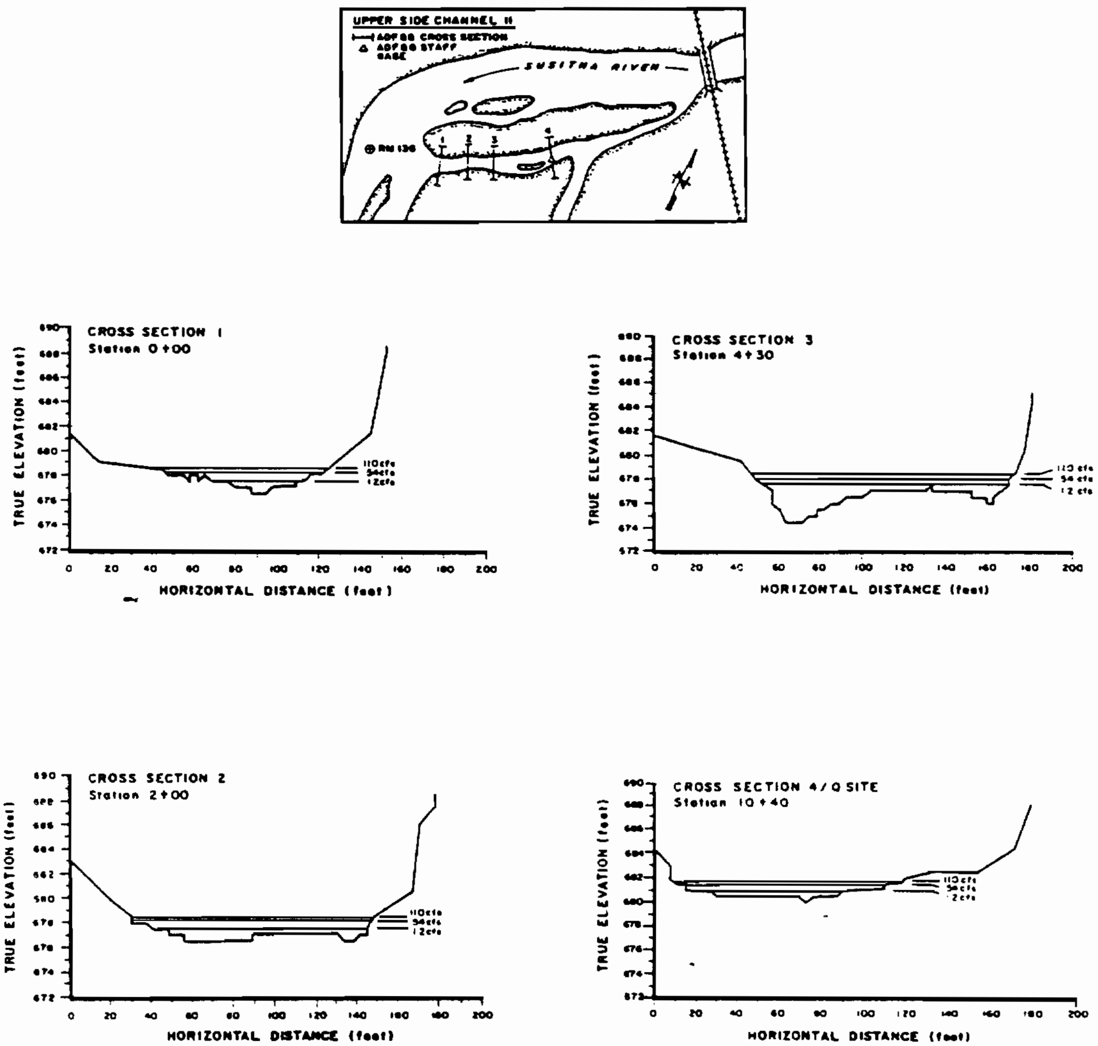


Figure 7-3-31. Cross sections for Upper Side Channel 11 study site depicting water surface profiles at calibration discharges of 12, 54, and 110 cfs.

Table 7-3-10. Calibration data collected at Upper Side Channel 11 study site.

Date	Site Specific Flow (cfs)	Susitna River Discharge (cfs)
830914	2	10,700
830712	54	19,700
830608	107	22,000

3.3.6.3 Calibration

Three sets of field data were collected at the study site for side channel flows of 2, 54, and 107 cfs. These data were used to calibrate an IFG-4 model. Water surface elevations corresponding to the three calibration flows were forecast as well as the water surface profile for a side channel flow of 250 cfs. This flow was selected to evaluate the predictive capability of the model at the upper limit of the recommended extrapolation range for a three-flow IFG-4 model. The streambed profile, stage of zero flow, and observed and predicted water surface elevations are plotted to scale in Figure 7-3-32. Differences between the observed and predicted water surface elevations at 2 cfs were as large as 0.07 ft, and the predicted water surface profile for 250 cfs was not considered reliable. The field data were re-examined and it was determined that the 2 cfs data set was obtained at a side channel flow too small to be reliably used in the hydraulic model. Therefore, this data set was deleted and the model calibrated using only the 54 and 107 cfs data sets. Water surface profiles for flows of 10 and 250 cfs were forecast and plotted to scale. The predicted depths and velocities at 10 cfs were compared to the measured values in the 2 cfs data set.

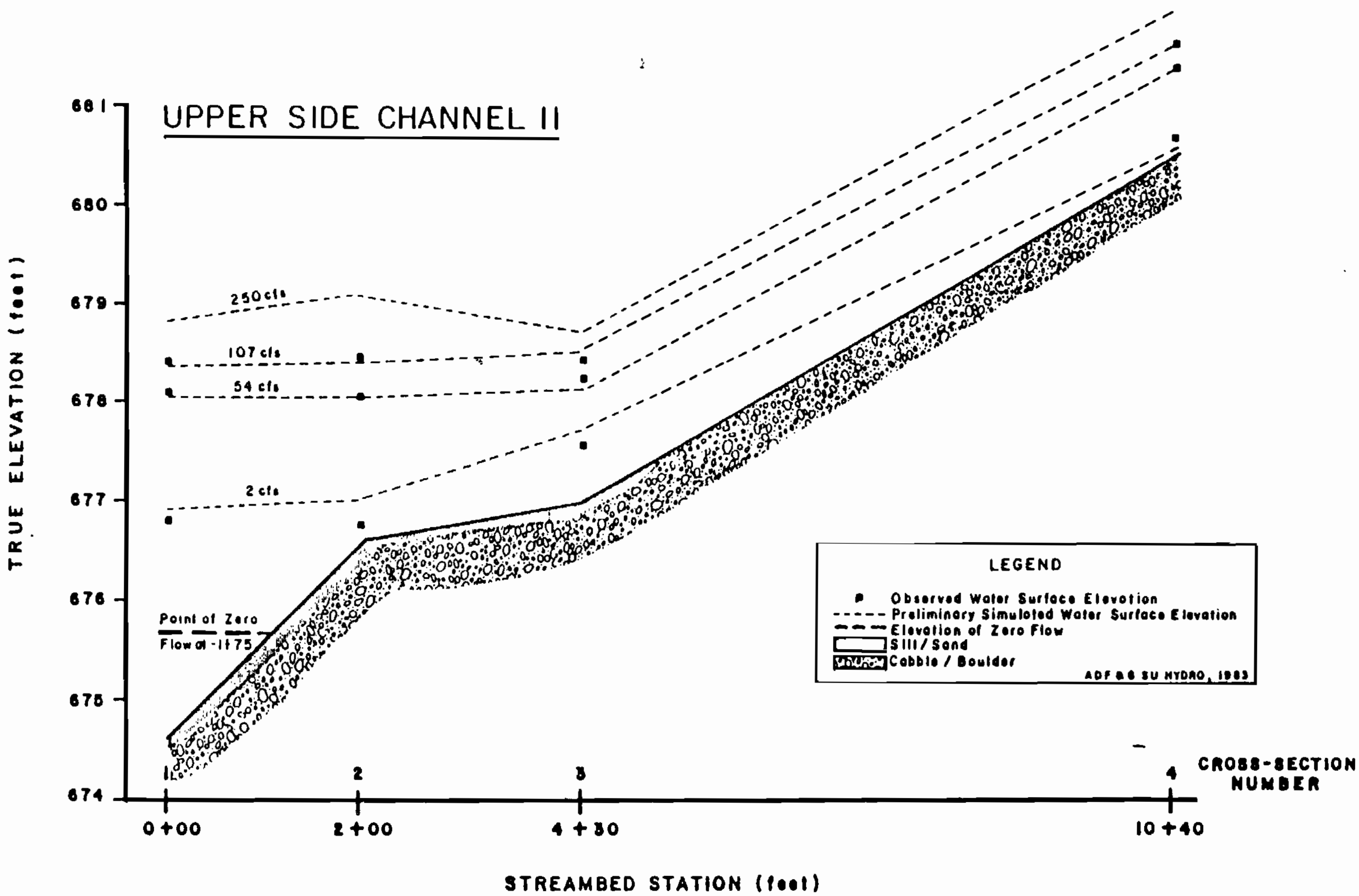


Figure 7-3-27. Comparison of observed and predicted water surface profiles from non-calibrated model at Upper Side Channel 11 study site.

Velocity distribution patterns were similar to observed values and depths, as expected, were slightly greater than observed. Thus, the depths and velocities for a flow of 10 cfs was accepted as being a more reasonable estimate of hydraulic conditions near the low end of the calibration range for the model than the 2 cfs data set. The 10 cfs flow was therefore used as a synthesized calibration data set. In this manner sufficient data were obtained to calibrate a three-flow IFG-4 model for the study site. The water surface profiles forecast by the model are provided as Figure 7-3-33.

To evaluate the reliability of the IFG-4 hydraulic model calibrated for Upper Side Channel 11, observed and predicted water surface elevations, discharges, and velocities were reviewed (Appendix Table 7-A-7). The maximum difference in water surface elevations for each calibration flow was 0.01 ft at the four cross sections. Means of the discharges predicted by the model were 12, 54 and 110 cfs, in comparison with input values of 10, 54, and 107 cfs. The velocity adjustment factors for the model were in the range from 0.96 to 1.06.

3.3.5.4 Verification

For Upper Side Channel 11, the three-flow hydraulic model (12, 54 and 110 cfs), has an extrapolation range from 5 to 250 cfs. The channel breaches at a mainstem discharge of 16,000 cfs. The model is calibrated for Susitna River discharges ranging from 16,000 to 25,000 cfs, which corresponds to a side channel flow of 25 to 250 cfs (Figure 7-3-34). Side channel flow under unbreached conditions ranges from 5 to 25 cfs.

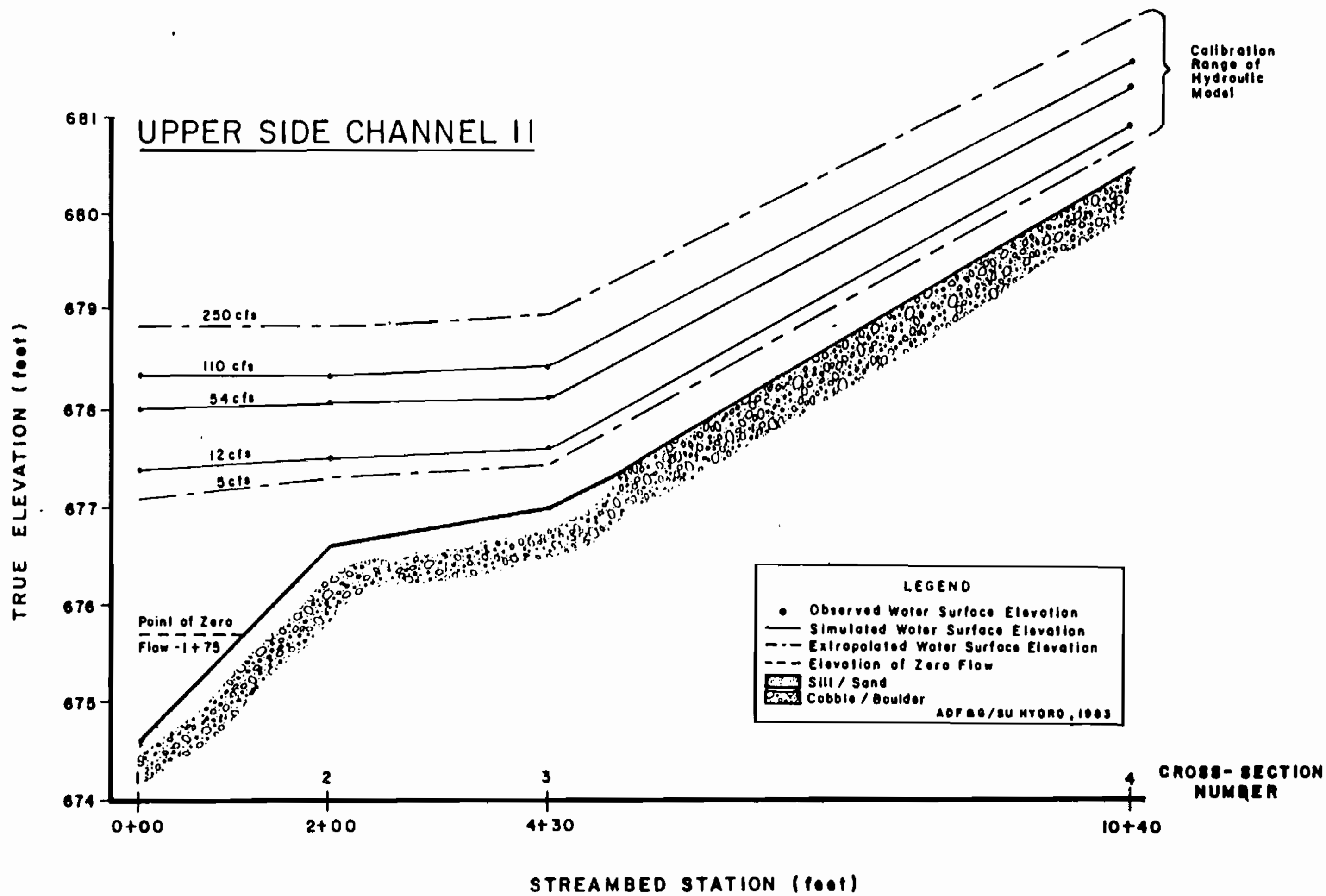


Figure 7-3-33. Comparison of observed and predicted water surface profiles from calibrated model at Upper Side Channel 11 study site.

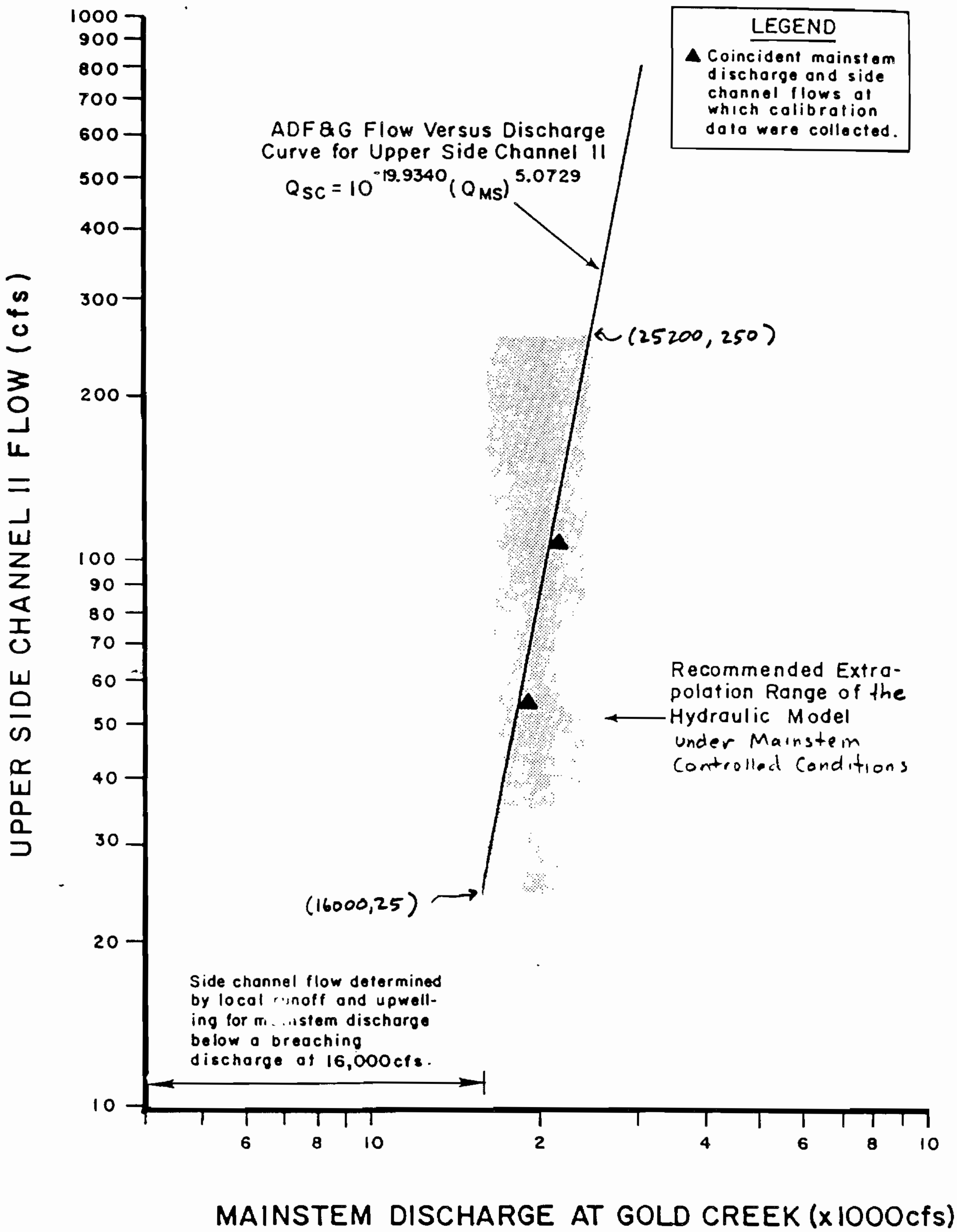


Figure 7-3-34. Relationship between extrapolation range of Upper Side Channel 11 model and ADF&G flow-versus-discharge curve.

A comparison was made between water surface elevations predicted by the IFG-4 hydraulic model for selected flows at the discharge cross section and the empirical rating curve developed by ADF&G (Figure 7-3-35). The statistical test for coincidence between the two regression lines was completed for the Upper Side Channel 11 model. The hypothesis that the lines were the same was rejected. The differences in water surface elevations at the extreme extrapolated flows was minimal, an indication that the synthesized data was adequate (Table 7-3-11).

Table 7-3-11. Comparisons between water surface elevations predicted by the IFG-4 model and the ADF&G rating curve for the extreme calibration flows AT THE Upper Side Channel 11 study site.

Flow (cfs)	Water Surface Elevation (ft) Model	Rating	Acutal Diff.
5	680.72	680.61	0.11
250	681.87	681.94	0.07

3.3.5.5 Application

The study site in Side Channel 11 was chosen to represent a known chum salmon spawning area and possible salmon rearing habitat in the free-flowing portion of the side channel from streambed station 4+30 to 22+32 (Part 1, Section 2, Figure 2-7). The model is based upon calibration flows of 12, 54 and 110 cfs and is suitable for forecasting hydraulic conditions for both breached and non-breached conditions. It has been calibrated to reliably forecast depths and velocities

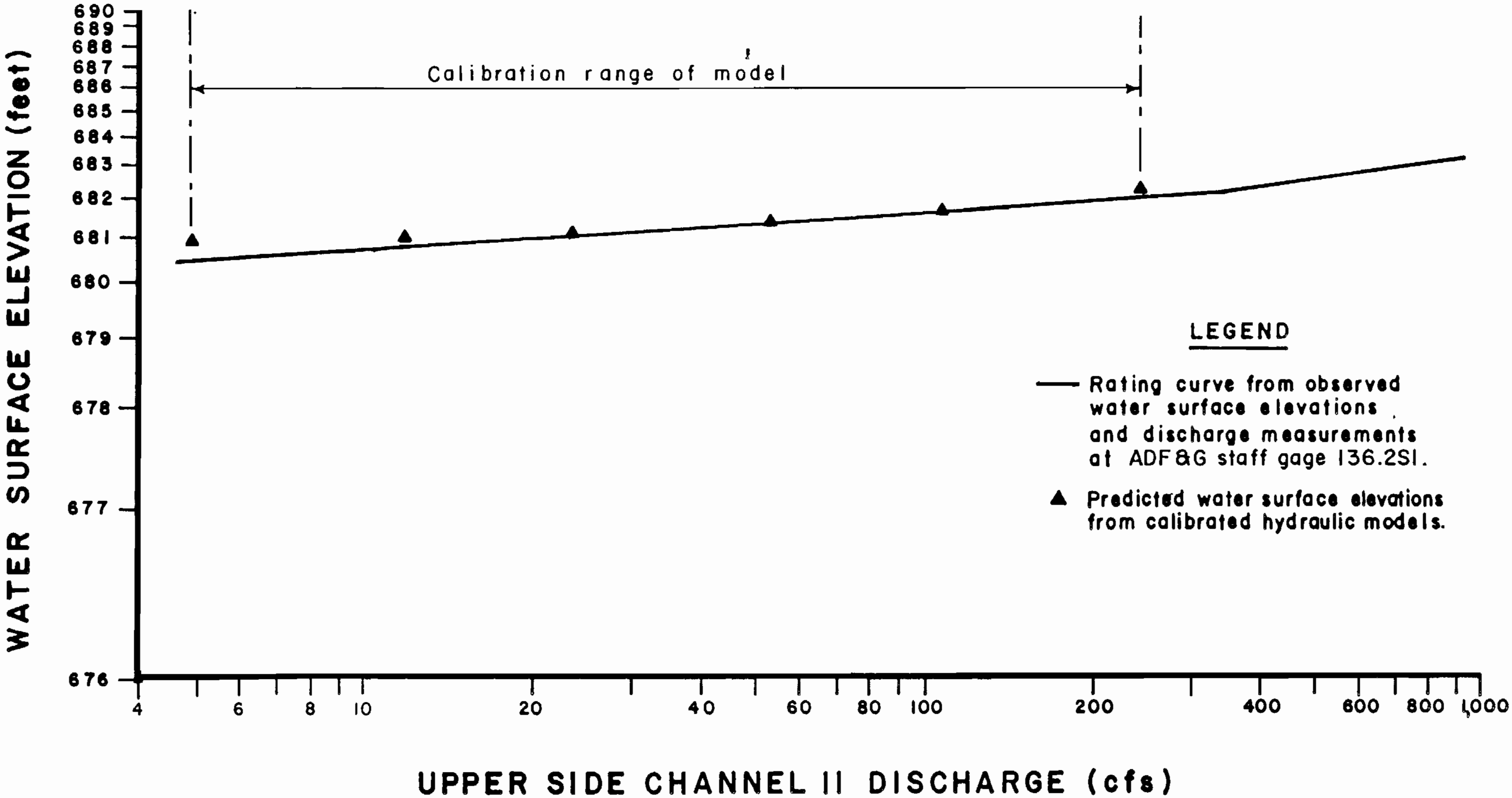


Figure 7-3-35. Comparison between ADF&G rating curve and model predicted water surface elevations.

associated with side flows between 5 and 250 cfs. This corresponds to mainstem discharge up to 25,000 cfs. Field observations indicate that side channel flow is approximately 2 cfs when the mainstem discharge is not large enough to control the side channel (less than 16,000 cfs). During side channel flows, when the channel is first breached, a backwater area caused by the mainstem exists in the lower portion of the study site. Therefore, data from cross sections 1 and 2 should not be applied to any other segments in the side channel. Data from cross sections 3 and 4 can be applied to the free-flowing portion of the side channel from streambed station 4+30 to 22+32.

3.3.7 Side Channel 21 (River Mile 141.2)

3.3.7.1 Site Description

A multiple cross section study site was established in the Side Channel 21 study reach in June 1983 (Plate 7-2-7). Five cross sections define the channel geometry for this 886 ft study reach (Figure 7-3-36). As explained in the description of the Slough 21 study site, the streambed stationing for the Slough 21 Complex is referenced to the mouth of Slough 21. Therefore, the station of each cross section in the study reach represents its distance downstream from the mouth of Slough 21 and is reported as a negative value. Cross sections 1 and 5 describe pool areas. Cross sections 2 and 4 are located in the transition areas between the pools and the riffle that is defined by cross section 3.

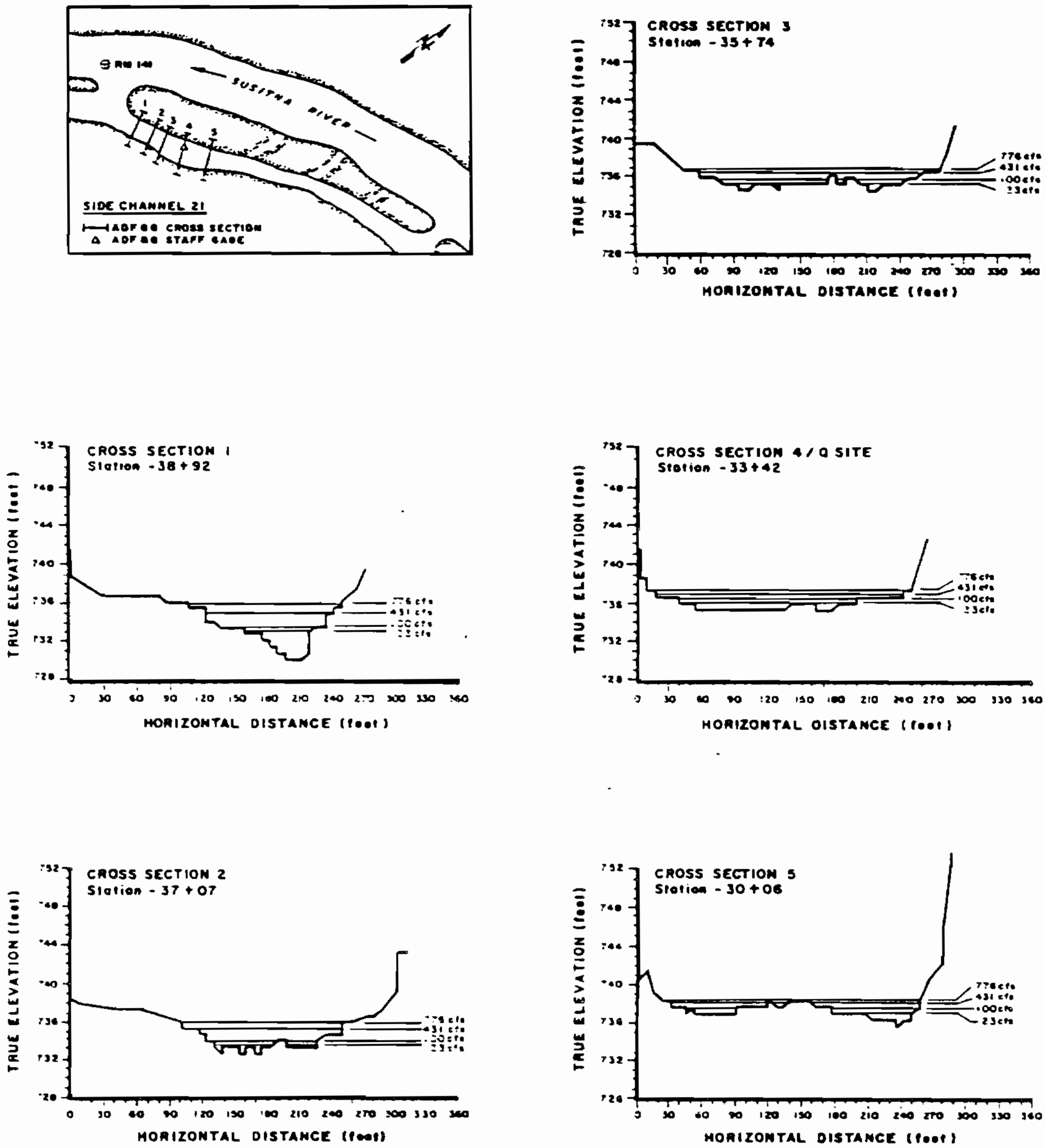


Figure 7-3-36. Cross sections for Side Channel 21 study site depicting water surface profiles at calibration discharges of 23, 100, 431, and 776 cfs.

3.3.7.2 Data Collected

Mean daily discharge for the Susitna River on the dates that calibration data were collected at the Side Channel 21 study site were determined from provisional USGS streamflow data (Table 7-3-12).

Table 7-3-12. Calibration data collected at Side Channel 21 study site.

Date	Site Specific Flow (cfs)	Susitna River Discharge (cfs)
830914	23	10,700
830711	426	20,000
830606	775	26,000

3.3.7.3 Calibration

Calibration data were collected at side channel flows of 23, 426, and 775 cfs. These data were used to calibrate an IFG-4 model. A gravel bar extends diagonally through the study reach and forms the riffle at cross section 3. At low side channel flows, the angle of flow is altered and differences as large as 0.60 ft occur between left and right bank water surface elevations. Since the IFG-4 model requires a horizontal water surface elevation at each cross section, the 0.60 ft difference in right and left bank water surface elevations had to be adjusted. The largest portion of flow occurred to the right of the gravel bar, therefore the streambed elevations used in the IFG-4 model for cross section 3 were determined by subtracting the measured depth of flow at each vertical from the right bank water surface elevation associated with the 23 cfs discharge. The streambed profile, elevation of zero flow, and observed and predicted water surface elevations for the study reach were plotted to scale (Figure 7-3-37).

The backwater effects at cross sections 1 and 2 can be observed for the 775 cfs flow. Because of the large gap between the 23 and 426 cfs data sets and the divergence between predicted and observed water surface elevations, an additional data set was simulated. A side channel flow of 100 cfs was selected as approximating the side channel flow which fully wetted the streambed and served as the transition between low flow and high flow regimes.

A two-flow IFG-4 model was prepared for high flow conditions based on the 426 and 775 cfs data sets and used to predict a water surface profile at 100 cfs (Figure 7-3-38). This profile was as much as 0.65 ft lower at cross section 1 than the profile forecast by the three-flow model previously calibrated using flows of 23, 426, and 775 cfs. However, at the upstream cross sections, both predicted water surface profiles compared favorably. The mean of these two predicted water surface elevations were used as the representative profile for a 100 cfs synthesized data set. Little difference existed between the magnitude of the velocities simulated by either model for 100 cfs. Therefore, the velocities predicted by the three-flow model were used with the 100 cfs profile, thus forming a four-flow hydraulic model for the study reach.

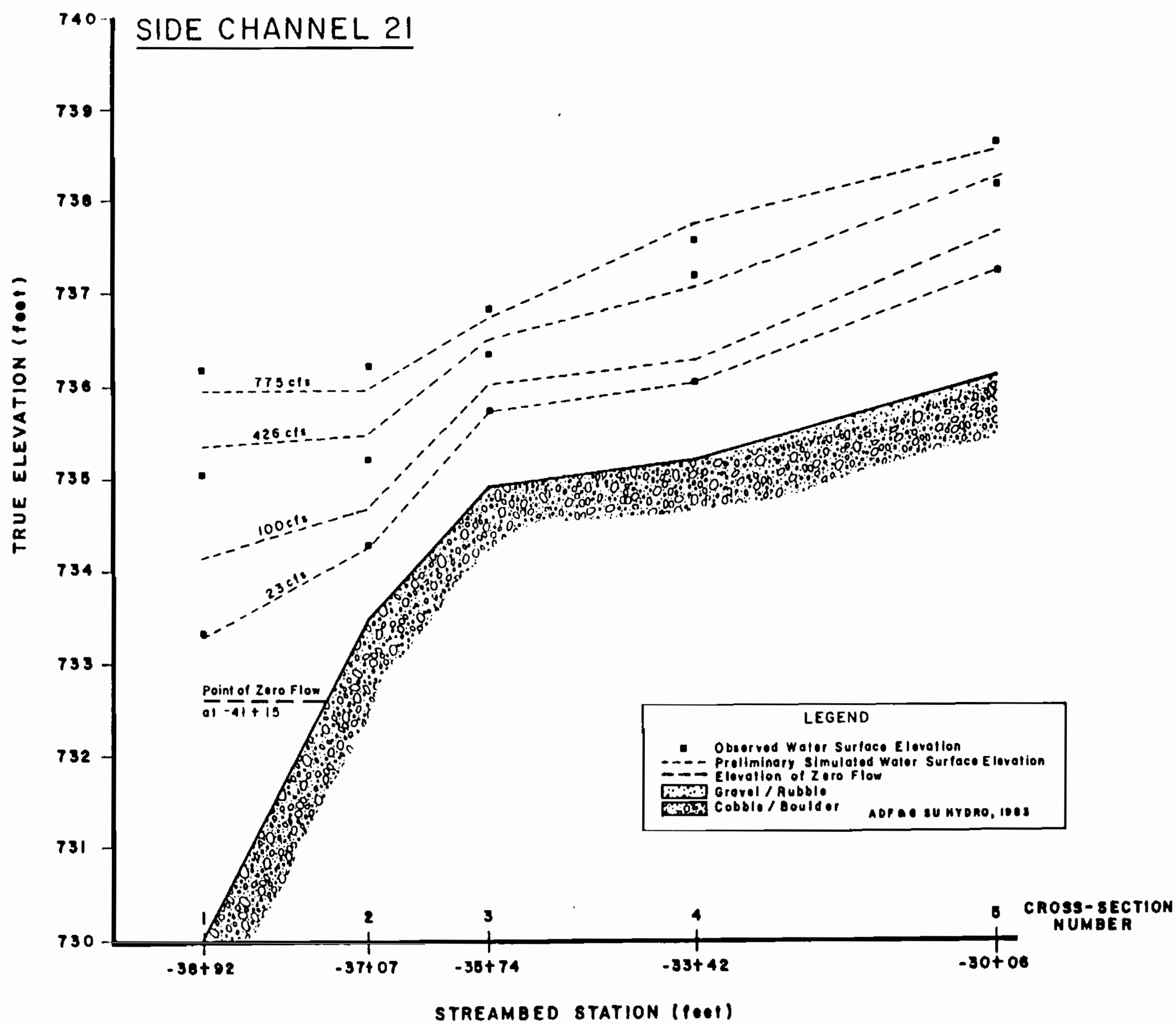


Figure 7-3-37. Comparison of observed and predicted water surface profiles from non-calibrated model at Upper Side Channel 21 study site.

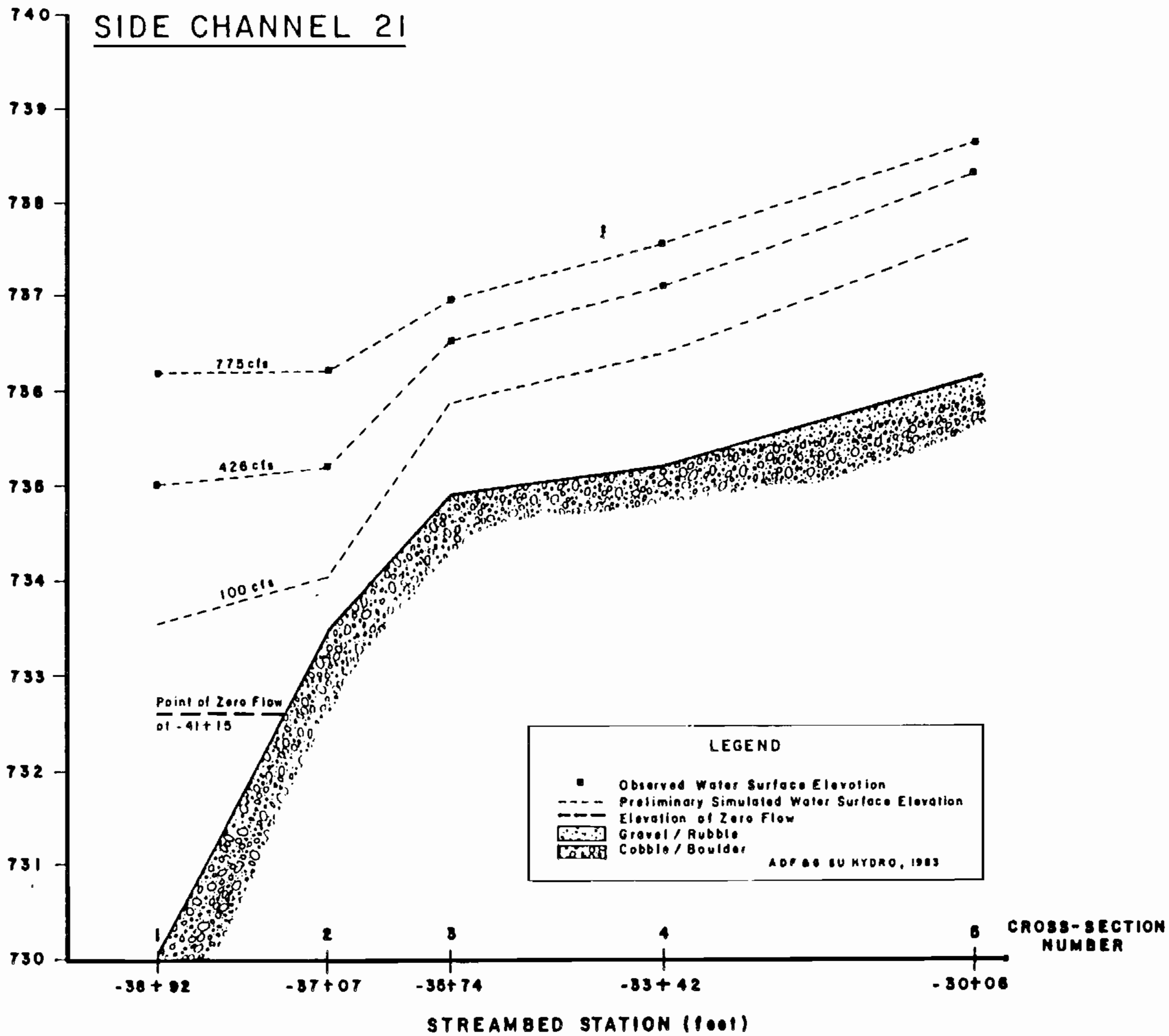


Figure 7-3-38. Comparison of observed and predicted water surface profiles from non-calibrated model at Side Channel 21 study site.

A 1,500 cfs flow was selected as the upper limit of extrapolation and its predicted water surface profile was plotted with the water surface profiles for the four calibration flows (Figure 7-3-39). The difference between the observed and predicted profiles at cross sections 1 to 3 was reduced by dividing the IFG-4 hydraulic model into two separate models to better simulate the backwater effect present at the mouth of the side channel when side channel flow is 100 cfs or larger. One model is for no backwater conditions with the 23 and 100 cfs data sets (Figure 7-3-40) and the other is for backwater conditions with 100, 426, and 775 cfs data sets (Figure 7-3-41).

To evaluate the reliability of the IFG-4 hydraulic models observed and predicted water surface elevations, discharge and velocities were compared (Appendix Tables 7-A-8 and 7-A-9). The maximum difference in water surface elevations for each calibration flow was 0.02 ft at the five cross sections. The mean calibration discharges predicted by the IFG-4 hydraulic models were 23, 100, 431, and 776 cfs, as compared to input values of 23, 100, 426, and 775. The velocity adjustment factors for both models ranged from 0.96 and 1.05.

3.3.7.4 Verification

Two models were developed for this site because backwater effects were present at the mouth of the side channel and in the study site when side channel flows were 100 cfs or greater. Therefore, the upper extrapolation limit for the two-flow model and the lower limit for the three-flow model is 100 cfs. For Side Channel 21, the two-flow model

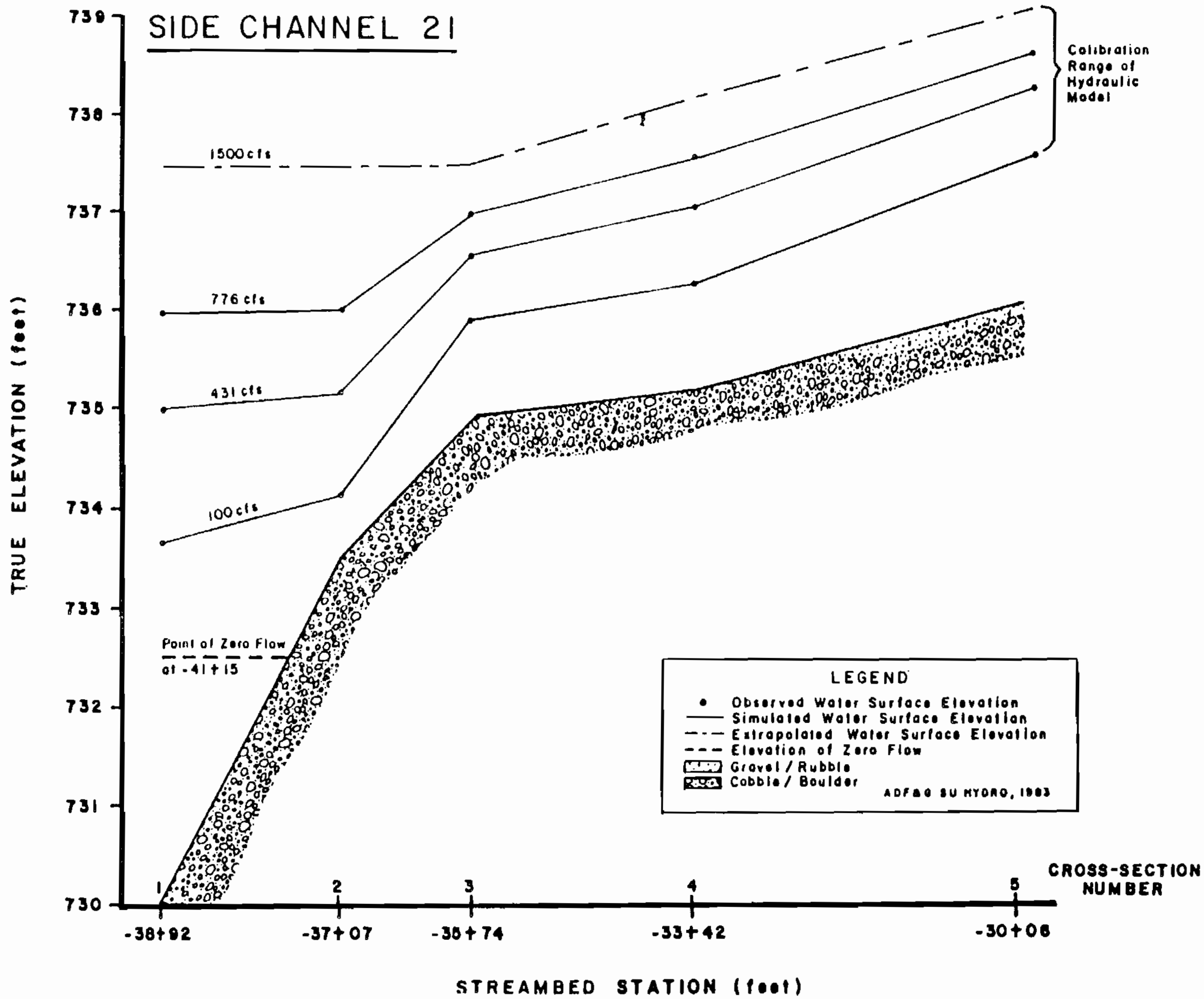


Figure 7-3-39. Comparison of observed and predicted water surface profiles from non-calibrated model at Side Channel 21 study site.

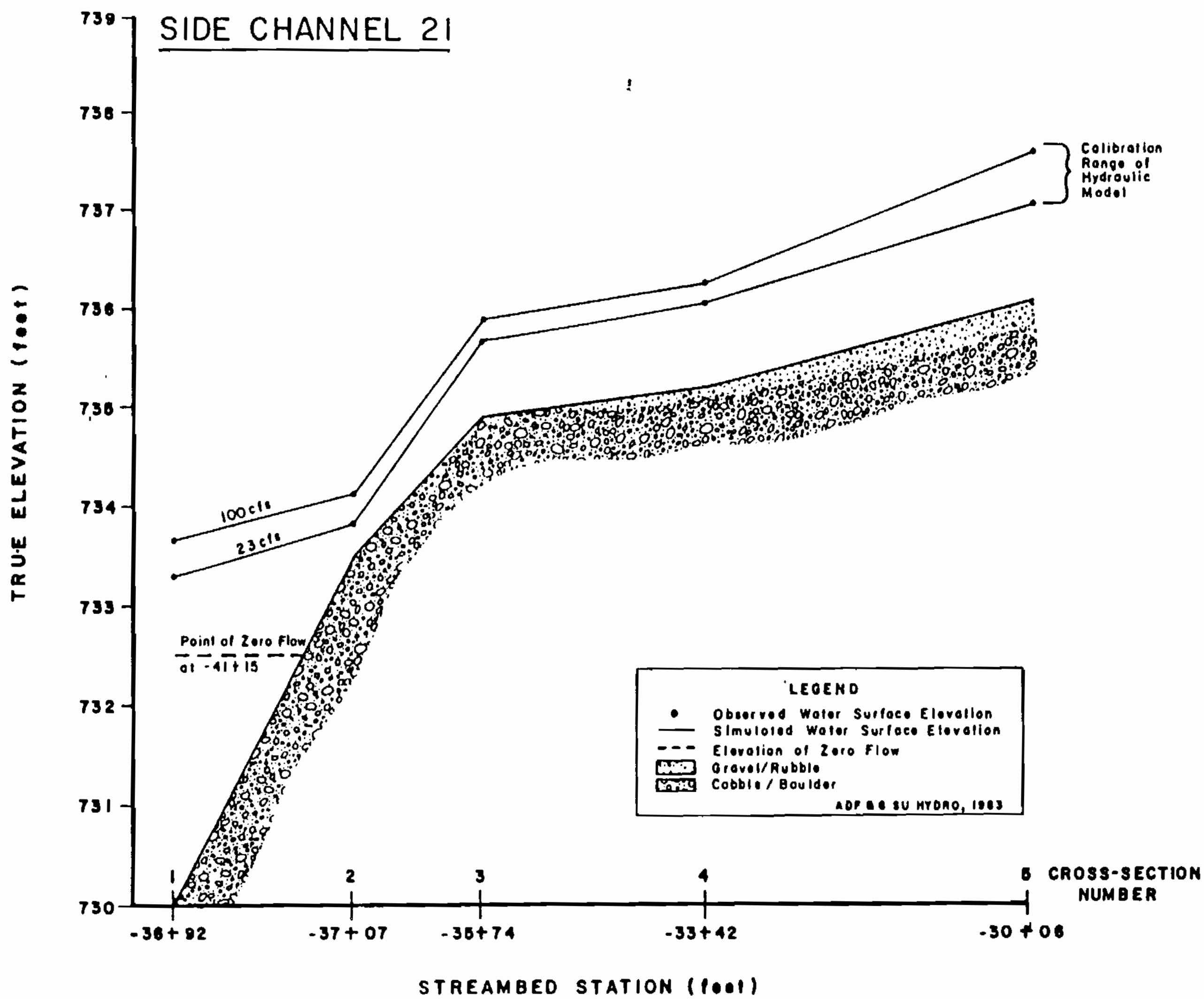


Figure 7-3-40. Comparison of observed and predicted water surface profiles from calibrated model at Side Channel 21 study site for low flow regime.

7-3-86

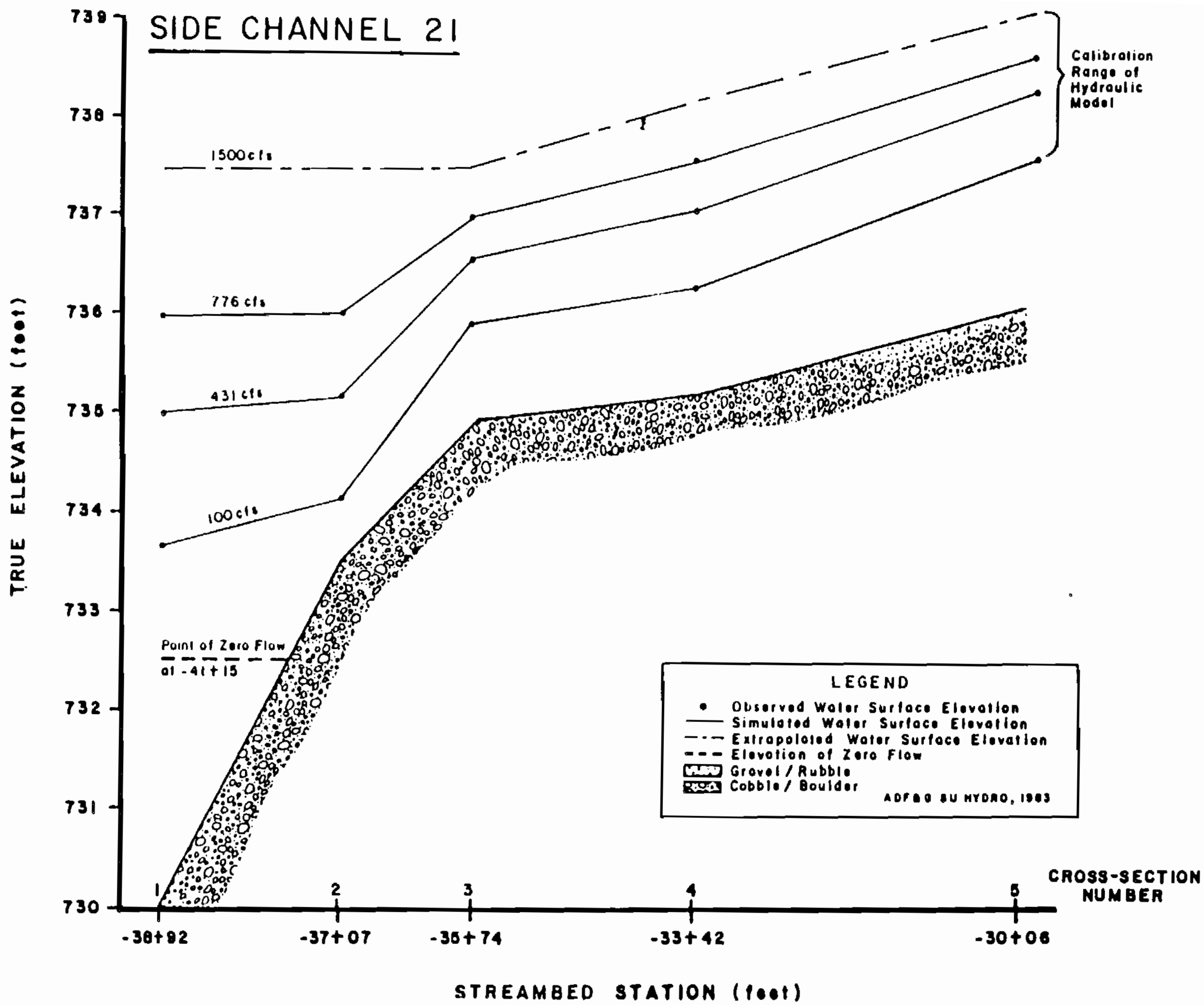


Figure 7-3-42. Comparison of observed and predicted water surface profiles from calibrated model at Side Channel 21 study site for high flow regime.

(23 and 100 cfs) describing no backwater conditions has an extrapolation range from 20 to 100 cfs. This corresponds to Susitna River discharges below 12,000 cfs. The three-flow model (100, 431, and 776 cfs) describing side channel flow with backwater conditions present at the mouth of the side channel has an extrapolation range from 100 to 1,500 cfs. This corresponds to Susitna River discharges at Gold Creek of 12,000 to 30,000 cfs (Figure 7-3-42).

A comparison was made between water surface elevations predicted by the IFG-4 hydraulic models for selected flows at cross section 4 and the empirical rating curve developed by ADF&G (Figure 7-3-43). A statistical test for coincidence was used to evaluate the reliability of both the high and low flow models. Although the hypothesis that the regression lines were the same was rejected for both models, the difference in water surface elevations at the extrapolation limits indicate they are suitably calibrated to predict hydraulic conditions at the site (Table 7-3-13).

Table 7-3-13. Comparisons between water surface elevations predicted by the IFG-4 models and the ADF&G rating curve for the extreme calibration flows.

Flow (cfs)	Water Surface Elevation (ft) Model	Rating	Diff.
HIGH FLOW MODEL			
100	736.26	736.52	0.26
1500	737.94	737.76	0.18
LOW FLOW MODEL			
23	736.09	735.93	0.16
100	736.28	736.52	0.24

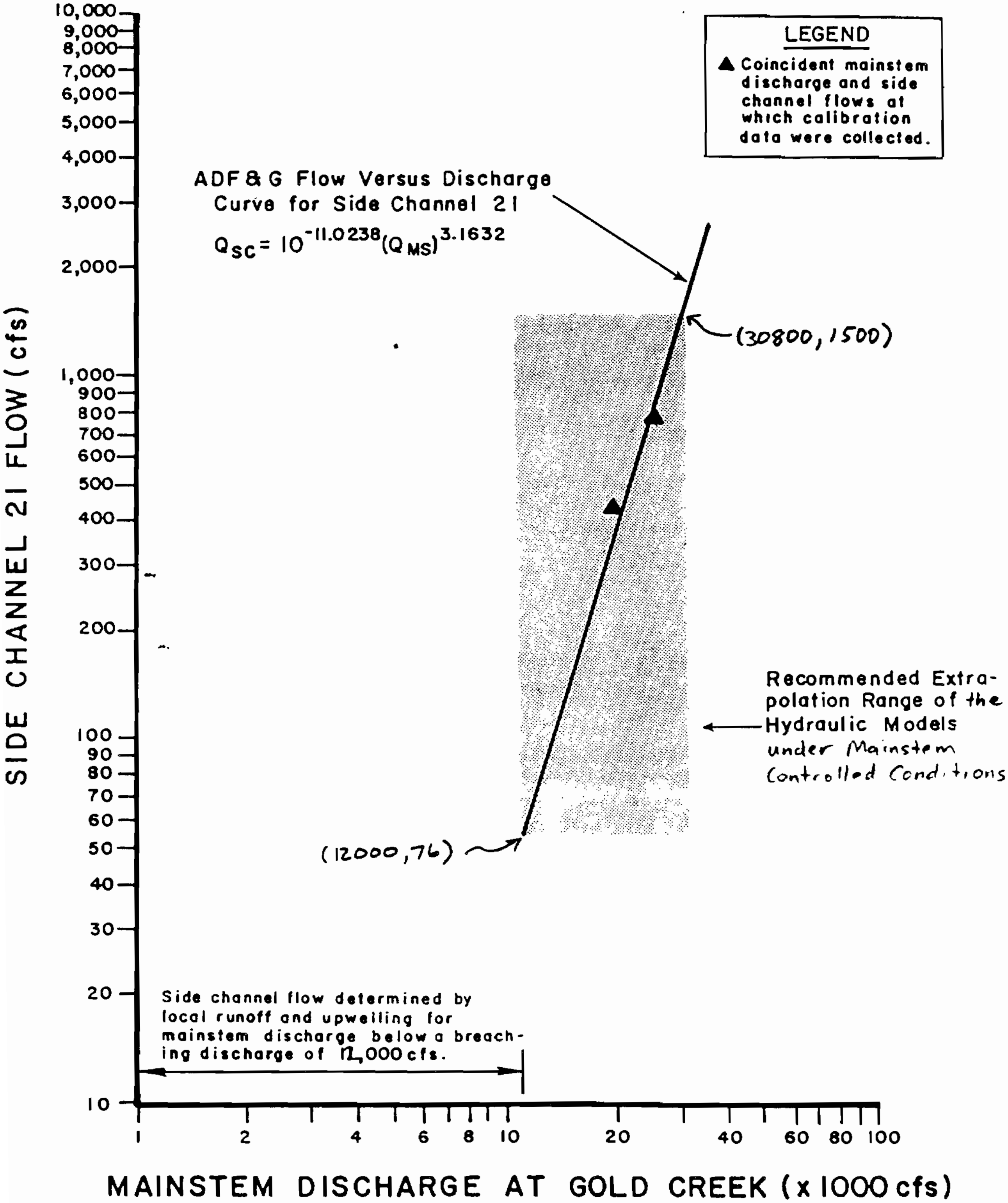


Figure 7-3-42 Relationship between extrapolation range of Side Channel 21 low and high flow models and ADF&G flow-versus-discharge curve.

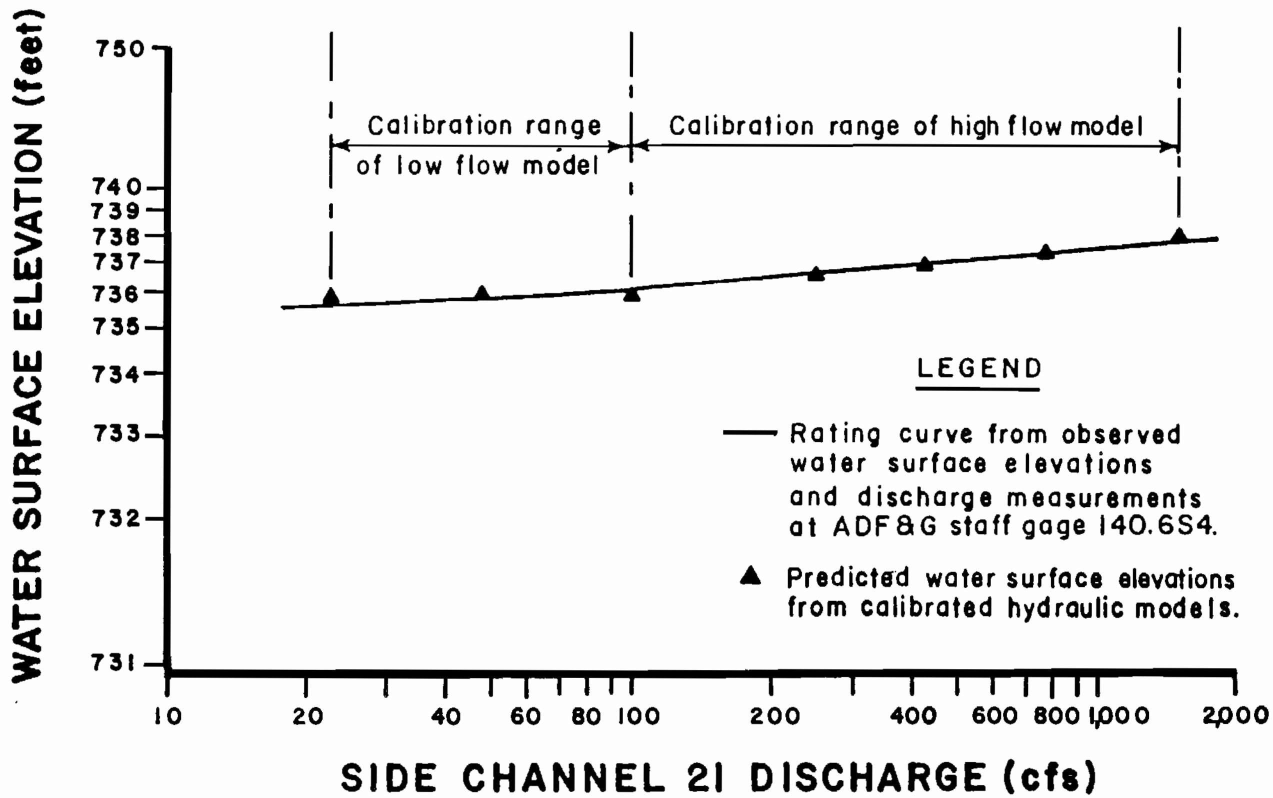


Figure 7-3-43. Comparison between ADF&G rating curve and model predicted water surface elevations.

The use of the synthesized data set apparently was not detrimental to the models.

3.3.7.5 Application

The study site in Side Channel 21 was chosen to represent potential chum salmon spawning and juvenile salmon rearing habitat in the free-flowing portion of the side channel (Part 1, Section 1, Figure 2-9). In general, this extends from station -50+00 to -4+57 for unbreached conditions and -38+92 to -4+57 when the channel is mainstem controlled. Downstream of station -38+92 depths and velocities within the side channel are more significantly influenced by mainstem backwater effects than by side channel flow. Hence, the high flow hydraulic model for Side Channel 21 should not be applied to this portion of the side channel.

Calibration data were available for side channel flows of 23, 431, and 776 cfs. Preliminary calibration runs indicated that the flow range between the 23 and 431 cfs data sets was too great to simulate with an acceptable degree of confidence. Therefore, it was assumed that the bed of the side channel became fully wetted at a flow of 100 cfs (the transition from low to high flow conditions) and a calibration data set for 100 cfs was simulated (Section 3.3.7.3). This assumption and calibration technique have greatly improved the plausibility of the hydraulic model throughout its calibration range. It must be remembered, however, that the calibration data for the 100 cfs flow were simulated and not measured values. Subsequent analysis suggests that the transition flow might be closer to 60 or 70 cfs rather than 100 cfs.

Used in conjunction with one another, the Side Channel 21 hydraulic models will span a range of side channel flows between 20 and 1,500 cfs. Side Channel 21 is mainstem controlled via Channel A5 when mainstem discharge exceeds 12,000 cfs. During breached conditions, the side channel flows range from 100 to 1,500 cfs which corresponds to mainstem discharges of 12,000 to 25,000 cfs. At mainstem discharges less than 12,000, side channel flow is maintained by clear water inflow from Slough 21 and upwelling. Unbreached slough flows are generally in the range of 20 to 30 cfs and should be modelled by the low flow model.

3.4 DISCUSSION

Ten hydraulic models were calibrated for seven slough and side channel locations. Several of these models were developed to account for a small amount of channel change (Slough 9) or varying degrees of flow resistance present under high and low flow conditions (Slough 8A, Slough 21, and Side Channel 21). Comparisons between corresponding sets of forecasted and measured hydraulic parameters indicate that the models provide reliable estimates of depths and velocities within their recommended calibration ranges.

In two instances, field data were limited and synthetic data sets were used to calibrate models for Upper Side Channel 11 and Side Channel 21. Although the forecasts of these calibrated hydraulic models cannot be compared to measured depths and velocities, the models appear to provide reasonable forecasts of depths and velocities.

Relationships have also been defined between a site specific flow and mainstem discharge at the USGS stream gage at Gold Creek (Table 7-3-14). When the mainstem discharge is sufficient to control the channel flow, the flow rate through the study site is directly dependent upon the mainstem discharge.

When the mainstem discharge is too small to control the channel flow, the flow rate through a study site is dependent upon local surface runoff or groundwater inflow. A correlation cannot be demonstrated with existing data between site specific flow and mainstem discharge when sloughs or side channels are not breached. Site specific flow rates for unbreached conditions can only be estimated on the basis of field observations and a limited number of instantaneous discharge measurements.

The hydraulic models are intended to support an analysis of the effects of incremental changes in flow on the availability of salmon spawning and rearing habitat in side sloughs and side channels. The models maybe used to forecase flows outside the recommended extrapolation ranges, however, the reliability of the models deteriorates outside these ranges.

The utilization of various depth and velocity combinations by spawning salmon in slough habitat is discussed in the following section of this report.

Table 7-3-14. Summary of comparison of mainstem discharges at Gold Creek for which extrapolation ranges of IFG models apply streamflow at IFG model sites (cfs)[1]

Mainstem Discharge	Lower Side Channel 11 A	Lower Side Channel 11 B	Side Channel 21 A	Side Channel 21 B	Upper Side Channel 11 A	Upper Side Channel 11 B	Side Channel 10 A	Side Channel 10 B	Slough 9 A	Slough 9 B	Slough 21 A	Slough 21 B	Slough 8A A	Slough 8A B
		400		20		5		5		5		5		4
8,000	640		30		5		5		5		5		10	
10,000	900		30		5		5		5		5		10	
12,000	1,200		76#		5		5		5		5		10	
14,000	1,500		120		5		5		5		5		10	
16,000	1,900	2000	190		25#		5		5		5		10	
18,000	2,200		270		45		5		5		10		10	
20,000	2,600		380		77		16#		14		10		10	
22,000	3,100		520		120		35		34		10		10	
24,000	3,500		680		190	250	74	100	75		10#		10	
26,000	4,000		870		290		150		160		23		10	
28,000	4,400		1,100		420		280		300		54		10	
30,000	4,900		1,400	1500	600		500		570	600	120		10	
32,000	5,500		1,700		830		870		1,000		240	400	10	
34,000	6,000		2,000		1,100		1,500		1,800		480		28#	70
Mainstem Controlled Discharge at Gold Creek	*		12,000		16,000		19,000		19,000		24,000		33,000	

1 Slough and side channel flows determined by the ADF&G flow-versus-discharge curves.
\# Site specific flow becomes a function of mainstem discharge at Gold Creek.
Channel A6 Upper in Slough 21 Complex breaches at 18,000 (Gold Creek).
* Undefined at this time
Extrapolation range of hydraulic models.
A Flow associated with mainstem discharge.
B Calibration range of models.

4.0 FISH HABITAT CRITERIA ANALYSIS

4.1 Introduction

This section presents the results of the second step of the IFIM physical habitat simulation (PHABSIM) modelling process. A discussion is presented of the spawning habitat utilization data collected in side slough and side channel habitats in the middle river reach, the methods used to analyze the data, and the resulting spawning suitability criteria developed for chum and sockeye salmon spawning in side sloughs and side channel habitats in the middle reach.

Fish habitat criteria studies were initiated in 1982 as part of the IFIM PHABSIM study. Field efforts had the objective of collecting sufficient measurements of selected habitat variables (depth, velocity, substrate, and upwelling) at individual chum and sockeye salmon redd sites (henceforth referred to as utilization data) to determine the behavioral responses of spawning chum and sockeye salmon to the various levels of these selected physical variables. The collection of availability data, that is, the combinations of the various habitat variables which were available to spawners (Baldrige and Amos 1981) was limited to modelled study sites due to resource constraints.

Spawning utilization data collected in 1982 were inadequate to develop suitability criteria due to low discharge and flow conditions limiting access of adult salmon into sloughs. A summary of the 1982 data and the modified analysis used to evaluate the data is presented in ADF&G (1983b, Appendix D). Additional utilization data were collected in 1983, which when combined with 1982 data, information derived from literature, and professional judgment, were sufficient for developing chum and sockeye salmon spawning suitability criteria curves for use in the PHABSIM modelling system. All results and conclusions relating to spawning suitability which are presented in this report supersede those presented in earlier reports.

4.2 METHODS

4.2.1 Site Selection

Site selection for the collection of utilization data in the sloughs and side channels was based on the presence of spawning salmon and the ability to observe their activities. Data collection efforts were concentrated in the areas of the sloughs (Sloughs 8A, 9, and 21) and side channels (Side Channels 21 and Upper 11) where hydraulic modelling data was being collected. This enabled field staff to maximize the collection of combined utilization and availability data (to evaluate preference) given the availability of resources. Other sloughs and side channels in the Talkeetna to Devil Canyon reach were also surveyed for spawning activity and if present, selected as additional study sites to extend the utilization data base. The non-modelled sites included Sloughs 9A, 11, 17, 20, and 22 (Figure 7-4-1). Time and resource constraints, however, prevented the collection of availability data at these non-modelled sites.

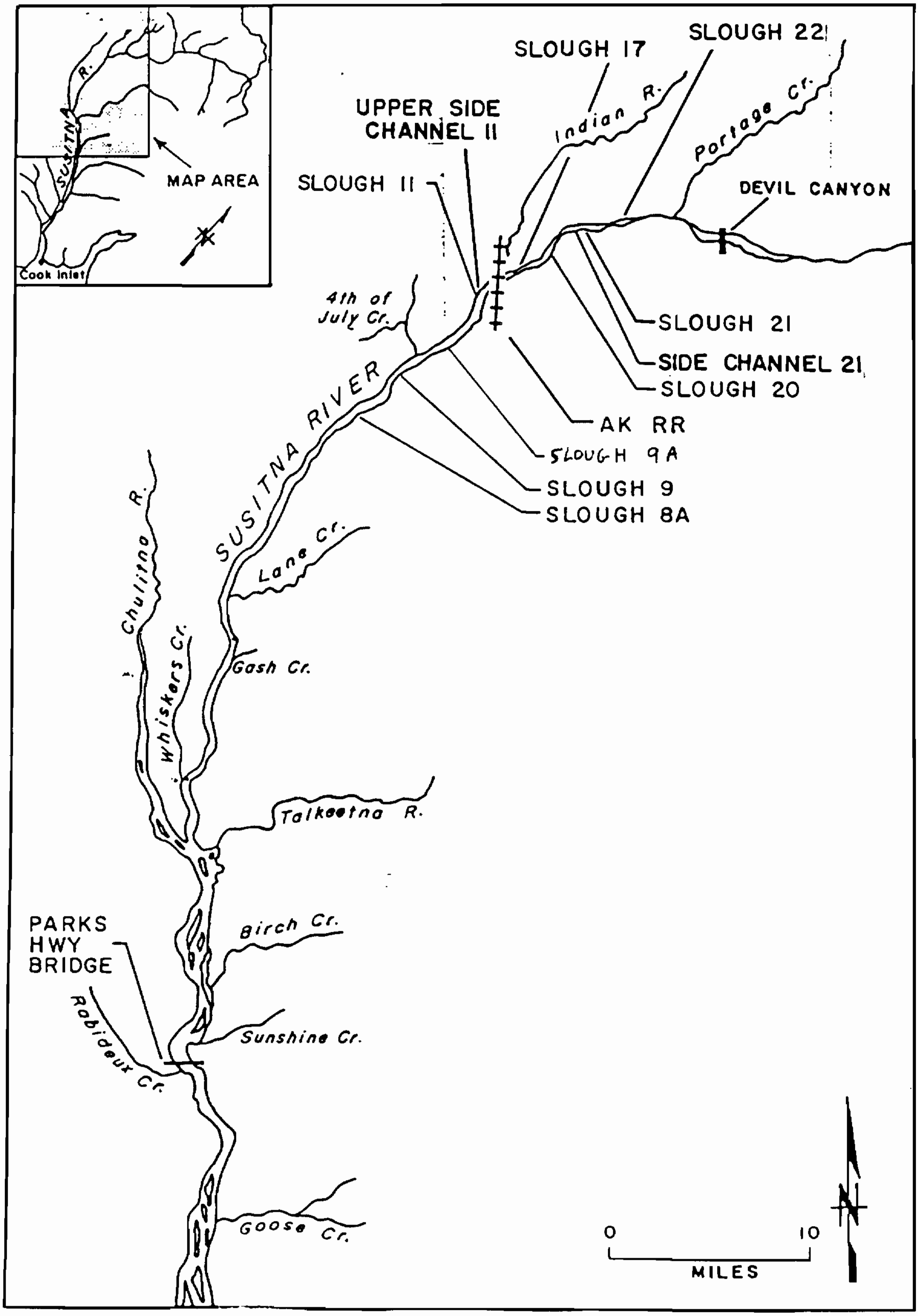


Figure 7-4-1 Side slough and side channel locations where fish habitat criteria where data were collected.

Utilization data were also collected in tributary mouth and tributary habitat locations. These data were not included in this analysis due to their inapplicability to side slough and side channel habitats, but are discussed in Chapters 8 and 9, respectively, in relation to their associated habitat types.

4.2.2 Field Data Collection

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

Water depth and velocity measurements were collected at the upstream end of each active redd using a topsetting wading rod and a Marsh McBirney or Price AA meter. The substrate composition of each redd was visually evaluated using the size classification scheme presented in Table 7-4-1. A visual assessment of the presence of upwelling in the vicinity of the redd and the distance to the upwelling from the redd were also noted.

Within modelling sites, staff gage readings were recorded to estimate the flow via rating curves presented in Chapter 1 of this report at the time redd measurements were obtained. These flows were then used to predict available depth, velocity, and substrate, data which were used in the evaluation of preference and subsequent derivation of the suitability criteria.

Table 7-4-1. Substrate classification scheme utilized to evaluate substrate composition at spawning redds.

Substrate Category	Size Class
Silt	Very Fine
Sand	Fines
Fine Gravel	$\frac{1}{4}$-1"
Course Gravel	1-3"
Cobble	3-5"
Rubble	5-10"
Boulder	greater than 10"

4.2.3 Analytical Approach

The primary objective of this portion of the study is the development of weighted habitat criteria for use in the PHABSIM system models for calculation of WUA. Weighted habitat criteria representing microhabitat preferences of fish habitat are usually expressed in the form of "habitat curves". These curves describe the preference of species/life phase for different levels of a selected variable, with the peak indicating the greatest preference and the tails tapering towards more less preferred values. Curves are developed for each habitat variable considered to influence the selection of habitat for a life phase activity (Bovee, Lochnauer, and Milhous 1982).

Could be confused with use of Flow or Habitat Index Curves.

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

Typically, each of these curves are constructed by plotting standardized scaled criteria index values indicating utilization, preference, or suitability (depending on the curve type being evaluated) on the y-axis versus the habitat variable to be evaluated on the x-axis. The criteria index is scaled between 0 and 1, with 1 denoting the greatest habitat utilization, preference, or suitability and 0 denoting no utilization, preference, or suitability. The criteria index value corresponding to the particular level of each habitat variable is then used in the HABTAT model to "weight" each cell (as defined by transects in the study area) in terms of its relative usability as spawning habitat. The weighted cell usabilities are then summed for the entire site at each particular flow level to calculate the total WUA (see section 5.0). Depending on the available data base, utilization, preference, or suitability criteria indices can be input into the habitat simulation model to weight each cell. In this report, suitability criteria indices were developed for several habitat variables and evaluated for input into the habitat simulation model. Suitability criteria indices for the habitat variables of depth, velocity, substrate, upwelling, and a composite index representing substrate and upwelling were developed for chum and sockeye salmon spawning in side slough and side channel habitats of the middle Susitna River following the methods described below.

Depth, Velocity, and Substrate

The first step in development of suitability criteria indices for the habitat variables of depth, velocity, and substrate involved the evaluation of spawning utilization data collected in side slough and side channel habitats in the middle Susitna River. Utilization data for each species were plotted as frequency histograms. The data were standardized by dividing the frequency of observations in each increment of the appropriate habitat variable by the frequency of observations in the increment with the highest occurrence. This standardization achieved a 0 to 1 scaling index for frequency on the y-axis. The resultant scaled frequency histograms represent the "utilization" curves as described earlier.

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

Additional histograms are constructed in order to ensure development of utilization curves which do not exhibit spurious characteristics such as irregular fluctuations or multi-modal structures. As utilization curves are developed for one species/life stage, it is assumed that there should only be one most utilized increment of a particular habitat variable, and that the curves should be relatively smooth (i.e. no irregular fluctuations). As sample size is increased, it is expected that utilization curves developed from increments at the original measuring accuracy will approach the ideal of uni-modal structure and smoothness. However, lower sample sizes often lead to multi-modes and irregular fluctuations. Accordingly, additional scaled frequency histograms were developed for depth and velocity increments of size 0.2 ft and ft/sec and 0.3 ft and ft/sec in order to smooth the utilization data. Several groupings of the data are possible if increment sizes of 0.2 and 0.3 are used, depending on the starting value of the increment. Therefore, a total series of six scaled histograms were developed for depth and seven for velocity as summarized in Table 7-4-2.

A seventh scaled histogram for velocity was constructed to have the first increment be composed of all 0.0 velocities only. This not warranted for depths as depths of 0 were not utilized. Histogram 1 (Table 7-15) differs from Histogram 2 only in that the first increment is different. Histogram 1 defines all observed values that are equal to 0.0 as one increment, while the first increment in Histogram 2 contains

Table 7-4-2. Summary of histograms used to evaluate utilization data.

Histogram	Increment Size	Increment Starting Value
1	0.0	0.0
2	0.1	0.1
3	0.2	0.0
4	0.2	0.1
5	0.3	0.0
6	0.3	0.1
7	0.3	0.2

all values which are less than or equal to 0.1, including all 0.0 values. Incremental plots of substrate are not appropriate because substrate data is not continuous.

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

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

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

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

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

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

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

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

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

H_o: All variances are equal;

H_a: At least one of the variances are different.

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

H_o: One of the variances is the same as one particular variance of the other five (or six).

H_a: One of the variances is not the same as one particular variance of the other five (or six).

A series of 15 to 21 possible pairwise comparisons were made. However, the comparisons between histograms with smaller variance values were those of primary interest (except in cases of violation of the third criteria above, that is, minimal irregular fluctuations).

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

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

2. Total magnitude of irregular fluctuations:

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

$$\sum_{i=M.V.+1}^{LG} [\text{group}_{(i)} - \text{group}_{(i-1)}]^{*}$$

where,

M.V. = maximum value

L.G. = last group

* = only when this difference is greater than 0

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

4. Average fluctuation (total magnitude of irregular fluctuations/number of irregular fluctuations).

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

The minimal irregular fluctuation criterion sometimes led to rejection of the minimal variance curve. Rejection of minimal variance curves due to this criteria involved professional judgment as to the tradeoffs involved. This tradeoff generally involved choosing between a non-smooth curve with many increments and a smooth curve with fewer increments (often with a higher variance). A non-smooth curve with many increments was often indicative of low numbers of observations (i.e., frequencies).

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

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

where,

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

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

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

A modification of the above formula was implemented in cases where the peak occurred in the first or last increment of the curve. In this case the formula used was:

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

where,

$F_{(x)} = F_{(m+1)}$ when $F_{(m)}$ was the first increment of the curve,

or

$F_{(x)} = F_{(m-1)}$ when $F_{(m)}$ was the last increment of the curve.

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

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

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

Caution is necessary when applying the above criteria for curve selection. Hopothetically, a curve which is radically different from the original observation curve (for example the medium or mean variable value is altered greatly) might be chosen as a best curve. Additionally, a curve which is artificially to flat (heavy-tailed) might result if sample sizes are very low. Accordingly, a comparison of the selected "best" curve with the original observations as well as review by biologists familiar with the species/life stage of interest was made. In no instance of the analysis presented here was a "best" utilization curve judged to be unrealistic.

The last step used in the development of suitability criteria indices for depth, velocity, and substrate was to modify the best utilization curves selected for depth, velocity, and substrate on the basis of habitat availability data (i.e., evaluation of preference) and professional judgment using previously published data and opinion of field biologists.

Low escapement and low flow conditions during 1982 and 1983 limited utilization of areas which were modelled for physical habitat availability. Thus, most of the additional utilization data was collected in areas outside of the physical habitat availability modelling sites. Time and resource constraints prevented the collection of availability data in these areas. Therefore, the analysis of preference by spawning fish for selected habitat variables was based on the limited amount utilization and availability data collected within the modelled sites.

Due to its limited data base, the analysis of preference was only used in the derivation of the suitability criteria to refine the best utilization curves based on professional judgement. Preference was evaluated by considering the scaled frequency of use of each habitat variable increment utilized in relation to the sided frequency of that habitat increment available to select from. This was accomplished by comparing the utilization data collected within a specific study site at a particular flow with availability data generated by the hydraulic availability model for that site and flow then compositing these data for all sites and flows. Because upwelling was assumed to be a controlling factor (i.e., spawning only occurs if upwelling is present, see next part) only availability data specific to areas of upwelling were used in this analysis. The configuration of water depths, velocities, and substrates available at upwelling locations within the modelled study sites were simulated for the flows at which within-site utilization data were collected. Availability data for each flow and site were then weighted according to the relative number of redd measurements taken and combined in the form of scaled histogram plots. The grouping of depth, and velocity, and substrate availability data corresponded to the increments specified by the associated best utilization histograms. The frequency of observations within each increment of the availability data was then compared with the corresponding value from the utilization data.

Substrate availability data was collected on a finer level of resolution than substrate utilization data which necessitated reduction in the level of resolution of the utilization data collection to evaluate preference. This was done by combining substrate availability data size classes 1 and 2 into utilization data class silt, availability data classes 3 and 4 into utilization data class sand, availability data classes 5 and 6 into utilization data class small gravel, availability data classes 7 and 8 into utilization data class large gravel, availability data classes 9 and 10 into utilization data class rubble, availability data classes 11 and 12 into utilization data class cobble, and availability data class 13 into utilization data class boulder.

Mathematically, preference was then evaluated as the ratio of utilized to available habitat within a study area with values of less than 1.0 indicating a lesser degree of preference and values exceeding 1.0 reflecting a greater degree of preference for the habitat conditions being considered.

The preference data were then subjectively used in conjunction with additional field data, previously published information on the species/life stage being evaluated, and professional judgement to modify the best utilization curves for each habitat variable into suitability curves.

The methodology described above was used to develop suitability criteria for the habitat variables of depth, velocity, and substrate for adult chum salmon spawning in sloughs and side channels of the middle Susitna River. The same methods were used to develop suitability criteria for adult sockeye spawning with the exception that the approach did not include an analysis of preference. Insufficient utilization data were collected in physical habitat availability modelling areas (for reasons previously stated) to permit an analysis of preference for depth, velocity, and substrate. Thus, suitability criteria for adult sockeye spawning in side sloughs and side channels were derived from utilization curves which were refined by professional judgment using previously published data and opinion of field biologists.

Upwelling

Development of the chum and sockeye salmon spawning suitability criteria for upwelling differed from the methods used in the development of the suitability criteria for depth, velocity, and substrate in that a binary criteria approach (Bovee 1982) was used. Due to the difficulty of measuring upwelling rates within the ranges detectable by spawning salmon, suitability criteria for the upwelling habitat variable are based primarily on field observations and professional judgment for these two species. That is, a suitability index value of 1.0 was assigned to "upwelling present" and an index value of 0.0 was assigned to "upwelling absent". The assignment of a suitability index value of 1.0 to upwelling present is predicated on extensive field observations concerning the spawning behavior of chum and sockeye salmon in the middle Susitna River (ADF&G 1983b). In areas of side sloughs and side channels where salmon spawning has been observed, visual evidence frequently indicated that upwelling was present. Winter observations of spawning areas used to locate upwelling by the presence of open water leads, generally confirmed the presence of upwelling in those sites where no visual evidence of upwelling existed at the time of spawning observations.

Combined Substrate/Upwelling Variable

The habitat simulation model used to project weighted usable area of spawning habitat (refer to section 5.0) can only accommodate a maximum of three habitat variables (two of which, depth and velocity, are integral to the operation of the model). Because substrate and upwelling are both considered important habitat components for chum and sockeye salmon spawning, a combined substrate/upwelling suitability criteria index was developed. This was accomplished by multiplying the weighting factors of each of the possible combinations of substrate and upwelling criteria. In effect, a value of 0.0 is assigned when upwelling is absent, and a value ranging from 0.0 to 1.0 is assigned when upwelling is present. The latter values are identical to those determined for substrate suitability criteria. The resultant data were plotted as scaled frequency histograms representing the suitability of the combined substrate/upwelling habitat variable function.

4.3 Results

4.3.1 Chum Salmon

A total of 333 chum salmon redds were sampled during 1982 and 1983 for the habitat variables of depth, velocity, substrate, and presence of upwelling groundwater (Table 7-4-3). Of this total, 131 were within the hydraulic modelling sites and thus had associated availability data. Because of the limited number of measurements in Slough 8A and Side Channel 21, only utilization data (128 measurements) and availability

Table 7-4-3. Number of measurements made at chum salmon redds in sloughs and side channels of the middle Susitna River, 1982 and 1983.

Site	RM	Number of Redds 1982		Number of Redds 1983		Total Within Modeling Site	Total
		Within Modeling Site	Outside Modeling Site	Within Modeling Site	Outside Modeling Site		
Slough 8A	125.3	1	36	---	15	1	52
Slough 9	126.3	45	---	31	---	76	76
Fourth of July Creek - mouth	131.0	---	---	---	28	---	28
Slough 9A	133.3	---	---	---	24	---	24
Slough 11	135.3	---	15	---	19	---	34
Upper Side Channel 11	136.2	---	---	---	2	---	2
Indian River - mouth	138.6	---	---	---	3	---	3
Slough 17	138.9	---	---	---	6	---	6
Slough 20	140.1	---	---	---	11	---	11
Side Channel 21	140.6	---	---	2	---	2	2
Slough 21	141.1	33	1	19	30	52	83
Slough 22	144.3	---	---	---	12	---	12
Totals		79	52	52	150	131	333

data obtained in Sloughs 9 and 21 were used in the evaluation of preference. Raw field data are presented in Appendix 7-B-1.

The derivation of the suitability criteria for each of these habitat variables for use in the habitat simulation model is presented below by habitat variable.

4.3.1.1 Depth

The first step in the development of depth suitability criteria for chum salmon spawning was to select a best depth utilization curve. Depth measurements at 333 chum salmon redds were grouped into six incremental groupings as described in the methods section. These groupings were plotted as histograms (Figure 7-4-2). Table 7-4-4 summarizes the statistics used to determine the "best" utilization curve from the six histograms. The statistically minimal variance curve is the histogram labelled A (see Appendix Table 7-C-1). However, histogram A had large indices of irregular fluctuations, and accordingly was not selected as the best curve. Histograms B through F were not distinguishable in terms of the minimal variance criteria. The minimal irregular fluctuation criteria indicated that histograms C, D, and F were the next most likely candidates for the best utilization curve. Of these three histograms, curve F had the lowest distinguishable peakedness index and was thus chosen as the best depth utilization curve (Figure 7-4-3).

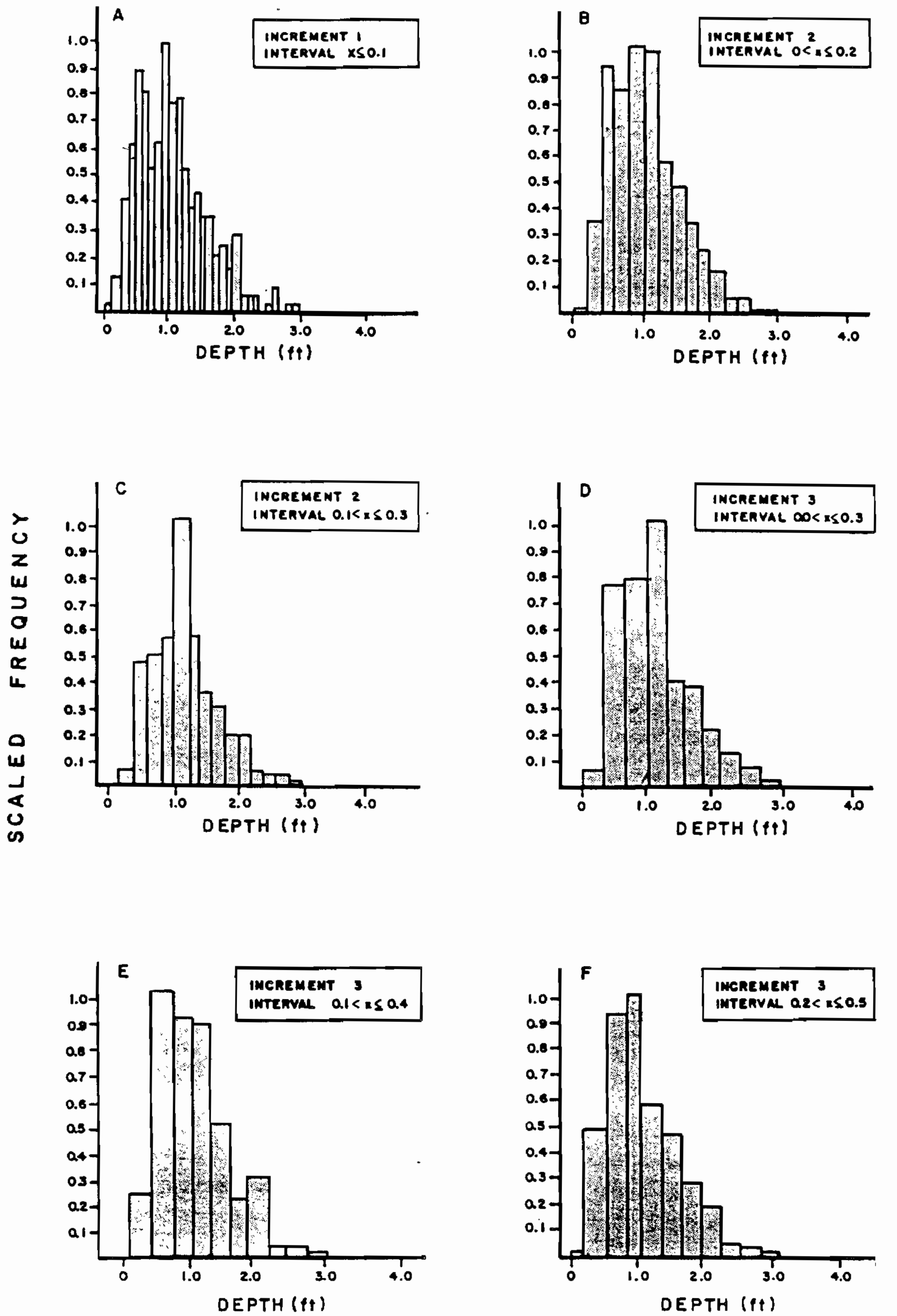


Figure 7-4-2 Incremental plots of chum salmon spawning depth utilization data.

Table 7-4-4. Summary of statistics on various incremental groupings for chum salmon utilization depth histograms.

HISTOGRAM LABEL	A	B	C	D	E	F
INCREMENT SIZE	0.1	0.2	0.2	0.3	0.3	0.3
INCREMENT START	0.0	0.0	0.1	0.0	0.1	0.2
VARIANCE	107.0	405.9	474.8	892.9	916.0	828.8
COEFFICIENT OF VARIATION	0.90	0.91	0.92	0.90	0.91	0.95
IRREGULAR FLUCTUATIONS						
Magnitude	25	5	0	0	7	0
Number	9	1	0	0	1	0
Mean	2.78	5.00	---	---	7.00	---
Maximum	10	5	---	---	7	---
PEAKEDNESS	0.24	0.06	0.41	0.37	0.39	0.18

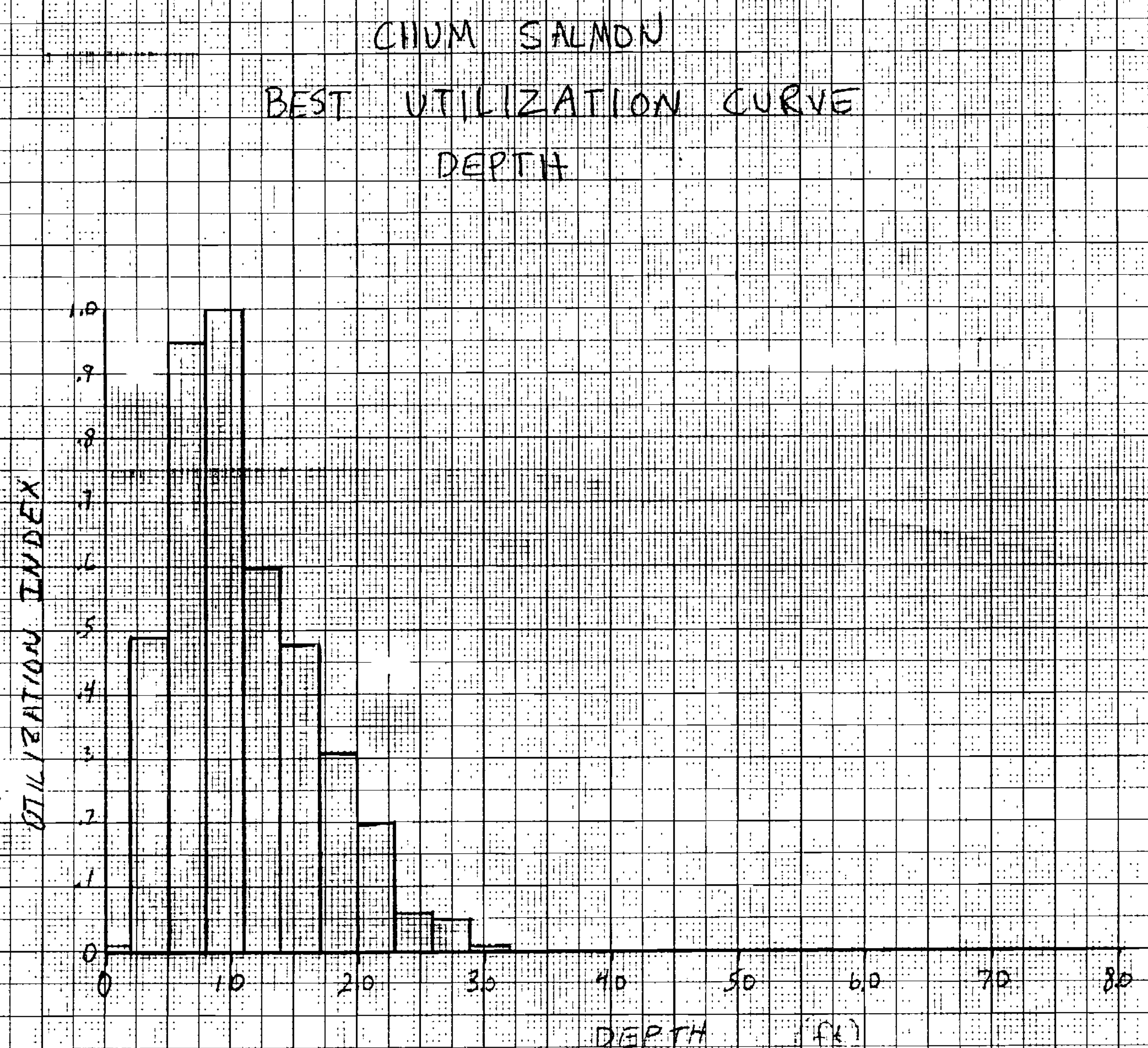


Figure 7-4-3 Best depth utilization curve for chum salmon spawning

The next step in the development of the depth suitability criteria was to evaluate the best depth utilization curve in terms of depth availability data (i.e., evaluate preference) and professional judgment. A plot comparing available depths to utilized depths for the subset of utilization data having availability data (Figure 7-4-4) reveals that depths less than 0.2 feet, although available, were not used. For this reason, depths under 0.2 feet were assigned a suitability index of 0.0. The plots also reveals a strong preference for depths between 0.8 and 2.3 feet, that is, the frequency of utilization is greater than the frequency of availability. For this reason, these depths were assigned a suitability index of 1.0. From a consideration of previously published data (Hale, 1981) and the opinion of field biologists familiar with chum salmon spawning in the Susitna River, it was decided that depth alone, if greater than 2.3 feet, would not likely limit spawning within the range of conditions encountered in the study sites. The maximum predicted depth at all modelled study site was 7.5 feet at Side Channel 21 at 1,500 cfs. Consequently, the suitability factor of 1.0, assigned to the depths from 0.8 to 2.3 feet, was extended out to 8.0 feet. For the depths between 0.2 feet and 0.8, the plot revealed a smaller ratio of utilization to availability for the depth increment of 0.2 - 0.5 feet than for 0.5 - 0.8 feet increment. Therefore, it was assumed that the suitability of depth for spawning increased exponentially over the range of 0.2 to 0.8 feet. This was reflected by assigning a suitability index value of 0.2 to to a depth of 0.5 feet. The resultant depth suitability curve and criteria for chum salmon spawning are presented in Figure 7-4-5.

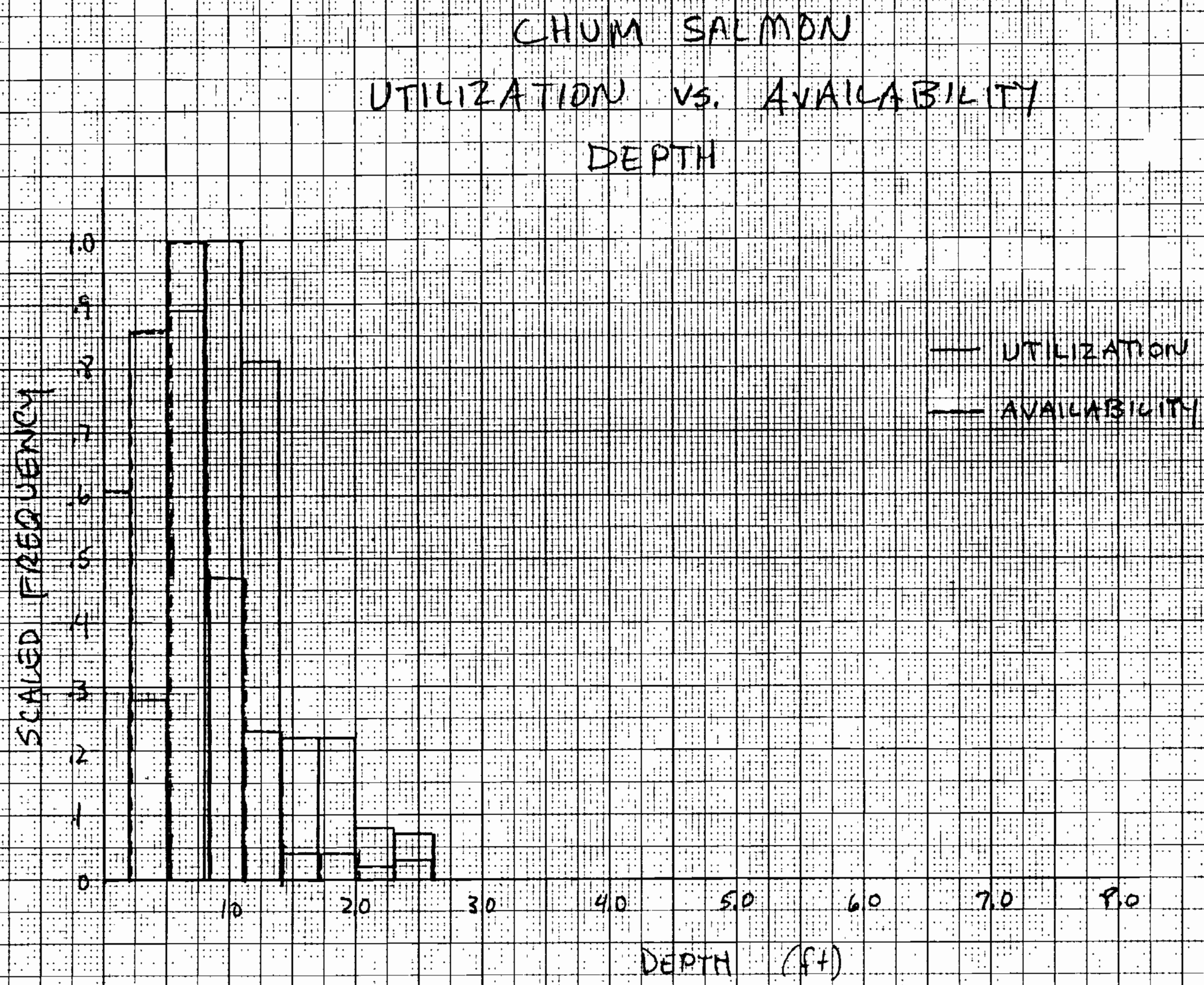
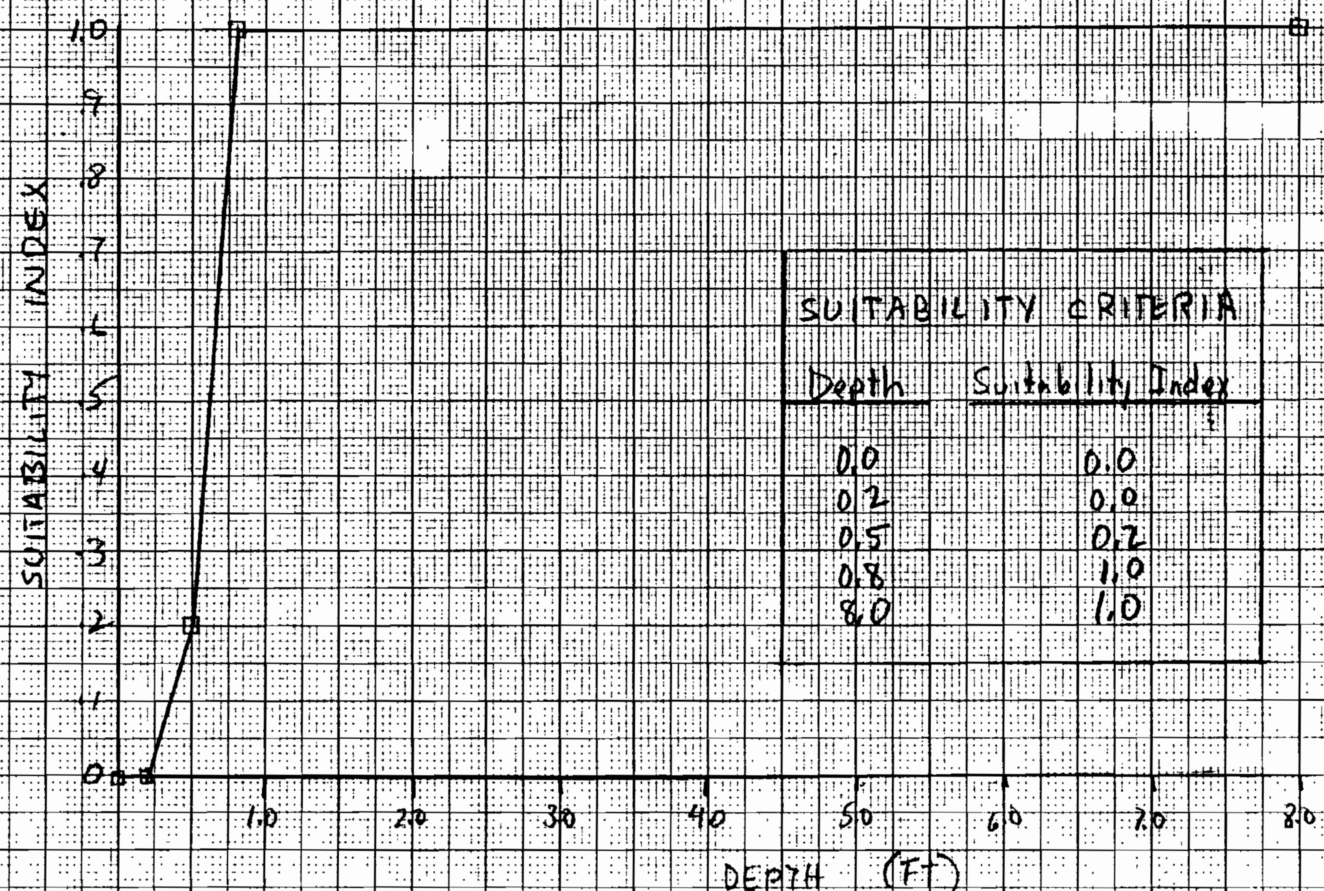


Figure 7-4-4. Depth utilization versus availability for chum salmon spawning used to evaluate preference.

K•E 10 X 10 TO THE CENTIMETER 18 X 25 CM KEUFFEL & ESSER CO. MADE IN U.S.A. 461510

CHUM SALMON
SUITABILITY CRITERIA CURVE
DEPTH



SUITABILITY CRITERIA

Depth	Suitability Index
0.0	0.0
0.2	0.0
0.5	0.2
0.8	1.0
8.0	1.0

Figure 7-4-5. Depth suitability curve for chum salmon spawning.

4.3.1.2 Velocity

The first step in the development of velocity suitability criteria for chum salmon spawning was to select a best utilization curve. Velocity measurements at 333 chum salmon redds were grouped into seven incremental groupings as described in the methods section. These groupings were plotted as seven histograms (Figure 7-4-6). Table 7-4-5 summarizes the statistics used to determine which of the seven histograms to choose as the "best" utilization curve. The statistically minimal variance curve is the histogram labelled A (See Appendix Table 7-C-2). Histogram B's variance was statistically larger than histogram A's variance, but it was smaller than the other six curves. Histograms C and D both had variances which were significantly smaller than histogram G. Histograms A and B both had large indices of irregular fluctuations, and could not be chosen as the best curve. According to the minimal variance criteria there were no clear alternatives between curves C through F (note that curve G had a statistically large variance). Of these three histograms, curve F had minimal indices of irregular fluctuations and the minimal distinguishable peakedness index. Accordingly, histogram F was chosen as the best velocity utilization curve for chum salmon spawning (Figure 7-4-7).

The next step in the development of the velocity suitability criteria was to assess the best utilization curve in light of availability data (i.e., evaluate preference) and professional judgment. A plot comparing available and utilized velocities for the subset of utilized data having

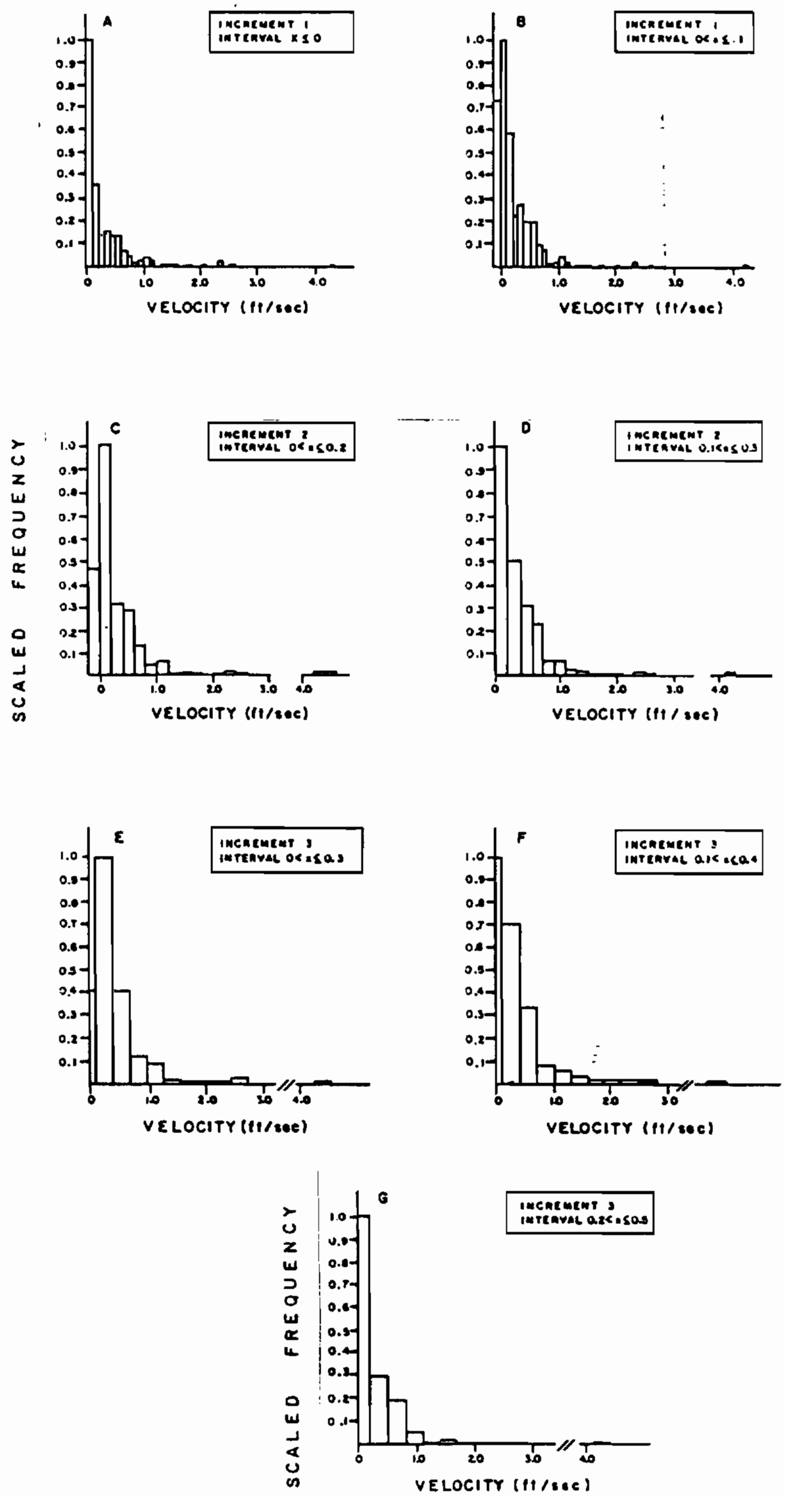


Figure 7-4-6 Incremental plot of chum salmon spawning velocity utilization data.

Table 7-4-5. Summary of statistics on various incremental groupings for chum salmon utilization velocity histograms.

HISTOGRAM LABEL	A	B	C	D	E	F	G
INCREMENT SIZE	0.1	0.1	0.2	0.2	0.3	0.3	0.3
INCREMENT START	0.0	0.1	0.0	0.1	0.0	0.1	0.2
VARIANCE	330.5	606.0	1114.8	1289.6	2004.2	1949.4	2948.0
COEFFICIENT OF VARIATION	2.46	3.25	2.21	2.37	2.02	2.12	2.45
IRREGULAR FLUCTUATIONS							
Magnitude	13	13	6	3	3	2	2
Number	9	9	5	2	2	2	2
Mean	1.44	1.44	1.20	1.50	1.50	1.00	1.00
Maximum	3	3	2	2	2	1	1
PEAKEDNESS	0.29	0.49	0.69	0.35	0.67	0.22	0.52

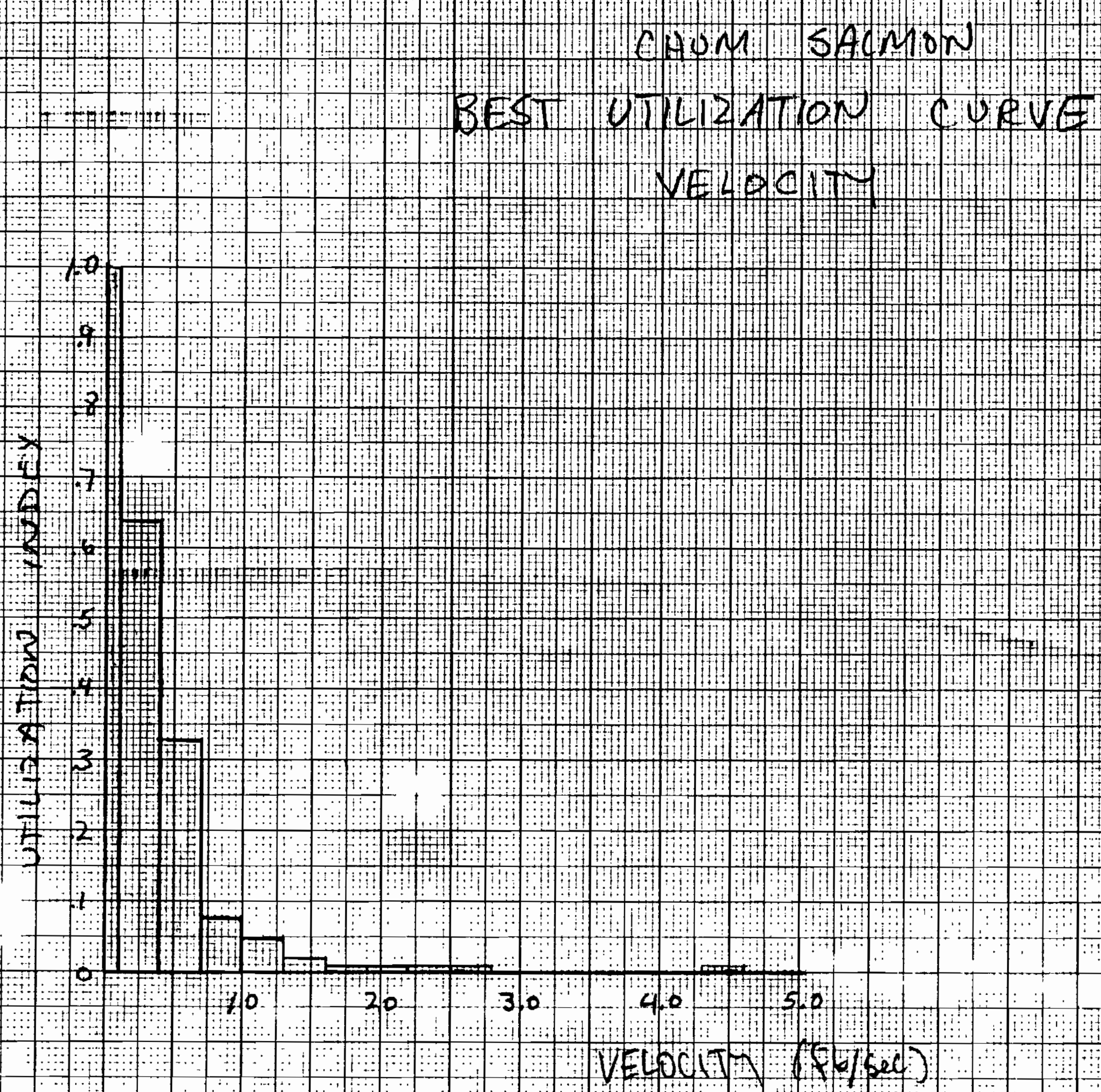


Figure 7-4-7. Best velocity utilization curve for chum salmon spawning.

availability data (Figure 7-4-8) reveals that a general preference was exhibited for velocities between 0.0 and 1.3 feet/second (ft/sec). For this reason, a suitability index value of 1.0 was assigned to this range of velocities. Because no availability data were collected for velocities exceeding 1.3 ft/sec, suitability for higher velocities were subjectively determined. Since the maximum utilized velocity measured was 4.3 ft/sec, a velocity of 4.5 ft/sec was chosen as an endpoint and assigned a suitability index of 0.0. Comparatively greater utilization occurred between 1.3 ft/sec and 2.8 ft/sec compared to utilization recorded for the 2.8 and 4.5 ft/sec. Therefore, a higher suitability was assigned to the lower velocity range than the higher velocity range. This was reflected by assigning a suitability factor of 0.2 to a velocity of 2.8 ft/sec. The resultant velocity suitability curve and criteria for chum salmon spawning are presented in Figure 7-4-9.

4.3.1.3 Substrate

The first step in the development of substrate suitability criteria for chum salmon spawning was to construct a plot of utilized substrates (Figure 7-4-10). Incremental plots of substrate are not appropriate because substrate data is not continuous. Therefore, the utilization data plot was treated as the best substrate utilization curve.

The next step in the development of the substrate suitability criteria was to assess the substrate utilization curve in terms of availability data (i.e., evaluate preference) and professional judgment. As previously stated in the methods section, substrate utilization data

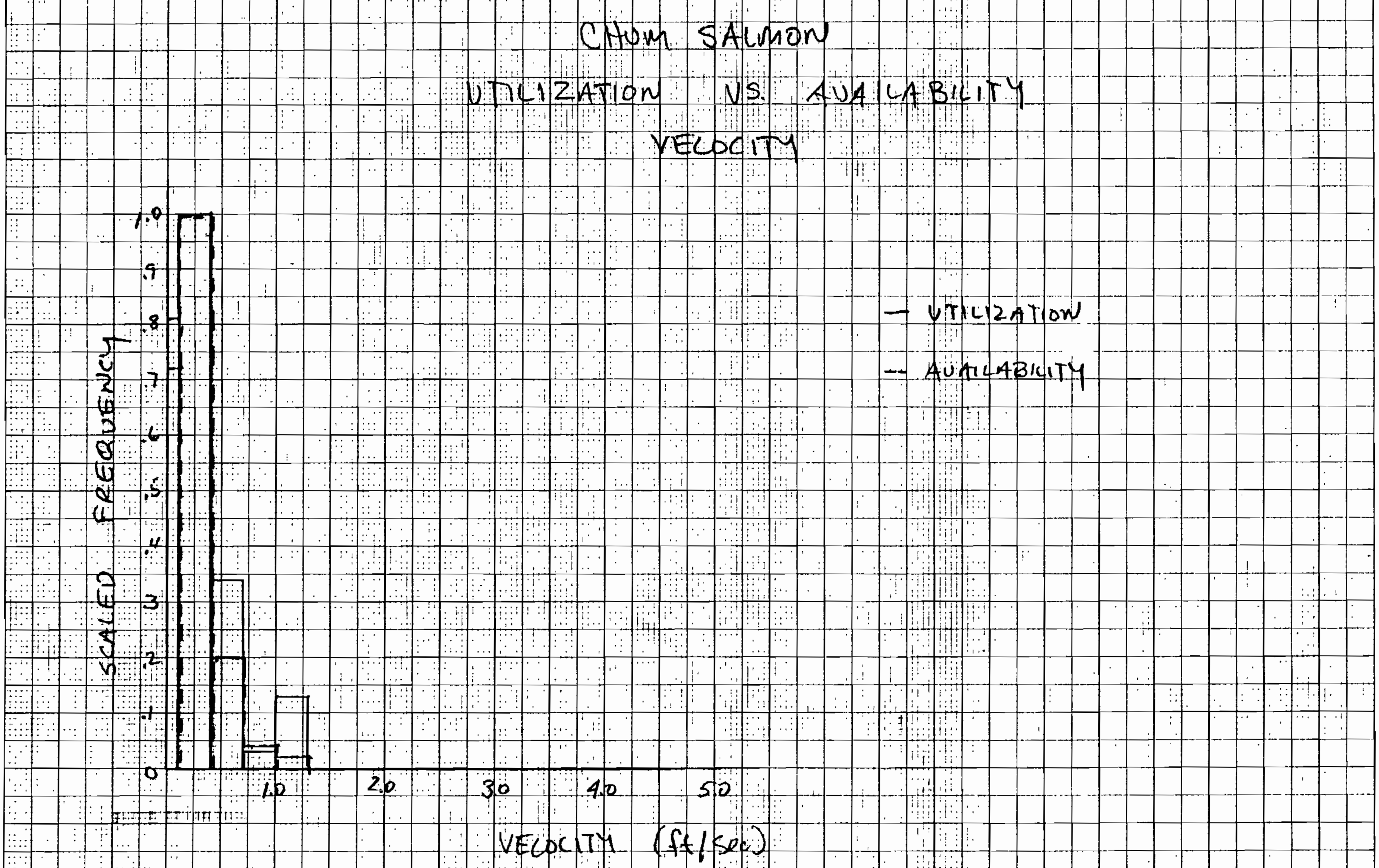
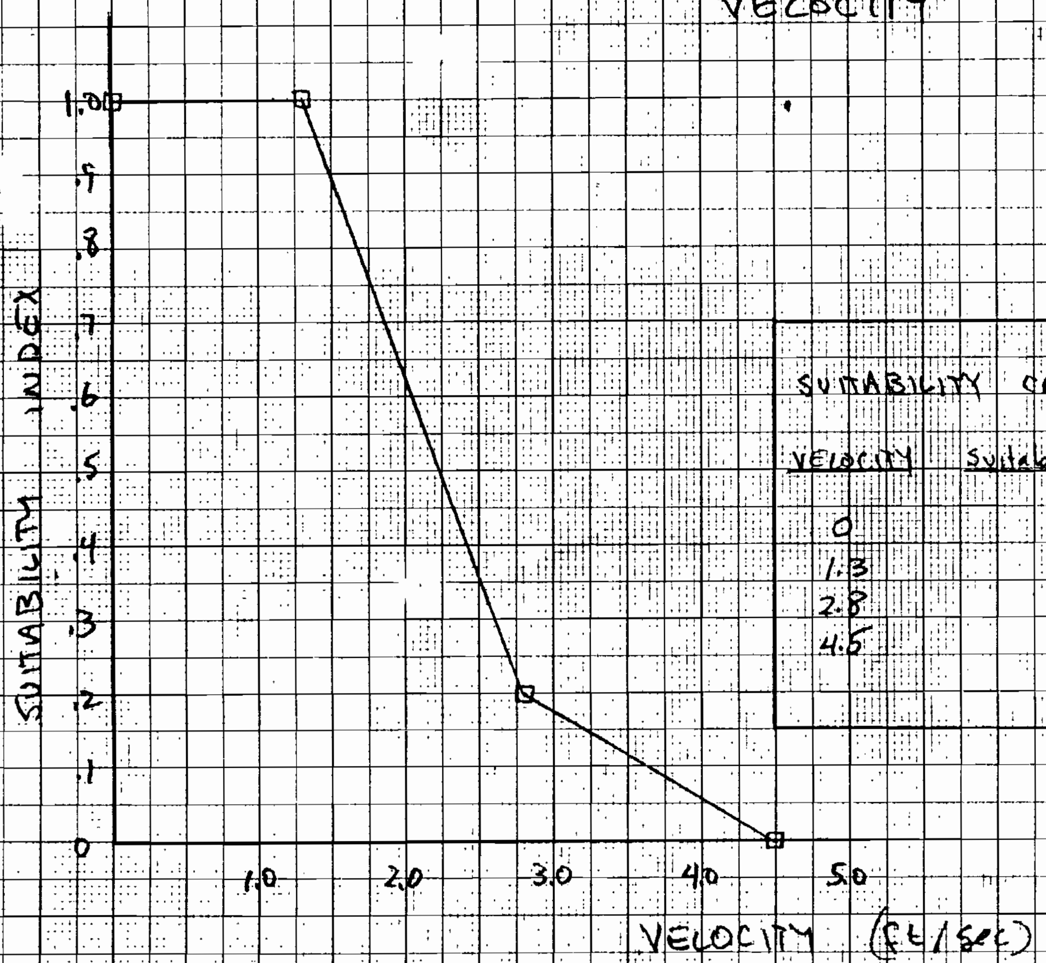


Figure 7-4-8. Velocity utilization versus availability for chum salmon spawning used to evaluate preference.

CHUM SALMON

SUITABILITY CRITERIA CURVE

VELOCITY

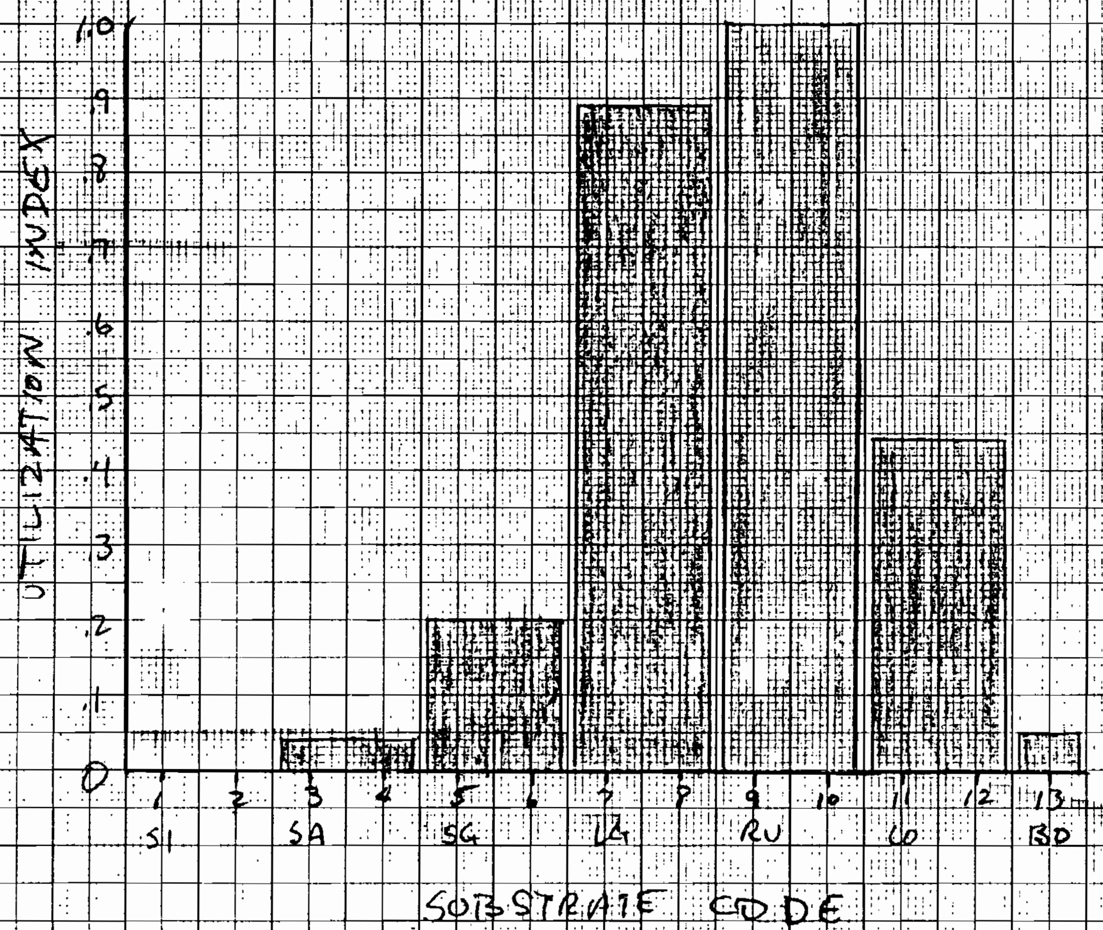


SUITABILITY CRITERIA

VELOCITY	suitability index
0	1.0
1.3	1.0
2.8	.2
4.5	0

Figure 7-4-9. Velocity suitability curve for chum salmon spawning

CHUM SALMON
UTILIZATION CURVE
SUBSTRATE



SUBSTRATE CODE		PARTICLE SIZE
1	SI	SILT
2		
3	SA	SAND
4		
5	SG	⅛"–1"
6		
7	LG	1"–3"
8		
9	RU	3"–5"
10		
11	CO	5"–10"
12		
13	BO	7 10"

Figure 7-4-10. Substrate utilization curve for chum salmon spawning.

were collected at a lower level of resolution than substrate availability data. For this reason, substrate availability data were grouped in order to evaluate preference. However, when assigning suitability index values to substrate data for use in the habitat projection model, the higher level of resolution was once again used.

A plot comparing utilized substrate to available substrate for the subset of utilized data for which availability data exists (Figure 7-4-11) reveals that substrates ranging from large gravel to cobble appear to be preferred. However, a review of literature data (Hale 1981; Wilson et al. 1981) reveals that cobble substrates are a less preferred substrate size for chum salmon spawning than are large gravels and rubbles. Furthermore, based on discussions with field personnel, there is a strong likelihood of a sampling bias for larger substrates since field personnel more likely to overestimated substrate sizes. For these reasons, a suitability index value of 1.0 was assigned to substrate size classes 7 through 9 (corresponding to large gravel and rubble substrates) and suitability index values of 0.85 and 0.70 were assigned to size classes of 10 and 11, respectively, based on assumptions concerning the suitability of cobble as a spawning substrate. The largest two substrate classes, 12 (large cobbles) and 13 (boulders), were assigned indices of 0.25 and 0.0, respectively, after taking sampling bias into account.

The suitability indices for the smaller substrate size classes (1 through 6) were assigned as follows. Based on the lack of utilization in the substrate size classes 1 and 2 (silt), a suitability index of 0

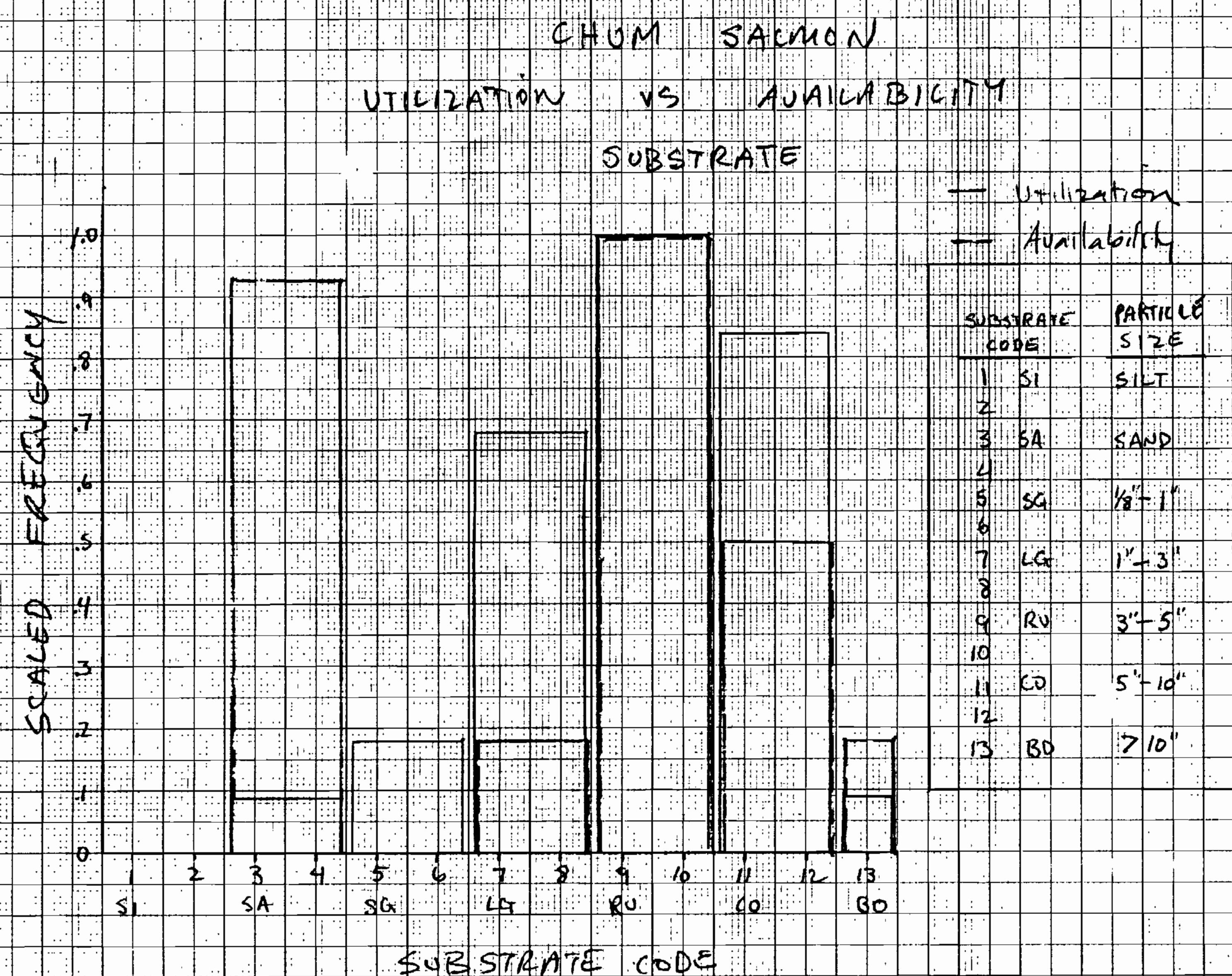


Figure 7-4-11 Substrate utilization versus availability for chum salmon spawning used to evaluate preference.

was assigned to these substrate classes. The small ratio of frequencies of utilized to available for substrate classes 3 and 4 (sand), in addition to literature information showing little preference for this substrate class (Hale 1981; Wilson et al. 1981), resulted in low suitability indices (0.025 and 0.05, respectively) being assigned to these size classes. Suitability indices for the substrates classes 5 and 6 were assigned by assuming a linearly increasing suitability of substrates between size classes 4 and 7.

The resultant substrate suitability curve and criteria developed for chum salmon spawning are presented in Figure 7-4-12.

4.3.1.4 Upwelling

Based on professional opinion and field observations, suitability criteria for upwelling were assigned using a binary function (see methods sections). That is, a suitability index of 1.0 was assigned to upwelling present and a suitability index of 0.0 was assigned to upwelling absent. This approach seems justified based on accumulated field data indicating that spawning chum salmon appear to key on upwelling.

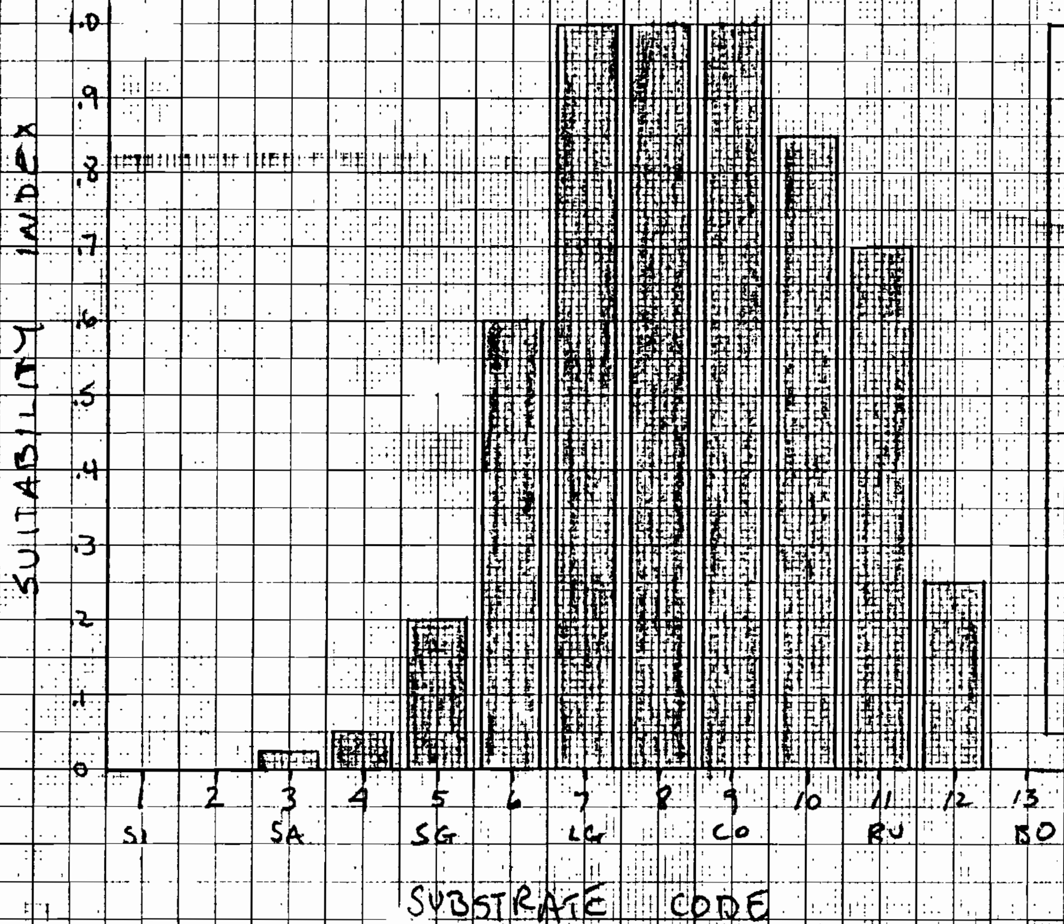
4.3.1.5 Combined Substrate/Upwelling

The combined substrate/upwelling suitability criteria developed for use in the habitat simulation model are identical to the individual substrate suitability criteria when upwelling is present. When

CHUM SALMON

SUITABILITY CRITERIA CURVE

SUBSTRATE



SUITABILITY CRITERIA

SUBSTRATE CODE		SIZE	SUITABILITY INDEX
1	SI	SILT	0
2			0
3	SA	SAND	.025
4			.05
5	SG	1/8"–1"	.2
6			.6
7	LG	1"–3"	1.0
8			1.0
9	RU	3"–5"	1.0
10			.85
11	CO	5"–10"	.70
12			.25
13	BO	> 10"	0

Figure 7-4-12. Substrate suitability curve for chum salmon spawning.

upwelling is not present, a suitability index value of 0.0 is assigned to each substrate class. Table 7-4-6 is a tabulation of the development of the suitability index for this combined variable. The resultant suitability curve and criteria developed for the combined substrate/upwelling variable are presented in Figure 7-4-13.

4.3.2 Sockeye Salmon

A total of 81 sockeye salmon redds were sampled during 1982 and 1983 for depth, velocity, substrate, and presence of upwelling groundwater. Of this total, one was located within a hydraulic modelling site. For this reason, an analysis of preference could not be conducted on the utilization data base. Thus, the derived suitability criteria are based only on the utilization data base as modified by professional judgement using literature data and field observations.

The sampling sites and number of redds sampled per site are tabulated in Table 7-4-7. The raw field data are presented in Appendix 7-B-3. The derivation of the suitability criteria for each of these habitat variables from these raw data for use in the habitat simulation model is presented below by habitat variable.

4.3.2.1 Depth

The first step in the development of the depth suitability criteria for sockeye salmon spawning was to select a best depth utilization curve. Depth measurements at 81 sockeye salmon redds were grouped into six

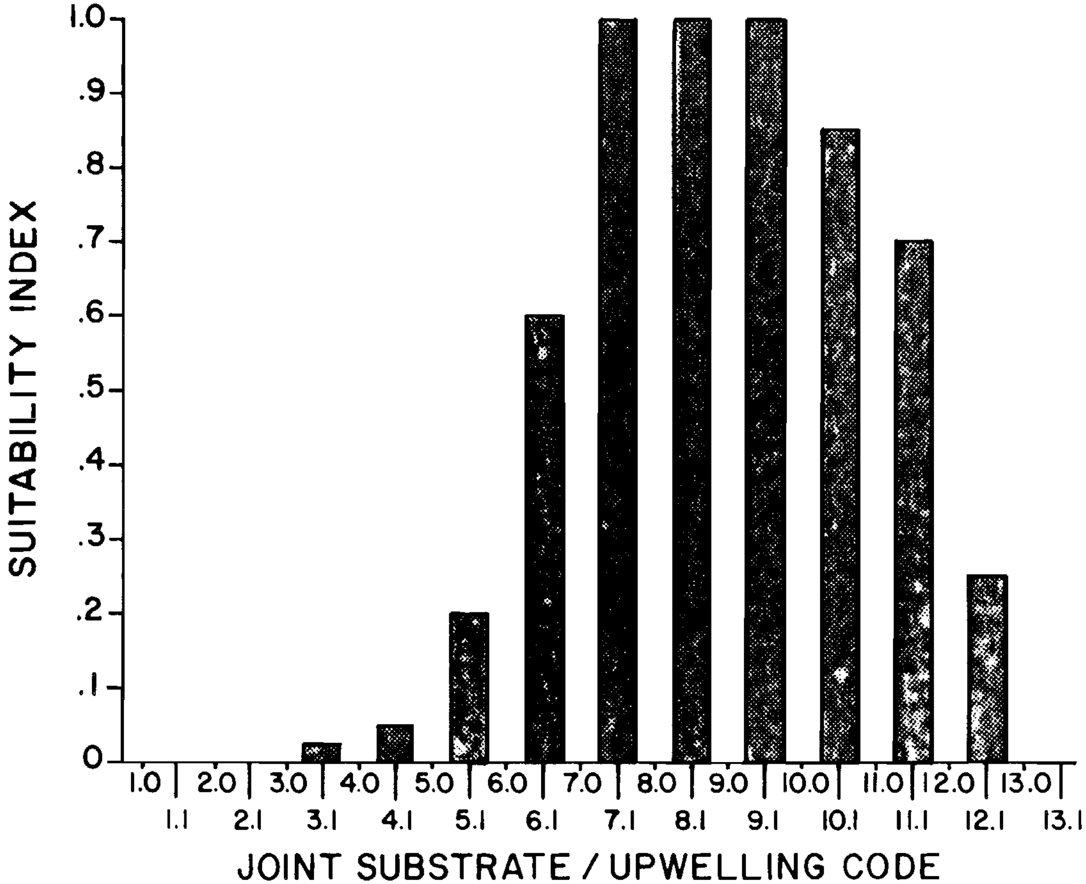
Table 7-4-6. Data used to develop joint (substrate and upwelling) suitability curve for chum salmon.

Description		Code		Weighting Factor		Combined Factor	
Substrate 1/	Upwelling 2/	Substrate	Upwelling	Substrate	Upwelling	Joint Code	Suitability Index
SI	A	1	0	0.00	0.00	1.0	0.00
SI	P	1	1	0.00	1.00	1.1	0.00
SI/SA	A	2	0	0.00	0.00	2.0	0.00
SI/SA	P	2	1	0.00	1.00	2.1	0.00
SA	A	3	0	0.03	0.00	3.0	0.00
SA	P	3	1	0.03	1.00	3.1	0.025
SA/SG	A	4	0	0.05	0.00	4.0	0.00
SA/SG	P	4	1	0.05	1.00	4.1	0.05
SG	A	5	0	0.20	0.00	5.0	0.00
SG	P	5	1	0.20	1.00	5.1	0.20
SG/LG	A	6	0	0.60	0.00	6.0	0.00
SG/LG	P	6	1	0.60	1.00	6.1	0.60
LG	A	7	0	1.00	0.00	7.0	0.00
LG	P	7	1	1.00	1.00	7.1	1.00
LG/RU	A	8	0	1.00	0.00	8.0	0.00
LG/RU	P	8	1	1.00	1.00	8.1	1.00
RU	A	9	0	1.00	0.00	9.0	0.00
RU	P	9	1	1.00	1.00	9.1	1.00
RU/CO	A	10	0	0.85	0.00	10.0	0.00
RU/CO	P	10	1	0.85	1.00	10.1	0.85
CO	A	11	0	0.70	0.00	11.0	0.00
CO	P	11	1	0.70	1.00	11.1	0.70
CO/BO	A	12	0	0.25	0.00	12.0	0.00
CO/BO	P	12	1	0.25	1.00	12.1	0.25
BO	A	13	0	0.00	0.00	13.0	0.00
BO	P	13	1	0.00	1.00	13.1	0.00

1/ SI - Silt, SA - Sand, SG - Small Gravel, LG - Large Gravel, RU - Rubble, Co - Cobble, BO - Boulder

2/ A - Absent, P - Present

CHUM SALMON
COMBINED SUITABILITY CRITERIA CURVE
SUBSTRATE / UPWELLING



SUITABILITY CRITERIA

CODE	SUITABILITY INDEX
1.0	0.00
1.1	0.00
2.0	0.00
2.1	0.00
3.0	0.00
3.1	0.025
4.0	0.00
4.1	0.05
5.0	0.00
5.1	0.20
6.0	0.00
6.1	0.60
7.0	0.00
7.1	1.00
8.0	0.00
8.1	1.00
9.0	0.00
9.1	1.00
10.0	0.00
10.1	0.85
11.0	0.00
11.1	0.70
12.0	0.00
12.1	0.25
13.0	0.00
13.1	0.00

Figure 7-4-13. Combined substrate/upwelling suitability curve for chum salmon spawning.

Table 7-4-7. Number of measurements made at sockeye salmon redds in sloughs and side channels of the middle Susitna River in 1982 and 1983.

Site	RM	Number of Redds 1982 Within Modeling Site	Number of Redds 1982 Outside Modeling Site	Number of Redds 1983 Within Modeling Site	Number of Redds 1983 Outside Modeling Site	Total Within Modeling Site	Total
Slough 8A	125.3	---	1	---	16	---	17
Slough 11	135.3	---	19	---	23	---	42
Slough 17	138.9	---	---	---	2	---	2
Slough 21	141.1	---	---	1	19	1	20
Totals		0	20	1	60	1	81

incremental groupings as described in the methods section (Section 2.3). These groupings were plotted as six histograms (Figure 7-4-14). Table 7-4-8 summarizes the statistics used to determine the "best" utilization curve from the six histograms. The statistically minimal variance curve is the histogram labelled A (see Appendix Table 7-C-3). However, histogram A had large indices of irregular fluctuations, and accordingly was not chosen as the "best" curve. Histograms B through F were not distinguishable in terms of the minimal variance criteria. While the minimal irregular fluctuation criteria indicated that histograms D, E, and F were the next most likely candidates for the best utilization curve. Of these three histograms, curve E had the lowest distinguishable peakedness index and was accordingly chosen as the "best" utilization curve (Figure 7-4-15).

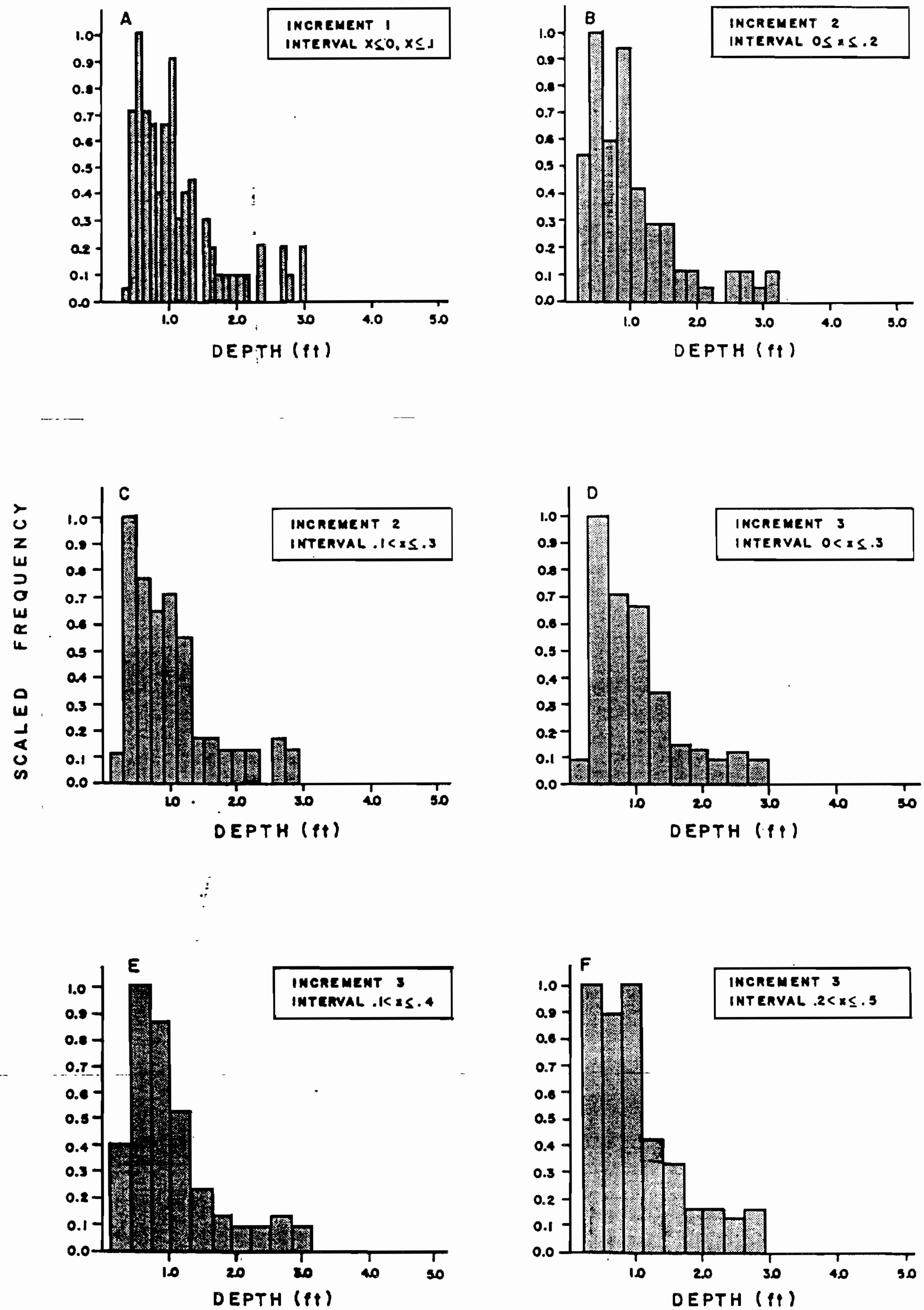


Figure 7-4-14 Incremental plots of sockeye salmon spawning depth utilization data.

Table 7-4-8. Summary of statistics on various incremental groupings for sockeye salmon utilization depth histograms.

HISTOGRAM LABEL	A	B	C	D	E	F
INCREMENT SIZE	0.1	0.2	0.2	0.3	0.3	0.3
INCREMENT START	0.0	0.0	0.1	0.0	0.1	0.2
VARIANCE	8.5	29.1	29.4	63.9	61.4	53.8
COEFFICIENT	0.97	0.93	0.94	0.99	0.97	0.81
IRREGULAR FLUCTUATIONS						
Magnitude	16	8	4	1	1	3
Number	8	3	2	1	1	2
Mean	2.00	2.67	2.00	1.00	1.00	1.50
Maximum	3	6	3	1	1	2
PEAKEDNESS	0.25	0.42	0.59	0.67	0.33	0.58

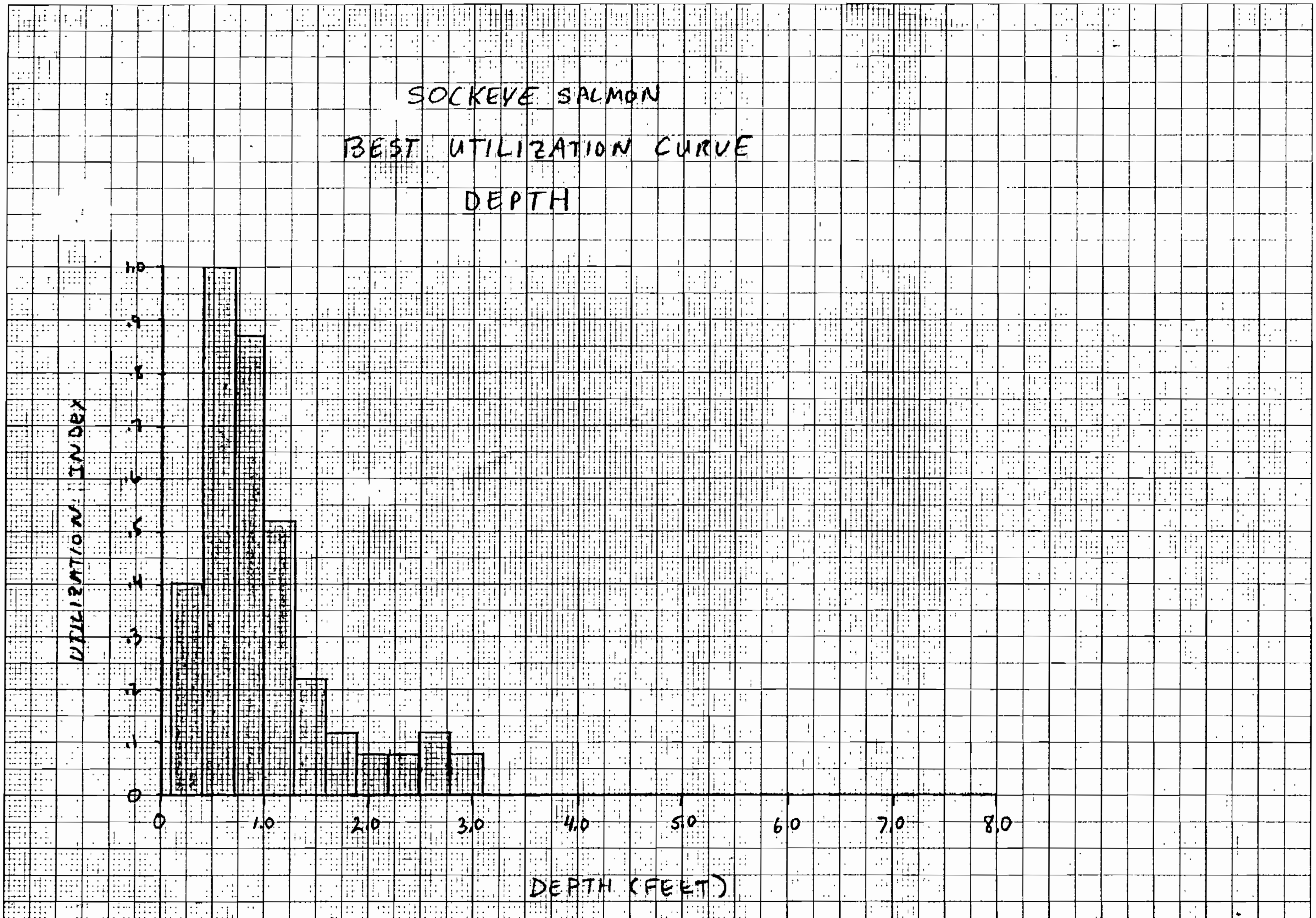


Figure 7-4-15. Best depth utilization curve for sockeye salmon spawning

The next step in the development of the depth suitability criteria was to evaluate the best depth utilization curve in terms of professional judgement using published data and opinion of field biologists. No evaluation of preference could be made due to the lack of concurrent availability data collection.

Depths ranging from 0.0 to 0.20 feet were not utilized for spawning. For this reason, these depths were assigned a suitability index of 0.0. Based on utilization patterns depicted in Figures 7-4-14 and 7-4-15, depths centering around 0.75 feet appear to be often utilized. For this reason, a suitability index of 1.0 was assigned to a depth of 0.75 feet. Based on professional judgement that depth alone, if greater then 0.75 feet, would not likely limit spawning within the range of conditions in the study sites (i.e., the maximum predicted depth at a study site was 7.5 feet in Side Channel 21 at 1,500 cfs), the suitability factor of 1.0 was extended out to 8.0 feet. It was felt that depths ranging from 0.2 to 0.5 feet would be less suitable for spawning than depths ranging from 0.5 to 0.75 feet. For this reason a lower suitability index was assigned to the lower range than was assigned to the higher range. This was reflected by assigning a suitability index of 0.9 to a depth of 0.5 feet.

The resultant depth suitability curve and criteria for sockeye salmon spawning is presented in Figure 7-4-16.

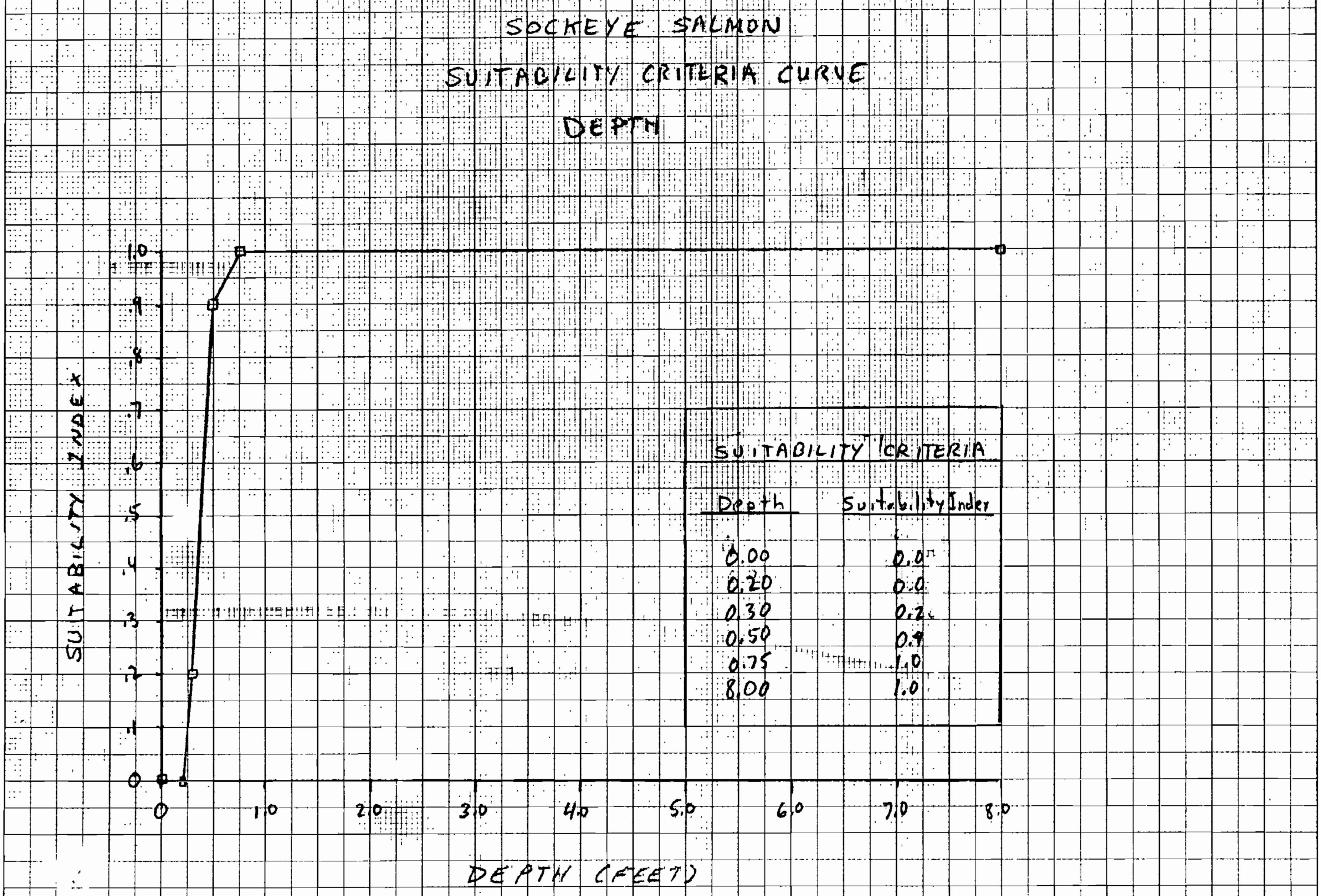


Figure 7-4-16. Depth suitability curve for sockeye salmon spawning.

4.3.2.2 Velocity

The first step in the development of the velocity suitability criteria for sockeye salmon was to select a best velocity utilization curve. Velocity measurements at sockeye salmon redds were grouped into seven incremental groupings. These groupings were plotted as seven histograms (Figure 7-4-17). Table 7-4-9 summarizes the statistics used to select the "best" utilization curve from the seven histograms. The seven histograms were not distinguishable in terms of the minimal variance criteria (see Appendix Table 7-C-4). Whereas, histograms A and B both had comparatively large indices of irregular fluctuations, and could not be chosen as the best curve, histograms C through G had no irregular fluctuations. Of these five histograms, curve F had the minimal distinguishable peakedness index. Accordingly, histogram F was selected as the "best" utilization curve (Figure 7-4-18).

The next step in the development of the velocity suitability criteria was to evaluate the best velocity utilization curve in terms of professional judgement using previously published data and opinion of field biologists. No evaluation of preference could be made due to the lack of concurrent availability data collection.

Based on the best velocity utilization curve, a suitability index of 1.0 was assigned to a velocity of 0.0 ft/sec. Based on a review of literature data (Hoopes, 1968) and opinion of field biologists familiar with sockeye salmon spawning in the Susitna River, the suitability index of 1.0 was extended out to a velocity of 1.0 ft/sec. A suitability

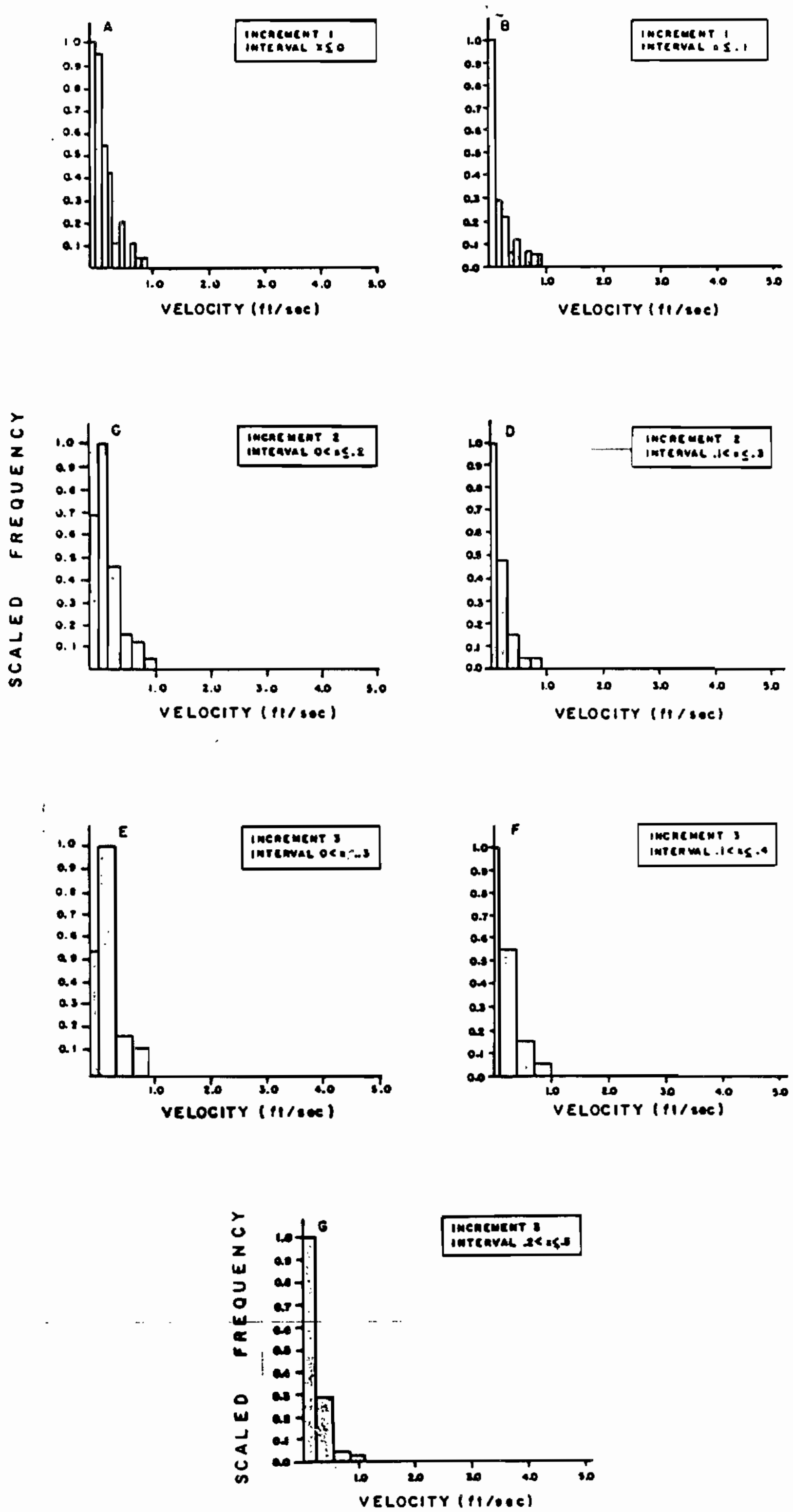


Figure 7-4-17 Incremental plots of sockeye salmon spawning velocity utilization data.

Table 7-4-9. Summary of statistics on various incremental groupings for sockeye salmon utilization velocity histograms.

HISTOGRAM LABEL	A	B	C	D	E	F	G
INCREMENT SIZE	0.1	0.1	0.2	0.2	0.3	0.3	0.3
INCREMENT START	0.0	0.1	0.0	0.1	0.0	0.1	0.2
VARIANCE	50.3	136.2	113.4	223.0	217.6	250.9	452.9
COEFFICIENT OF VARIATION	1.09	1.62	0.98	1.15	0.91	0.97	1.31
IRREGULAR FLUCTUATIONS							
Magnitude	4	4	0	0	0	0	0
Number	2	2	0	0	0	0	0
Mean	2.00	2.00	---	---	---	---	---
Maximum	2	2	---	---	---	---	---
PEAKEDNESS	0.03	0.57	0.47	0.35	0.77	0.30	0.54

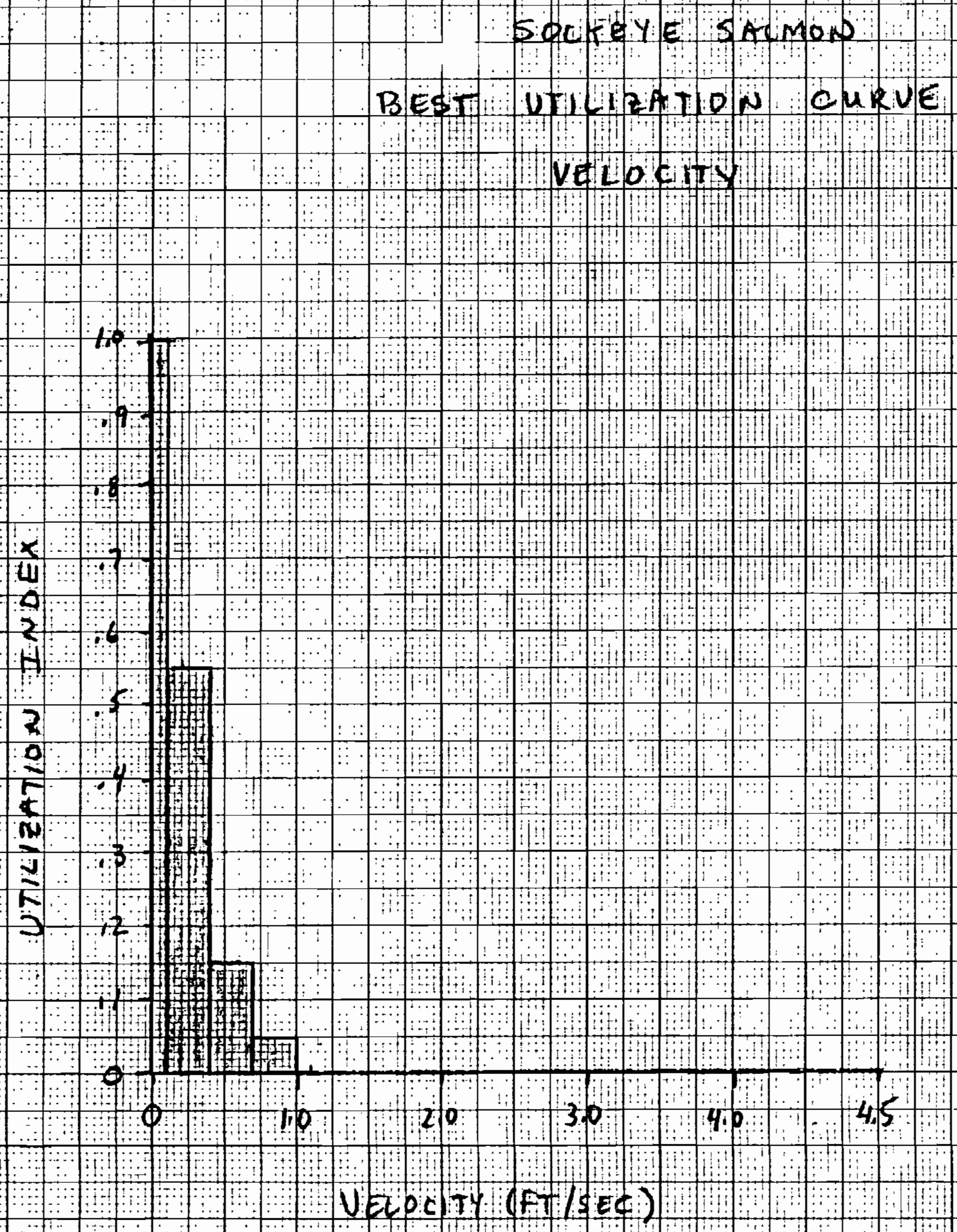


Figure 7-4-18. Best velocity utilization curve for sockeye salmon spawning

index of 0.0 was assigned to a velocity of 4.5 ft/sec because it was decided to establish the endpoint of the curve to be the same as the chum salmon curve. This was done because it was felt that velocities for sockeye salmon spawning could be no greater than for chum salmon spawning and that there was no data base to support lower velocities as an end point. Because it was felt that velocities ranging from 1.0 to 3.0 ft/sec would be more suitable for sockeye salmon spawning than velocities from 3.0 to 4.5 ft/sec, the lower range of velocities were assigned a higher suitability index than was the higher range. This was reflected by assigning a suitability index of 0.10 to a velocity of 3.0 ft/sec.

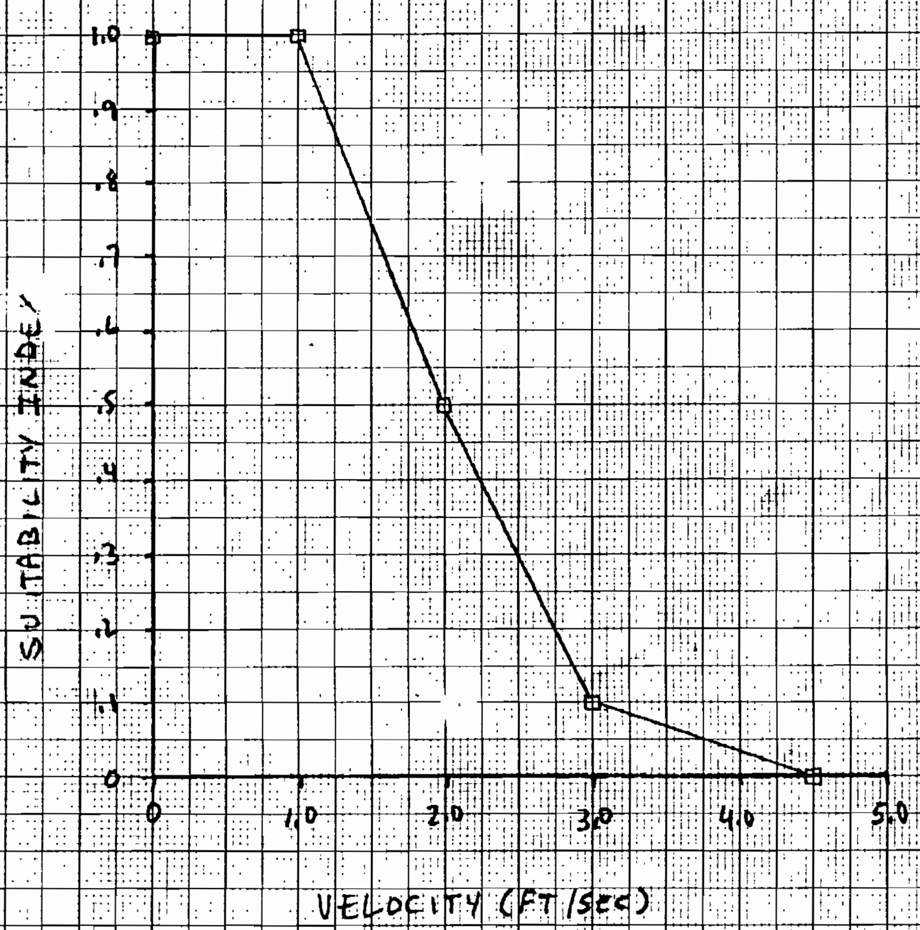
The resultant velocity suitability curve and criteria for sockeye and salmon spawning are presented in Figure 7-4-19.

4.3.2.3 Substrate

The first step in the development of substrate suitability criteria for sockeye salmon spawning was to construct a plot of utilized substrates (Figure 7-4-20). Incremental plots of substrate are not appropriate because substrate data is not continuous. Therefore, the substrate utilization data plot was treated the best substrate utilization curve.

The next step in the development of the substrate suitability criteria was to evaluate the substrate utilization curve in terms of professional judgement using literature data and opinion of field biologists. No

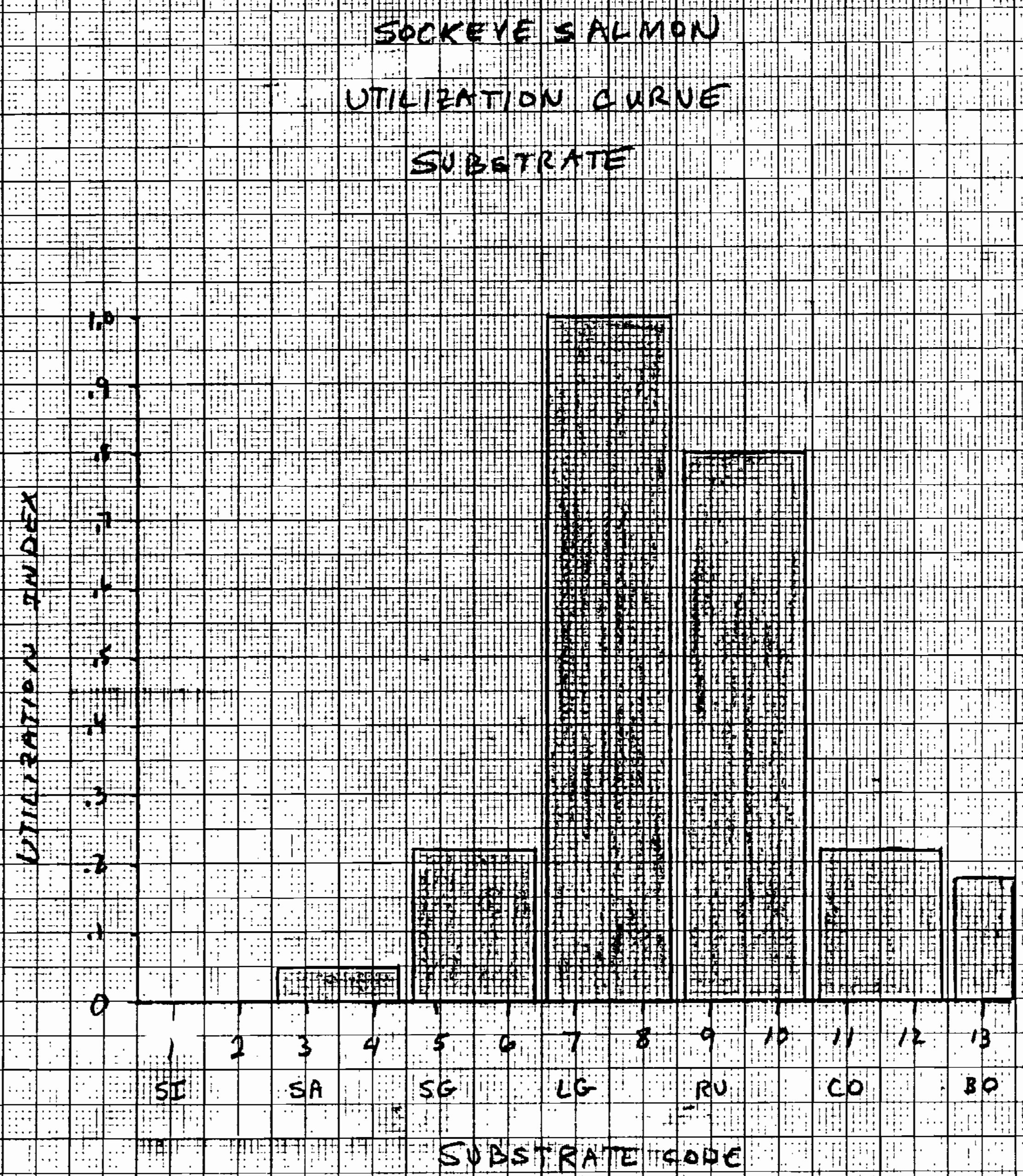
SOCKEYE SALMON
SUITABILITY CRITERIA CURVE
VELOCITY



SUITABILITY CRITERIA

VELOCITY	SUITABILITY INDEX
0.0	1.0
1.0	1.0
2.0	0.5
3.0	0.1
4.5	0.0

Figure 7-4-19. Velocity suitability curve for sockeye salmon spawning



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

Figure 7-4-20. Substrate utilization curve for sockeye salmon spawning

evaluation of preference could be made due to the lack of concurrent availability data collection.

As previously stated in the methods section, substrate utilization data were collected at a lower level of precision than substrate availability data. For this reason, the higher level precision was used when assigning suitability criteria for substrate for input in the habitat projection model. However, when assigning suitability index values to substrate data for use in the habitat projection model, the higher level of precision was once again used.

The plot of utilized substrate reveal that large gravels and rubbles appear to be most often utilized for sockeye salmon spawning. Because this agrees well with literature information (USFS 1983), these substrates (classes 7, 8, and 9) were assigned a suitability index value of 1.0. Further analysis of the plot reveals that cobble and boulder substrates were also utilized for spawning but to a lesser extent than were large gravels and rubbles. It was felt, however, that the apparent utilization of the larger substrate classes was based more on a sampling bias toward larger substrates than smaller substrates, that is, field personnel more likely noted larger substrate sizes than smaller substrate sizes. This combined with information available in the literature which show that cobble and boulder substrates are not as preferred as large gravels and rubbles for spawning lead to substrate class 10 being assigned a suitability index of 0.90, substrate class 11 a suitability index of 0.25, and substrate class 12 a suitability index 0.10. Substrate class 13 (boulder) was assigned a suitability index of

0.0 based on the noted sampling bias and the judgment that substrates consisting of only boulders would not be adequate for spawning.

The plot of utilized substrates also reveals no utilization of silt substrates and only limited utilization of sand substrates for spawning. Based on this and the opinion that pure silt and sand substrates would not be suitable for spawning, a suitability index of 0.0 was assigned to substrates classes 1 through 3. The plot also reveals moderate utilization of small gravel substrates (substrate class 4-6) for spawning. Based on field experience and literature information (reference) it was felt that the larger substrates in this range would be more suitable for spawning than would the smaller substrates. For these reasons, the larger substrates in this range were assigned a higher suitability index than were the smaller substrates. This was done by assigning a suitability index of 0.10 to substrate class 4, a suitability index of 0.50 to substrate class 5, and a suitability index of 0.95 to substrate class 6.

The resultant substrate suitability curve and criteria for sockeye salmon spawning is presented in Figure 7-4-21.

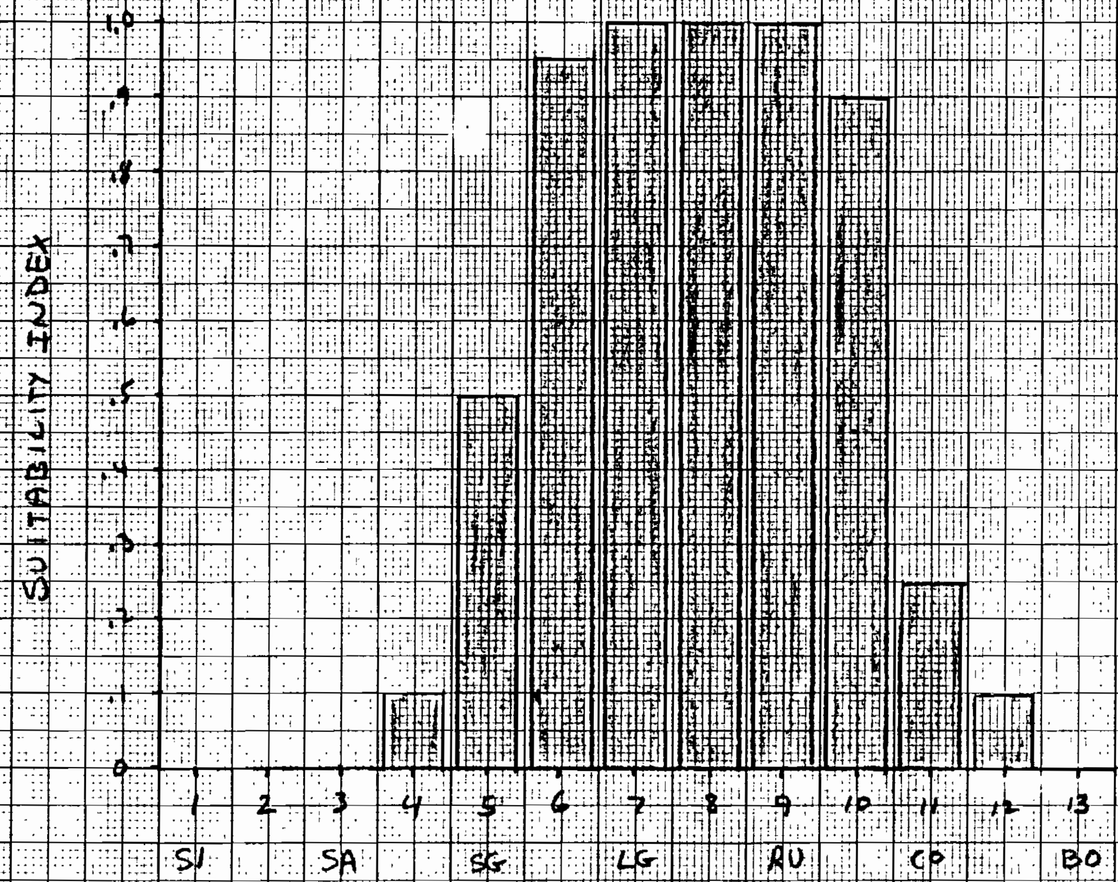
4.3.2.4 Upwelling

Based on professional opinion and field observations, suitability criteria for upwelling were assigned using a binary approach (see methods sections). That is, a suitability index of 1.0 was assigned to upwelling present and a suitability index of 0.0 was assigned to

SOCKEYE SALMON

SUITABILITY CRITERIA CURVE

SUBSTRATE



SUITABILITY CRITERIA			
SUBSTRATE CODE		PARTICLE SIZE	SUITABILITY INDEX
1	SI	SILT	0.00
2			0.00
3	SA	SAND	0.00
4			0.10
5	SG	1/8-1"	0.50
6			0.95
7	LG	1-3"	1.00
8			1.00
9	RU	3-5"	1.00
10			0.90
11	CO	5-10"	0.25
12			0.10
13	BO	>10"	0.00

Figure 7-4-21. Substrate suitability curve for sockeye salmon spawning

upwelling absent. These assignments were predicated on accumulated field observations which showed that sockeye salmon appeared to key on upwelling for spawning.

4.3.2.5 Combined Substrate/Upwelling

The combined substrate/upwelling suitability criteria developed for use in the habitat simulation model are identical to the individual substrate suitability criteria when upwelling is present. When upwelling is not present, a suitability index value of 0.0 is assigned to each substrate class. Table 7-4-10 is a tabulation of the development of the suitability index for this combined variable. The resultant suitability curve and criteria developed for the combined substrate/upwelling variable are presented in Figure 7-4-22.

4.4 DISCUSSION

4.4.1 Assumptions and Limitations of the Data Base

The techniques used in the derivation of the habitat suitability criteria presented in this report are an adaptation of those presented in Baldrige and Amos (1983) and Bovee and Cochnauer (1977). Several underlying assumptions are made in developing and applying suitability criteria as they relate to chum and sockeye salmon spawning. These include:

Table 7-4-10. Data used to develop joint (substrate and upwelling) suitability curve for sockeye salmon.

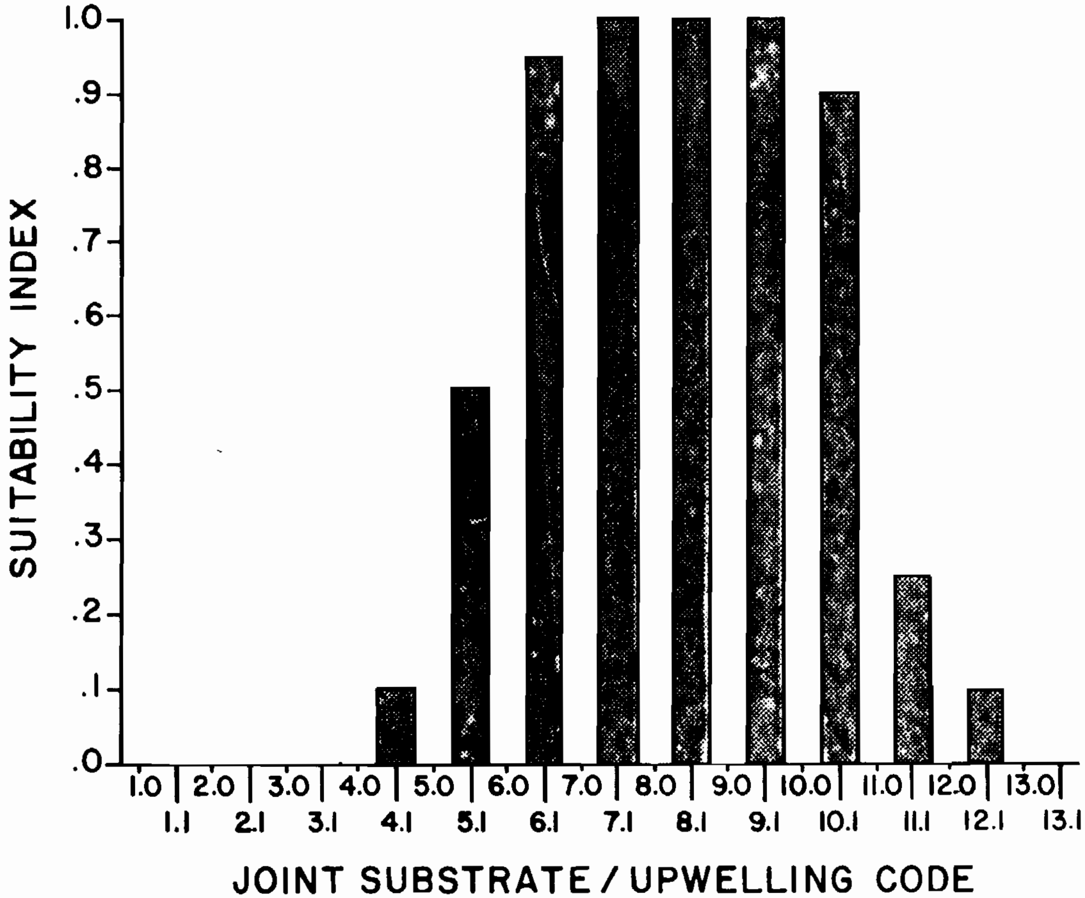
Description		Code		Weighting Factor		Combined Factor	
Substrate 1/	Upwelling 2/	Substrate	Upwelling	Substrate	Upwelling	Joint Code	Weight Factor
SI	A	1	0	0.00	0.00	1.0	0.00
SI	P	1	1	0.00	1.00	1.1	0.00
SI/SA	A	2	0	0.00	0.00	2.0	0.00
SI/SA	P	2	1	0.00	1.00	2.1	0.00
SA	A	3	0	0.00	0.00	3.0	0.00
SA	P	3	1	0.00	1.00	3.1	0.00
SA/SG	A	4	0	0.01	0.00	4.0	0.00
SA/SG	P	4	1	0.01	1.00	4.1	0.10
SG	A	5	0	0.05	0.00	5.0	0.00
SG	P	5	1	0.05	1.00	5.1	0.50
SG/LG	A	6	0	0.95	0.00	6.0	0.00
SG/LG	P	6	1	0.95	1.00	6.1	0.95
LG	A	7	0	1.00	0.00	7.0	0.00
LG	P	7	1	1.00	1.00	7.1	1.00
LG/RU	A	8	0	1.00	0.00	8.0	0.00
LG/RU	P	8	1	1.00	1.00	8.1	1.00
RU	A	9	0	1.00	0.00	9.0	0.00
RU	P	9	1	1.00	1.00	9.1	1.00
RU/CO	A	10	0	0.90	0.00	10.0	0.00
RU/CO	P	10	1	0.90	1.00	10.1	0.90
CO	A	11	0	0.25	0.00	11.0	0.00
CO	P	11	1	0.25	1.00	11.1	0.25
CO/BO	A	12	0	0.10	0.00	12.0	0.00
CO/BO	P	12	1	0.10	1.00	12.1	0.10
BO	A	13	0	0.00	0.00	13.0	0.00
BO	P	13	1	0.00	1.00	13.1	0.00

1/ SI - Silt, SA - Sand, SG - Small Gravel, LG - Large Gravel, RU - Rubble, Co - Cobble, BO - Boulder

2/ A - Absent, P - Present

7-4-63

SOCKEYE SALMON
COMBINED SUITABILITY CRITERIA CURVE
SUBSTRATE / UPWELLING



SUITABILITY CRITERIA

CODE	SUITABILITY INDEX
1.0	0.00
1.1	0.00
2.0	0.00
2.1	0.00
3.0	0.00
3.1	0.00
4.0	0.00
4.1	0.10
5.0	0.00
5.1	0.50
6.0	0.00
6.1	0.95
7.0	0.00
7.1	1.00
8.0	0.00
8.1	1.00
9.0	0.00
9.1	1.00
10.0	0.00
10.1	0.90
11.0	0.00
11.1	0.25
12.0	0.00
12.1	0.10
13.0	0.00
13.0	0.00

Figure 7-4-22 Combined substrate/upwelling suitability curve for sockeye salmon spawning

1) Depth, velocity, substrate, and upwelling are the most critical habitat variables affecting the selection of spawning areas by chum and sockeye salmon;

2) These habitat variables are mutually independent (i.e., varying the level of one variable does not affect the level of another);

3) A sufficiently large random sample was obtained to accurately represent the range of utilized and available habitat conditions found in sloughs and side channels;

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

5) Suitability criteria developed from data collected at representative study site can be assumed to be representative of suitability of habitats in other areas.

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

The question of whether these four habitat variables act independent of one another was addressed by statistically analyzing the relationship between these habitat variables. Plots depicting the relationship between utilized depths versus velocities, utilized depths versus substrates, and utilized velocities versus substrates for each species are depicted in Figure 7-4-23 and 7-4-24. Included on each plot is the coefficient of linear correlation (r) computed for each relationship. It was not possible to statistically analyze the relationship of depth, velocity, or substrate to upwelling due to the limited nature of the upwelling data. Based on the coefficients of linear correlation values, there does not appear to be a statistically significant relationship between any of these habitat variables for either chum or sockeye salmon; that is, they do appear to act independent of one another.

Although systematic random sampling of the entire spawning population was attempted, portions of the population were undoubtedly overlooked. Turbid water conditions accompanying high flows during spawning periods made it difficult to locate active chum and sockeye salmon redds. Because of this, redds located in side channel habitats are likely to be underrepresented in the analyses.

The number of redd measurements obtained within modelling study sites was limited by low escapement and low flow conditions during 1982 and

CHUM SALMON

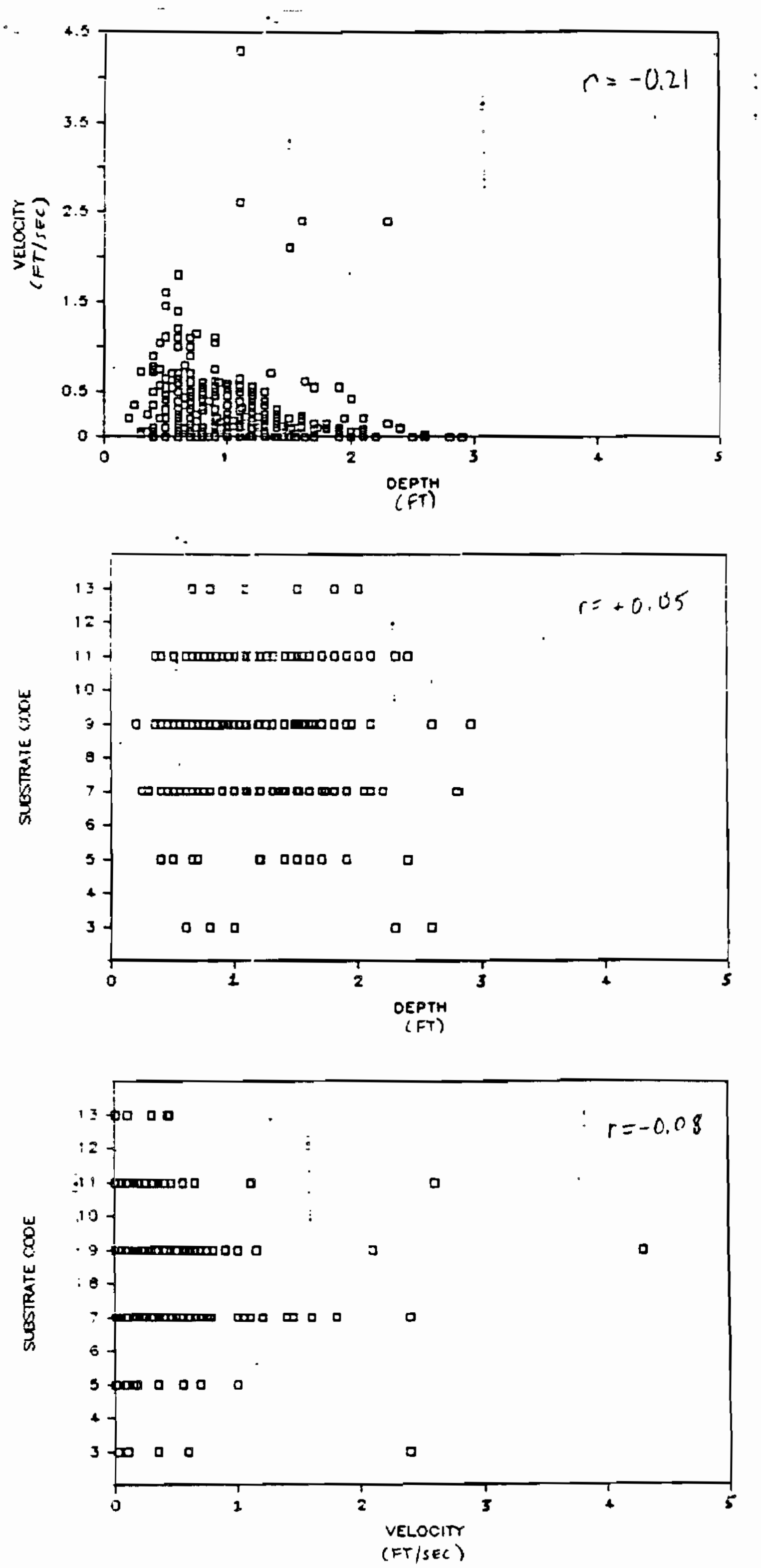


Figure 7-4-23. Plots depicting the relationship between utilized depths versus velocities, utilized depths [illegible] and utilized velocities versus substrates for chum salmon spawning.

SOCKEYE SALMON

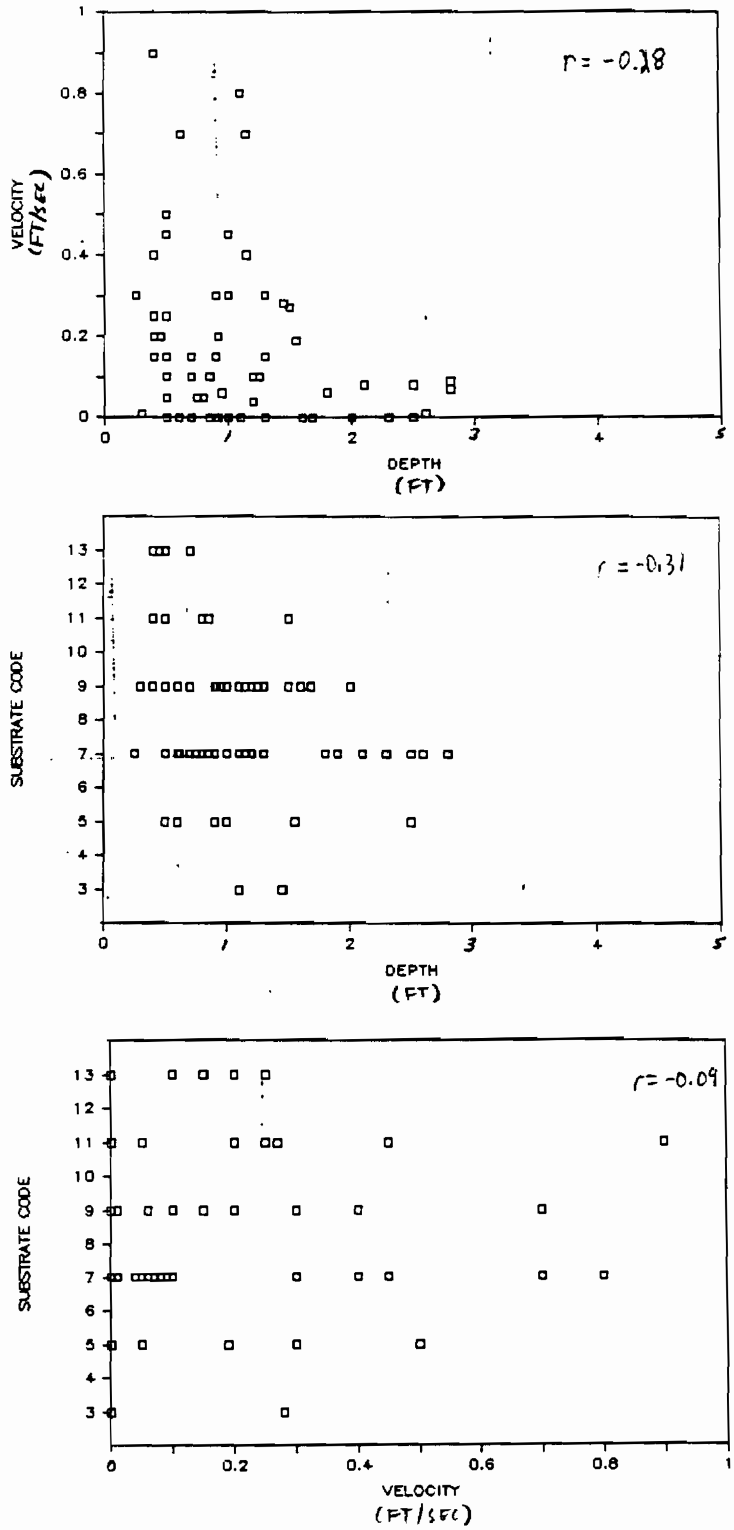


Figure 7-4-24. Plots depicting the relationship between utilized depths versus velocities, utilized depths versus substrates, and utilized velocities versus substrates for sockeye salmon spawning.

1983. Sample sizes, therefore, may affect both the occurrences and the representativeness of the suitability criteria. This problem was partially circumvented by collecting additional utilization data in areas outside of the availability modelling sites. Time and resource constraints, however, precluded the collection of concurrent availability data in areas outside of the modelling sites. For this reason, it could not be determined whether the spawning habitat utilization data collected outside of modelling areas represented a preference data base. Since only a limited amount of concurrent utilization/availability data were collected and evaluated, it is questionable whether the preference data base should be used to evaluate the suitability of habitats in other areas.

In summary, the inherent assumptions used in the development of the suitability criteria presented in the report appear justified. Although, specific assumptions may be violated under certain circumstances. The extent to which these violations influence our analyses, however, is different to evaluate. It is believed however that such violations exert only a limited influence.

4.4.2 Suitability Criteria

4.4.2.1 Chum Salmon

The suitability criteria developed in this section for the habitat variables of depth, velocity, substrate, and upwelling represent our best estimation of the suitability of these habitat variables for chum salmon spawning in side sloughs and side channels in the middle reach of the Susitna River where spawning currently occurs. The criteria are based on an evaluation of utilization of these habitat variables and modified using an evaluation of preference and professional judgment based on literature information and opinion of field biologists.

These data and analyses may be compared with information available in literature to assess their adequacy. Two literature sources were located summarizing chum salmon spawning data which could be used to evaluate the suitability criteria developed in this study. These include the literature survey by Hale (1981) and the Terror Lake environmental assessment by Wilson et al. (1981). Utilization data collected within the Susitna River drainage are similar to the ranges summarized in Hale. However, since the author did not develop criteria curves, comparisons of preference or suitability criteria could not be made. Hale emphasized the importance of upwelling groundwater to chum salmon spawning which lends credence to the binary criteria developed for upwelling in this study.

In the Terror Lake study, Wilson et al. (1981) developed suitability curves for chum salmon spawning. Although the ranges of the curves described in this study fall within the range of the Terror Lake data, differences between the two sets of criteria emphasize the importance of developing curves specific to the drainage and stock being considered. For example, the chum salmon velocity curves developed for the Susitna River indicate a peak suitability in much slower waters than do the Terror Lake curves. The upper limits of the two curves, however, differed by only 0.5 ft/sec. The substrate suitability curves for chum salmon spawning for the two studies were similar, although, the Susitna curve had a slightly wider range than the Terror Lake curve.

4.4.2.2 Sockeye Salmon

The suitability criteria developed in this section for the habitat variables of depth, velocity, substrate, and upwelling represent our best estimation of the suitability of these habitat variables for sockeye salmon spawning in side sloughs and side channels in the middle reach of the Susitna River which currently support spawning. The criteria are based on a limited utilization data base without corresponding availability data to support a preference analysis. Professional judgment based on literature data and opinion of field biologists was used to modify the utilization data.

Studies which summarized sockeye salmon habitat characteristics were presented in a literature review by the U.S. Fish and Wildlife Service (USFWS 1983). The ranges of depth, velocity, and substrate conditions observed in the side sloughs were within the ranges outlined in the USFWS review. Suitability curves were not developed; therefore, these data were of minimal value for comparison.

4.4.3 Recommended Applications and Limitations of the Suitability Criteria

The suitability criteria developed in this section represent the suitability of several critical habitat variables important for chum and sockeye salmon spawning (depth, velocity, substrate, and upwelling) in modelled side sloughs and side channels of the middle Susitna River reach. They represent a synthesis of limited utilization and availability data using statistical methods, literature information, and professional judgment. They were developed for input into the HABTAT portion of the PHABSIM models to calculate joint preference factors to be used to project weighted usable areas of spawning habitat at study sites (see following section).

Application of these criteria to areas outside of modelling sites must be determined on a case-by-case basis. For example, although it is likely that the criteria presented in this section can be applied to other non-modelled side slough and side channel habitats in the middle reach of the Susitna River which currently support spawning as discussed in section 2.0, it must first be determined whether the underlying assumptions used in the derivation of these criteria can be applied to such other habitats.

Prior to such uses, it is recommended that additional field data be obtained to verify the use of the criteria in other habitats.

5.0 SPAWNING HABITAT PROJECTIONS

5.1 Introduction

This section presents the results of the third step of the IFIM physical habitat simulation (PHABSIM) modelling system: the projection of weighted usable area (WUA), an index of spawning habitat availability. A discussion is presented of the final processes for linking the physical habitat availability models (developed in Section 2.0) with the spawning habitat criteria (developed in Section 3.0) using a habitat simulation (model HABTAT to project WUA for chum and sockeye salmon spawning habitat as a function of flow variation at selected physical availability modelling study sites.

5.2 Methods

5.2.1 Analytical Approach and Methodology

The final stage in calculating WUA of spawning habitat using the PHABSIM system involves linking the output of the physical habitat availability models with fish habitat criteria using the HABTAT computer model (Milhous et al. 1981). In the initial step of this process, habitat suitability criteria values (derived from the spawning habitat suitability criteria presented in section 3.0) are assigned to each of the three habitat variable values determined for each cell within the study site for a given flow using the physical availability model presented in section 2.0.

Two of the habitat variables, depth and velocity, are integral to the operation of the model. Depth and velocity values for each cell were provided by hydraulic simulation runs of physical availability models. The third habitat variable can represent any other habitat variable considered important for spawning. This variable is assumed to be independent of flow; that is, the habitat variable value and the corresponding suitability criteria index value assigned to the cell remains constant for all flows evaluated. Substrate, upwelling, and cover are the most common habitat variables used in conjunction with depth and velocity in the model. Because upwelling and substrate are both of importance in terms of spawning at the study sites evaluated, the model was run using a combined substrate/upwelling criteria to represent the third habitat variable.

A combined substrate/upwelling habitat variable value was assigned to each cell using a two digit code. The first digit represented the substrate classification value and the second indicated the presence or absence of upwelling. Each cell was assigned a value of either 1.0 for upwelling present or 0.0 for upwelling absent. The upwelling classification was based on field data and experience, winter observations, and aerial photography of open thermal leads.

After habitat suitability values are determined and assigned to the three habitat variable values for each cell, a Joint Preference Factor (JPF) is calculated for that cell which is a function of the three habitat suitability values for that cell. There are three methods commonly used to calculate the JPF (Bovee and Cochnauer 1977):

1. Standard Calculation Method - The JPF is calculated as the geometric mean of the habitat suitability values determined for the three habitat variable values. This technique implies synergistic action; that is, optimum habitat exists within a cell if only the suitability of all variables is optional.

2. Geometric Mean Method - The JPF is calculated as the geometric mean of the habitat suitability values determined for the three habitat variable values. This technique implies compensation effects; that is, if two of the three variables are in the optimum range, the value of the third variable has little effect unless it is zero.

3. Lowest Limiting Parameter Method - The JPF is equal to the lowest habitat suitability value of the three habitat variable values being considered for a cell. In other words, the availability of habitat within a cell is determined by the most limiting variable present. This implies a limiting factor concept; that is, that the habitat is no better than its least suitable factor.

The standard calculation method for computing the JPF was selected for analysis because it was felt the assumptions of this method best suited the available data. Alternative methods for computing the JPF were judged inappropriate; however, the use of binary criteria for upwelling implicitly acknowledges the limiting factor concept. All other habitat variables appear to act synergistically, justifying the selection of the standard calculation method of evaluation. Output from habitat simulation runs using alternative computational methods (Table 7-5-1) are on file at the ADF&G Su Hydro Office, 2207 Spenard Road, Anchorage, Alaska 99503.

After calculation of the JPF is completed for each cell, the model computes the WUA of the cell by multiplying the cell area derived from the output of the physical availability model by the JPF. The WUA values for all cells are summed to obtain the total WUA for the modelling site for the particular flow being evaluated. The final WUA value is expressed in square feet per 1,000 feet of channel. The entire process is then repeated for other flows to assess the influence of flow variation on WUA at the study site.

The HABTAT model was run for the physical availability modelling study sites that currently support chum and sockeye salmon spawning (Sloughs 8A, 9, and 21, Upper Side Channel 11, and Side Channel 21) and for the two sites which did not support spawning (Side Channel 10 and Lower Side Channel 11) over the range of flows within the extrapolation range of the hydraulic availability model. Because no spawning was documented at Side Channel 10 and Lower Side Channel 11, the WUA projections for these sites were not used as an index of available spawning habitat at the sites. Instead, these projections were only made for comparison with model projections at sites which support spawning (refer to section 5.2.2) The output of these runs were entered into a microcomputer worksheet program so additional analyses of the data could be performed.

Table 7-5-1. Runs of the HABTAT model completed using other computational methods.*

JPF Computational Method	Third Habitat Variable Evaluated
Standard Calculation	Substrate
Standard Calculation	Upwelling
Geometric Mean	Substrate
Geometric Mean	Upwelling
Lowest Limiting Factor	Substrate
Lowest Limiting Factor	Upwelling
Lowest Limiting Factor	Combined Substrate/Upwelling

* Output from these additional runs of the model are on file at the ADF&G Su Hydro Office, 2207 Spenard Road, Anchorage, Alaska 99503.

Plots comparing WUA of spawning habitat to gross surface area as a function of site flow were constructed for each study site. Additional plots of WUA as a function of site flow using an expanded y axis were also constructed for each site to better depict and compare trends of WUA within and between study sites. The controlling breaching discharge (i.e., the mainstem discharge at which the site flow becomes directly controlled by mainstem discharge) was superimposed on each of these plots.

The relationships between WUA and gross surface area to mainstem discharge were also plotted for periods when the site flow was directly controlled by mainstem discharge during the peak months of spawning (August and September). Additional plots using an expanded y axis were constructed for each site to better depict and compare trends of WUA at and between study sites. The x-coordinate values on these plots were derived using site - specific flow/mainstem discharge rating curves (Table 7-5-2). Plots of WUA of spawning habitat as a function of mainstem discharge were not constructed for Slough 8A as this site is rarely controlled by mainstem during August or September.

From these data, predictions of WUA of spawning habitat that corresponded to the mean daily discharge levels observed from August 1 to September 30 for the years 1981, 1982, and 1983 were selected by interpolating from the WUA/mainstem discharge relationship to construct a time series plot of WUA at each of the study sites. If the mainstem discharge for a particular day exceeded the extrapolation range of the

Table 7-5-2. Relationships of site flow to mainstem discharge used to derive plots of WUA of spawning as a function of mainstem discharge for each site when the site flow was directly controlled by mainstem discharge (see Chapter 1 of this report).

Study Site	Site Flow/Mainstem Discharge Relationship
Slough 8A	$Qs = 10^{-19.2034} (Qms)^{4.6359}$
Slough 9	$Qs = 10^{-37.7897} (Qms)^{9.0556}$
Slough 21	$Qs = 10^{-48.6021} (Qms)^{11.3182}$
Side Channel 10	$Qs = 10^{-35.5566} (Qms)^{8.5446}$
Lower Side Channel 11	$Qs = 10^{-3.2278} (Qms)^{1.5460}$
Upper Side Channel 11	$Qs = 10^{-19.9340} (Qms)^{5.0729}$
Side Channel 21	$Qs = 10^{-11.0238} (Qms)^{3.1632}$

Key: Qs = Site Flow

Qms = Mainstem Discharge

model, a WUA value of 0.0 was entered into the time series. For days when the mainstem discharge did not control the site flow, the WUA associated with an average base flow present during uncontrolled conditions at each site was entered into the time series (Table 7-5-3). The mainstem discharge record for Gold Creek (USGS 1981, 1982, 1983) for the same period was superimposed on each of these plots.

5.2.2 Model Validation

Projections of spawning habitat WUA were completed for the two modelling study sites at which no chum/sockeye salmon spawning has not been observed (Side Channels 10 and Lower 11) for comparison with the projections of WUA calculated for the study sites which currently support chum/sockeye salmon spawning.

The ratio of chum and sockeye salmon spawning WUA to gross surface area projected for each of the study sites modelled at a mainstem discharge of 16,500 cfs were also determined to compare the relative amount of projected spawning habitat available at each study site to the relative density of spawner use at each study site. The ratio of projected WUA to gross surface area was used as an indicator of the relative amount of spawning habitat at study sites per unit area. The comparisons were based on a mainstem discharge for the months of August and September. For sites at which the site flow was controlled by mainstem discharges exceeding 16,500 cfs, the typical base level value of WUA and gross surface area present during uncontrolled conditions at each site was used (Table 7-5-3) to calculate the ratio.

Table 7-5-3. Typical base flows and associated WUA's for non-controlled flow conditions at study sites.

Study Site	Base Site Flow	WUA (x1000) Chum	WUA (x1000) Sockeye
Slough 8A	20	5.8	6.0
Slough 9	8	3.4	5.6
Slough 21	8	6.9	8.0
Upper Side Channel 11	15	5.7	8.2
Side Channel 21	40	3.0	4.4
Side Channel 10	10	0.4	1.0
Lower Side Channel 11	-*	-*	-*

* Site was never not controlled by mainstem discharge during August and September 1981, 1982, and 1983.

5.3 Results

5.3.1 Weighted Usable Area Projections

5.3.1.1 Chum Salmon

Projection of gross surface area and WUA of chum salmon spawning habitat as a function of site flow for the modelling study sites at which

spawning has been documented (Sloughs 8A, 9, and 21, Upper Side Channel 11, and Side Channel 21) are presented in Figures 7-5-1 through 7-5-5. For the range of flows at each study site that are directly controlled by mainstem discharge, the gross area and WUA projections as a function of mainstem discharge are also presented. Data used to develop these plots are presented in Appendix Table 7-D-1 through 7-D-5.

Typically, projections of gross surface area at each of the study sites increase with increasing site flow and mainstem discharge. The most rapid increase in surface area generally occurs at the lower site flows prior to the site flow becoming controlled by the mainstem. Subsequent to controlling mainstem discharges, the increase in gross area begins to level off.

Projections of WUA of chum salmon spawning habitat at each study site generally follow similar trends as the projections of gross surface area, with the exception that projections of WUA peak or level off at some site flow/mainstem discharge. Overall, the projections of WUA are

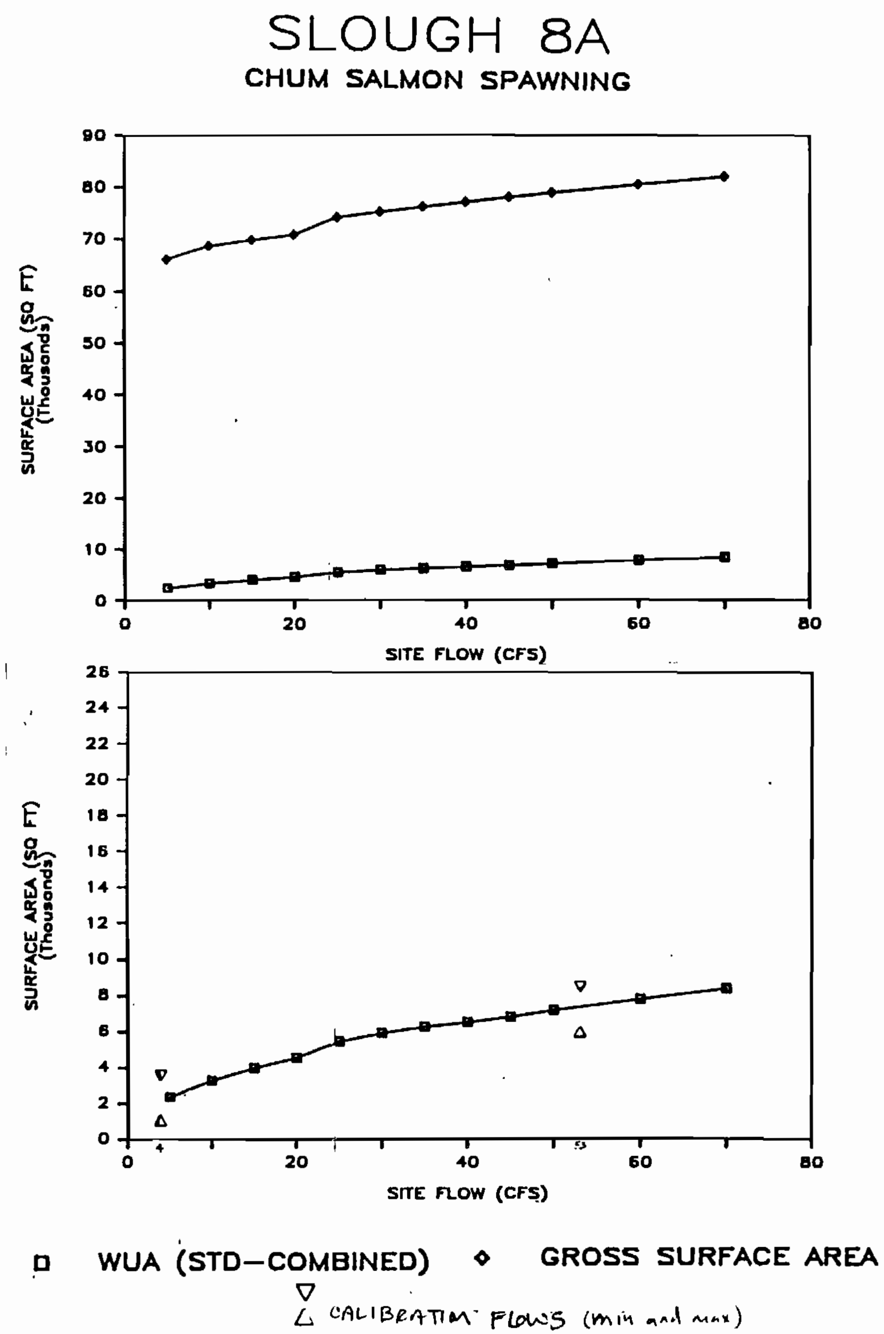


Figure 7-5-1 Projections of gross surface area and WUA of chum salmon spawning habitat as a function of site flow and mainstem discharge for the Slough 8A modelling site.

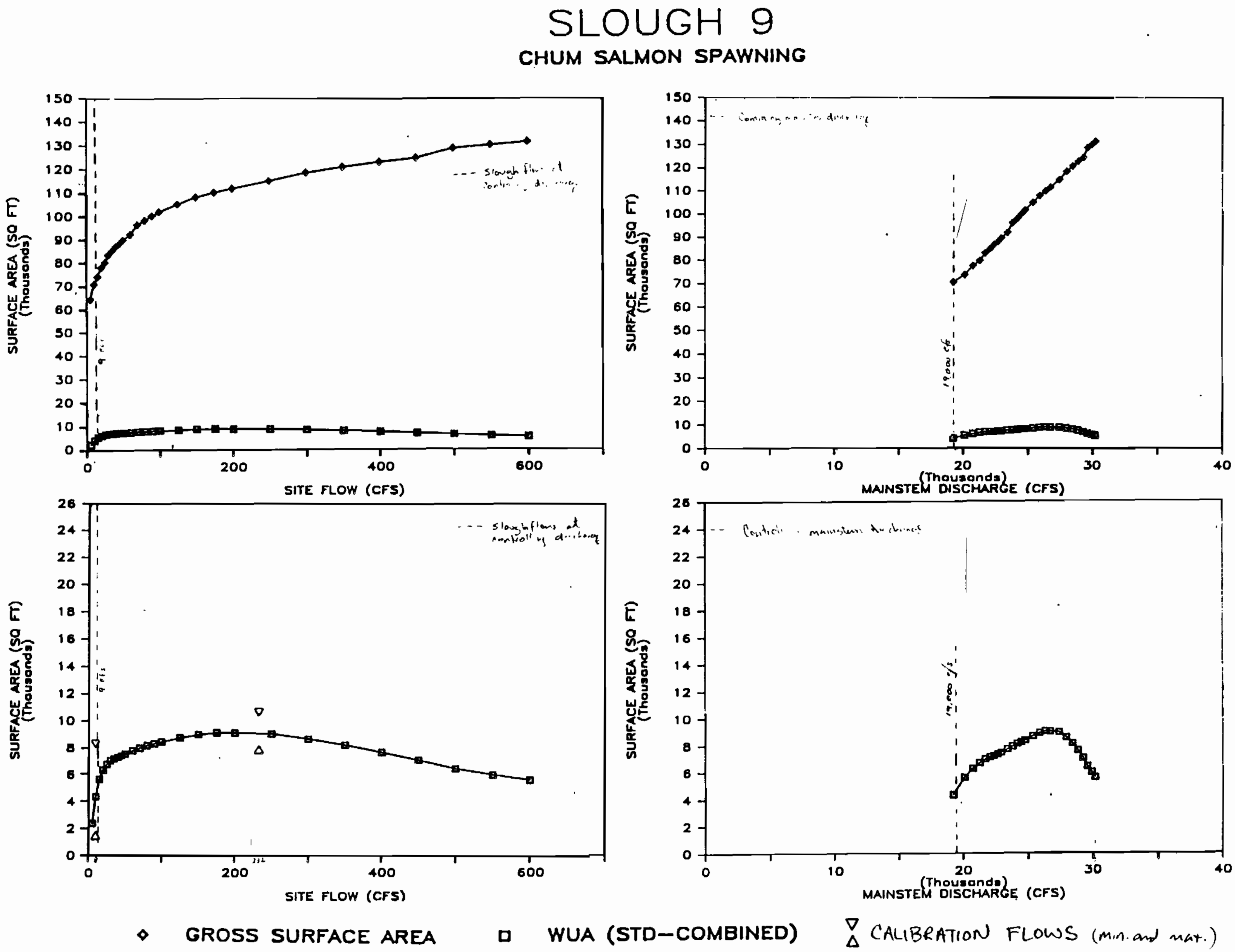


Figure 7.5-2. Projections of gross surface area and WUA of chum salmon spawning habitat as a function of site flow and mainstem discharge for the Slough 9 modelling site.

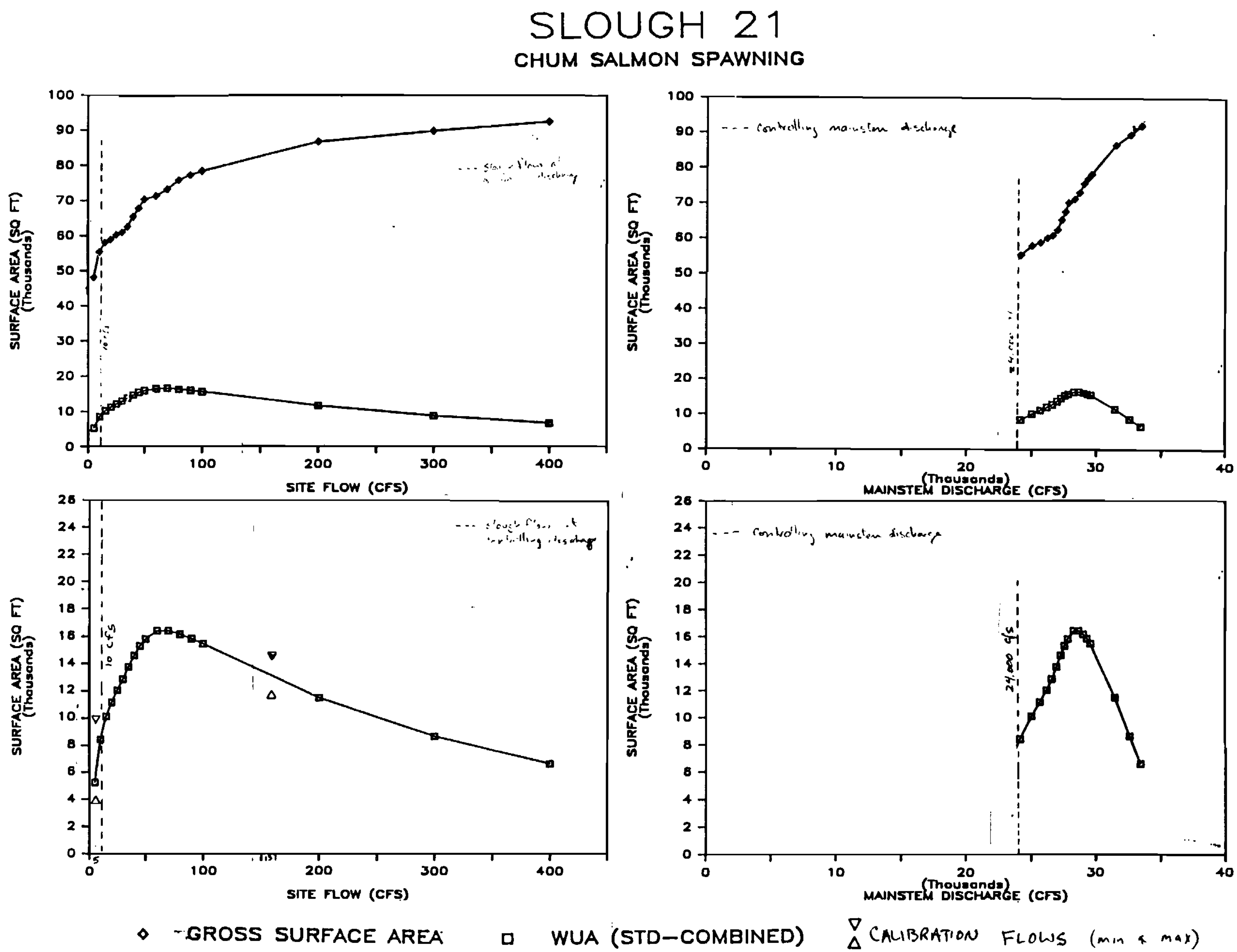


Figure 7-5-3. Projections of gross surface area and WUA of chum salmon spawning habitat as a function of site flow and mainstem discharge for the slough 21 modelling site.

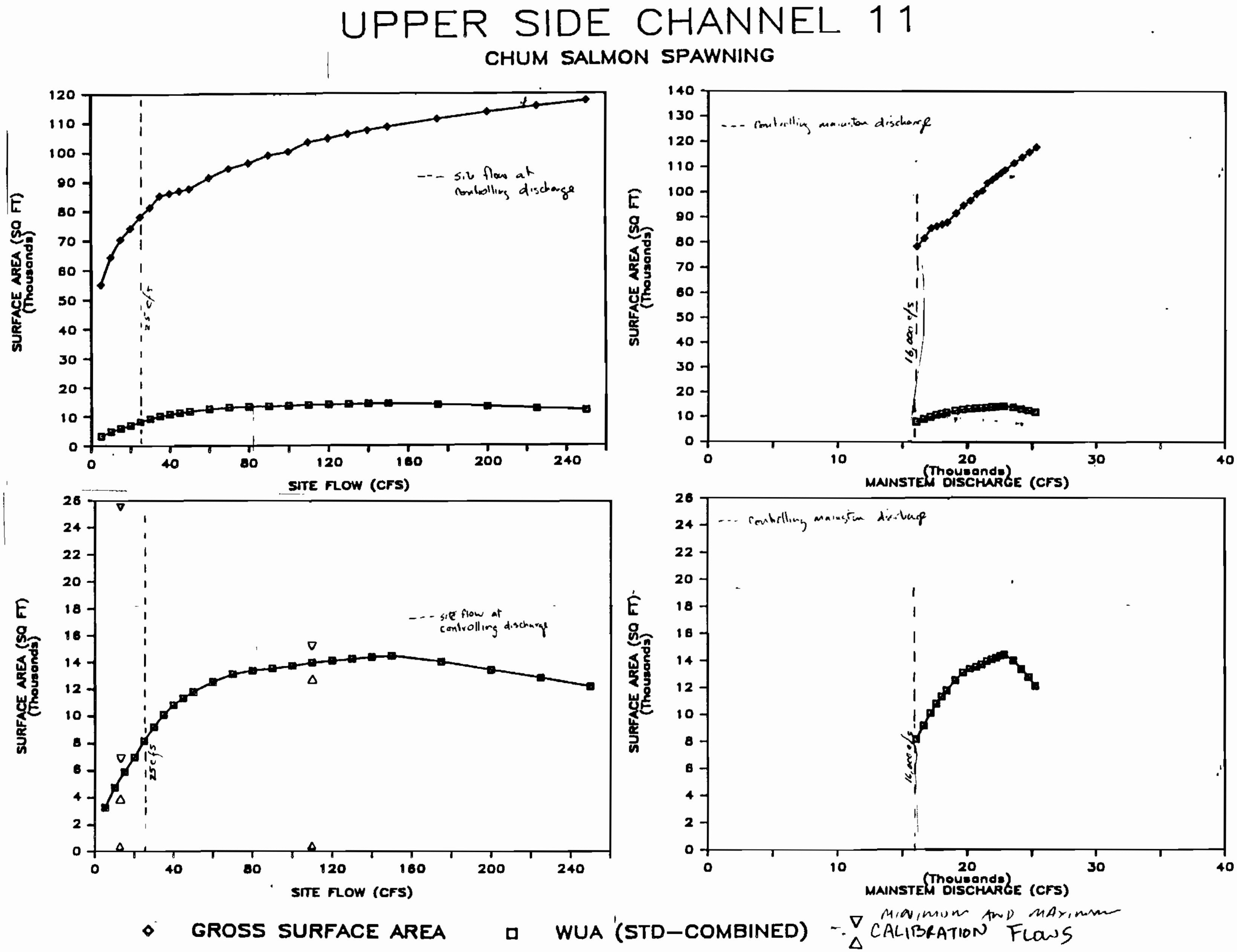


Figure 7.5.4. Projections of gross surface area and WUA of chum salmon spawning habitat as a function of site flow and mainstem discharge for the Upper Side Channel 11 modelling site.

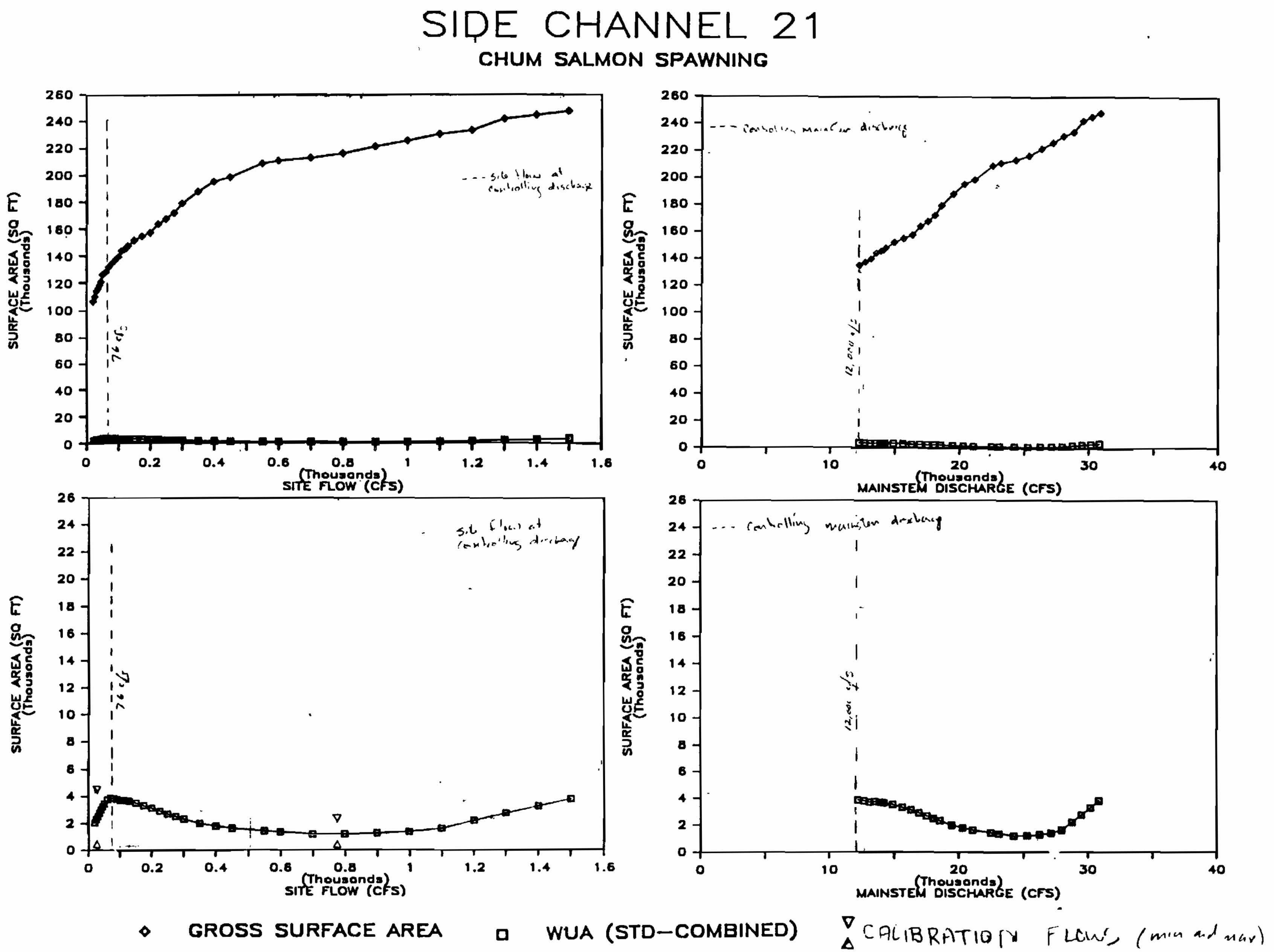


Figure 7-5-5. Projections of gross surface area and WUA of chum salmon spawning habitat as a function of site flow and mainstem discharge for the Side Channel 21 modelling site.

less than 20% of the projected gross surface area at a given study site. Typically, the peaks in WUA of spawning habitat occur when the site flow is directly controlled by mainstem discharge, usually in the range of mainstem discharges extending from 20,000 to 35,000 cfs. An exception to this trend is Side Channel 21, where two peaks in WUA of spawning habitat occur. The first peak coincides with site overtopping by the mainstem, and the second occurs at a mainstem discharge of 30,000 cfs. The bimodal shape of the WUA curve is likely linked to the specific channel geometry and hydraulic characteristics of this side channel.

Although peaks in WUA typically occur when the site flow is directly controlled by mainstem discharge, these conditions generally prevail less than 40% of the time in August and September for slough study sites and less than 75% of the time for side channel study sites (Table 7-5-4). Whereas high values for WUA may be projected for a particular study site, these projected values occur infrequently under isolated high mainstem discharge conditions. For example, comparatively high WUA values exceeding 7,800 square feet are possible for Slough 8A at mainstem discharges exceeding 33,000 cfs. However, based on the historical 30 year discharge record, these discharges occur only 4% of the time during the period of peak spawning (August through September).

Time series plots of spawning WUA projections as a function of mainstem discharge for the period August through September for the years 1981, 1982, and 1983 are presented in Figures 7-5-6 through 7-5-10. These plots depict the temporal variability of WUA at each study site during the months of peak spawning activity. In general, sites which have

Table 7-5-4. Range of WUA of chum salmon spawning habitat during non-controlling and controlling mainstem discharges and the percent of time the sites are not controlled and controlled by mainstem discharge during August and September.

Study Site	Controlling Breaching Discharge (cfs)	NOT CONTROLLED BY MAINSTEM Q		CONTROLLED BY MAINSTEM Q	
		% of Days in August & September[1]	Range of WUA (x1000)	% of Days in August & September[1]	Range of WUA (x1000)
Slough 8A	33,000	96	2.4-7.8	4	7.8-8.3
Slough 9	19,000	60	2.4-4.3	40	4.3-9.1
Slough 21	24,000	84	5.2-8.5	16	6.6-16.4
Upper Side Channel 11	16,000	47	3.3-8.2	53	8.2-14.4
Side Channel 21	12,000	27	2.1-3.9	73	1.2-3.8

[1] Based on 30 year historical record.

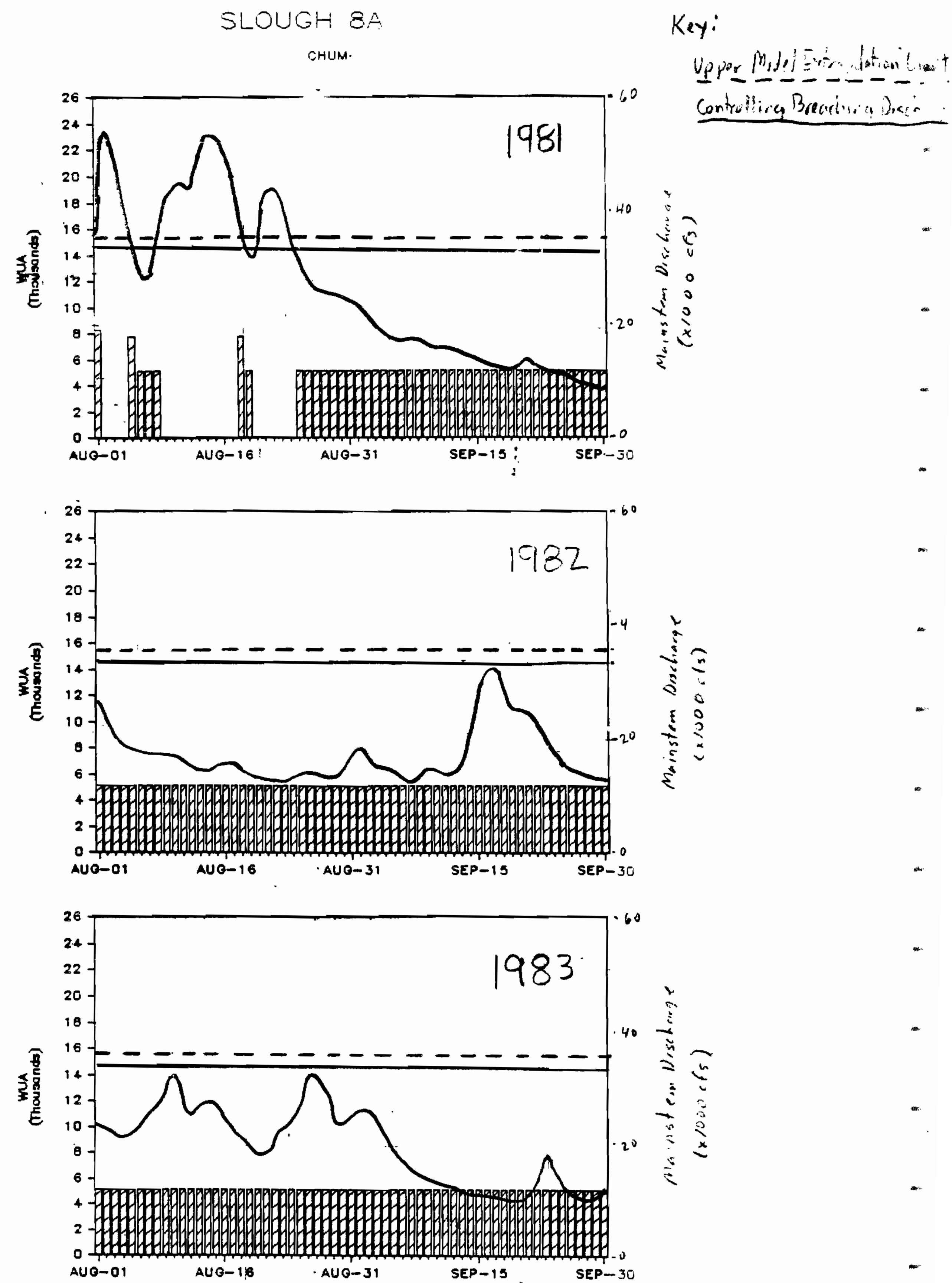


Figure 7-5-6. Time series plots of chum salmon spawning WUA as a function of mainstem discharge for the months of August through September, 1981, 1982, and 1983 for the Slough 8A modeling site.

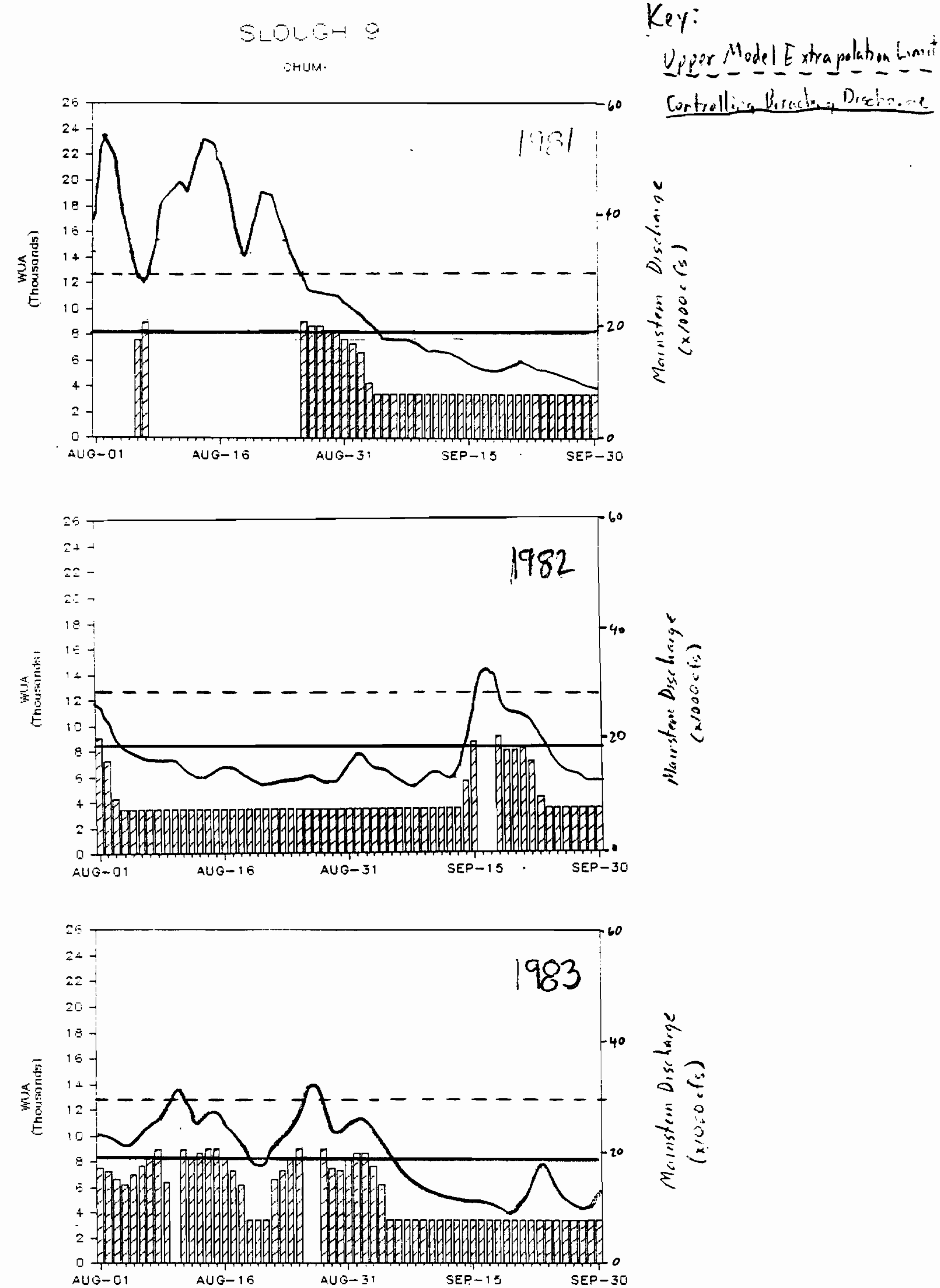


Figure 7-5-7. Time series plots of chum salmon spawning WUA as a function of mainstem discharge for the months of August and September, 1981, 1982, and 1983 for the Slough 9 modeling site.

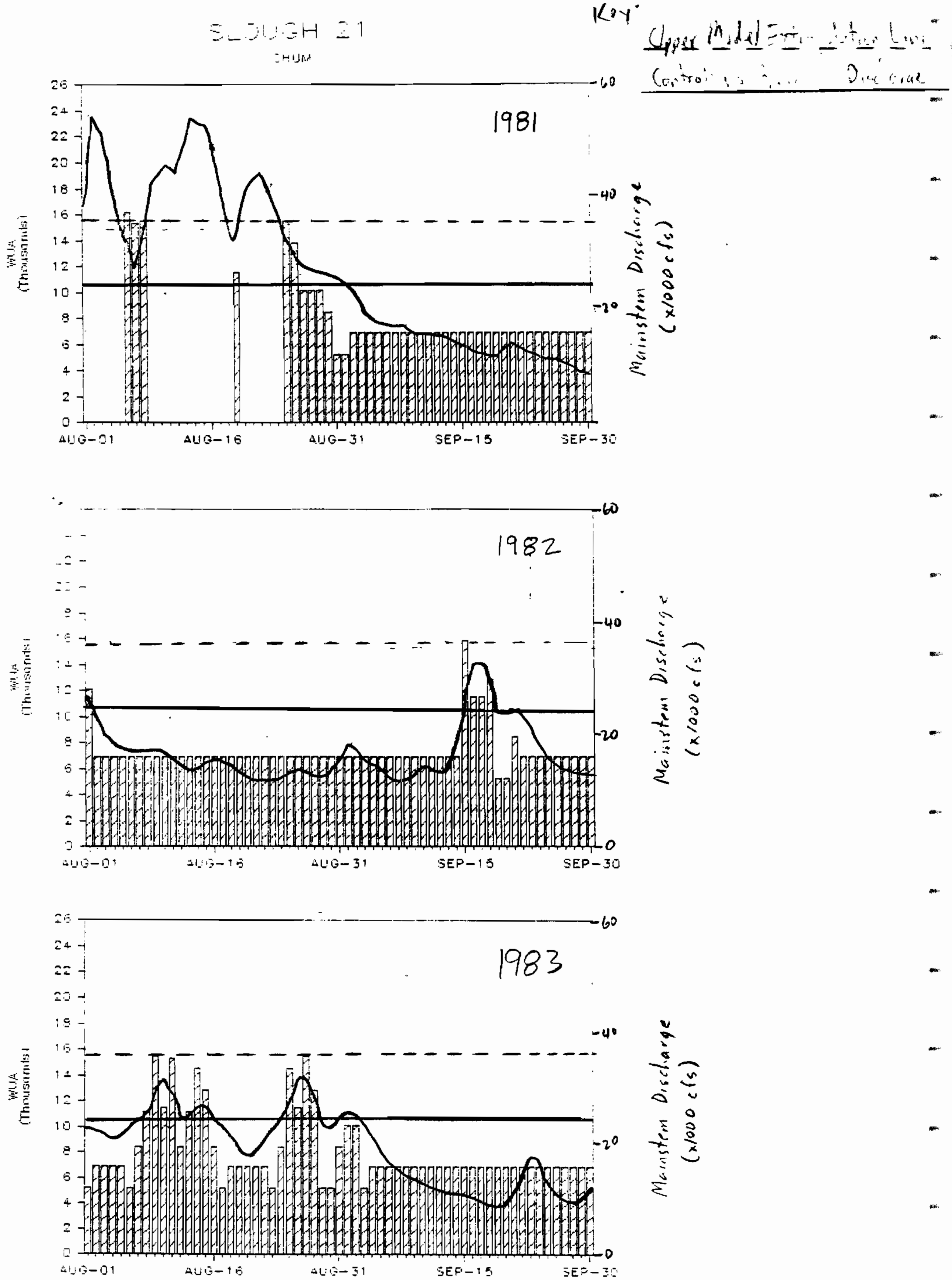


Figure 7-5-8, Time series plot of chum salmon spawning WUA as a function of mainstem discharge [illegible] the months of August through September, 1981, 1982, and 1983 for the [illegible] 21 modelling site

Upper Model Extrapolation Unit
Controlling Breaching Discharge

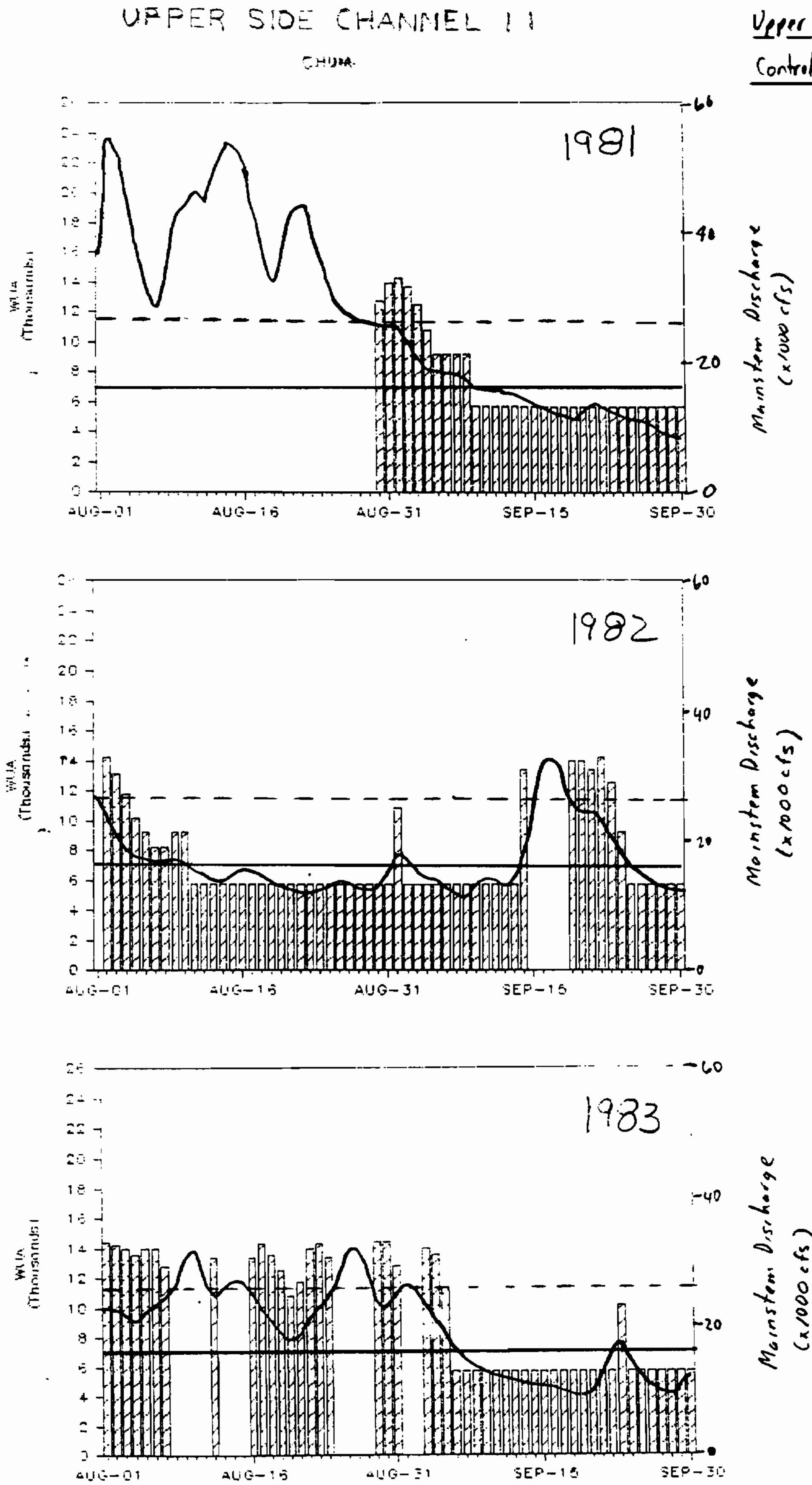


Figure 7-5-9. Time series plots of chum salmon spawning WUA as a function of mainstem discharge for the months of August through September, 1981, 1982, and 1983 for the Upper Side Channel 21 modelling site.

Key:

Upper Model Extrapolation Limit

Controlling Spawning Discharge

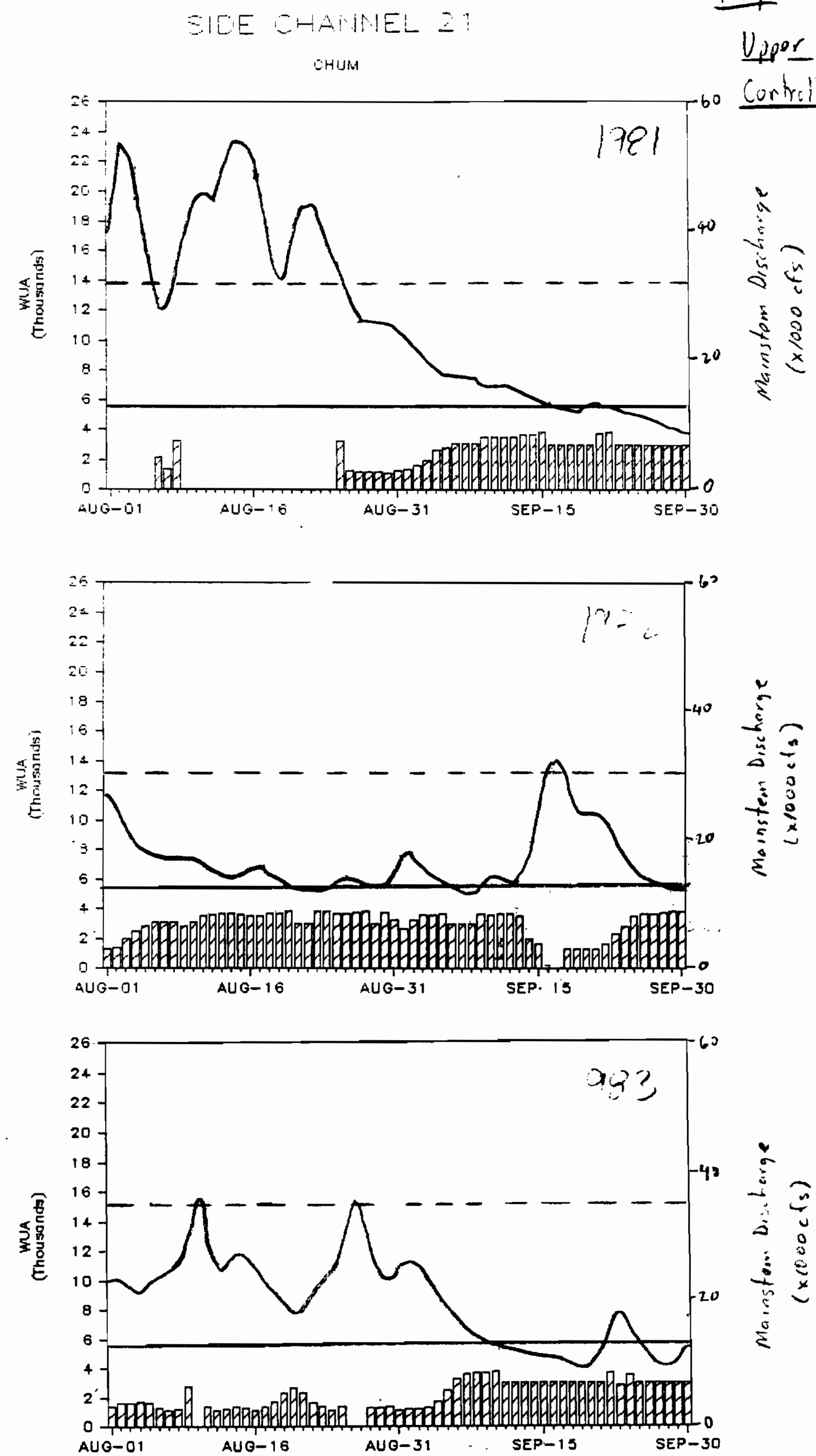


Figure 7-5-10. Time series plots [illegible] as a function of mainstem discharge for the months of August [illegible] 1981, [illegible] Side channel 21 modelling site.

lower controlling breaching discharges provide more spawning WUA over time (e.g., Slough 9 and 21) than do sites which have higher controlling breaching discharges (e.g., Slough 8A). The exception to this general trend is Side Channel 21, which has a low controlling breaching discharge and low projections of WUA of spawning habitat. Additionally, sites which have lower controlling breaching discharges such as Slough 21 and Upper Side Channel 11 exhibit larger variations in WUA over time than do sites which have higher controlling breaching discharges as does Slough 8A.

The projections of available chum spawning WUA were generally greater in 1983 than in 1982 since mainstem discharges during the months of August and September were higher in 1983 than in the previous year (Figure 7-5-11). Insufficient data are available on the 1981 time series plots (due to the occurrence of high flows above the upper calibration range) to compare the 1981 WUA projections to 1982 or 1983 projections.* However, based on the information presented in Figure 7-5-11, it appears that available habitat in the relatively high flow year of 1981 would have exceeded that available in either 1982 or 1983. Information presented in Figures 7-5-11 and 7-2-2 indicates that the 1983 period of measurement most closely approximates the historical 30 year period of measurement.

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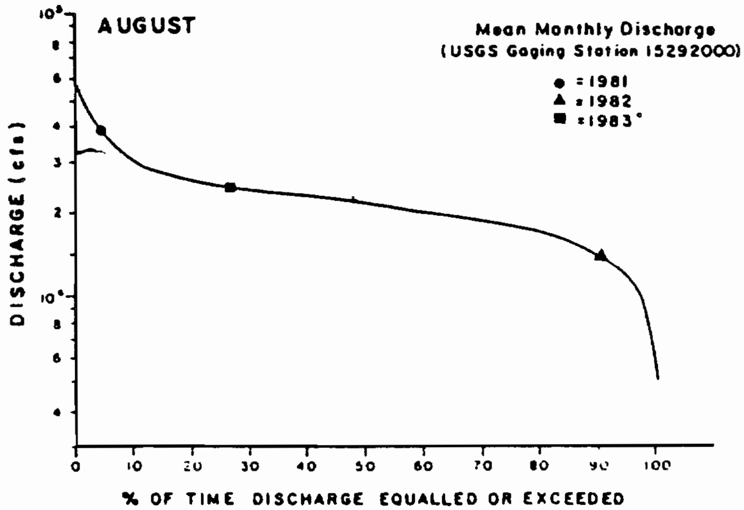
* Models were calibrated to assess changes in WUA at naturally occurring discharges within the range of discharges expected to result from development of the proposed hydroelectric facility. Consequently, upper extrapolation ranges are often lower than naturally occurring discharges. Therefore, projections of WUA could not be made for high discharge events.

Fatal Flaw



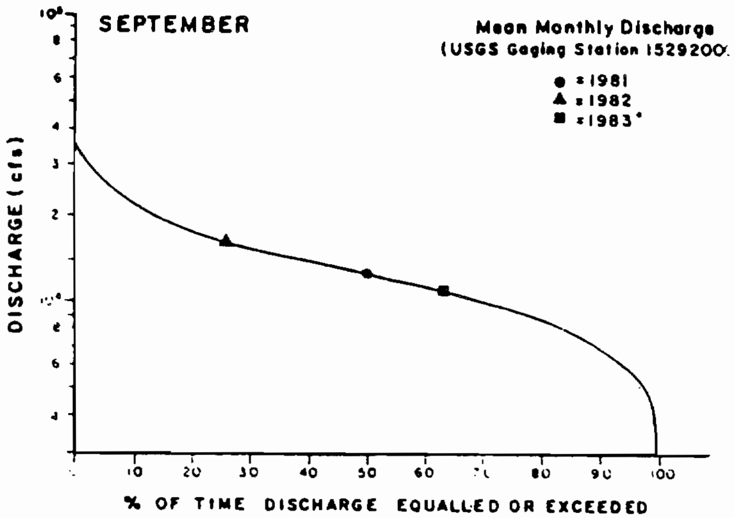


Figure 7-5-11. Time duration curves and mean monthly discharges for August and September based on the 30 year record of Susitna River discharge at Gold Creek. Sources: time duration curves – Bredthauer and Drage (1982); mean monthly discharges – USGS (19[illegible]), Lamke et al. (1983), and USGS (prov[illegible]).

5.3.1.2 Sockeye Salmon

Projections of gross surface area and WUA of sockeye salmon spawning habitat as a function of site flow for the modelling study sites at which spawning has been documented (Sloughs 8A, 9, and 21, Upper Side Channel 11, and Side Channel 21) are presented in Figures 7-5-12 through 7-5-16. The gross surface area and WUA projections as a function of mainstem discharge are also presented for the range of flows at each study site that are directly controlled by mainstem discharge. Data used to develop these plots are presented in Appendix Tables 7-D-6 through 7-D-10.

Projections of gross surface area and WUA for sockeye spawning at study sites follow trends similar to the WUA projections for chum spawning, with the exception that projections of sockeye salmon spawning WUA is generally higher than are the projections of chum salmon spawning WUA during site flows which are not controlled by mainstem discharge. For example, the WUA of sockeye salmon spawning habitat at Slough 9 ranges from 5,000 to 6,100 square feet for site flows which are not controlled by mainstem discharge as compared to WUA of chum salmon spawning habitat at this site which ranges from 2,400 to 4,300 square feet under similar non-controlled site flow conditions. Projections of WUA of sockeye salmon spawning habitat for site flows which are directly controlled by mainstem discharge are generally lower, and occur at lower flows or discharges, than do the projections of WUA of chum salmon spawning habitat at the same site. For example, a peak WUA value of 16,400 square feet occurs for chum salmon spawning habitat at Slough 21 at a

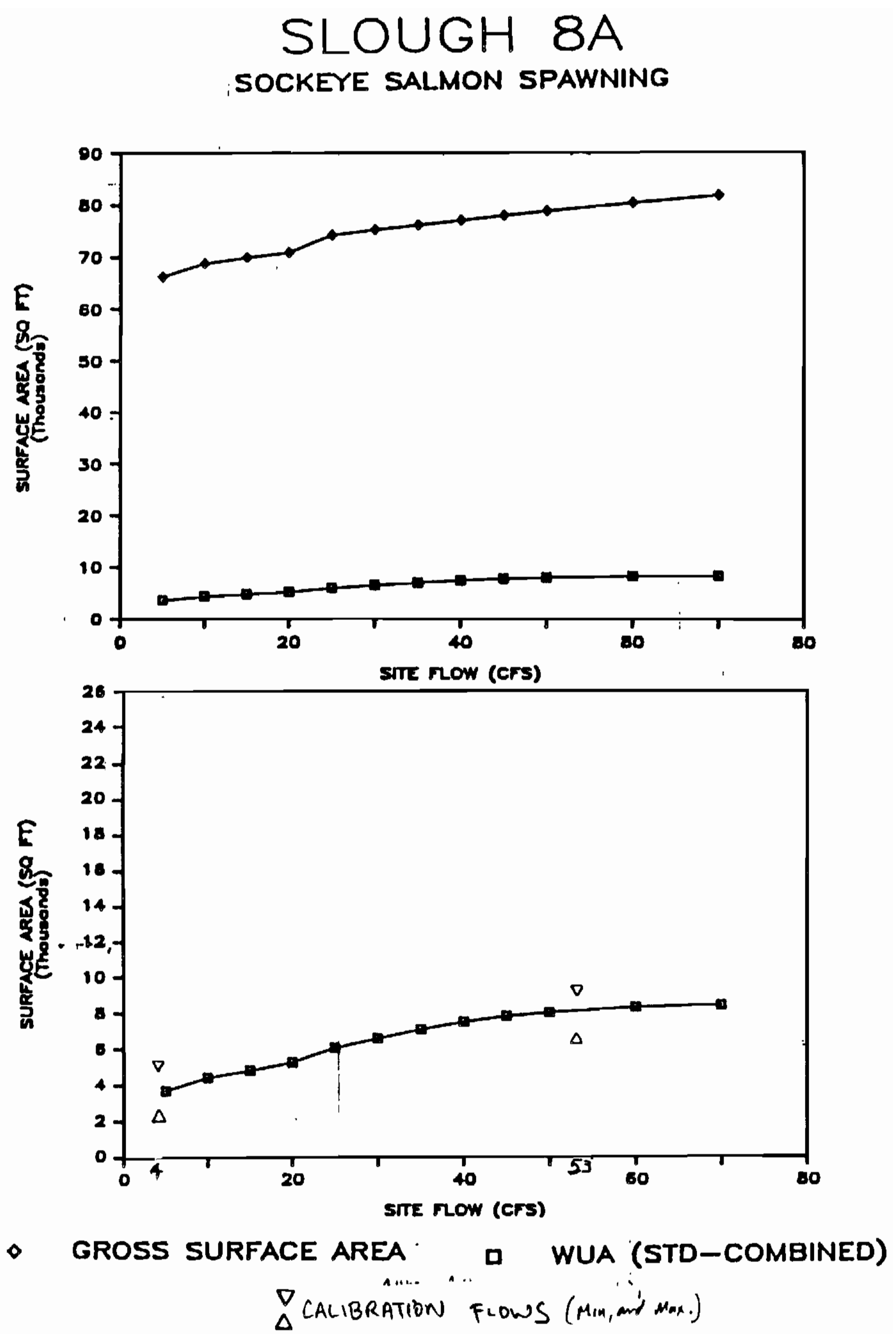


Figure 7-5-12. Projections of gross surface area and WUA [illegible] on spawning habitat as a function of site flow and mainstem discharge for the Slough 8A modelling site.

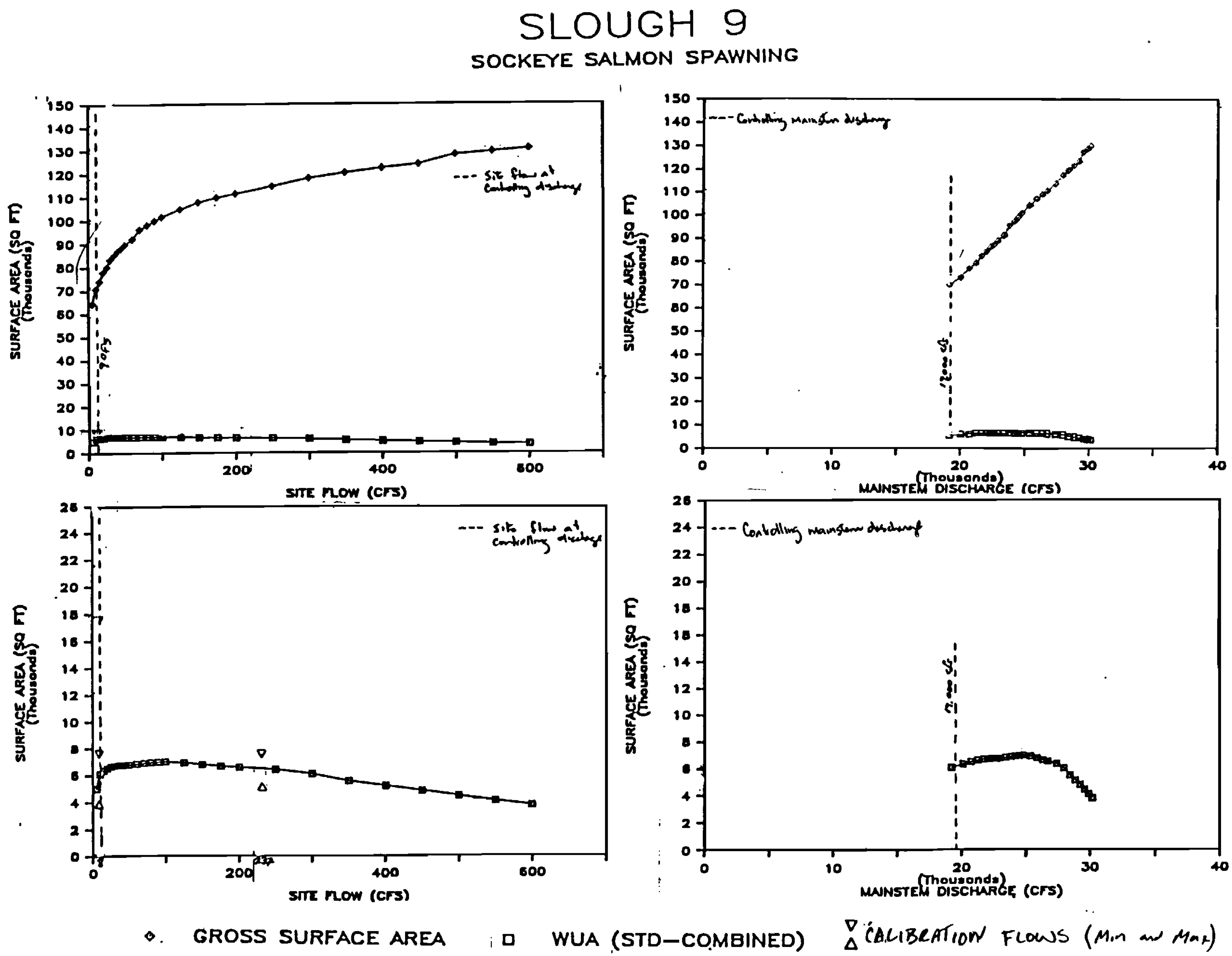


Figure 7-5-13. Projections of gross surface area and WUA of sockeye salmon spawning habitat as a function of site flow and mainstem discharge [illegible] for the Slough 9 modelling site.

SLOUGH 21

SOCKEYE SALMON SPAWNING

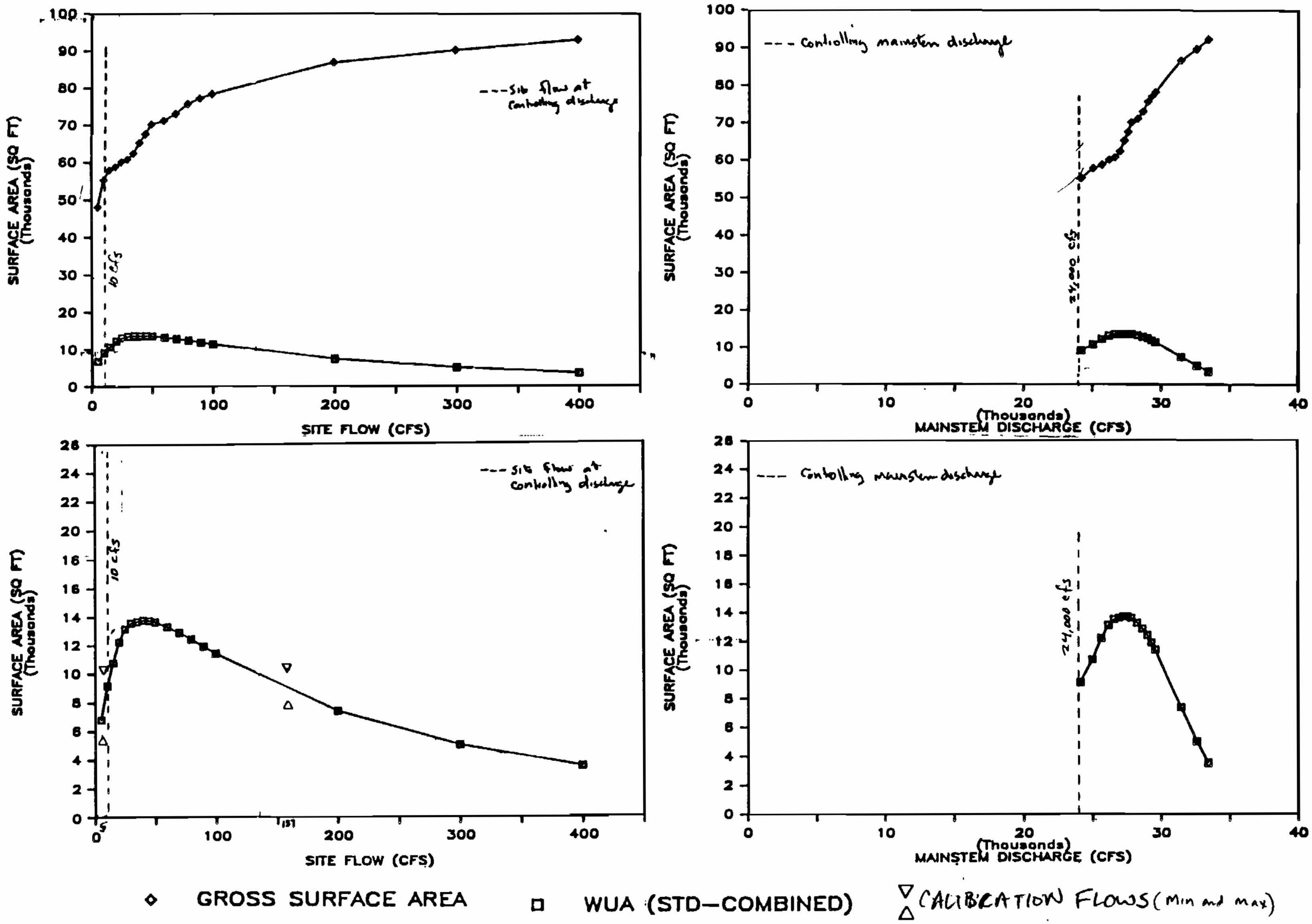


Figure 7-5-14. Projections of gross surface area and WUA of sockeye salmon spawning habitat as a function of site flow and mainstem discharge for the Slough 21 modelling site.

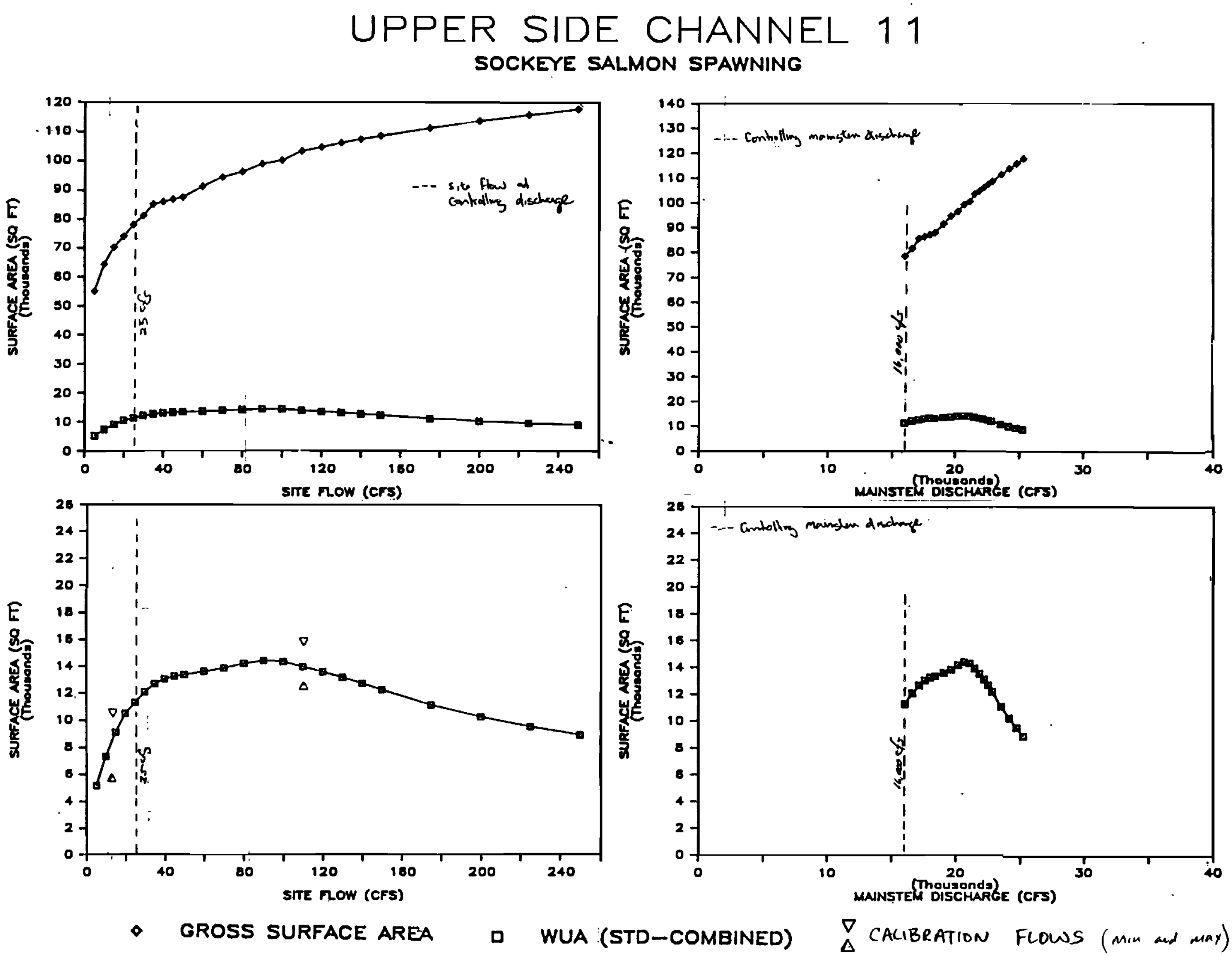


Figure 7-5-15. Projections of gross surface area and WUA of sockeye salmon spawning habitat as a function of site flow and mainstem discharge for the Upper Side Channel 11 modelling site.

SIDE CHANNEL 21
SOCKEYE SALMON SPAWNING

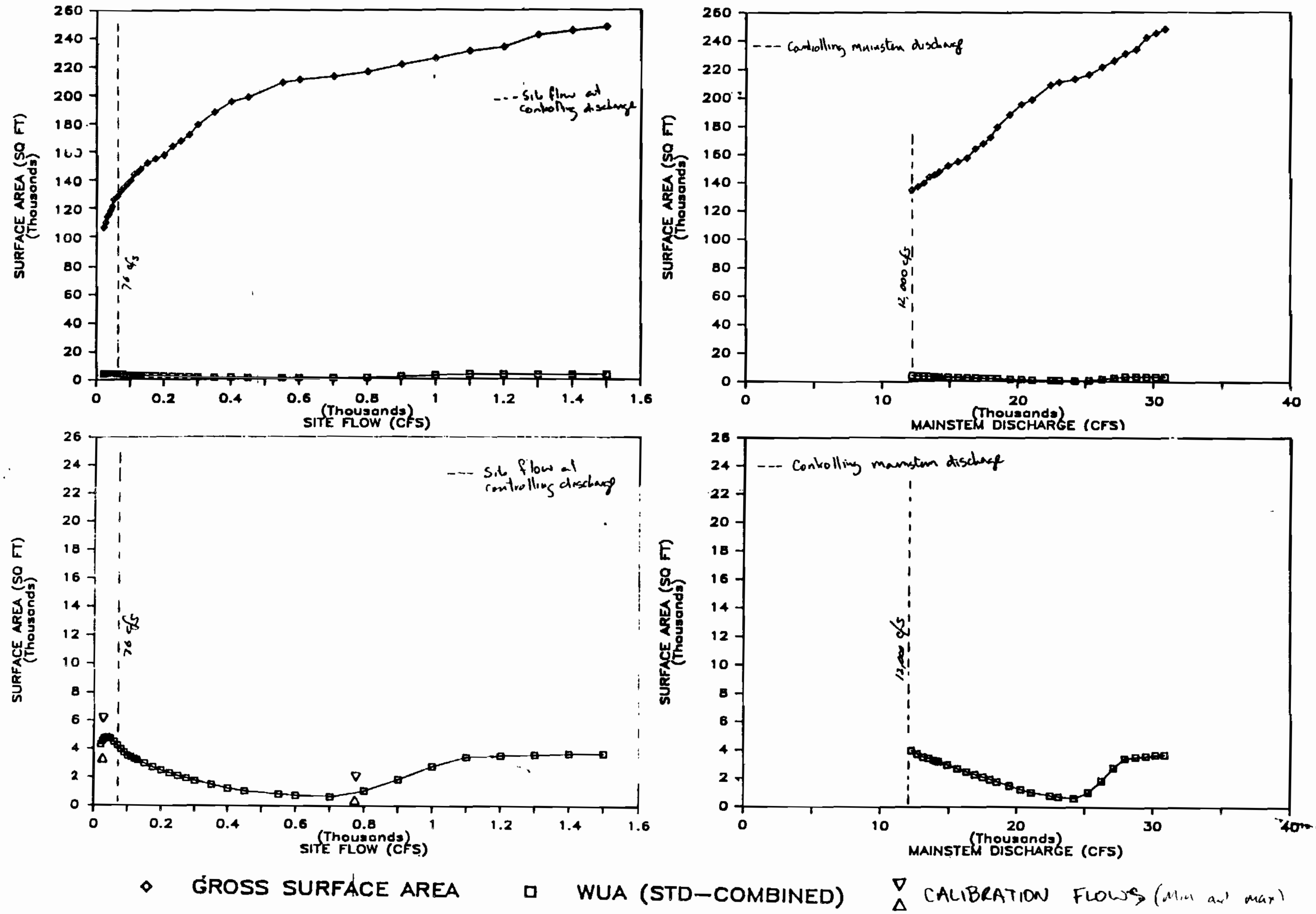


Figure 7-5-16. Projections of gross surface area and WUA of sockeye salmon spawning habitat as a function of site flow and mainstem discharge for the Side Channel 21 modelling site.

mainstem discharge of 28,700 cfs as compared to a peak WUA value of 13,700 square feet for sockeye salmon spawning habitat at this slough at a mainstem discharge of 27,200 cfs.

As with the chum salmon projections, peaks in WUA of sockeye salmon spawning habitat occur when the site flow is directly controlled by mainstem discharge. As previously noted, however, these discharge conditions generally occur less than 40% of the time in August and September for slough study sites and 75% of the time for side channel study sites (Table 7-5-5).

Time series plots of WUA of sockeye salmon spawning habitat as a function of mainstem discharge for the period of peak spawning activity (August through September) for the years 1981, 1982, and 1983 (Figures 7-5-17 through 7-5-21) also follow trends similar to the time series plots for WUA of chum salmon spawning habitat, with the exception that more WUA of sockeye salmon spawning habitat occurs during non-controlling mainstem discharges and less during controlling mainstem discharges than for chum salmon spawning WUA a given study site.

5.3.2 Model Validation

To test the hypothesis that sites which do not currently support chum/sockeye salmon spawning should have low WUA projections as compared to sites which support chum sockeye salmon spawning, projections of gross surface area and WUA for chum and sockeye salmon spawning as a function of site flow were made for the study sites at which no spawning

Table 7-5-5. Range of WUA of sockeye salmon spawning habitat during non-controlling and controlling mainstem discharges and the percent of time the sites are not controlled and controlled by mainstem discharge during August and September.

Study Site	Controlling Breaching Discharge (cfs)	NOT CONTROLLED BY MAINSTEM Q: % of Days in August & September[1]	NOT CONTROLLED BY MAINSTEM Q: Range of WUA (x1000)	CONTROLLED BY MAINSTEM Q: % of Days in August & September[1]	CONTROLLED BY MAINSTEM Q: Range of WUA (x1000)
Slough 8A	33,000	96	3.7-8.3	4	8.3-8.4
Slough 9	19,000	60	5.0-6.1	40	6.1-7.0
Slough 21	24,000	84	6.8-9.2	16	3.5-13.7
Upper Side Channel 11	16,000	47	5.2-11.3	53	11.3-14.4
Side Channel 21	12,000	27	4.0-4.8	73	0.7-4.0

[1] Based on 30 year historical record.

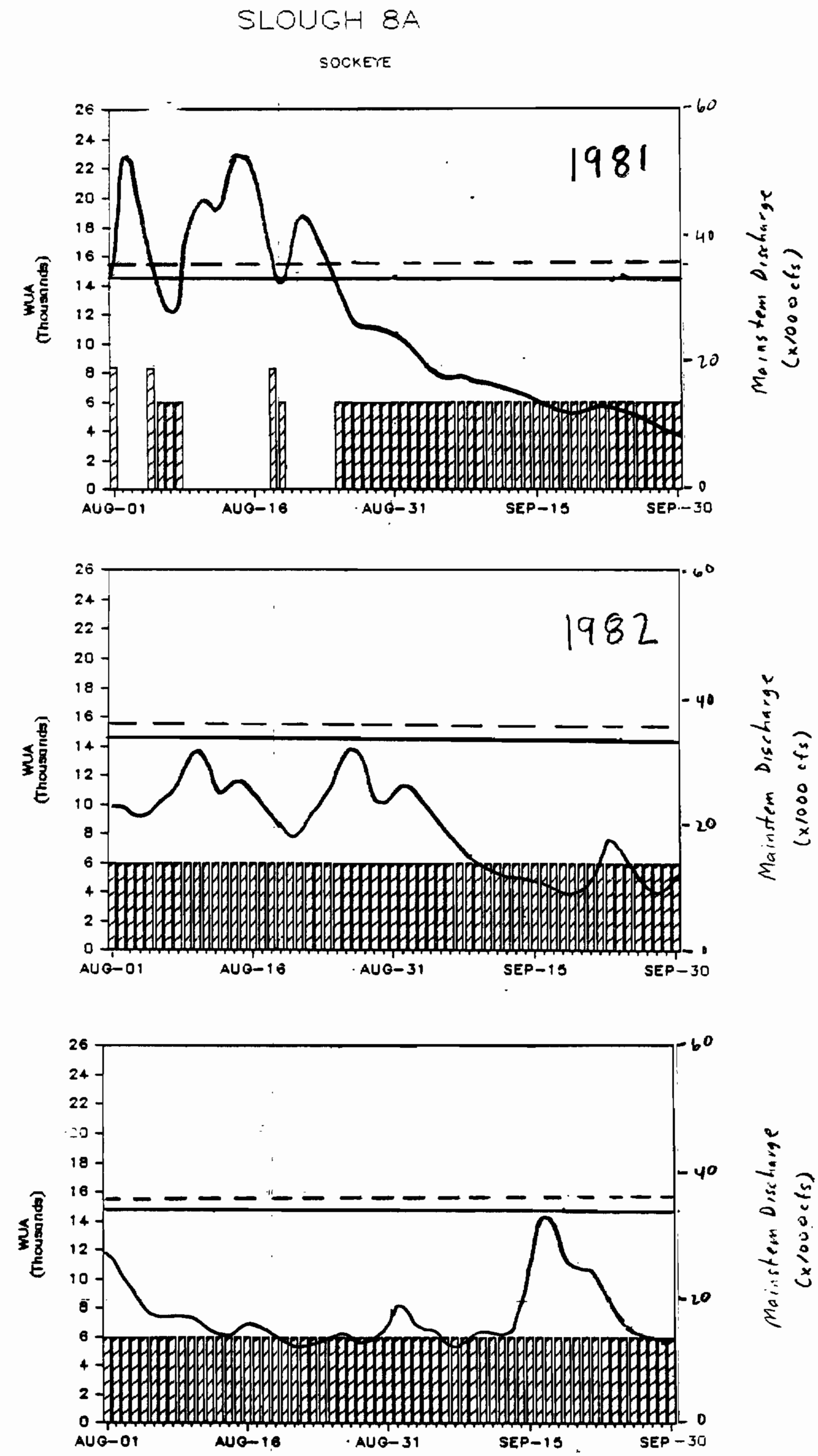


Figure 7-5-17. Time series plots of sockeye salmon spawning WUA as a function of mainstem discharge for the months of August through September, 1981, 1982 and 1983 for the Slough 8A modelling site.

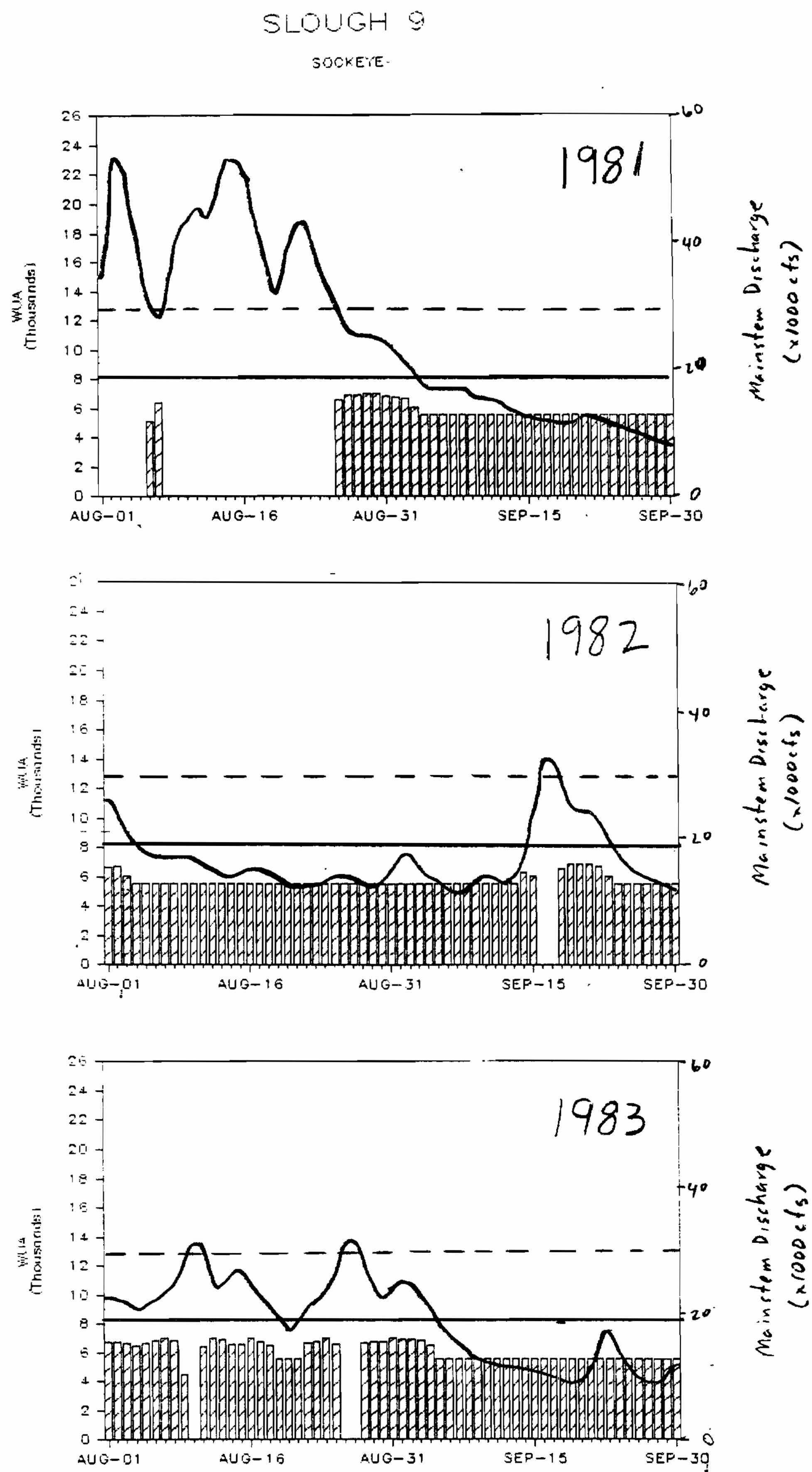


Figure 7-5-18. Time series plots of sockeye salmon [illegible] WUA as a function of mainstem discharge for the [illegible] of [illegible] [illegible] for the Slough 9 modelling site.

SLOUGH 21

SOCKEYE

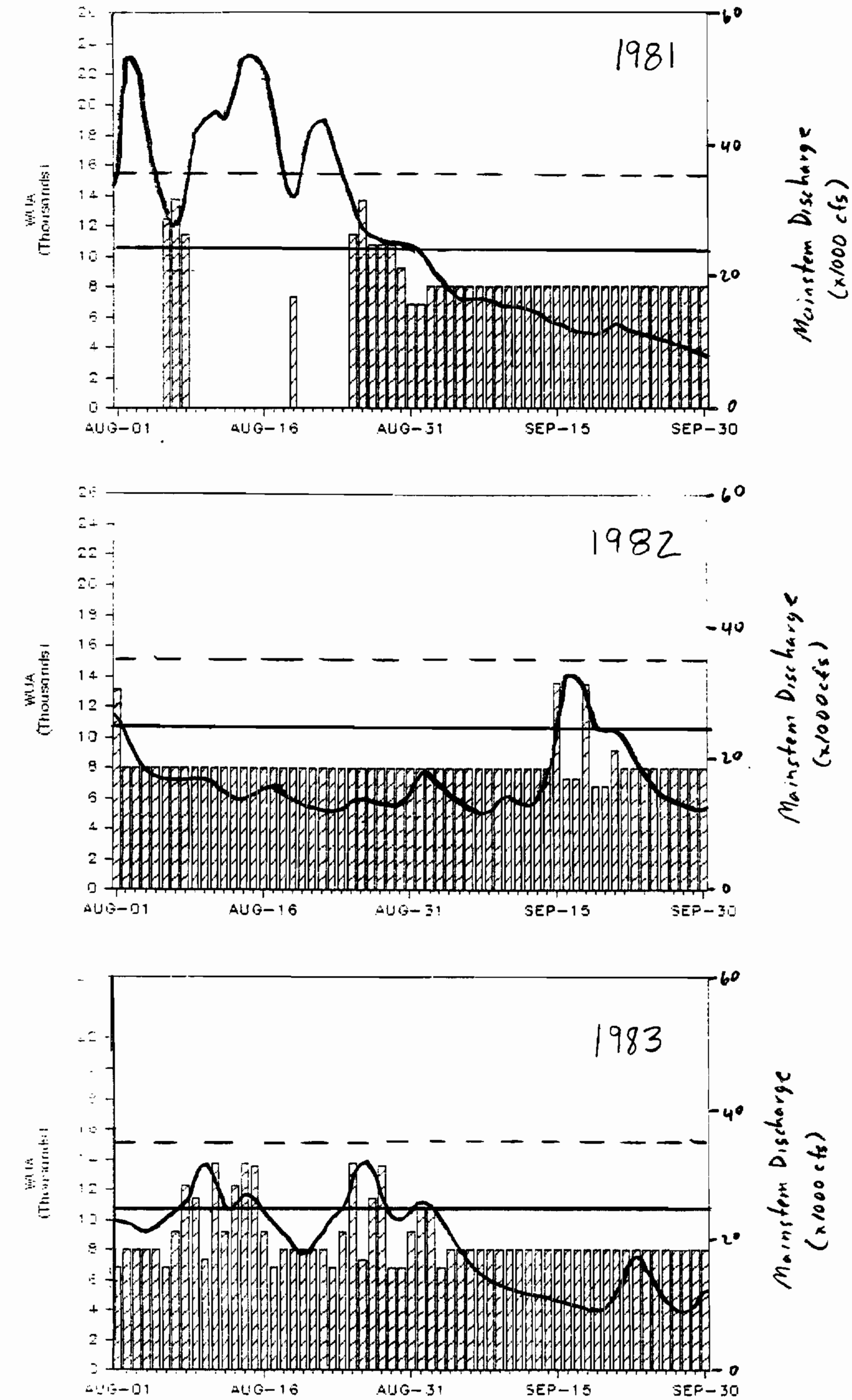


Figure 7-5-19 Time series plots of sockeye salmon spawning WUA as a [illegible] of mainstem [illegible] for months of August [illegible] 198[illegible] [illegible] for the Slough 2[illegible] [illegible]

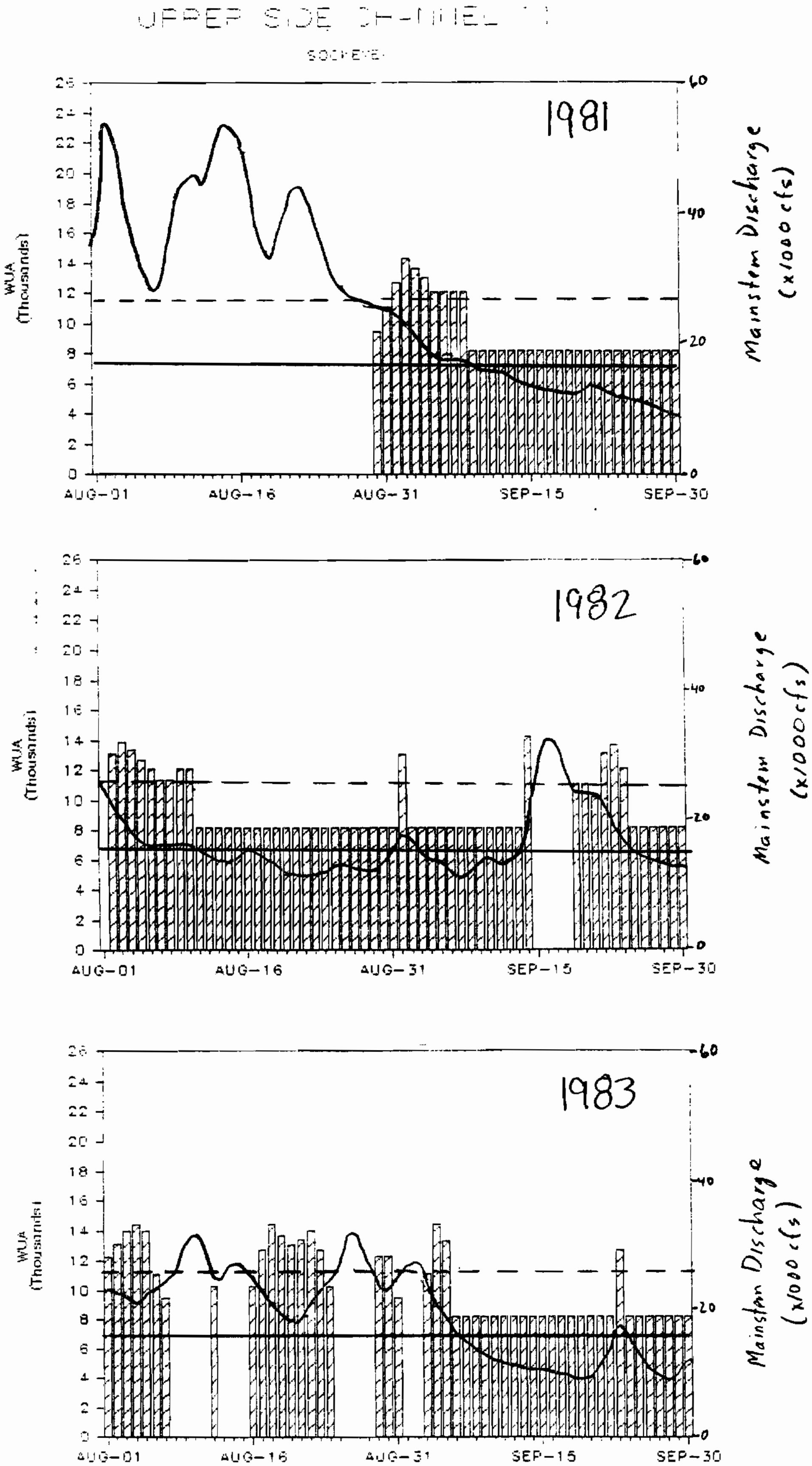


Figure 7-5-20 Time series plots of [illegible] WUA as [illegible] of mainstem discharge for the months August through September, 1981, 1982 and [illegible] for the Upper Side Channel 11 modeling site.

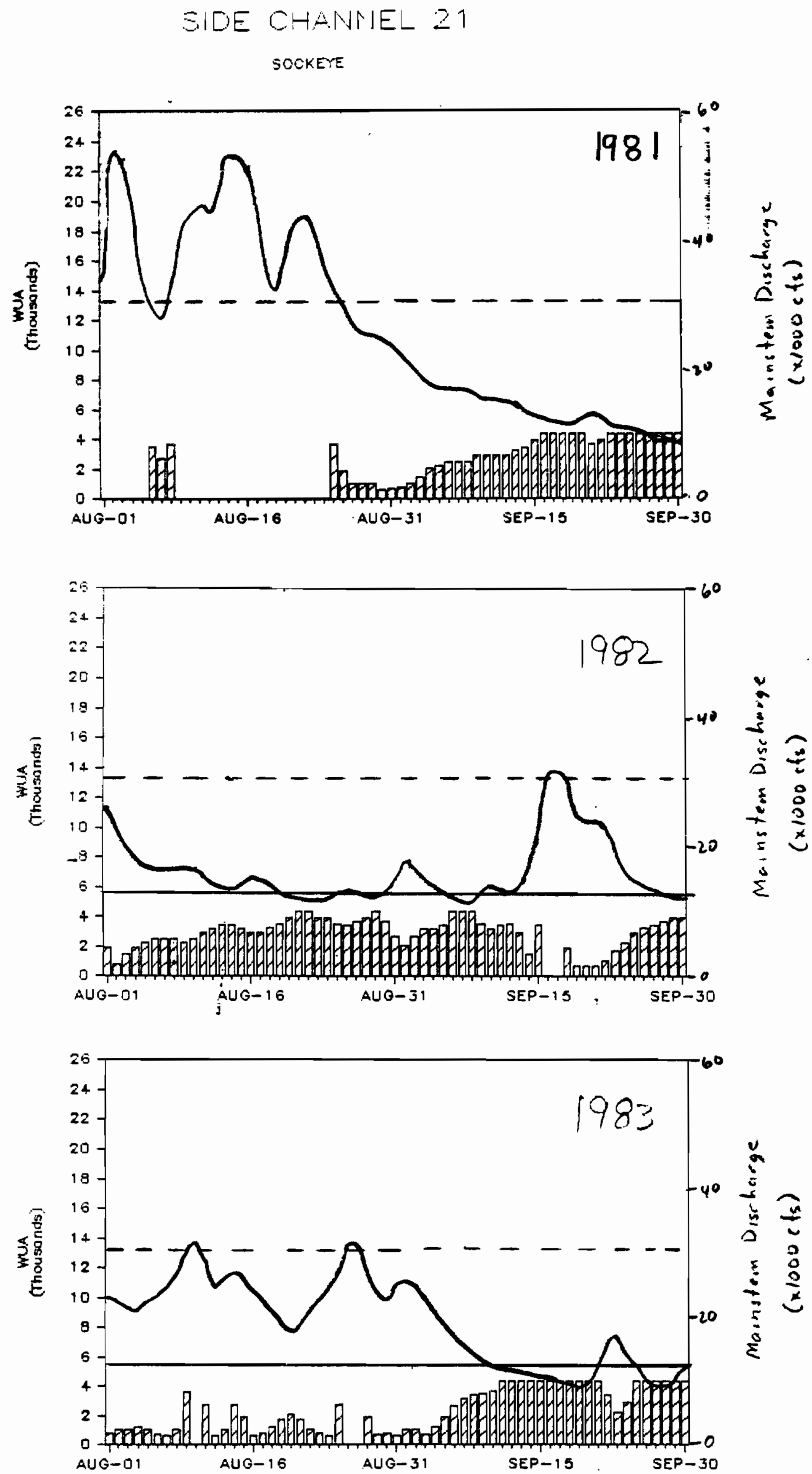


Figure 7-5-21. Time series plots of sockeye salmon spawning WUA as a function of mainstem discharge for the months August through September, 1981, 1982, and 1983 for the Side Channel 21 modelling site.

has been documented (Side Channel 10 and Lower Side Channel 11) (Figures 7-5-22 through 7-5-25). The gross surface area and WUA projections as a function of mainstem discharge are also presented for the range of site flows at each of these study sites that are directly controlled by mainstem discharge. Data used to develop these plots are presented in Appendix Table 7-D-6 and 7-D-7.

Generally, projections of gross area and WUA for chum and sockeye spawning at these sites follow trends which are similar to the projections for sites at which spawning has been observed; however, exceptions are evident. Projections of WUA of spawning habitat at Side Channel 10 are generally lower over the range of flows evaluated than are the projections for the study sites which support spawning. Projections of WUA at Lower Side Channel 11, however, are generally higher over the range of flows evaluated for this site than the sites which support spawning. The reason for this apparent discrepancy is likely linked to the relatively large surface area of this study site. A comparison of the ratio of WUA to gross surface area (Figure 7-5-26 and 7-5-27) shows that the relative amount of projected spawning habitat at this study site is low as compared to sites which support spawning.

The time series plots of WUA of chum and sockeye salmon spawning habitat at Side Channel 10 (Figures 7-5-28 and 7-5-29) indicate that projections of WUA as a function of site flow and mainstem discharge follow trends similar to the projections of WUA at sites which currently support spawning. However, the quantity of WUA which occurs over the range of discharges which typically occur during the period of peak spawning

SIDE CHANNEL 10

CHUM SALMON SPAWNING

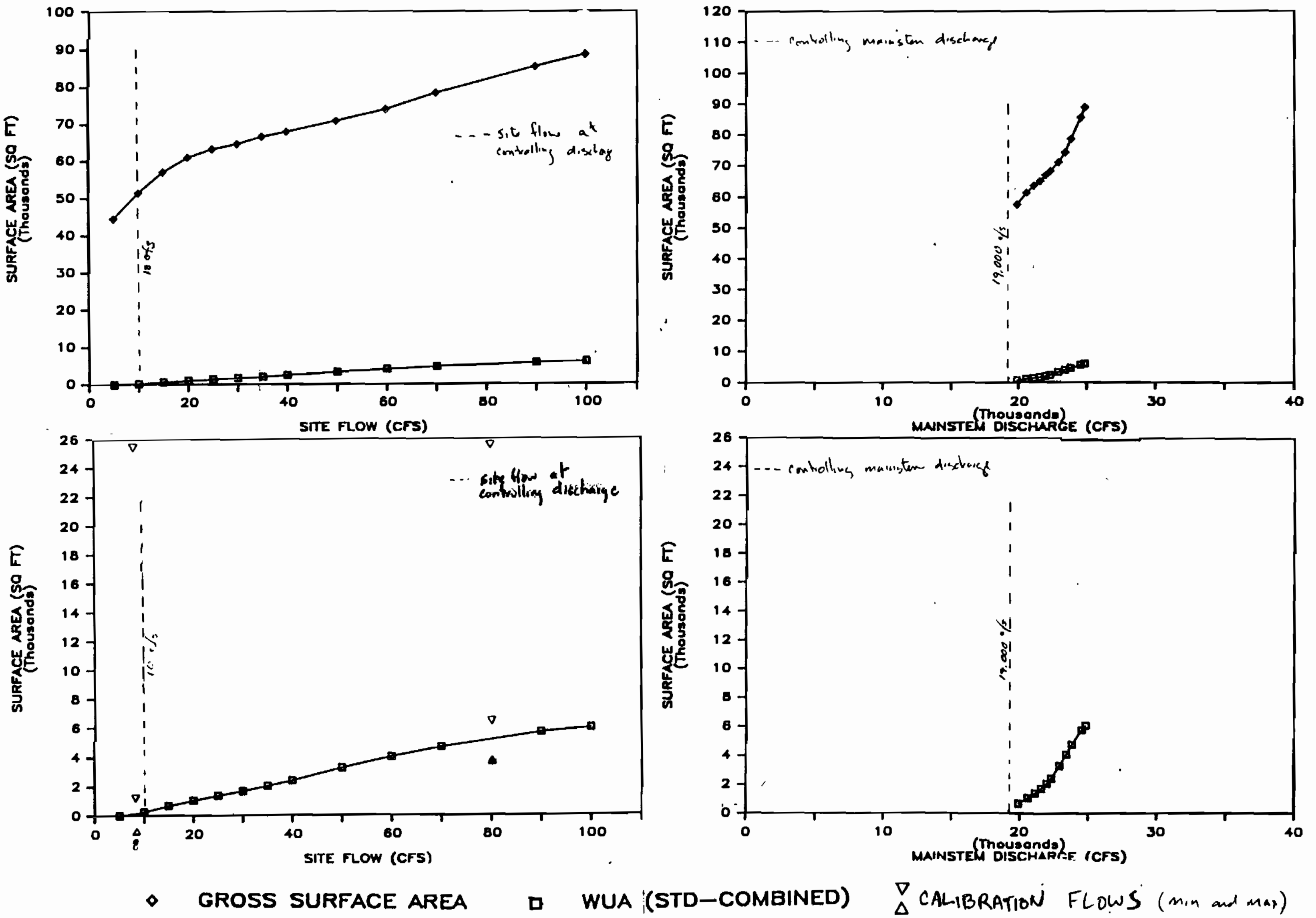


Figure 7-5-22. Projections of gross surface area and WUA of chum salmon spawning habitat as a function of site flow and mainstem discharge for the side channel 10 modelling site

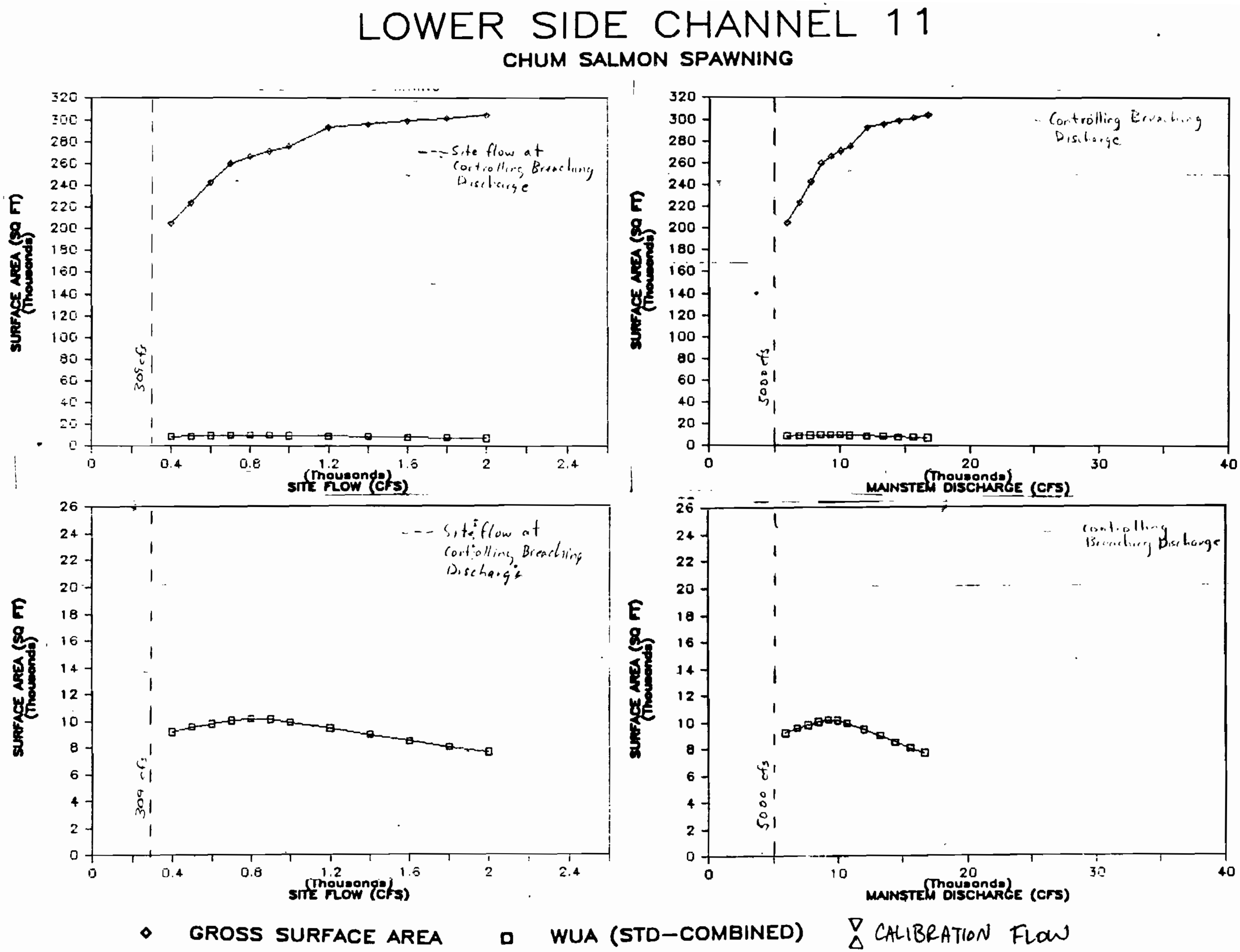


Figure 7.5-23. Projections of gross surface area and WUA of chum salmon spawning habitat as a function of site flow and mainstem discharge for the [illegible] modeling site

SIDE CHANNEL 10
SOCKEYE SALMON SPAWNING

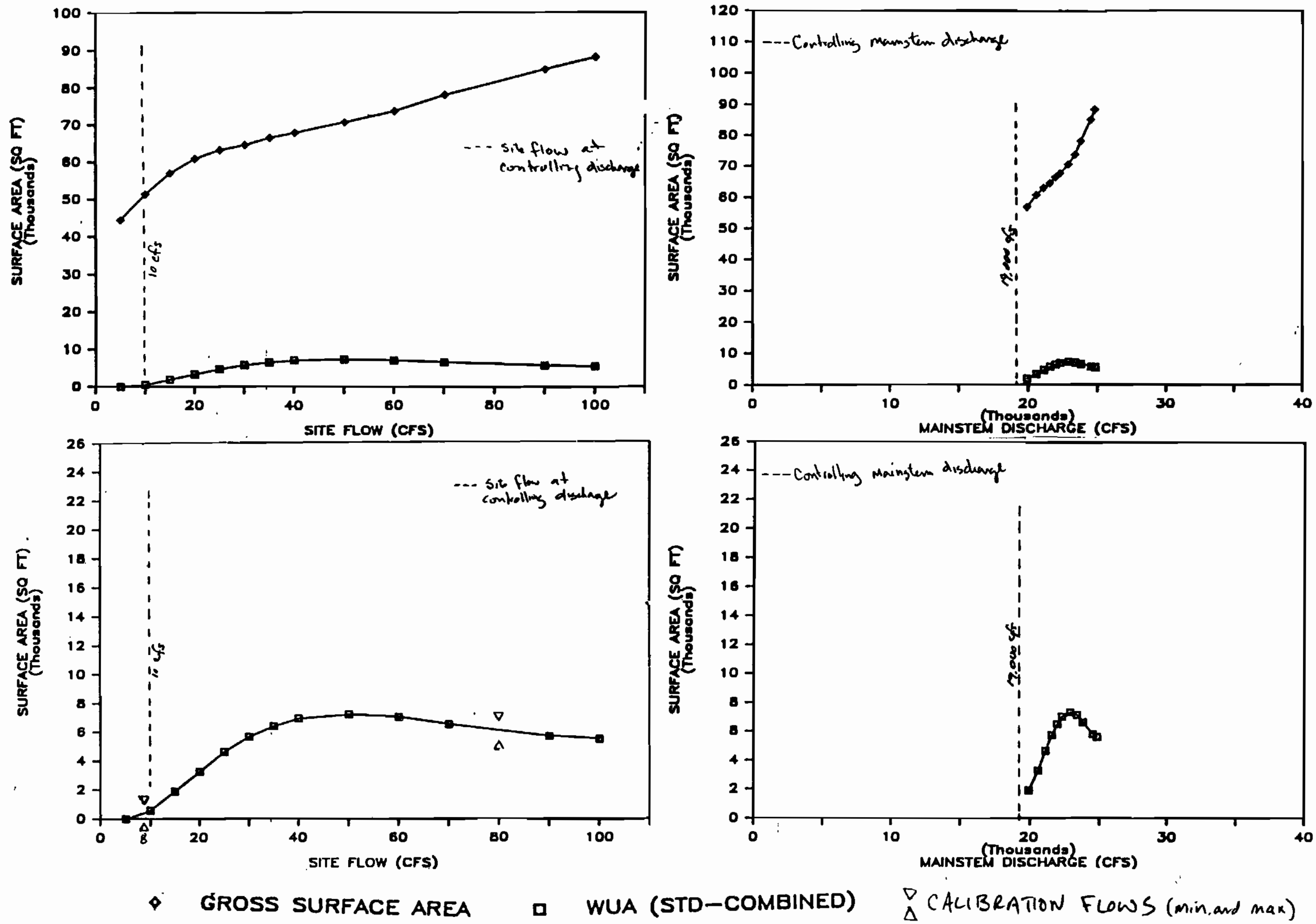


Figure 7-5-24. Projections of gross surface area and total area of sockeye salmon spawning habitat as a function of site flow and mainstem discharge for the Side Channel 10 modelling site.

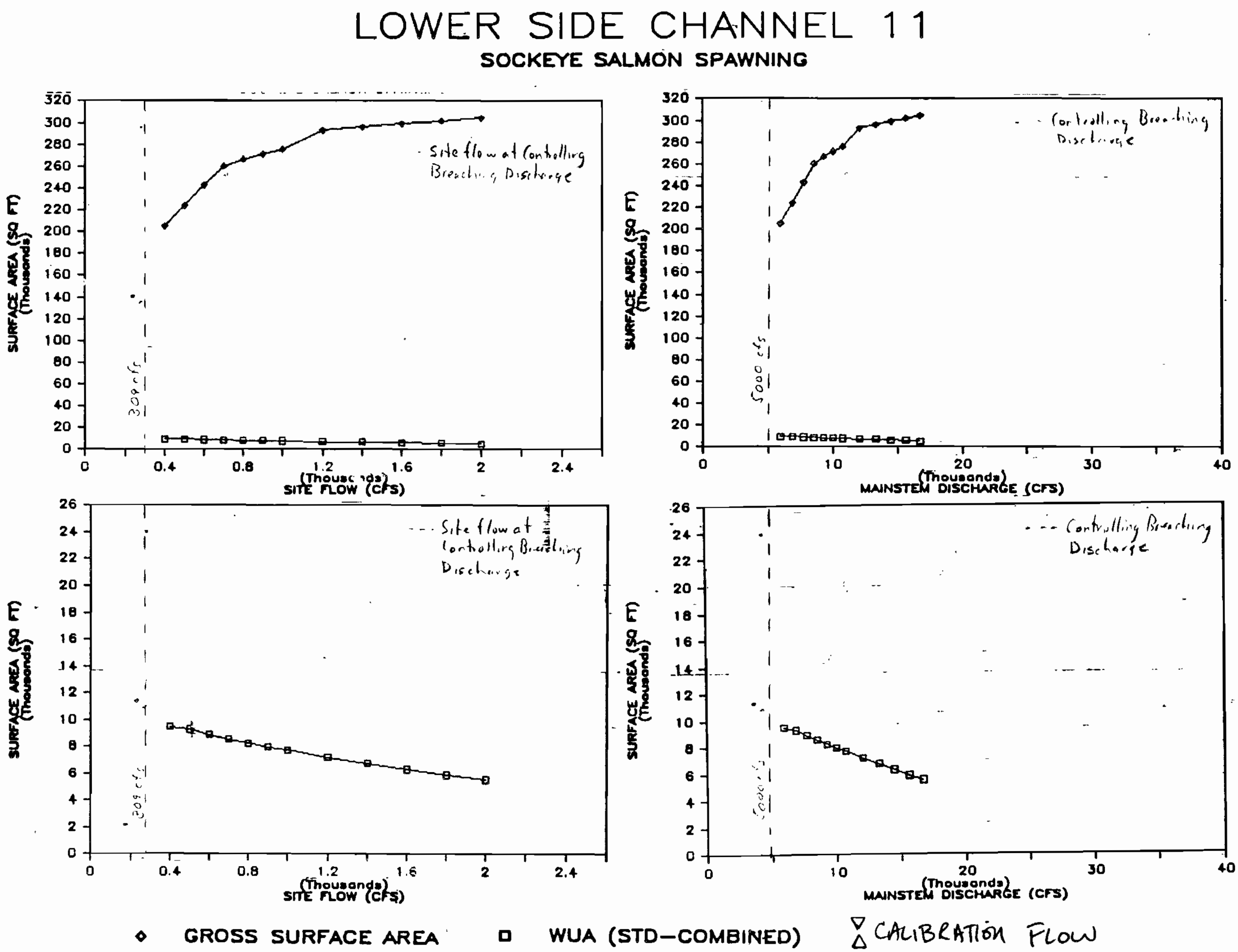


Figure 7.6.25. Projections of gross surface area and WUA of sockeye salmon spawning habitat as a function of site flow and mainstem discharge for the Lower Side Channel 11 modelling site.

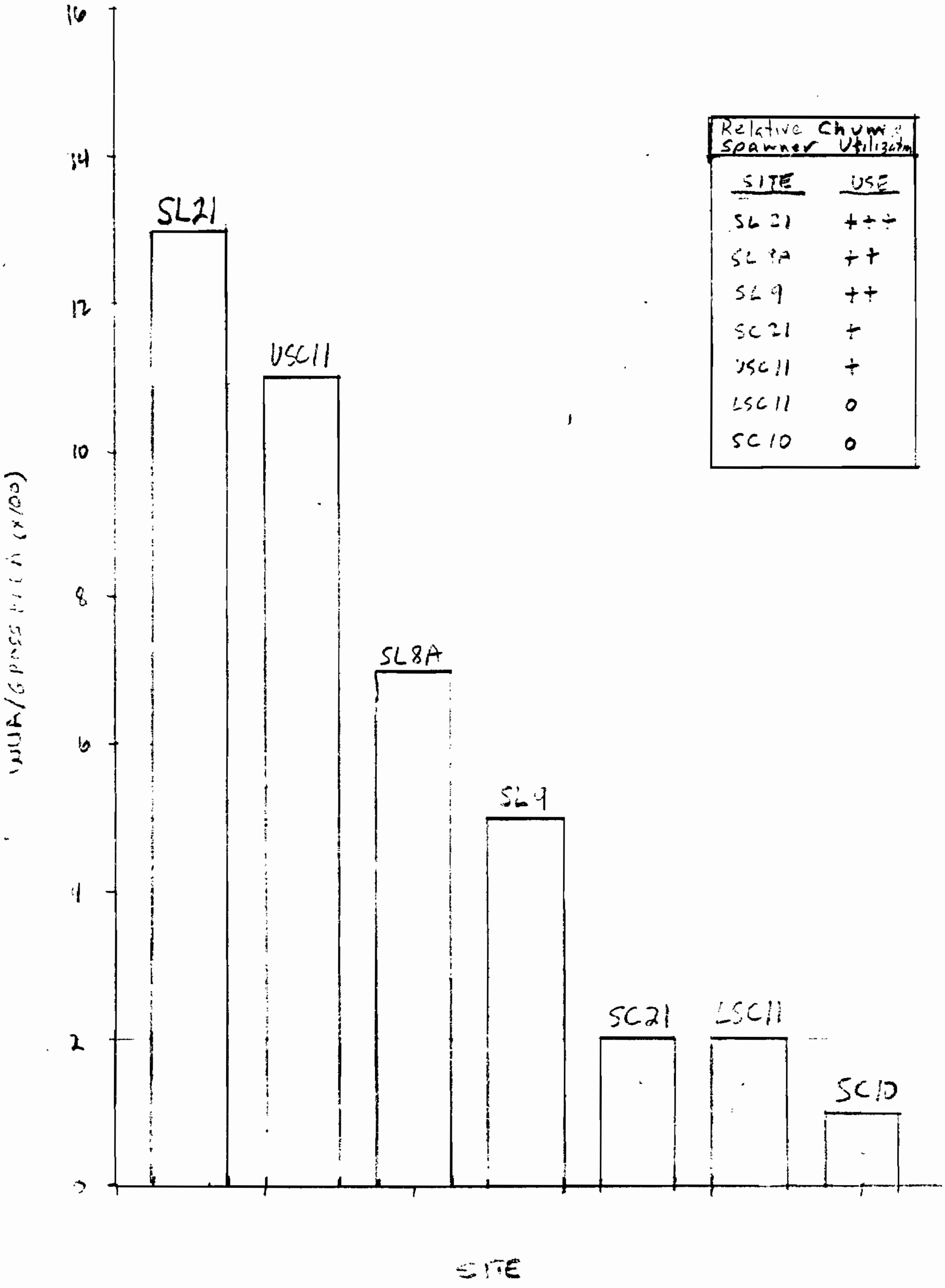
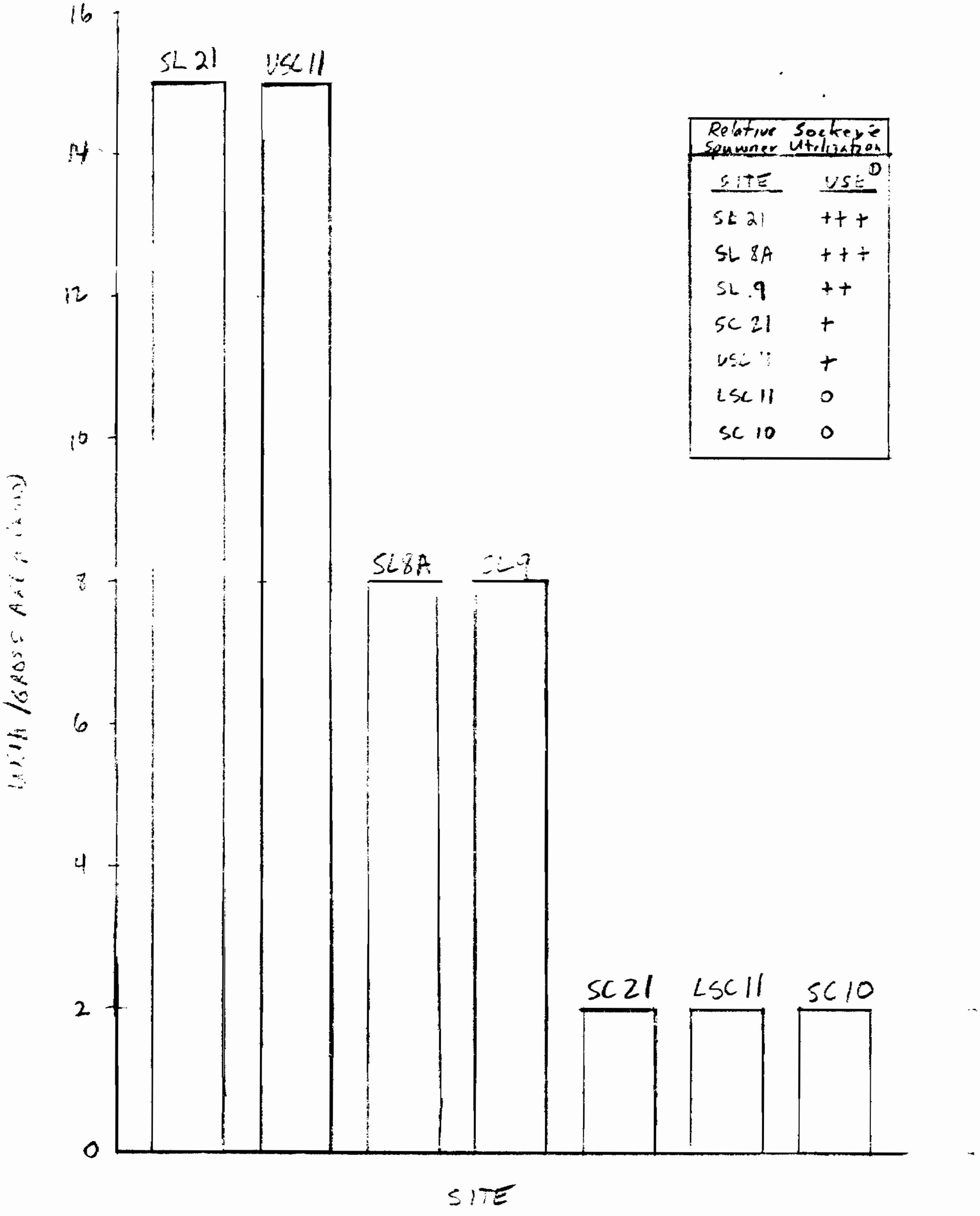


Figure 7-5-26. Comparisons of the ratio of chum salmon spawning WUA to gross area projected at a mainstem discharge of 16,500 cfs for each of the modelled slough sites



Relative Sockeye Spawner Utilization	
SITE	USE[1]
SL 21	+++
SL 8A	+++
SL 9	++
SC 21	+
USC 11	+
LSC 11	0
SC 10	0

Figure 7-5-27. Comparisons of the ratio of sockeye salmon spawning WUA to gross area projected [illegible] discharge of 16,500 cfs for [illegible] sites.

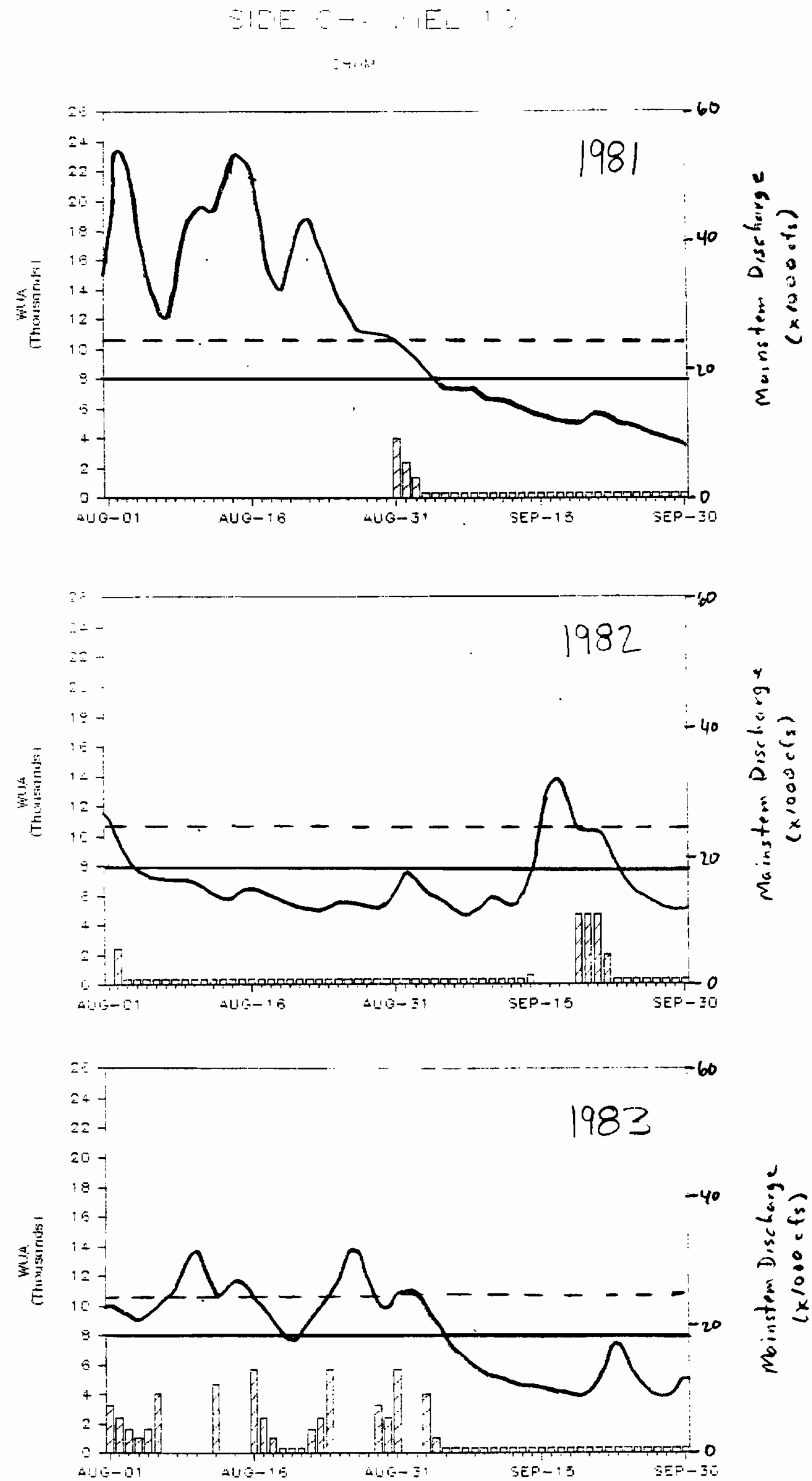


Figure 7-5-28. Time series [illegible] of chum salmon spawning WUA as a function of mainstem discharge for the months of August through September, 1981, 1982, and [illegible] for the Side Channel 10 modeling site.

SIDE CHANNEL 10

SOCKEYE

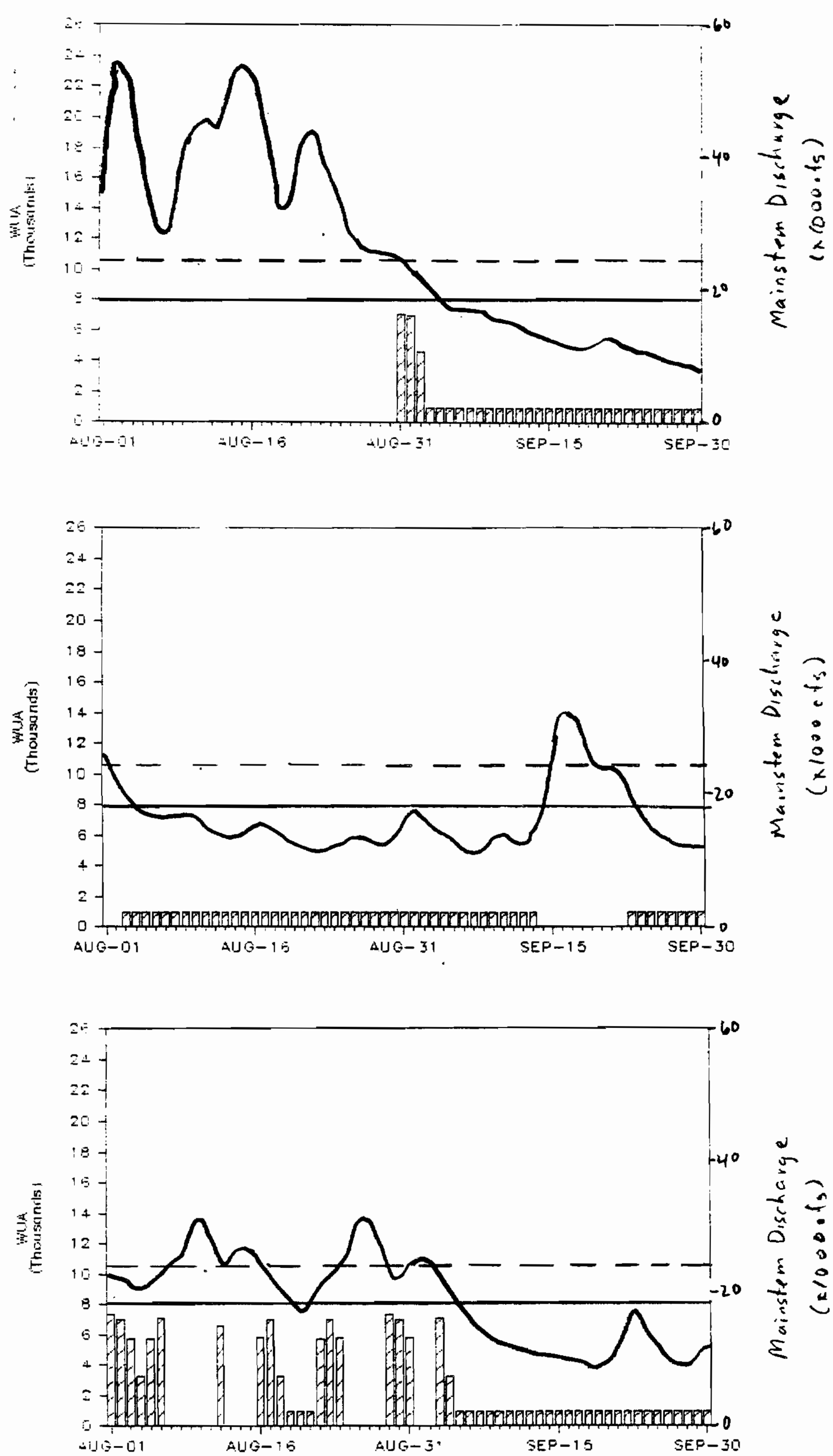


Figure 7-5-29. Time series plots of sockeye [illegible] [illegible] of [illegible] September, 1981, 1982 [illegible] for the Side Channel 10 model [illegible].

(August through September) is substantially less. The projections of WUA over time for Lower Side Channel 11 depicted in Figures 7-5-30 and 7-5-31 may be overestimated for reason stated above.

To evaluate the correlation between the relative amount of projected available spawning habitat at each study site to the relative spawner use of that study site, comparisons were made of the ratio of WUA to gross surface area projected at each study site at a mainstem discharge of 16,500 cfs to the relative density of spawner use of that study site (Figure 7-5-26 and 7-5-27). These comparisons indicate that sites which have relatively higher WUA to gross surface area ratios, generally have relatively higher utilization by spawning chum and sockeye salmon. One exception to this general trend is Upper Side Channel 11. The reason for this apparent discrepancy is likely linked to error involved in inputting upwelling into the model developed for this site. Upwelling at this site was input into the model using limited field data and winter aerial photography. Areas of open leads were assigned upwelling presence codes. Because of this, the presence of upwelling at this site was likely overestimated (due to assignment of upwelling to areas of velocity leads), resulting in abnormally high WUA projections.

5.4 Discussion

5.4.1 Assumptions §used in the Application of the HABTAT Models

Weighted usable area (WUA), as used in this report, is an index of the capacity of a site to support chum or sockeye salmon spawning. Several

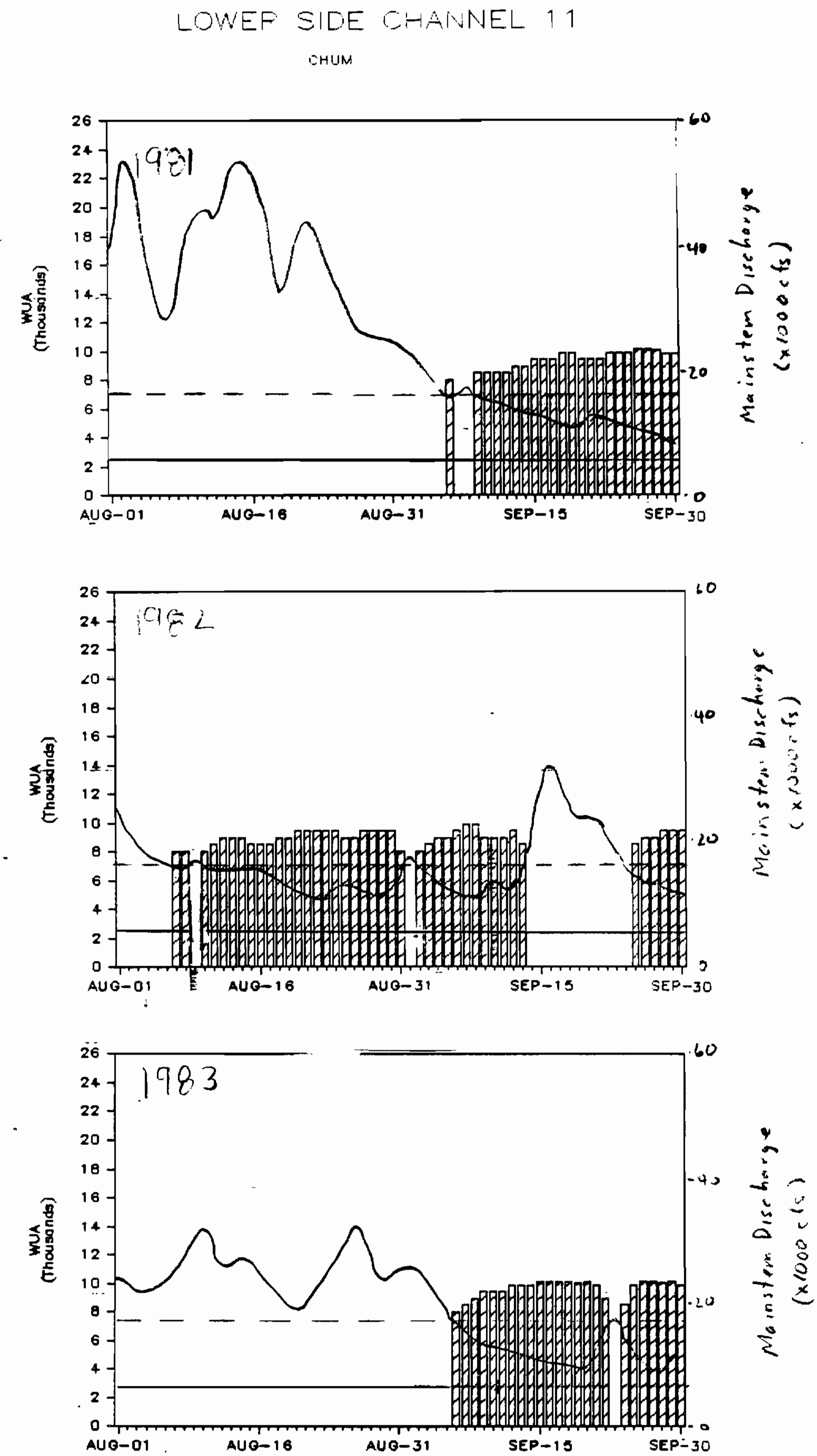


Figure 7-5-30. Time series plots of sockeye salmon spawning [illegible] as a function of mainstem discharge for the months of [illegible] 1981, 1982, and [illegible] for the Lower Side Channel 11 modeling site

LOWER SIDE CHANNEL 11

SOCKEYE

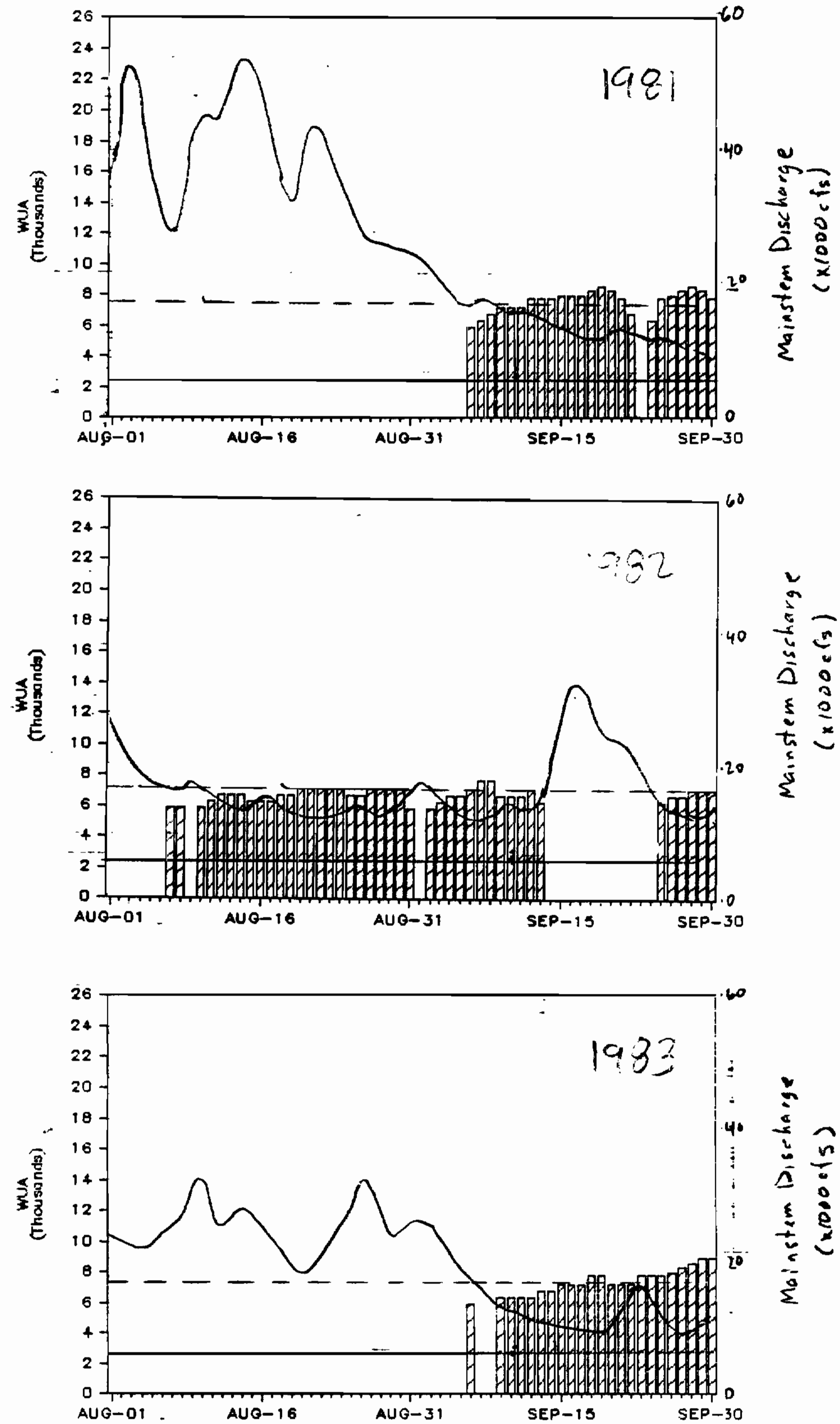


Figure 7-5-31 Time series plots of sockeye salmon spaw[illegible] … of mainstem discharge for the … 1981, 1982 … for the Lower Side Channel 11 modelling site.

underlying assumptions are made in calculating WUA using the incremental methodology approach (Orth and Maughan 1982). In regard to this study, these assumptions may be stated as follows:

1) Depth, velocity, substrate, and upwelling are the most important habitat variables affecting chum and sockeye salmon spawning under varying flow conditions;

2) The effects of depth, velocity, substrate, and upwelling are independent when salmon select spawning areas;

3) The channel of the study site is not altered significantly by changes in flow;

4) The study reach can be representatively modelled by evaluating selected study transects; and,

5) There is a positive correlation between weighted usable area and habitat use.

The first assumption is difficult to evaluate since flow related changes at a study site may have significant effects on many interrelated habitat conditions used for spawning. In the derivation of WUA, it is assumed that the usability of spawning habitat within a site can be accurately indexed if all the variables affecting spawning are known. Since this is not likely, we have identified four variables which appear to be most critical for spawning at the sites. Other habitat variables, notably water quality and temperature, may also potentially affect the usability of a site, but are believed to exert only a limited influence on salmon spawning in sloughs and side channels of the middle Susitna River. For these reasons, this assumption is justified for all of the study sites evaluated with the exception of Side Channel 10 and Lower Side Channel 11, where it is believed that some other habitat component is limiting spawning.

As discussed in Section 4.0, the second assumption also appears to be justified; that is, depth, velocity, substrate, and upwelling appear to act as independent variables in the selection of spawning sites by salmon.

The third assumption appears justified on a general level. Channel geometry and morphology at each of the study sites generally remained relatively stable during the period of study, although, specific changes in channel geometry and morphology did occur. For example, large amounts of silt were deposited along two transects in the Slough 9 modelling study site during a flood event in September of 1982. Thus, both short and long term changes in channel geometry and morphology on a site specific basis are possible. However, such changes probally reflect a dynamic, but generally stable, equilibrium and are therefore believed to exert only a limited influence on the long-term habitat availability within the system.

Transects that were both critical in terms of spawning and representative in terms of habitat availability were selected for evaluation at each study reach. For this reason, the results from the transects sampled are believed to be representative of the associated study reach and the fourth assumption appears justified. The issue of study site representativeness is addressed in Section 2.3 and 5.4.3.

The fifth assumption also appears to hold true. Based on comparisons of relative spawning habitat availability to spawning utilization at modelling study sites (Figure 7-5-29 and 7-5-30), there appears to be a general positive correlation between projected WUA and habitat use at study sites. That is, sites with relative high utilization for spawning by chum and sockeye salmon (e.g., Sloughs 21 and 8A) exhibited higher projected WUA's than did site with little or no utilization (e.g. Lower Side Channel 11 and Side Channel 10).

In summary, the inherent assumptions of the incremental methology approach of habitat analysis as applied to this study appear generally justified although, specific assumptions were violated under isolated conditions. The extent to which the effects of these violations biased our results however, is difficult to evaluate. It is believed, however, that such violations exerted only limited influence.

5.4.2 Weighted Usable Area Projections

The results of this study indicate that slough and side channel study sites generally exhibit similar trends in chum and sockeye salmon spawning WUA projections as a function of mainstem discharge with one notable exception: due to higher controlling breaching discharges in sloughs, WUAs peak at higher discharges in slough habitats than in side channel habitats. The WUA projections for chum and sockeye salmon spawning habitat generally follow similar trends, with the exception that WUA of sockeye salmon spawning habitat typically peaks at lower mainstem discharges than do the WUA projections for chum salmon spawning habitat. The reason for this is that velocities become limiting to sockeye salmon spawning at lower mainstem discharges that they do for chum salmon spawning (see section 4.0, velocity spawning suitability criteria).

The results of this study indicate that usable area of chum and sockeye salmon spawning habitat in modelled sloughs and side channels in the middle reach of the Susitna River generally peak at mainstem discharges ranging from 20,000 to 35,000 cfs. An important factor appears to be the overtopping of the sites by mainstem discharge and the subsequent controlling of the site flows by mainstem discharge. Assuming that these modelled sloughs and side channels are representative of other non-modelled sloughs and side channels in the middle reach which currently support spawning, the theoretical maximum WUA for slough and side channel habitats in the middle river reach would thus occur slightly after the mainstem discharge overtops and controls the hydraulics at a maximum number of these habitats.

Although peak WUA of chum and sockeye salmon spawning habitat in modelled sloughs and side channels generally occurs at mainstem discharges in the range from 20,000 to 35,000 cfs, typical mainstem discharges during the period of peak spawning activity (August through

September) are much lower, such that peak WUA are values rarely attained. Average monthly discharges based on the 30 year historical discharge record (Figure 7-5-11) for the months of August and September are 22,000 and 14,000 cfs, respectively. Because of this, the realized WUA of spawning habitat is much lower at study sites during the range of mainstem discharges typically present during the period of spawning. Sites which have relatively low controlling breaching discharges (Slough 9 and Side Channel 21) typically have observed maximum WUA values which more closely approximate the theoretically predicted maximum WUA values than do sites with higher controlling breaching discharges (Slough 8A).

Based on a review of the time series plots, flows at study sites which currently support chum and sockeye salmon spawning are infrequently controlled by mainstem discharge. For this reason, the WUA at study sites remains relatively low and stable during the period of peak spawning activity (August through September), except during flood events.

In summary, WUA projections for chum and sockeye salmon spawning habitat in sloughs and side channels exhibit certain species - specific and habitat-specific trends. However, it should be stressed that the projections of WUA must be carefully evaluated in conjunction with other conditions at the site in order to determine their utility as an index of spawning habitat availability.

5.4.3 Recommended Applications and Limitations of the Data

The WUA projections developed in this report represent a synthesis of our current understanding of the relationship between usable spawning habitat and flow variations at several slough and side channel study sites. As used in this report, weighted usable area is an index of the capacity of a site to support chum or sockeye salmon spawning. It represents the availability of potential spawning habitat at a site. As such, it should not be used as an estimate of fish numbers or production at a site, nor as a confirmation that fish will utilize an area projected as being suitable for spawning at a site. WUA projections only indicate the availability of suitable depth, velocity, substrate, and upwelling conditions for spawning at a particular study site.

Application of the WUA projections to describe changes in usable spawning habitat at evaluated study sites must be done on a case-by-case basis. Weighted usable area indices are only valid if all other required habitat conditions at the site are also acceptable. Other habitat variables including water quality, temperature, and adequate passage depths must also be evaluated. Additionally, a better understanding of the relationship between unbreached mainstem discharge conditions and slough flows as well as the relative contribution of various water sources (e.g., groundwater upwelling, seepage, and surface waters) to slough and side channel flows is needed. Frequency analysis of local flows and a better quantifications of upwelling conditions are also recommended. For these reasons, the WUA projections presented in this report should not be the sole deciding factor used to evaluate the availability of salmon spawning habitat condition at modelled study sites.

Application of these projections to areas outside of modelling sites must also be approached with caution. Although it is likely that the projections presented in this section can be extrapolated to other non-modelled sloughs and side channels in the middle reach of the Susitna River that support spawning, it must first be determined whether the underlying assumptions used in the derivation of the projections can be applied to nonmodelled areas. Prior to such uses, it is recommended that additional field data be collected to justify the application of the projections to other such areas.

6.0 SUMMARY

This chapter presented an evaluation of the suitability of selected slough and side channel habitats of the middle reach of the Susitna River for spawning by chum and sockeye salmon as a function of flow variation.

Section 1.0 described the rationale and objectives of this evaluation, as well as a general description of the instream flow incremental methodology (IFIM) study approach used in this evaluation.

Section 2.0 described the general concepts and rationale used in the selection of slough and side channel study sites. Additionally, the representativeness of selected study sites was discussed and general descriptions of selected study sites was presented. Three sloughs (8A, 9 and 21) and four side channels (10, Lower and Upper 11, and 21) were selected for evaluation. These sites are thought to represent the range of slough and side channel habitats in the middle river reach which currently support chum and sockeye salmon spawning.

Section 3.0 described the data collection and analysis required in the development of hydraulic simulation models for the three side sloughs and the four side channels selected for evaluation. Ten hydraulic simulation models were calibrated to forecast depths and velocities associated with a range of site-specific flows at the seven study sites. Comparisons between corresponding sets of forecasted and measured hydraulic parameters indicate that the models provide reliable estimates of depths and velocities within this recommended calibration ranges.

Section 4.0 presented the spawning habitat utilization data collected in sloughs and side channels in the middle reach and the methods used to analyze the data to develop spawning habitat suitability criteria for input into the habitat simulation models discussed in Section 5.0. Habitat suitability criteria were developed for chum and sockeye salmon spawning for the habitat variables of depth, velocity, substrate, and upwelling. The spawning suitability criteria developed for chum salmon were based on a statistical analysis of utilization data as modified by limited preference data, literature information, and opinion of field biologists familiar with Susitna River chum salmon stocks. The spawning suitability criteria developed for sockeye salmon were developed using the same analytical approach for chum salmon with the exception that no analysis of preference could be made for sockeye salmon due to the lack of concurrently collected availability/utilization data. The developed suitability criteria generally agree with previously published information.

Section 5.0 presented a discussion of the linking of the physical habitat availability models (developed in Section 3.0) with the spawning habitat suitability criteria (developed in Section 4.0) using a habitat simulation model (HABTAT) to project weighted usable area (WUA) of chum and sockeye salmon spawning habitat as a function of flow variation for the selected study sites. Runs of these models indicate that projections of chum and sockeye spawning WUA made at study sites show that spawning habitat in sloughs and side channels exhibit certain species - specific and site - specific trends. Generally, projections of WUA at study sites peak at mainstem discharges ranging from 20,000 to 35,000 cfs, with the controlling factor appearing to be the overtopping of the site by mainstem discharge and the subsequent control of the site flow by mainstem discharge. Thus, assuming that the modelled sloughs and side channels are representative of other non-modelled sloughs and side channels in the middle reach which currently support spawning, the theoretical maximum WUA for slough and side channel habitats in the middle reach would thus occur slightly after the mainstem discharge overtops and controls the hydraulics at a maximum number of these habitats. However, based on a review of time series plots of WUA over time at each study site, flows at study sites which currently support chum and sockeye spawning are infrequently controlled by mainstem discharge. For this reason, the WUA at study sites remains relatively low and stable during the period of peak spawning activity (August through September), except during flood events. There also appears to be a general positive correlation between projected WUA and habitat use at study sites.

In conclusion, the IFIM was used successfully to evaluate the suitability of selected slough and side channel habitats of the middle reach of the Susitna River for spawning by chum and sockeye salmon as a function of flow variation. Conditions which must be satisfied prior to application of these sites - specific modelling results to other non-modelling areas are also discussed in Section 5.0.

7.0 GLOSSARY

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

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

Binary Criteria: Evaluation of the suitability of a particular habitat component for a selected species/life phase using only two (binary) options (e.g., present or absent). If the component is present the conditions are acceptable; if the component is absent the conditions are unacceptable.

Breaching: Any of the conditions of overtopping of the head of a side channel or side slough. (See also initial, intermediate, and controlling breaching discharges and non-controlling conditions).

Cell: The surface area surrounding each vertical between adjacent verticals and transects which is assumed to have the same habitat characteristics as the vertical at the center of the cell.

GLOSSARY (continued)

Coefficient of Variation: The sample standard deviation divided by the sample mean for the frequency counts.

Computer Models: See PHABSIM, IFG-2 (WSP), IFG-4, HABTAT.

Controlling Breaching Discharge: The breaching condition in which mainstem discharges at Gold Creek are equal to or greater than the mainstem discharge required to directly govern the hydraulic characteristics within a side slough or side channel. This condition can be denoted as equalling the segment of the flow rating curve beginning with the point of inflection and beyond.

Critical Reaches: Sites at which microhabitat characteristics are generally atypical of the microhabitat in the associated river segment. The two criteria used to define a critical reach are:

1. The microhabitat characteristics of the critical reach are controlling or limiting to the evaluation species (such as limiting migration or spawning); and

2. These microhabitat characteristics are unavailable or in short supply in the representative reaches.

Curve Types: See spawning habitat curve types.

GLOSSARY (continued)

Data Types: See availability data, utilization data, measured data, observed data, synthetic data, predicted data, and forecast.

Discharge: Water volume passing a fixed point per unit time. In this report, the term specifically refers to mainstem habitat.

Elevation Of Zero Flow: The streambed elevation of a hydraulic control at which no flow occurs. See also point of zero flow.

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

Flow: Water volume passing a fixed point per unit time. In this report, the term specifically refers to non-mainstem habitats.

Forecast: Trend or conclusion drawn from the interpretation of predicted values.

Habitat: The physical conditions which are needed to support life processes for a particular species and life stage.

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

GLOSSARY (continued)

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

HABTAT: A computer model which is part of the IFG's PHABSIM model used to combine hydraulic models output and suitability criteria curves in order to determine habitat usability (weighted usable area) for a particular species and life stage of interest.

Hydraulic Control: A channel section with a specific relationship between stage and discharge.

IFG: Cooperative Instream Flow Service Group of the United States Fish and Wildlife Service.

IFG-2 Model: A computer model based on theory used to simulate hydraulic conditions (depth and velocity) within a study site. The model is calibrated using one set of hydraulic measurements. It is also referred to as the WSP Model.

IFG-4 Model: A computer model based on empiracal data used to simulate hydraulic conditions (depth and velocity) within a study site. The model is calibrated using a minimum of two or preferably three or more sets of hydraulic measurements.

GLOSSARY (continued)

Initial Breaching Discharge: The mainstem discharge at Gold Creek when mainstem water initially begins to enter the upstream head (berm) of a side slough or channel.

Intermediate Breaching Discharge: The range of mainstem discharges at Gold Creek representative of the conditions between the Initial and Controlling Breaching Discharges. Intermediate breaching discharges occur from immediately after mainstem surface water begins to overtop the head (berm) of a side slough or side channel up to the point when the mainstem discharge begins to govern the hydraulic characteristics of the site.

Joint Preference Factor (JPF): A function which quantifies a species preference or tolerance for combined suitability criteria (e.g., combined velocity, depth, substrate, and upwelling suitability criteria).

Lower Reach (of the Susitna River): The segment of the Susitna River between Cook Inlet and the Chulitna River confluence. (See also middle reach and upper reach).

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

GLOSSARY (continued)

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

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

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

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

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

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

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

GLOSSARY (continued)

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

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

Physical Habitat Simulation Model (PHABSIM): A collection of computer models, developed by the Cooperative Instream Flow Service Group of the USFWS (IFG), used to simulate hydraulic habitat conditions for fish, benthic in invertebrates, and recreational value.

Point Of Zero Flow: The location along the thalweg where no flow occurs. See also elevation of zero flow.

Predicted Data: Individual numbers or sets of numbers that result from a computer model simulation run.

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

GLOSSARY (continued)

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

Representative Reaches: Sites selected through a random or uniform sampling process which are used to describe the typical microhabitat in a segment.

Scaled Frequency: The label for the y-axis indicating data which has been standarized to the 0 - 1 scale.

Side Channel Habitat: Consists of those portions of the Susitna River that normally convey water during the open water season but become appreciably dewatered during periods of low mainstem discharge. Side channel habitat may exist either in well defined overflow channels, or in poorly defined reaches flowing through partially submerged gravel bars and islands along the margins of the mainstem river. Side channel streambed elevations are typically lower than the mean monthly water surface elevations of the mainstem Susitna River observed during June, July and August. Side channel habitats are characterized by shallower depths, lower velocities and smaller streambed materials than the adjacent habitat of the mainstem river.

GLOSSARY (continued)

Side Slough Habitat: These habitats are located in overflow channels between the edge of the floodplain and the mainstem and side channels of the Susitna River. They are usually separated from the mainstem and/or side channels by well vegetated bars. An exposed alluvial berm often separates the head of the slough from mainstem discharge or side channel flows. The controlling streambed/bank elevations at the upstream end of the side sloughs are slightly less than the water surface elevations of the mean monthly discharges of the mainstem Susitna River observed for June, July, and August. At intermediate and low-discharge periods, the side sloughs convey clear water from small tributaries and/or upwelling groundwater. These clear water inflows are essential contributors to the existence of this habitat type. The water surface elevation of the Susitna River generally causes a backwater area to extend well up into the slough from its lower end. Even though this substantial backwater area exists, the sloughs function hydraulically very much like small stream systems and several hundred feet of the slough channel often conveys water independent of mainstem backwater effects. At high discharges the water surface elevations of the mainstem river is sufficient to overtop the upper end of the slough. Surface water temperatures in the side sloughs during summer months are principally a function of air temperature, solar radiation, and the temperature of the local runoff.

GLOSSARY (continued)

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

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

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

Suitability Curve: See suitability criteria curve.

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

Synthetic Data: Estimated data sets based on professional judgment used in the hydraulic modeling calibration process to fill in data gaps.

Upper Reach (of the Susitna River): The segment of the Susitna River between Devil Canyon and the headwaters (See also lower reach and middle reach).

GLOSSARY (continued)

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

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

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

Velocity Adjustment Factor (VAF): The ratio of predicted to observed (input) discharges computed for an IFG-4 hydraulic model. The IFG considers a model acceptably calibrated when the VAF is between 0.9 and 1.1.

Vertical: The point on a transect where a measurement is made (the measurement is perpendicular to the horizontal plane defined by the water surface).

GLOSSARY (continued)

Water Surface Profile (WSP) Model: See IFG-2 Model.

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

DRAFT

August 15, 1984

GLOSSARY OF SCIENTIFIC NAMES

Scientific Name	Common Name
Onorhynchus keta (Welbaum)	Chum salmon
Oncorhynchus nerka (Walbaum)	Sockeye salmon

8.0 CONTRIBUTORS

Aquatic Habitat and Instream Flow Studies (AH) Project Leader and Principal Contact	Christopher Estes
AH Fish Habitat Utilization Subproject Leader and Report Coordinator, Part 2	Andrew Hoffmann
Hydraulic Engineering	E. Woody Trihey & Associates
Data Processing Project Leader	Allen Bingham
Data Reduction and Graphics Coordinator	Camille Stephens
Graphics	Sally Donovan Carol Kerkvliet Ann Reilly
Typing Staff	Vicki Cunningham Mary Gressett
Editors	Doug Vincent-Lang Allen Bingham Christopher Estes Andrew Hoffmann
Data Collection	Jeff Blakely Christopher Estes Diane Hilliard Andrew Hoffmann Isaac Queral Sheryl Salasky Gene Sandone Joe Sautner Don Seagren Kathy Sheehan Rick Sinnot Kim Sylvester Woody Trihey Len Vining
Data Analysis	
Physical Modelling	Diane Hilliard Kim Sylvester Woody Trihey
Fish Habitat Criteria Analysis	Allen Bingham Doug Vincent-Lang Christopher Estes Andrew Hoffmann

CONTRIBUTORS (continued)

Weighted Usable Area Analysis	Doug Vincent-Lang Allen Bingham Christopher Estes Andrew Hoffmann

Text

Physical Modelling	Diane Hilliard Don Seagren E. Woody Trihey
Fish Habitat Criteria	Allen Bingham Doug Vincent-Lang Christopher Estes Andrew Hoffmann
Usable Habitat Analysis	Doug Vincent-Lang Allen Bingham Christopher Estes Andrew Hoffmann

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11.0 APPENDICES

Appendix 7-A

Calibration Data for Hydraulic Availibility Models

Appendix Table 7-A-1. Comparison between observed and predicted water surface elevations, discharges, and velocities for 1983 Slough 8A low flow hydraulic model.

Streambed Station (ft)	Water Surface Elevation Observed (ft)	Water Surface Elevation Predicted (ft)	Discharge Observed (cfs)	Discharge Predicted (cfs)	Velocity Adjustment Factor
28+14	565.47	565.48	4	4	1.00
29+25	565.48	565.49	4	4	0.95
30+15	565.52	565.53	4	4	0.99
31+47	565.84	565.85	4	4	1.00
32+36	566.01	566.01	4	4	0.96
33+02	566.06	566.06	4	4	1.00
33+43	566.31	566.31	4	4	1.01
34+46	566.62	566.62	3	4	1.00
36+22	567.20	567.20	4	4	1.00
37+35	567.20	567.20	4	4	1.00
38+23	567.21	567.20	3	4	1.00
			Qo = 4	Qp = 4	
28+14	565.59	565.57	8	7	1.01
29+25	565.59	565.58	7	7	0.99
30+15	565.64	565.62	8	7	0.99
31+47	566.01	565.99	7	7	1.00
32+36	566.13	566.13	8	7	0.99
33+02	566.15	566.15	7	7	1.01
33+43	566.36	566.36	7	7	0.99
34+46	566.68	566.68	8	7	1.03
36+22	567.28	567.28	7	7	1.01
37+35	567.28	567.28	7	7	1.00
38+23	567.28	567.29	8	7	1.02
			Qo = 7	Qp = 7	
28+14	565.75	565.76	18	19	1.00
29+25	565.75	565.76	19	20	1.00
30+15	565.80	565.81	17	18	0.99
31+47	566.25	566.26	19	19	1.00
32+36	566.36	566.36	20	21	0.99
33+02	566.36	566.36	19	20	0.99
33+43	566.49	566.49	20	21	1.00
34+46	566.79	566.79	19	20	0.98
36+22	567.44	567.44	20	20	1.00
37+35	567.45	567.45	21	20	1.00
38+23	567.46	567.46	19	20	0.98
			Qo = 19	Qp = 20	

Qo is the mean observed calibration discharge.

Qp is the mean predicted calibration discharge.

Appendix Table 7-A-2. Comparison between observed and predicted water surface elevations, discharges, and velocities for 1983 Slough 8A high flow hydraulic model.

Streambed Station	Water Surface Elevation		Discharge		Velocity
	Observed	Predicted	Observed	Predicted	Adjustment
(ft)	(ft)	(ft)	(cfs)	(cfs)	Factor
28+14	565.75	565.75	17	17	1.00
29+15	565.75	565.75	19	19	1.00
30+15	565.80	565.80	16	16	1.00
31+47	566.25	566.25	19	19	1.00
32+36	566.36	566.36	19	19	1.00
33+02	566.36	566.36	20	20	0.99
33+43	566.49	566.49	18	18	1.00
34+46	566.79	566.79	18	18	0.99
36+22	567.44	567.44	20	20	1.00
37+35	567.45	567.45	20	20	1.00
38+23	567.46	567.46	19	19	1.00
			Qo = 19	Qp = 19	
28+14	566.76	566.76	54	54	1.00
29+15	566.76	566.76	53	53	1.00
30+15	566.78	566.78	59	59	1.00
31+47	566.84	566.84	52	52	0.99
32+36	566.85	566.85	53	53	1.00
33+02	566.86	566.86	53	53	0.96
33+43	566.88	566.88	54	54	0.98
34+46	567.10	567.10	52	52	0.97
36+22	567.70	567.70	54	54	0.99
37+35	567.76	567.76	50	50	1.00
38+23	567.77	567.77	50	50	0.95
			Qo = 53	Qp = 53	

Qo is the mean observed calibration discharge.

Qp is the mean predicted calibration discharge.

Appendix Table 7-A-3. Comparison between observed and predicted water surface elevations, discharges and velocities for 1983 Slough 9 hydraulic model.

Streambed Station	Water Surface Elevation		Discharge		Velocity
	Observed	Predicted	Observed	Predicted	Adjustment
(ft)	(ft)	(ft)	(cfs)	(cfs)	Factor
16+47	592.40	592.40	8	8	0.99
19+42	592.60	592.60	8	8	1.01
20+00	592.75	592.75	8	8	0.99
21+77	593.37	593.36	8	8	0.98
22+93	593.46	593.46	8	8	0.99
24+80	593.46	593.46	8	8	0.99
26+48	593.50	593.50	8	8	0.99
28+06	593.53	593.53	8	8	0.99
			Qo = 8	Qp = 8	
16+47	593.19	593.18	89	89	1.02
19+42	593.35	593.35	86	89	1.04
20+00	593.41	593.41	88	91	1.03
21+77	593.96	594.00	89	90	1.02
22+93	594.05	594.05	86	88	1.02
24+80	594.08	594.08	90	89	1.02
26+48	594.10	594.11	90	88	1.02
28+06	594.11	594.13	88	90	1.02
			Qo = 88	Qp = 89	
16+47	593.43	593.45	148	148	1.00
19+42	593.59	593.58	150	148	1.01
20+00	593.63	593.66	153	151	1.02
21+77	594.15	594.18	151	150	0.99
22+93	594.20	594.23	148	146	1.00
24+80	594.24	594.26	145	148	1.01
26+48	594.28	594.29	144	146	1.01
28+06	594.33	594.31	147	149	1.00
			Qo = 148	Qp = 148	
16+47	593.74	593.73	233	232	0.96
19+42	593.82	593.83	232	230	0.97
20+00	593.96	593.93	242	238	0.99
21+77	594.42	594.36	237	237	0.96
22+93	594.43	594.40	232	229	0.98
24+80	594.47	594.45	234	230	0.99
26+48	594.49	594.47	230	229	0.98
28+06	594.49	594.49	238	232	0.98
			Qo = 234	Qp = 232	

Qo is the mean observed calibration discharge.

Qp is the mean predicted calibration discharge.

Appendix Table 7-A-4. Comparison between observed and predicted water surface elevations, discharges, and velocities for 1983 Slough 21 low flow hydraulic model.

Streambed Station	Water Surface Elevation		Discharge		Velocity
	Observed	Predicted	Observed	Predicted	Adjustment
(ft)	(ft)	(ft)	(cfs)	(cfs)	Factor
-4+57	744.22	744.22	5	5	0.98
-3+57	744.30	744.30	5	5	0.96
-2+16	744.31	744.31	5	5	0.98
-1+84	744.59	744.59	4	4	1.00
-0+95	744.77	744.77	5	5	1.00
			Qo = 5	Qp = 5	
-4+57	744.58	744.58	11	11	0.99
-3+57	744.59	744.59	10	10	1.00
-2+16	744.60	744.60	10	10	1.00
-1+84	744.73	744.73	9	9	1.00
-0+95	744.88	744.88	9	9	1.00
			Qo = 10	Qp = 10	

Qo is the mean observed calibration discharge.

Qp is the mean predicted calibration discharge.

Appendix Table 7-A-5. Comparison between observed and predicted water surface elevations, discharges, and velocities for 1983 Slough 21 high flow hydraulic model.

Streambed Station (ft)	Water Surface Elevation Observed (ft)	Water Surface Elevation Predicted (ft)	Discharge Observed (cfs)	Discharge Predicted (cfs)	Velocity Adjustment Factor
-4+57	744.58	744.58	10	10	1.00
-3+57	744.59	744.59	10	10	1.00
-2+16	744.60	744.59	10	10	0.99
-1+84	744.73	744.73	10	10	1.01
-0+95	744.88	744.87	9	9	1.00
			Qo = 10	Qp = 10	
-4+57	745.32	745.34	76	75	1.01
-3+57	745.33	745.35	74	74	1.02
-2+16	745.35	745.38	76	74	1.03
-1+84	745.38	745.41	75	74	1.00
-0+95	745.53	745.56	70	72	1.02
			Qo = 74	Qp = 74	
-4+57	745.79	745.77	157	159	0.99
-3+57	745.80	745.78	158	158	1.00
-2+16	745.85	745.82	154	157	1.00
-1+84	745.86	745.83	155	157	0.97
-0+95	745.99	745.96	156	154	0.98
			Qo = 156	Qp = 157	

Qo is the mean observed calibration discharge.

Qp is the mean predicted calibration discharge.

Appendix Table 7-A-6. Comparison between observed and predicted water surface elevations, discharges, and velocities for 1983 Side Channel 10 hydraulic model.

Streambed Station (ft)	Water Surface Elevation Observed (ft)	Water Surface Elevation Predicted (ft)	Discharge Observed (cfs)	Discharge Predicted (cfs)	Velocity Adjustment Factor
7+46	651.27	651.27	8	8	0.87
9+86	652.16	652.16	8	8	0.99
14+78	653.53	653.53	8	8	1.00
17+06	654.39	654.39	8	8	1.00
19+42	654.72	654.72	8	8	0.99
			Qo = 8	Qp = 8	
7+46	651.90	651.90	79	79	0.95
9+86	652.70	652.70	84	84	1.01
14+78	654.35	654.35	78	78	0.97
17+06	655.10	655.10	79	79	1.01
19+42	655.57	655.57	79	79	1.01
			Qo = 80	Qp = 80	

Qo is the mean observed calibration discharge.

Qp is the mean precited calibration discharge.

Appendix Table 7-A-7. Comparison between observed and predicted water surface elevations, discharges, and velocities for 1983 Upper Side Channel 11 hydraulic model.

Streambed Station	Water Surface Elevation		Discharge		Velocity Adjustment Factor
	Observed	Predicted	Observed	Predicted	
(ft)	(ft)	(ft)	(cfs)	(cfs)	
0+00	677.38	677.38	13	13	0.98
2+00	677.51	677.51	11	11	1.00
4+30	677.60	677.60	12	12	0.99
10+40	680.95	680.95	11	11	1.00
			Qo = 12	Qp = 12	
0+00	678.00	677.99	55	55	1.06
2+00	678.04	678.03	55	54	1.01
4+30	678.11	678.10	55	55	1.02
10+40	681.35	681.34	53	52	1.01
			Qo = 55	Qp = 54	
0+00	678.35	678.36	106	107	0.96
2+00	678.35	678.36	113	114	1.00
4+30	678.44	678.45	112	112	0.98
10+40	681.63	681.64	107	108	0.99
			Qo = 110	Qp = 110	

Qo is the mean observed calibration discharge.

Qp is the mean predicted calibration discharge.

Appendix Table 7-A-8. Comparison between observed and predicted water surface elevations, discharges, and velocities for 1983 Side Channel 21 low flow hydraulic model.

Streambed Station (ft)	Water Surface Elevation Observed (ft)	Water Surface Elevation Predicted (ft)	Discharge Observed (cfs)	Discharge Predicted (cfs)	Velocity Adjustment Factor
-38+92	733.28	733.28	22	22	0.99
-37+07	733.81	733.81	23	23	0.99
-35+74	735.68	735.68	25	25	0.96
-33+42	736.09	736.09	23	23	0.90
-30+06	737.08	737.08	24	24	1.00
			Qo = 23	Qp = 23	
-38+92	733.64	733.64	100	100	0.99
-37+07	734.12	734.12	99	99	1.01
-35+74	735.90	735.90	100	100	1.00
-33+42	736.28	736.28	100	100	1.00
-30+06	737.61	737.61	100	100	1.00
			Qo = 100	Qp = 100	

Qo is the mean observed calibration discharge.

Qp is the mean predicted calibration discharge.

Appendix Table 7-A-9. Comparison between observed and predicted water surface elevations, discharges, and velocities for 1983 Side Channel 21 high flow hydraulic model.

Streambed Station (ft)	Water Surface Elevation Observed (ft)	Water Surface Elevation Predicted (ft)	Discharge Observed (cfs)	Discharge Predicted (cfs)	Velocity Adjustment Factor
-38+92	733.64	733.64	100	100	0.98
-37+07	734.12	734.12	99	100	0.99
-35+74	735.90	735.90	100	100	1.00
-33+42	736.28	736.28	100	100	1.00
-30+06	737.61	737.61	100	100	1.00
			Qo = 100	Qp = 100	
-38+92	734.99	735.01	431	431	1.05
-37+07	735.18	735.18	433	433	1.01
-35+74	736.55	736.57	430	430	1.00
-33+42	737.06	737.07	431	430	1.00
-30+06	738.29	738.28	430	430	1.02
			Qo = 431	Qp = 431	
-38+92	735.98	735.96	775	775	0.98
-37+07	736.02	736.02	783	783	0.99
-35+74	736.97	736.95	775	777	1.00
-33+42	737.54	737.53	773	774	1.00
-30+06	738.63	738.63	773	773	1.00
			Qo = 776	Qp = 776	

Qo is the mean observed calibration discharge.

Qp is the mean predicted calibration discharge.

APPENDIX 7B

Salmon Spawning Utilization Data Form

Slough And Side Channels

Table 7-B-1 Habitat data collected at chum salmon redds.

LOCATION	DATE	DEPTH (FT)	WATER VELO-CITY (FT/S)	SUBSTRATE PRIMARY	SUBSTRATE SECONDARY	WATER TEMPERATURE (C) INTRAGRAVEL	WATER TEMPERATURE (C) SURFACE	REDD NO.	UPWELLING	DISTANCE (FT) TO UPWELLING
SLOUGH 9	830906	.90	.30	COBBLE	LARGE GRAVEL	5.6	6.3	1	PRESENT	6
SLOUGH 9	830906	1.30	.02	RUBBLE	LARGE GRAVEL	5.2	6.3	2	PRESENT	3
SLOUGH 9	830906	1.00	.25	COBBLE	LARGE GRAVEL	4.7	6.2	3	PRESENT	10
SLOUGH 9	830906	1.30	.35	RUBBLE	LARGE GRAVEL	4.3	6.6	4	PRESENT	3
SLOUGH 9	830906	1.10	.10	COBBLE	SAND	4.6	6.5	5	PRESENT	3
SLOUGH 9	830906	1.00	.35	SAND	LARGE GRAVEL	4.3	6.7	6	UNKNOWN	
SLOUGH 9	830906	1.20	.35	SMALL GRAVEL	RUBBLE	4.3	6.8	7	UNKNOWN	
SLOUGH 9	830906	1.10	.30	LARGE GRAVEL	RUBBLE	4.1	6.8	8	UNKNOWN	
SLOUGH 9	830906	.70	.05	LARGE GRAVEL	SMALL GRAVEL	4.1	5.9	9	PRESENT	4
SLOUGH 9	830906	.65	.80	RUBBLE	SMALL GRAVEL	4.0	7.4	10	UNKNOWN	
SLOUGH 9	830906	.70	.50	RUBBLE	SMALL GRAVEL	4.1	7.4	11	UNKNOWN	
SLOUGH 9	830906	.60	.70	RUBBLE	SMALL GRAVEL	4.2	7.4	12	UNKNOWN	
SLOUGH 9	830906	.75	1.15	RUBBLE	SMALL GRAVEL	4.0	7.5	13	UNKNOWN	
SLOUGH 9	830906	.90	1.10	COBBLE	SMALL GRAVEL	3.9	7.5	14	UNKNOWN	
SLOUGH 9	830906	.60	1.20	LARGE GRAVEL	SMALL GRAVEL	4.1	7.6	15	UNKNOWN	
SLOUGH 9	830906	1.00	.55	RUBBLE	SMALL GRAVEL	4.0	7.8	16	UNKNOWN	
SLOUGH 9	830906	.80	.60	SAND	RUBBLE	4.0	7.9	17	UNKNOWN	
SLOUGH 9	830906	.50	.55	SMALL GRAVEL	RUBBLE	4.6	7.9	18	UNKNOWN	
SLOUGH 9	830906	.50	.45	COBBLE	SMALL GRAVEL	3.6	7.6	19	UNKNOWN	
SLOUGH 9	830906	.90	.45	COBBLE	SMALL GRAVEL	3.9	7.7	20	UNKNOWN	
SLOUGH 9	830906	1.00	.45	RUBBLE	SMALL GRAVEL	3.9	8.0	21	UNKNOWN	
SLOUGH 9	830906	.60	.10	SAND	RUBBLE	4.4	8.2	22	UNKNOWN	
SLOUGH 9	830906	.75	0.00	RUBBLE	SMALL GRAVEL	4.8	8.8	23	UNKNOWN	
SLOUGH 9	830906	.60	0.00	LARGE GRAVEL	SMALL GRAVEL	4.7	8.8	24	UNKNOWN	
SLOUGH 9	830906	1.00	.25	RUBBLE	LARGE GRAVEL	6.2	7.1	25	UNKNOWN	
SLOUGH 9	830906	1.50	.20	LARGE GRAVEL	RUBBLE	5.9	7.1	26	UNKNOWN	

Table 7-B-1 Continued

LOCATION	DATE	DEPTH (FT)	WATER VELO-CITY (FT/S)	SUBSTRATE PRIMARY	SUBSTRATE SECONDARY	WATER TEMPERATURE (C) INTRAGRAVEL	WATER TEMPERATURE (C) SURFACE	REDD NO.	UPWELLING	DISTANCE (FT) TO UPWELLING
SLOUGH 9	830906	.40	0.00	SMALL GRAVEL	RUBBLE	5.7	6.9	27	UNKNOWN	
SLOUGH 9	830906	.70	.70	SMALL GRAVEL	RUBBLE	5.2	7.3	28	UNKNOWN	
SLOUGH 9	830906	.60	.40	LARGE GRAVEL	SMALL GRAVEL	5.5	7.3	29	UNKNOWN	
SLOUGH 9	830906	.55	.55	RUBBLE	SMALL GRAVEL	6.9	8.8	30	UNKNOWN	
SLOUGH 9	830906	.60	.15	LARGE GRAVEL	SMALL GRAVEL	5.6	7.3	31	UNKNOWN	
SLOUGH 8A	830815	1.60	.23	RUBBLE	LARGE GRAVEL	6.0	9.2	1		
SLOUGH 8A	830815	1.30	.25	RUBBLE	LARGE GRAVEL	6.2	9.3	2		
SLOUGH 8A	830815	1.40	.25	RUBBLE	LARGE GRAVEL	5.2	9.1	3		
SLOUGH 8A	830815	1.40	.30	RUBBLE	LARGE GRAVEL	5.0	9.6	4		
SLOUGH 8A	830815	1.30	.50	RUBBLE	LARGE GRAVEL	5.6	9.1	5		
SLOUGH 8A	830815	1.00	.45	RUBBLE	LARGE GRAVEL	6.4	9.1	6		
SLOUGH 8A	830815	1.10	.65	RUBBLE	SMALL GRAVEL	5.4	9.1	7		
SLOUGH 8A	830816	1.55	0.00	RUBBLE	LARGE GRAVEL	5.3	10.0	8	UNKNOWN	
SLOUGH 8A	830816	1.50	.08	SMALL GRAVEL	RUBBLE	5.8	10.3	9	UNKNOWN	
SLOUGH 8A	830902	.90	.05	LARGE GRAVEL	RUBBLE	4.7	9.7	10	UNKNOWN	
SLOUGH 8A	830902	.90	0.00	LARGE GRAVEL	RUBBLE	4.9	9.8	11	UNKNOWN	
SLOUGH 8A	830902	1.00	0.00	LARGE GRAVEL	RUBBLE	5.8	9.4	12	UNKNOWN	
SLOUGH 8A	830902	1.20	.05	RUBBLE	SMALL GRAVEL	5.9	10.2	13	UNKNOWN	
SLOUGH 8A	830902	1.00	.20	RUBBLE	LARGE GRAVEL	7.2	10.3	14	UNKNOWN	
SLOUGH 8A	830902	2.80	0.00	LARGE GRAVEL	SMALL GRAVEL		10.2	15	UNKNOWN	
4TH OF JULY CREEK MOUTH	830817	1.00	.60	LARGE GRAVEL	RUBBLE	10.6	11.6	1	UNKNOWN	
4TH OF JULY CREEK MOUTH	830817	1.70	.75	COBBLE	RUBBLE	11.5	11.6	2	UNKNOWN	

Table 7-B-1 Continued

LOCATION	DATE	DEPTH (FT)	WATER VELOCITY (FT/S)	SUBSTRATE PRIMARY	SUBSTRATE SECONDARY	WATER TEMPERATURE (C) INTRAGRAVEL	WATER TEMPERATURE (C) SURFACE	REDD NO.	UPWELLING	DISTANCE (FT) TO UPWELLING
4TH OF JULY CREEK MOUTH	830817	1.60	.70	LARGE GRAVEL	RUBBLE	11.2	11.6	3	UNKNOWN	
4TH OF JULY CREEK MOUTH	830817	2.20	.60	LARGE GRAVEL	RUBBLE	10.2	11.6	4		
4TH OF JULY CREEK MOUTH	830817	2.00	.60	LARGE GRAVEL	RUBBLE	10.8	11.7	5		
4TH OF JULY CREEK MOUTH	830817	2.30	.60	LARGE GRAVEL	RUBBLE	10.7	11.6	6		
4TH OF JULY CREEK MOUTH	830817	2.10	.10	COBBLE	RUBBLE	11.0	11.9	7		
4TH OF JULY CREEK MOUTH	830817	1.00	.25	SMALL GRAVEL	LARGE GRAVEL	11.3	11.9	8		
4TH OF JULY CREEK MOUTH	830817	1.00	.25	RUBBLE	LARGE GRAVEL	11.3	11.9	9		
4TH OF JULY CREEK MOUTH	830817	1.70	.20	RUBBLE	LARGE GRAVEL	11.2	11.8	10		
4TH OF JULY CREEK MOUTH	830818	2.10	1.35	RUBBLE	COBBLE	11.8	12.2	12	UNKNOWN	
4TH OF JULY CREEK MOUTH	830818	1.50	.10	SMALL GRAVEL	SAND	10.4	12.0	13	UNKNOWN	
4TH OF JULY CREEK MOUTH	830818	1.70	2.10	LARGE GRAVEL	SMALL GRAVEL	7.5	12.3	14	UNKNOWN	
4TH OF JULY CREEK MOUTH	830818	1.90	4.50	RUBBLE	COBBLE	8.1	12.3	15	UNKNOWN	
4TH OF JULY CREEK MOUTH	830822	2.20	1.30	RUBBLE	LARGE GRAVEL	9.7	11.2	16		
4TH OF JULY CREEK MOUTH	830822	2.00	1.00	RUBBLE	LARGE GRAVEL	11.1	11.3	17		
4TH OF JULY CREEK MOUTH	830822	1.80	1.40	RUBBLE	SAND	11.0	11.3	18		
4TH OF JULY CREEK MOUTH	830822	2.00	1.80	RUBBLE	LARGE GRAVEL	9.3	11.3	19		
4TH OF JULY CREEK MOUTH	830822	1.30	2.20	RUBBLE	LARGE GRAVEL	9.8	11.2	20		
4TH OF JULY CREEK MOUTH	830822	.90	2.00	RUBBLE	LARGE GRAVEL	11.4	11.3	21	UNKNOWN	
4TH OF JULY CREEK MOUTH	830822	1.20	3.10	RUBBLE	LARGE GRAVEL	11.3	11.3	22	UNKNOWN	
4TH OF JULY CREEK MOUTH	830822	1.70	2.00	RUBBLE	COBBLE	11.4	11.3	23	UNKNOWN	
4TH OF JULY CREEK MOUTH	830828	.70	.40			9.5	10.7	24		
4TH OF JULY CREEK MOUTH	830828	1.70	2.50			9.4	10.7	25		
4TH OF JULY CREEK MOUTH	830828	.90	.80			9.0	10.6	26		

Table 7-8-1 Continued

LOCATION	DATE	DEPTH (FT)	WATER VELO-CITY (FT/S)	SUBSTRATE PRIMARY	SUBSTRATE SECONDARY	WATER TEMPERATURE (C) INTRAGRAVEL	WATER TEMPERATURE (C) SURFACE	REDD NO.	UPWELLING	DISTANCE (FT) TO UPWELLING
4TH OF JULY CREEK MOUTH	830828	.70	.75			8.7	10.6	27		
4TH OF JULY CREEK MOUTH	830828	.60	1.20			10.1	10.7	28		
4TH OF JULY CREEK MOUTH	830828	1.10	.10			5.7	10.8	29		
SIDE CHANNEL 250 FT ABOVE 4TH OF JULY	830823	1.60	2.40	LARGE GRAVEL	RUBBLE		8.8	1	UNKNOWN	
SLOUGH 9A	830910	.93	.60	RUBBLE	LARGE GRAVEL	6.7	6.0	1	PRESENT	20
SLOUGH 9A	830910	1.12	0.00	RUBBLE	LARGE GRAVEL	6.3	6.1	2	UNKNOWN	
SLOUGH 9A	830910	1.30	.40	RUBBLE	LARGE GRAVEL	6.4	6.0	3	PRESENT	15
SLOUGH 9A	830910	.90	.62	LARGE GRAVEL	RUBBLE	6.2	6.3	4	UNKNOWN	
SLOUGH 9A	830910	.60	1.80	LARGE GRAVEL	RUBBLE	5.8	6.0	5	UNKNOWN	
SLOUGH 9A	830910	1.45	0.00	COBBLE	LARGE GRAVEL	5.1	6.7	6	PRESENT	30
SLOUGH 9A	830910	1.63	.62	RUBBLE	LARGE GRAVEL	5.1	6.7	7	PRESENT	10
SLOUGH 9A	830910	1.20	.28	RUBBLE	LARGE GRAVEL	4.3	8.2	8	UNKNOWN	
SLOUGH 9A	830910	1.30	.10	RUBBLE	LARGE GRAVEL	4.6	7.5	9	UNKNOWN	
SLOUGH 9A	830910	1.38	0.00	LARGE GRAVEL	SMALL GRAVEL	4.4	7.0	10	UNKNOWN	
SLOUGH 9A	830910	1.41	0.00	LARGE GRAVEL	SMALL GRAVEL	4.7	7.1	11	UNKNOWN	
SLOUGH 9A	830910	1.31	0.00	LARGE GRAVEL	SMALL GRAVEL	4.6	6.9	12	UNKNOWN	
SLOUGH 9A	830910	1.10	0.00	LARGE GRAVEL	RUBBLE	4.7	6.9	13	UNKNOWN	
SLOUGH 9A	830910	1.00	0.00	RUBBLE	COBBLE	4.7	6.9	14	UNKNOWN	
SLOUGH 9A	830910	.90	.50	RUBBLE	LARGE GRAVEL	4.4	8.4	15	UNKNOWN	
SLOUGH 9A	830910	1.40	.10	RUBBLE	LARGE GRAVEL	5.8	8.5	16	UNKNOWN	
SLOUGH 9A	830910	1.54	.10	COBBLE	RUBBLE	8.2	8.7	17	UNKNOWN	
SLOUGH 9A	830910	1.10	.20	RUBBLE	LARGE GRAVEL	4.8	8.6	18	UNKNOWN	
SLOUGH 9A	830910	1.10	.10	RUBBLE	LARGE GRAVEL	4.0	8.5	19	UNKNOWN	
SLOUGH 9A	830910	1.30	.15	RUBBLE	COBBLE	5.3	8.5	20	UNKNOWN	

Table 7-B-1 Continued

LOCATION	DATE	DEPTH (FT)	WATER VELO-CITY (FT/S)	SUBSTRATE PRIMARY	SUBSTRATE SECONDARY	WATER TEMPERATURE (C) INTRAGRAVEL	WATER TEMPERATURE (C) SURFACE	REDD NO.	UPWELLING	DISTANCE (FT) TO UPWELLING
SLOUGH 9A	830910	1.48	.08	RUBBLE	COBBLE	4.1	8.5	21	UNKNOWN	
SLOUGH 9A	830910	1.80	.15	COBBLE	BOULDER	7.3	8.7	22	UNKNOWN	
SLOUGH 9A	830910	1.00	0.00	RUBBLE	LARGE GRAVEL	4.8	8.1	23	PRESENT	10
SLOUGH 9A	830910	.90	0.00	RUBBLE	LARGE GRAVEL	3.9	8.5	24	PRESENT	10
SLOUGH 11	830811	1.60	.18	SMALL GRAVEL	RUBBLE	6.2	7.2	21		
SLOUGH 11	830816	1.95	.20	RUBBLE	LARGE GRAVEL	4.4	9.2	8	UNKNOWN	
SLOUGH 11	830816	2.10	.20	RUBBLE	SMALL GRAVEL	7.2	9.1	9	UNKNOWN	
SLOUGH 11	830816	1.20	.20	LARGE GRAVEL	SMALL GRAVEL	4.6	8.9	10	UNKNOWN	
SLOUGH 11	830816	1.20	.20	LARGE GRAVEL	SMALL GRAVEL	5.4	8.9	11	UNKNOWN	
SLOUGH 11	830816	.65	.10	LARGE GRAVEL	SMALL GRAVEL	5.4	8.3	12	UNKNOWN	
SLOUGH 11	830820	.45	.20	LARGE GRAVEL	SMALL GRAVEL	3.7	5.3	1	UNKNOWN	
SLOUGH 11	830820	.60	.40	LARGE GRAVEL	RUBBLE	4.3	5.6	2	UNKNOWN	
SLOUGH 11	830820	.60	1.40	LARGE GRAVEL	RUBBLE	5.0	5.6	3	UNKNOWN	
SLOUGH 11	830820	.50	.20	LARGE GRAVEL	RUBBLE	3.8	5.4	4	UNKNOWN	
SLOUGH 11	830820	.70	.05	LARGE GRAVEL	RUBBLE	3.8	4.8	5	UNKNOWN	
SLOUGH 11	830820	2.20	0.00	LARGE GRAVEL	RUBBLE	3.2	5.9	6	UNKNOWN	
SLOUGH 11	830820	2.10	0.00	LARGE GRAVEL	RUBBLE	3.1	5.9	7	UNKNOWN	
SLOUGH 11	830820	2.10	0.00	LARGE GRAVEL	RUBBLE	3.2	5.9	13	UNKNOWN	
SLOUGH 11	830820	1.70	0.00	LARGE GRAVEL	RUBBLE	3.2	5.8	14	UNKNOWN	
SLOUGH 11	830820	1.40	.18	LARGE GRAVEL	RUBBLE	3.5	5.7	15	UNKNOWN	
SLOUGH 11	830820	.80	0.00	LARGE GRAVEL	RUBBLE	3.2	5.0	16	UNKNOWN	
SLOUGH 11	830820	1.20	0.00	LARGE GRAVEL	SMALL GRAVEL	3.1	4.5	17	UNKNOWN	
SLOUGH 11	830820	2.10	.08	RUBBLE	LARGE GRAVEL	2.9	4.6	18	UNKNOWN	

Table 7-B-1 Continued

LOCATION	DATE	DEPTH (FT)	WATER VELO-CITY (FT/S)	SUBSTRATE PRIMARY	SUBSTRATE SECONDARY	WATER TEMPERATURE (C) INTRAGRAVEL	WATER TEMPERATURE (C) SURFACE	REDD NO.	UPWELLING	DISTANCE (FT) TO UPWELLING
SLOUGH 11	830820	1.90	.08	SMALL GRAVEL	LARGE GRAVEL	2.9	4.6	19	UNKNOWN	
SLOUGH 11	830820	1.90	.10	LARGE GRAVEL	RUBBLE	2.9	4.7	20	UNKNOWN	
SLOUGH 11	830827	.95	.10				8.0	22	UNKNOWN	
SLOUGH 11	830827	1.00	.10				8.0	23	UNKNOWN	
SLOUGH 11	830827	.60	.05				8.5	24	UNKNOWN	
SLOUGH 11	830827	1.50	.10				8.0	25	UNKNOWN	
SLOUGH 11	830827	1.00	.05				8.0	26	UNKNOWN	
SLOUGH 11	830827	2.00	.05				8.0	27	UNKNOWN	
SLOUGH 11	830827	2.10	.05				8.0	28	UNKNOWN	
SLOUGH 11	830827	2.60	0.00				8.0	29	UNKNOWN	
SLOUGH 11	830827	.60	0.00				7.0	30	UNKNOWN	
SLOUGH 11	830827	1.50	0.00				8.5	31	UNKNOWN	
SLOUGH 11	830827	1.50	0.00				8.0	32	UNKNOWN	
SLOUGH 11	830827	2.00	.05				8.0	33	UNKNOWN	
SLOUGH 11	830827	1.90	0.00				8.0	34	UNKNOWN	
SLOUGH 11	830827	2.50	0.00				9.5	35	UNKNOWN	
SLOUGH 11	830910	1.55	0.00	RUBBLE	LARGE GRAVEL	3.6	7.2	36	UNKNOWN	
SLOUGH 11	830910	1.40	0.00	RUBBLE	LARGE GRAVEL	3.7	6.6	37	UNKNOWN	
SLOUGH 11	830910	1.63	0.00	RUBBLE	LARGE GRAVEL	3.5	6.9	38	UNKNOWN	
SLOUGH 11	830910	1.50	0.00	RUBBLE	COBBLE	4.0	7.0	39	UNKNOWN	
SLOUGH 11	830910	2.00	0.00	COBBLE	BOULDER			40	UNKNOWN	
SLOUGH 11	830910	.70	.15	SMALL GRAVEL	LARGE GRAVEL			41	UNKNOWN	
SLOUGH 11	830910	.96	.10	COBBLE	RUBBLE			42	UNKNOWN	
SLOUGH 11	830910	.60	0.00	COBBLE	RUBBLE			43	UNKNOWN	

Table 7-B-1 Continued

LOCATION	DATE	DEPTH (FT)	WATER VELO-CITY (FT/S)	SUBSTRATE PRIMARY	SUBSTRATE SECONDARY	WATER TEMPERATURE (C) INTRAGRAVEL	WATER TEMPERATURE (C) SURFACE	REDD NO.	UPWELLING	DISTANCE (FT) TO UPWELLING
SLOUGH 11	830910	1.52	0.00	RUBBLE	COBBLE			44	UNKNOWN	
SLOUGH 11	830910	1.10	0.00	RUBBLE	COBBLE			45	UNKNOWN	
SLOUGH 11	830910	1.18	0.00	RUBBLE	COBBLE			46	UNKNOWN	
SLOUGH 11	830911	.40	.75	LARGE GRAVEL	SMALL GRAVEL			47	UNKNOWN	
SLOUGH 11	830911	.24	.35	LARGE GRAVEL	SMALL GRAVEL			48	UNKNOWN	
SLOUGH 11	830911	.90	0.00	RUBBLE	COBBLE			49	UNKNOWN	
SLOUGH 11	830911	1.20	.05	LARGE GRAVEL	RUBBLE			50	UNKNOWN	
SLOUGH 11	830911	1.70	0.00	RUBBLE	LARGE GRAVEL			51	PRESENT	
SLOUGH 11	830911	2.90	0.00	RUBBLE	LARGE GRAVEL			52	PRESENT	10
SLOUGH 11 SIDE CHANNEL (UPPER)	830823	1.50	2.10	RUBBLE	LARGE GRAVEL		9.1	1	UNKNOWN	
SLOUGH 11 SIDE CHANNEL (UPPER)	830823	2.30	2.40	SAND	RUBBLE		9.1	2	UNKNOWN	
INDIAN RIVER (MOUTH)	830820	1.40	.60	RUBBLE	LARGE GRAVEL	8.5	8.2	1		
INDIAN RIVER (MOUTH)	830820	1.20	.15	RUBBLE	LARGE GRAVEL	8.4	8.7	2		
INDIAN RIVER (MOUTH)	830820	1.90	.42	RUBBLE	LARGE GRAVEL	8.8	8.2	3		
SLOUGH 17	830820	.70	.20	LARGE GRAVEL	RUBBLE	5.0	5.4	1	PRESENT	60
SLOUGH 17	830820	.80	.40	LARGE GRAVEL	RUBBLE	5.1	5.2	2	PRESENT	65
SLOUGH 17	830901	1.70	0.00	LARGE GRAVEL	RUBBLE	4.8	5.0	4	UNKNOWN	
SLOUGH 17	830901	1.50	0.00	LARGE GRAVEL	SMALL GRAVEL	4.7	4.8	5	UNKNOWN	
SLOUGH 17	830901	1.90	0.00	RUBBLE	COBBLE	4.1	4.8	6	UNKNOWN	
SLOUGH 17	830901	2.60	0.00	RUBBLE	COBBLE		5.0	7	UNKNOWN	

Table 7-B-1 Continued

LOCATION	DATE	DEPTH (FT)	WATER VELOCITY (FT/S)	SUBSTRATE PRIMARY	SUBSTRATE SECONDARY	WATER TEMPERATURE (C) INTRAGRAVEL	WATER TEMPERATURE (C) SURFACE	REDD NO.	UPWELLING	DISTANCE (FT) TO UPWELLING
SLOUGH 20	830819	.60	1.00	RUBBLE	LARGE GRAVEL	5.8	9.8	1	PRESENT	10
SLOUGH 20	830819	.70	.90	RUBBLE	SMALL GRAVEL	5.5	10.1	2	PRESENT	15
SLOUGH 20	830819	.70	1.10	LARGE GRAVEL	SMALL GRAVEL	6.1	9.2	3	UNKNOWN	
SLOUGH 20	830819	.60	1.10	LARGE GRAVEL	SMALL GRAVEL	5.8	9.2	4	UNKNOWN	
SLOUGH 20	830819	.70	1.00	LARGE GRAVEL	SMALL GRAVEL	6.4	9.2	5	UNKNOWN	
SLOUGH 20	830819	.70	1.00	SMALL GRAVEL	LARGE GRAVEL	6.0	9.2	6	UNKNOWN	
SLOUGH 20	830819	.90	1.05	LARGE GRAVEL	SMALL GRAVEL	7.1	9.2	7	UNKNOWN	
SLOUGH 20	830819	.50	1.60	LARGE GRAVEL	SMALL GRAVEL	8.1	9.6	8	UNKNOWN	
SLOUGH 20	830904	.70	.50	RUBBLE	LARGE GRAVEL	4.7	6.8	9	PRESENT	20
SLOUGH 20	830904	.90	.20	RUBBLE	LARGE GRAVEL	6.5	6.6	10	UNKNOWN	
SLOUGH 20	830904	1.10	.50	LARGE GRAVEL	SMALL GRAVEL	6.9	6.5	11	UNKNOWN	
SLOUGH 21 (SLOUGH ONLY)	830831	.40	.50	LARGE GRAVEL	SMALL GRAVEL	4.8	5.8	31	UNKNOWN	
SLOUGH 21 (SLOUGH ONLY)	830831	.40	.10	LARGE GRAVEL	SMALL GRAVEL	4.0	5.9	32	UNKNOWN	
SLOUGH 21 (SLOUGH ONLY)	830831	.40	0.00	RUBBLE	SMALL GRAVEL	4.0	5.7	33	UNKNOWN	
SLOUGH 21 (SLOUGH ONLY)	830831	.50	.65	COBBLE	BOULDER	4.3	6.1	34	UNKNOWN	
SLOUGH 21 (SLOUGH ONLY)	830831	.60	.25	RUBBLE	LARGE GRAVEL	5.8	6.1	35	UNKNOWN	
SLOUGH 21 (SLOUGH ONLY)	830831	.70	.15	LARGE GRAVEL	RUBBLE	5.0	6.0	36	UNKNOWN	
SLOUGH 21 (SLOUGH ONLY)	830831	.60	.40	RUBBLE	SMALL GRAVEL	4.1	6.0	37	UNKNOWN	
SLOUGH 21 (SLOUGH ONLY)	830831	.35	.25	COBBLE	LARGE GRAVEL	4.5	6.3	38	UNKNOWN	
SLOUGH 21 (SLOUGH ONLY)	830831	.80	.05	RUBBLE	LARGE GRAVEL	4.3	6.3	39	UNKNOWN	
SLOUGH 21 (SLOUGH ONLY)	830831	.95	.08	RUBBLE	LARGE GRAVEL	4.0	6.3	40	UNKNOWN	
SLOUGH 21 (SLOUGH ONLY)	830831	.65	.10	COBBLE	LARGE GRAVEL	4.1	6.0	41	UNKNOWN	
SLOUGH 21 (SLOUGH ONLY)	830831	.65	.08	RUBBLE	LARGE GRAVEL	4.1	5.9	42	UNKNOWN	
SLOUGH 21 (SLOUGH ONLY)	830831	1.00	.03	RUBBLE	LARGE GRAVEL	4.0	6.1	43	UNKNOWN	

Table 7-B-1 Continued

LOCATION	DATE	DEPTH (FT)	WATER VELOCITY (FT/S)	SUBSTRATE PRIMARY	SUBSTRATE SECONDARY	WATER TEMPERATURE (C) INTRAGRAVEL	WATER TEMPERATURE (C) SURFACE	REDD NO.	UPWELLING	DISTANCE (FT) TO UPWELLING
SLOUGH 21 (SLOUGH ONLY)	830831	.50	.10	LARGE GRAVEL	RUBBLE	4.1	6.2	44	UNKNOWN	
SLOUGH 21 (SLOUGH ONLY)	830831	.60	.50	RUBBLE	LARGE GRAVEL	4.2	6.1	45	PRESENT	
SLOUGH 21 (SLOUGH ONLY)	830831	.50	.30	LARGE GRAVEL	SMALL GRAVEL	4.3	6.2	46	UNKNOWN	
SLOUGH 21 (SLOUGH ONLY)	830831	.80	.30	BOULDER	SAND	4.2	6.2	47	UNKNOWN	
SLOUGH 21 (SLOUGH ONLY)	830831	.65	.35	SMALL GRAVEL	RUBBLE	4.1	6.0	48	UNKNOWN	
SLOUGH 21 (SLOUGH ONLY)	830831	.65	.35	LARGE GRAVEL	BOULDER	4.3	6.1	49	UNKNOWN	
SLOUGH 21 MODELING SITE	830819	1.20	.08	RUBBLE	LARGE GRAVEL	3.9	8.2	1	PRESENT	6
SLOUGH 21 MODELING SITE	830819	1.90	.05	COBBLE	RUBBLE	4.3	8.9	2	UNKNOWN	
SLOUGH 21 MODELING SITE	830819	.90	.09	COBBLE	RUBBLE	4.8	7.5	3	PRESENT	15
SLOUGH 21 MODELING SITE	830819	1.20	.09	LARGE GRAVEL	RUBBLE	3.7	7.4	4	PRESENT	4
SLOUGH 21 MODELING SITE	830819	1.20	.20	RUBBLE	LARGE GRAVEL	3.8	5.7	5	PRESENT	5
SLOUGH 21 MODELING SITE	830819	.50	.10	COBBLE	RUBBLE	3.6	5.7	6	PRESENT	3
SLOUGH 21 MODELING SITE	830819	1.60	.12	COBBLE	RUBBLE	4.2	8.7	7	UNKNOWN	
SLOUGH 21 MODELING SITE	830819	1.20	.32	COBBLE	RUBBLE	3.8	9.1	8	UNKNOWN	
SLOUGH 21 MODELING SITE	830819	1.20	.25	LARGE GRAVEL	RUBBLE	3.8	9.5	9	UNKNOWN	
SLOUGH 21 MODELING SITE	830819	.80	.50	RUBBLE	LARGE GRAVEL	4.4	9.5	10	UNKNOWN	
SLOUGH 21 MODELING SITE	830819	.80	.42	RUBBLE	LARGE GRAVEL	4.7	9.7	11	UNKNOWN	
SLOUGH 21 MODELING SITE	830819	1.20	.40	RUBBLE	LARGE GRAVEL	5.3	9.7	12	UNKNOWN	
SLOUGH 21 MODELING SITE	830819	1.10	.40	RUBBLE	LARGE GRAVEL	4.0	9.1	13	UNKNOWN	
SLOUGH 21 MODELING SITE	830819	.80	.40	RUBBLE	LARGE GRAVEL	4.5	9.0	14	UNKNOWN	
SLOUGH 21 MODELING SITE	830819	1.52	.10	LARGE GRAVEL	RUBBLE	4.4	8.9	15	UNKNOWN	
SLOUGH 21 MODELING SITE	830819	1.00	.10	RUBBLE	LARGE GRAVEL	4.4	10.5	16	PRESENT	3
SLOUGH 21 MODELING SITE	830819	2.30	.15	COBBLE	RUBBLE	3.9	9.0	17	PRESENT	18
SLOUGH 21 MODELING SITE	830819	.92	.20	RUBBLE	LARGE GRAVEL	4.6	8.6	18	UNKNOWN	
SLOUGH 21 MODELING SITE	830819	.90	.12	RUBBLE	COBBLE	4.1	8.7	19	UNKNOWN	

Table 7-B-1 Continued

LOCATION	DATE	DEPTH (FT)	WATER VELO-CITY (FT/S)	SUBSTRATE PRIMARY	SUBSTRATE SECONDARY	WATER TEMPERATURE (C) INTRAGRAVEL	WATER TEMPERATURE (C) SURFACE	REDD NO.	UPWELLING	DISTANCE (FT) TO UPWELLING
SLOUGH 21 MODELING SITE	830819	.75	.25	LARGE GRAVEL	RUBBLE	4.6	9.5	20	UNKNOWN	
SLOUGH 21 MODELING SITE	830819	1.12	.32	LARGE GRAVEL	RUBBLE	4.3	9.0	21	UNKNOWN	
SLOUGH 21 MODELING SITE	830819	1.15	.22	LARGE GRAVEL	RUBBLE	4.7	8.8	22	UNKNOWN	
SLOUGH 21 MODELING SITE	830819	2.40	.09	SMALL GRAVEL	RUBBLE	5.5	11.0	23	UNKNOWN	
SLOUGH 21 MODELING SITE	830819	1.70	.09	SMALL GRAVEL	RUBBLE	4.5	10.0	24	UNKNOWN	
SLOUGH 21 MODELING SITE	830819	1.40	0.00	SMALL GRAVEL	LARGE GRAVEL	4.7	10.6	25	UNKNOWN	
SLOUGH 21 MODELING SITE	830819	1.19	.10	SMALL GRAVEL	LARGE GRAVEL	5.3	10.2	26	UNKNOWN	
SLOUGH 21 MODELING SITE	830819	1.73	.10	LARGE GRAVEL	RUBBLE	5.6	11.0	27	UNKNOWN	
SLOUGH 21 MODELING SITE	830819	1.19	.09	RUBBLE	SMALL GRAVEL	4.3	10.9	28	UNKNOWN	
SLOUGH 21 MODELING SITE	830819	.60	.20	LARGE GRAVEL	RUBBLE	5.4	10.4	29	UNKNOWN	
SLOUGH 21 MODELING SITE	830819	1.10	.20	RUBBLE	LARGE GRAVEL	4.1	9.2	30	PRESENT	15
SLOUGH 21 SIDE CHANNEL	830824	1.10	4.30	RUBBLE	COBBLE	6.7	9.2	1	PRESENT	
SLOUGH 21 SIDE CHANNEL	830824	1.10	2.60	COBBLE	RUBBLE	7.1	9.1	2	PRESENT	
SLOUGH 22	830819	.50	.65	LARGE GRAVEL	SMALL GRAVEL	5.8	7.4	1	UNKNOWN	
SLOUGH 22	830819	.60	.60	LARGE GRAVEL	RUBBLE	6.2	7.5	2	UNKNOWN	
SLOUGH 22	830819	.80	.55	RUBBLE	LARGE GRAVEL	6.1	7.0	3	UNKNOWN	
SLOUGH 22	830819	1.00	.55	RUBBLE	COBBLE	5.2	6.9	4	UNKNOWN	
SLOUGH 22	830819	1.20	.50	RUBBLE	COBBLE	5.9	7.0	5	UNKNOWN	
SLOUGH 22	830819	1.00	.55	LARGE GRAVEL	RUBBLE	5.2	7.1	6	UNKNOWN	
SLOUGH 22	830819	1.00	.55	RUBBLE	COBBLE	5.1	8.6	7	UNKNOWN	
SLOUGH 22	830819	1.20	.55	LARGE GRAVEL	COBBLE	5.8	8.6	8	UNKNOWN	
SLOUGH 22	830819	1.10	.55	RUBBLE	LARGE GRAVEL	6.1	8.9	9	UNKNOWN	
SLOUGH 22	830819	1.70	.55	COBBLE	BOULDER	5.6	9.2	10	UNKNOWN	
SLOUGH 22	830819	1.90	.55	COBBLE	RUBBLE	5.6	9.2	11	UNKNOWN	

Table 7-B-1 Continued

LOCATION	DATE	DEPTH (FT)	WATER VELOCITY (FT/S)	SUBSTRATE		WATER TEMPERATURE (C)		REDD NO.	UPWELLING	DISTANCE (FT) TO UPWELLING
				PRIMARY	SECONDARY	INTRAGRAVEL	SURFACE			
SLOUGH 22	830819	1.70	.55	COBBLE	RUBBLE	5.3	9.4	12	UNKNOWN	

Table 7-B-2 Habitat data collected at sockeye salmon redds.

LOCATION	DATE	DEPTH (FT)	WATER VELOCITY (FT/S)	SUBSTRATE PRIMARY	SUBSTRATE SECONDARY	WATER TEMPERATURE (C) INTRAGRAVEL	WATER TEMPERATURE (C) SURFACE	REDD NO.	UPWELLING	DISTANCE (FT) TO UPWELLING
SLOUGH 8A W. FORK B/L TR. #1	830909	.60		RUBBLE	COBBLE	5.9	10.4	1	UNKNOWN	
SLOUGH 8A W. FORK B/L TR. #1	830909	.70		RUBBLE	COBBLE	5.7	10.5	2	UNKNOWN	
SLOUGH 8A W. FORK B/L TR. #1	830909	.75		LARGE GRAVEL	COBBLE	4.7	7.2	3	UNKNOWN	
SLOUGH 8A W. FORK B/L TR. #1	830909	.90		LARGE GRAVEL	RUBBLE	6.6	9.3	4	UNKNOWN	
SLOUGH 8A W. FORK B/L TR. #1	830909	.70		LARGE GRAVEL	RUBBLE	5.0	9.3	5	UNKNOWN	
SLOUGH 8A W. FORK B/L TR. #1	830909	.60		RUBBLE	COBBLE	6.5	9.8	6	UNKNOWN	
SLOUGH 8A W. FORK B/L TR. #1	830909	.60		LARGE GRAVEL	RUBBLE	5.1	9.8	7	UNKNOWN	
SLOUGH 8A W. FORK B/L TR. #1	830909	.60		RUBBLE	COBBLE	4.4	9.5	8	UNKNOWN	
SLOUGH 8A W. FORK B/L TR. #1	830909	.40		RUBBLE	BOULDER	5.0	8.8	9	UNKNOWN	
SLOUGH 8A W. FORK B/L TR. #1	830909	.90		SMALL GRAVEL	LARGE GRAVEL	5.7	8.0	10	UNKNOWN	
SLOUGH 8A W. FORK B/L TR. #1	830909	1.00		LARGE GRAVEL	RUBBLE	6.1	7.9	11	UNKNOWN	
SLOUGH 8A W. FORK B/L TR. #1	830909	1.50		RUBBLE	COBBLE	6.5	8.9	12	UNKNOWN	
SLOUGH 8A W. FORK B/L TR. #1	830909	1.00		LARGE GRAVEL	RUBBLE	5.1	8.9	13	UNKNOWN	
SLOUGH 8A W. FORK B/L TR. #1	830909	1.00		LARGE GRAVEL	RUBBLE	5.3	8.7	14	UNKNOWN	
SLOUGH 8A W. FORK B/L TR. #1	830909	1.10		RUBBLE	COBBLE	6.4	9.0	15	UNKNOWN	
SLOUGH 8A W. FORK B/L TR. #1	830909	1.90		LARGE GRAVEL	COBBLE	5.1	9.0	16	UNKNOWN	
SLOUGH 11	830910	1.68	0.00	RUBBLE	COBBLE			1	UNKNOWN	
SLOUGH 11	830910	1.10	0.00	SAND	LARGE GRAVEL			2	PRESENT	15
SLOUGH 11	830910	.92	0.00	RUBBLE	COBBLE			3	UNKNOWN	
SLOUGH 11	830910	.92	.20	RUBBLE	SAND			4	UNKNOWN	
SLOUGH 11	830910	.62	.70	LARGE GRAVEL	SMALL GRAVEL			5	UNKNOWN	
SLOUGH 11	830911	2.00	0.00	RUBBLE	COBBLE			6	UNKNOWN	
SLOUGH 11	830911	.60	0.00	LARGE GRAVEL	SAND			7	UNKNOWN	
SLOUGH 11	830911	.50	0.00	RUBBLE	LARGE GRAVEL			8	UNKNOWN	

Table 7-B-2 Continued

LOCATION	DATE	DEPTH (FT)	WATER VELO-CITY (FT/S)	SUBSTRATE PRIMARY	SUBSTRATE SECONDARY	WATER TEMPERATURE (C) INTRAGRAVEL	WATER TEMPERATURE (C) SURFACE	REDD NO.	UPWELLING	DISTANCE (FT) TO UPWELLING
SLOUGH 11	830911	1.20	.10	RUBBLE	LARGE GRAVEL			9	PRESENT	1
SLOUGH 11	830911	.80	.05	LARGE GRAVEL	RUBBLE			10	UNKNOWN	
SLOUGH 11	830911	.60	0.00	RUBBLE	COBBLE			11	UNKNOWN	
SLOUGH 11	830911	1.30	0.00	LARGE GRAVEL	RUBBLE			12	PRESENT	
SLOUGH 11	830911	1.60	0.00	RUBBLE	LARGE GRAVEL			13	PRESENT	
SLOUGH 11	830911	1.30	0.00	LARGE GRAVEL	SAND			14	PRESENT	
SLOUGH 11	830911	1.00	0.00	SMALL GRAVEL	SAND			15	UNKNOWN	
SLOUGH 11	830911	.70	0.00	LARGE GRAVEL	RUBBLE			16	UNKNOWN	
SLOUGH 11	830911	.90	0.00	SMALL GRAVEL	LARGE GRAVEL			17	UNKNOWN	
SLOUGH 11	830911	.60	0.00	SMALL GRAVEL	RUBBLE			18	UNKNOWN	
SLOUGH 17	830901	2.30	0.00	LARGE GRAVEL	SMALL GRAVEL	4.0	4.9	1	UNKNOWN	
SLOUGH 17	830901	2.30	0.00	LARGE GRAVEL	SMALL GRAVEL	4.5	5.0	2	UNKNOWN	
SLOUGH 21 (SLOUGH ONLY)	830831	.40	.20	RUBBLE	LARGE GRAVEL	5.0	5.6	2	UNKNOWN	
SLOUGH 21 (SLOUGH ONLY)	830831	.40	.90	COBBLE	LARGE GRAVEL	4.6	6.3	3	UNKNOWN	
SLOUGH 21 (SLOUGH ONLY)	830831	.30	.01	RUBBLE	LARGE GRAVEL	4.3	7.0	4	PRESENT	
SLOUGH 21 (SLOUGH ONLY)	830831	.50	.10	LARGE GRAVEL	SMALL GRAVEL	4.7	6.6	5	UNKNOWN	
SLOUGH 21 (SLOUGH ONLY)	830831	.25	.30	LARGE GRAVEL	SMALL GRAVEL	4.3	6.1	6	UNKNOWN	
SLOUGH 21 (SLOUGH ONLY)	830831	.45	.20	BOULDER	LARGE GRAVEL	4.0	6.4	7	UNKNOWN	
SLOUGH 21 (SLOUGH ONLY)	830831	.50	0.00	BOULDER	SMALL GRAVEL	4.1	5.1	8	PRESENT	
SLOUGH 21 (SLOUGH ONLY)	830831	.80	.05	COBBLE	LARGE GRAVEL	4.7	6.2	9	UNKNOWN	
SLOUGH 21 (SLOUGH ONLY)	830831	.90	.15	RUBBLE	LARGE GRAVEL	4.6	6.1	10	UNKNOWN	
SLOUGH 21 (SLOUGH ONLY)	830831	.40	.40	RUBBLE	LARGE GRAVEL	4.4	6.1	11	UNKNOWN	
SLOUGH 21 (SLOUGH ONLY)	830831	.70	.15	BOULDER	LARGE GRAVEL	4.1	6.1	12	UNKNOWN	
SLOUGH 21 (SLOUGH ONLY)	830831	.70	.10	BOULDER	LARGE GRAVEL	4.2	6.2	13	UNKNOWN	

Table 7-8-2 Continued

LOCATION	DATE	DEPTH (FT)	WATER VELOCITY (FT/S)	SUBSTRATE PRIMARY	SUBSTRATE SECONDARY	WATER TEMPERATURE (C) INTRAGRAVEL	WATER TEMPERATURE (C) SURFACE	REDD NO.	UPWELLING	DISTANCE (FT) TO UPWELLING
SLOUGH 21 (SLOUGH ONLY)	830831	.50	.15	BOULDER	SMALL GRAVEL	4.1	6.0	14	PRESENT	
SLOUGH 21 (SLOUGH ONLY)	830831	.40	.15	RUBBLE	LARGE GRAVEL	4.5	6.1	15	UNKNOWN	
SLOUGH 21 (SLOUGH ONLY)	830831	.40	.20	COBBLE	LARGE GRAVEL	4.3	6.0	16	UNKNOWN	
SLOUGH 21 (SLOUGH ONLY)	830831	.50	.25	COBBLE	SMALL GRAVEL	4.3	6.2	17	UNKNOWN	
SLOUGH 21 (SLOUGH ONLY)	830831	.40	.25	BOULDER	LARGE GRAVEL	4.1	6.3	18	UNKNOWN	
SLOUGH 21 (SLOUGH ONLY)	830831	.50	.45	COBBLE	LARGE GRAVEL	4.1	6.4	19	PRESENT	
SLOUGH 21 (SLOUGH ONLY)	830831	.50	.45	LARGE GRAVEL	SMALL GRAVEL	4.6	6.1	20	UNKNOWN	
SLOUGH 21 MODELING SITE	830819	1.30	.15	RUBBLE	COBBLE	4.0	8.7	1	UNKNOWN	

APPENDIX 7C

Summary of Variance Statistics And Tests For Various Groupings Of Chum And Sockeye Salmon Utilization Depth Histograms

Table 7-C-1 Summary of variance statistics and tests for various groupings for chum salmon utilization depth histograms.

HISTOGRAM LABEL	INCREMENT SIZE	INCREMENT START	VARIANCE	df
A	0.1	0.0	106.9729	28
B	0.2	0.0	405.8857	14
C	0.2	0.1	474.7967	13
D	0.3	0.0	892.9000	9
E	0.3	0.1	916.0111	9
F	0.3	0.2	828.8182	10

LEVENE'S TEST

F STATISTIC	df	PROB
6.030000	5,83	0.0001

PAIRWISE COMPARISONS

PAIR	df	F VALUE	PROB
A,B	14,28	3.794285	0.0013
A,C	13,28	4.438476	0.0005
A,D	9,28	8.346974	0.0000
A,E	9,28	8.563020	0.0000
A,F	10,28	7.747927	0.0000
B,C	13,14	1.169779	0.3900
B,D	9,14	2.199880	0.0900
B,E	9,14	2.256820	0.0830
B,F	10,14	2.041999	0.1100
C,D	9,13	1.880594	0.1500
C,E	9,13	1.929270	0.1400
C,F	10,13	1.745628	0.1700
D,E	9,9	1.025883	0.4900
D,F	9,10	1.077317	0.4500
E,F	9,10	1.105201	0.4400

Table 7-C-2 Summary of variance statistics and tests for various groupings for chum salmon utilization velocity histograms.

HISTOGRAM LABEL	INCREMENT SIZE	INCREMENT START	VARIANCE	df
A	0.1	0.0	330.5182	44
B	0.1	0.1	605.9720	43
C	0.2	0.0	1114.7900	21
D	0.2	0.1	1289.5519	21
E	0.3	0.0	2004.1714	14
F	0.3	0.1	1949.3625	15
G	0.3	0.2	2948.0286	14

LEVENE'S TEST

F STATISTIC	df	PROB
3.090000	6,172	0.0068

PAIRWISE COMPARISONS

PAIR	df	F VALUE	PROB
A,B	43,44	1.833400	0.0240
A,C	21,44	3.372855	0.0003
A,D	21,44	3.901606	0.0001
A,E	14,44	6.063725	0.0000
A,F	15,44	5.897898	0.0000
A,G	14,44	8.919414	0.0000
B,C	21,43	1.839672	0.0450
B,D	21,43	2.128072	0.0180
B,E	14,43	3.307366	0.0013
B,F	15,43	3.216918	0.0014
B,G	14,43	4.864958	0.0000
C,D	21,21	1.156767	0.3700
C,E	14,21	1.797802	0.1100
C,F	15,21	1.748637	0.1200
C,G	14,21	2.644470	0.0220
D,E	14,21	1.554161	0.1800
D,F	15,21	1.511659	0.1900
D,G	14,21	2.286088	0.0150
E,F	14,15	1.028116	0.4800
E,G	14,14	1.470946	0.2400
F,G	14,15	1.512304	0.2200

Table 7-C-3 Summary of variance statistics and tests for various groupings for sockeye salmon utilization depth histograms.

HISTOGRAM LABEL	INCREMENT SIZE	INCREMENT START	VARIANCE	df
A	0.1	0.0	8.5385	26
B	0.2	0.0	29.1044	13
C	0.2	0.1	29.4121	13
D	0.3	0.0	63.8778	9
E	0.3	0.1	61.4333	9
F	0.3	0.2	53.7500	8

LEVENE'S TEST

F STATISTIC	df	PROB
5.470000	5,78	0.0002

PAIRWISE COMPARISONS

PAIR	df	F VALUE	PROB
A,B	13,26	3.408623	0.0038
A,C	13,26	3.444659	0.0035
A,D	9,26	7.481181	0.0000
A,E	9,26	7.194895	0.0000
A,F	8,26	6.295045	0.0002
B,C	13,13	1.010572	0.4900
B,D	9,13	2.194781	0.0960
B,E	9,13	2.110792	0.1100
B,F	8,13	1.846800	0.1600
C,D	9,13	2.171821	0.0990
C,E	9,13	2.088710	0.1100
C,F	8,13	1.827480	0.1600
D,E	9,9	1.039790	0.4800
D,F	9,8	1.188424	0.4100
E,F	9,8	1.142946	0.4300

Table 7-C-4 Summary of variance statistics and tests for various groupings for sockeye salmon utilization velocity histograms.

HISTOGRAM LABEL	INCREMENT SIZE	INCREMENT START	VARIANCE	df
A	Ø.1	Ø.Ø	5Ø.2778	9
B	Ø.1	Ø.1	136.1944	8
C	Ø.2	Ø.Ø	113.3667	5
D	Ø.2	Ø.1	223.ØØØØ	4
E	Ø.3	Ø.Ø	217.5833	3
F	Ø.3	Ø.1	25Ø.9167	3
G	Ø.3	Ø.2	452.9167	3

LEVENE'S TEST

F STATISTIC	df	PROB
1.25ØØØØ	6,35	Ø.3Ø35

Appendix 7-D

Weighted Usable Area

Projection Data

Appendix Table 7-D-1. Projections of gross area and WUA of chum ad sockeye salmon spawning habitat at Slough 8A.

Site Flow	Mainstem Discharge	Chum WUA	Chum Gross	Sockeye WUA	Sockeye Gross
5	--	2363	66216	3713	66218
10	--	3285	68778	4451	68778
15	--	3975	69863	4833	69863
20	--	4549	70912	5272	70912
25	--	5438	74188	6042	74188
30	--	5900	75248	6572	75248
35	--	6240	76142	7066	76142
40	--	6486	77064	7486	77064
45	--	6782	77938	7810	77938
50	--	7126	78754	8001	78754
60	33565	7749	80273	8279	80273
70	34700	8316	81711	8398	81711

-- site flow not controlled by mainstem discharge

Appendix Table 7-D-2. Projections of gross area and WUA of chum and sockeye salmon spawning habitat at Slough 9.

Site Flow	Mainstem Discharge	Chum WUA	Chum Gross	Sockeye WUA	Sockeye Gross
5	--	2367	64481	5011	64481
10	19209	4327	70947	6089	70947
15	20089	5594	74170	6356	74170
20	20737	6277	78065	6508	78065
25	21254	6702	80268	6625	80268
30	21687	6966	83525	6702	83525
35	22059	7135	85352	6727	85352
40	22387	7246	87186	6742	87186
45	22680	7365	88402	6762	88402
50	22945	7481	89986	6781	89986
60	23412	7707	92398	6829	92398
70	23814	7910	96544	6895	96544
80	24167	8107	98312	6946	98312
90	24484	8244	100229	6992	100229
100	24770	8378	101929	7014	101929
125	25388	8679	105280	6959	105280
150	25905	8925	108189	6823	108189
175	26349	9062	110150	6677	110150
200	26741	9030	111734	6571	111734
250	27408	8965	114982	6393	114982
300	27965	8591	118473	6081	118473
350	28446	8168	120769	5543	120769
400	28868	7643	122670	5172	122670
450	29246	7051	124344	4840	124344
500	29588	6429	128544	4487	128544
550	29901	5982	129888	4131	129888
600	30190	5603	131216	3848	131216

-- site flow not controlled by mainstem discharge

Appendix Table 7-D-3. Projections of gross area and WUA of chum and sockeye salmon spawning habitat at Slough 21.

Site Flow	Mainstem Discharge	Chum WUA	Chum Gross	Sockeye WUA	Sockeye Gross
5	--	5231	48143	6821	48143
10	24127	8453	55374	9179	55374
15	25007	10134	58055	10772	58055
20	25651	11175	58996	12235	58996
25	26162	12064	60280	13136	60280
30	26587	12885	60942	13544	60942
35	26951	13774	62571	13640	62571
40	27271	14609	65457	13726	65457
45	27556	15323	67779	13714	67779
50	27814	15840	70378	13611	70378
60	28266	16430	71364	13271	71364
70	28653	16433	73227	12869	73227
80	28993	16171	75853	12420	75853
90	29297	15851	77232	11906	77232
100	29571	15485	78424	11413	78424
200	31438	11512	86757	7382	86757
300	32585	8674	89749	5032	89749
400	33424	6636	92325	3533	92325

-- site flow not controlled by mainstem discharge

Appendix Table 7-D-4. Projections of gross area and WUA of chum and sockeye salmon spawning habitat at Upper Side Channel 11.

Site Flow	Mainstem Discharge	Chum WUA	Chum Gross	Sockeye WUA	Sockeye Gross
5	--	3287	55198	5198	55198
10	--	4769	64423	7328	64423
15	--	5899	70364	9142	70364
20	--	6968	74134	10516	74134
25	16035	8186	78120	11319	78120
30	16622	9208	81321	12130	81321
35	17135	10115	85287	12723	85287
40	17592	10818	86115	13066	86115
45	18005	11329	86902	13296	86902
50	18383	11794	87618	13389	87618
60	19056	12531	91321	13624	91321
70	19644	13087	94446	13876	94446
80	20168	13371	96357	14209	96357
90	20641	13511	99027	14429	99027
100	21075	13705	100245	14335	100245
110	21474	13933	103388	13950	103388
120	21846	14066	104770	13576	104770
130	22193	14204	106149	13151	106149
140	22520	14334	107433	12713	107433
150	22828	14414	108614	12247	108614
175	23533	13990	111336	11122	111336
200	24160	13354	113641	10234	113641
225	24728	12762	115707	9513	115707
250	25247	12142	117635	8902	1176035

-- site flow not controlled by mainstem discharge

Appendix Table 7-D-5. Projections of gross area and WUA of chum and sockeye salmon spawning habitat at Side Channel 21.

Site Flow	Mainstem Discharge	Chum WUA	Chum Gross	Sockeye WUA	Sockeye Gross
20	--	2057	106368	4288	106368
25	--	2288	109661	4523	109661
30	--	2510	113907	4699	113907
35	--	2764	115687	4766	115687
40	--	3001	118383	4797	118383
45	--	3231	120994	4755	120994
50	--	3434	126143	4694	126143
60	--	3744	128198	4454	128198
70	--	3856	131926	4217	131926
80	12208	3846	134739	3963	134739
90	12671	3773	137226	3712	137226
100	13100	3688	139614	3495	139614
110	13501	3719	144085	3413	144085
120	13878	3683	145555	3287	145555
125	14058	3656	146260	3225	146260
130	14233	3628	147685	3167	147685
150	14892	3491	151934	2949	151934
175	15636	3307	154915	2703	154915
200	16310	3094	157407	2481	157407
225	16929	2871	163901	2281	163901
250	17502	2662	167758	2097	167758
275	18037	2469	172210	1927	172210
300	18540	2290	179309	1771	179309
350	19466	1971	188071	1488	188071
400	20306	1762	195412	1243	195412
450	21076	1618	198723	1037	198723

-- site flow not controlled by mainstem discharge

Appendix Table 7-D-5. Continued.

Site Flow	Mainstem Discharge	Chum WUA	Chum Gross	Sockeye WUA	Sockeye Gross
700	24235	1172	213197	650	213197
550	22456	1412	209182	813	209182
600	23083	1325	211216	747	211216
800	25280	1191	216461	1046	216461
900	26240	1274	221721	1873	221721
1000	27128	1382	226073	2792	226073
1100	27958	1620	231116	3446	231116
1200	28738	2171	233790	3548	233790
1300	29474	2719	242382	3622	242382
1400	30173	3249	245228	3695	245228
1500	30838	3760	248203	3718	248203

Appendix Table 7-D-6. Projections of gross area and WUA of chum and sockeye salmon spawning habitat at Side Channel 10.

Site Flow	Mainstem Discharge	Chum WUA	Chum Gross	Sockeye WUA	Sockeye Gross
5	--	0	44519	0	44519
10	--	241	51396	587	51396
15	19904	668	57069	1911	57069
20	20585	1049	60975	3291	60975
25	21130	1377	63253	4654	63253
30	21586	1675	64655	5715	64655
35	21979	2034	66581	6485	66581
40	22325	2400	67914	7017	67914
50	22916	3273	70782	7305	70782
60	23410	4065	73925	7106	73925
70	23836	4727	78243	6624	78243
90	24547	5738	85177	5796	85177
100	24852	6068	88501	5588	88501

-- site flow not controlled by mainstem discharge

Appendix Table 7-D-7. Projections of gross area and WUA of chum and sockeye salmon spawning habitat at Lower Side Channel 11.

Site Flow	Mainstem Discharge	Chum WUA	Chum Gross	Sockeye WUA	Sockeye Gross
400	5901	9218	204918	9513	204918
500	6817	9590	224059	9302	224059
600	7671	9822	242666	8892	242666
700	8475	10064	260310	8551	260310
800	9239	10170	266575	8251	266575
900	9971	10149	271267	7979	271267
1000	10674	9931	275754	7743	275754
1200	12010	9458	292958	7217	292958
1400	13269	8986	296307	6759	296307
1600	14466	8509	299213	6318	299213
1800	15612	8061	301882	5903	301882
2000	16713	7686	304367	5558	304367

APPENDIX 7E

Flow Chart And Outline Of Salmon

Spawning Habitat Analysis

ALASKA DEPARTMENT OF FISH AND GAME / SU HYDRO
AQUATIC HABITAT AND INSTREAM FLOW (AH)
FY84 APPROACH
FOR EVALUATING SALMON SPAWNING HABITAT
UTILIZATION IN SLOUGHS AND SIDE CHANNELS

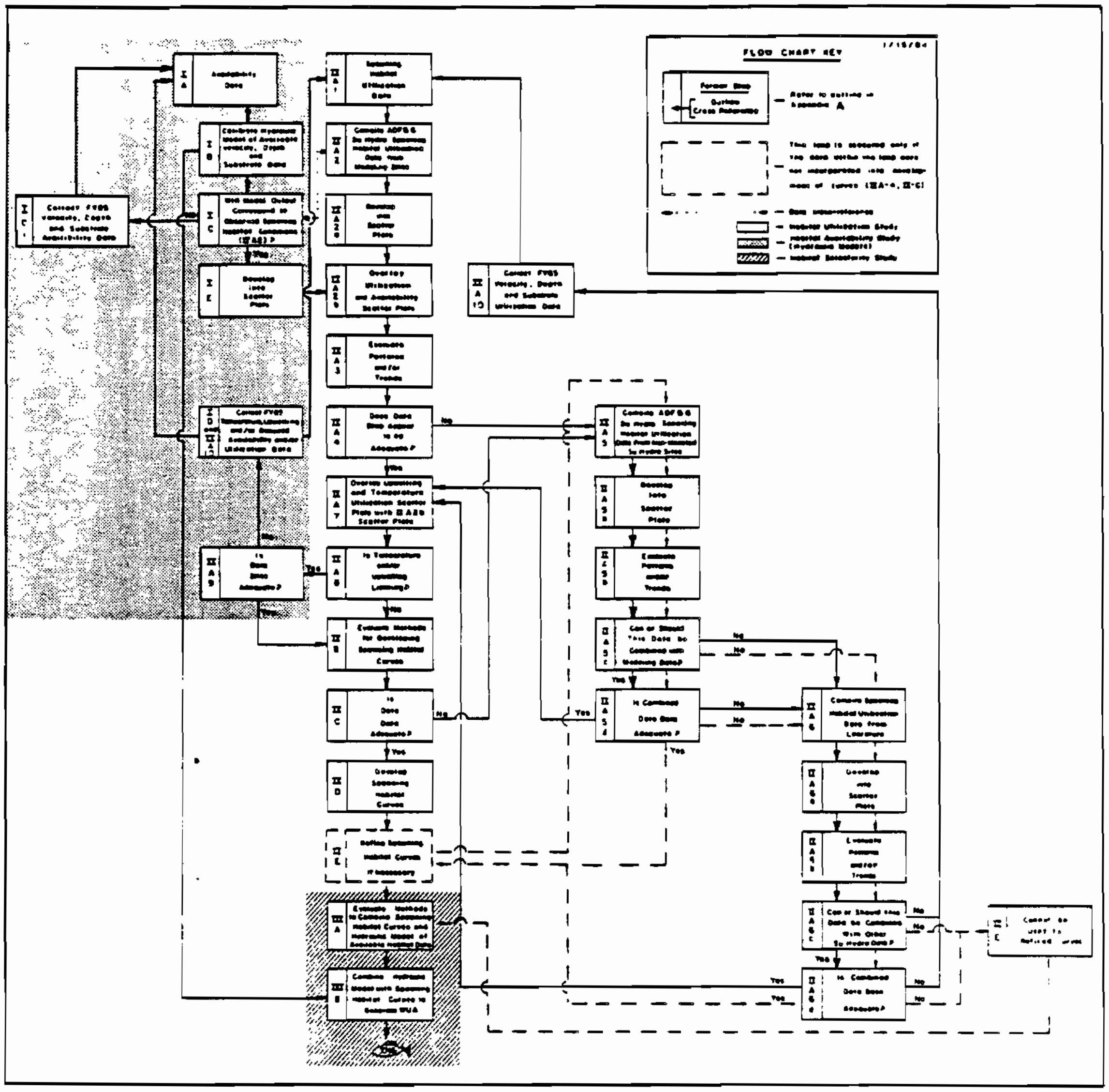

Figure 7-E-1 Flow diagram of salmon spawning habitat analysis.

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ALASKA DEPARTMENT OF FISH AND GAME/SU HYDRO

AQUATIC HABITAT AND INSTREAM FLOW (AH)

FY 84 APPROACH FOR

EVALUATING SALMON SPAWNING HABITAT UTILIZATION

IN SLOUGHS AND SIDE CHANNELS

I. Availability Model Assessment (Includes An Assessment Of Flow Related Velocity, Depth, And Substrate Characteristics.)[1]

A. Hydraulic Model Data Sites.

1) Slough Models (IFG-4)

a) Slough 8A

b) Slough 9

c) Slough 21

2) Side Channel Models (IFG-4)

a) Side Channel 10

b) Upper Side Channel 11

c) Side Channel 21

3) Side Channel Model (IFG-2)

a) Lower Side Channel 11

B. Calibration by EWT&A and ADF&G.

C. Evaluate Whether Model Output Corresponds To The Range Of Flows Which Occurred When Spawning Habitat Utilization Conditions Were Measured.

1) Determine slough flows which occurred during the periods when redd measurements were recorded at each modeling site (see II-A-2).

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1 See also IV-2

2) Determine if hydraulic model output for these flows can be generated in order to determine available depth, velocity, and substrate characteristics, or whether additional data must be collected.

D. Collect The Following FY85 Availability Data If Required:

1) velocity, depth, and substrate;

2) surface and intragravel water temperature; and,

3) upwelling presence or absence.

E. Develop Scatter Plots Of Available Habitat Which Illustrate Depth Versus Velocity With Substrate Indicated As Acceptable (+) Or Unacceptable (-).

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II. Spawning Habitat Utilization Assessment (Includes An Assessment Of Point Specific Velocity, Depth, Substrate, Temperature And Upwelling Characteristics At Redd Locations.)

A. Spawning Habitat Utilization Data Base Source Evaluation To Assess Which Spawning Habitat Utilization Data Sets Can Or Should Be Used And/Or Combined To Develop Adult Salmon Spawning Habitat Curves.

1) Sites and data sets are listed below. Number in parenthesis indicates the number of redd observations. An asterisk (*) indicates that a hydraulic model is available for the site.

Chum

1982 Field Data
- -Slough 9* (45)
- -Slough 8A* (37)
- -Slough 21* (34)
- -Slough 11 (15)

1983 Field Data
- -Slough 9* (31)
- -Slough 8A* (15)
- -Slough 21* (49)
- -Side Channel 21* (2)
- -Upper Side Channel 11* (2)
- -Slough 11 (15)
- -Other sloughs [sloughs 9A(24), 17(6), 20(11), 22(12)]
- -Mouth of 4th of July Creek (28)
- -Mouth of Indian River (3)

Sockeye

1982 Field Data
- -Slough 8A* (1)
- -Slough 11 (23)

1983 Field Data
- -Slough 8A* (16)
- -Slough 21* (20)
- -Slough 11 (22)
- -Slough 17 (2)

Chinook

1983 Field Data
- -Portage Creek (136)
- -Indian River (125)

Pink

1982 and 1983 Field Data
- -Insufficient Data (15)

Coho

1982 and 1983 Field Data
- -Insufficient Data (0)

Other

Literature Data
- -Bradley Lake
- -Terror Lake
- -Chakachamna
- -Willow Creek
- -Other sources if available

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2) Compile spawning habitat utilization data from ADF&G Su Hydro modeling sites (*) and reduce above data into a scatter plot format for evaluation and overlay on scatter plots of available habitat from section I-E above.

   a) Scatter plots of spawning habitat utilization data will be developed which illustrate:

      i) depths vs velocities with acceptable (+) or unacceptable substrate (-);

      ii) depths vs differences in surface and intragravel water temperature and;

      iii) depths vs velocities with upwelling presence (+) or absence (-).

   b) Spawning habitat utilization scatter plots from a-i above will be overlayed on scatter plots of available habitat from I-E above.

3) Evaluate trends shown by scatter plots.

4) Evaluate whether spawning habitat utilization data from modeling sites above (II-A-2) are sufficient to develop adequate curves; or, will it be necessary to combine these data with non-modeling site (II-A-5) and/or literature data (I-A-6)? If data are sufficient, continue to Step II-A-7 or if insufficient proceed to step II-A-5 following solid line processes only.

5) Compile ADF&G spawning habitat utilization data for non-modeled sites to evaluate whether these data can be combined with data from modeling sites for use in developing spawning habitat curves.

   a) Develop scatter plots of non-modeling sites data.

   b) Evaluate trends shown by scatter plots.

   c) Compare the above (II-A-5-a) spawning habitat utilization scatter plots to scatter plots of ADF&G Su Hydro modeling sites (II-A-2) to determine whether these data can be combined; and, if so, continue to step 5-d. If the data can not be combined, proceed to step II-A-6 to evaluate the use of literature data.

   d) Determine if the combined data bases are adequate and if they are, continue to step II-A-7. If they are insufficient, proceed to step II-A-6 to consider the use of literature data.

6) Compile spawning habitat utilization data from literature sources to evaluate whether these data can be combined with data from modeling sites for use in developing habitat curves.

a) Develop scatter plots of literature data.

b) Evaluate trends shown by scatter plots.

c) Compare the above (II-A-6-a) spawning habitat utilization scatter plots to scatter plots of ADF&G Su Hydro modeling sites (II-A-2) to determine whether these data can be combined and if so continue to step 6-d. If they cannot be combined, additional field data must be collected if FY85 (II-A-10).

d) Determine if the combined data bases are adequate and if they are, continue to step II-A-7. If they are insufficient, collect additional field data in FY85 (II-A-10).

7) Overlay utilization scatter plots of temperature and upwelling from II-A-2-a-ii and iii above and velocity, depth and substrate scatter plots of utilized and available spawning habitat from II-A-2-b (II-A-5-d and II-A-6-d data would also be included if these loops were required) above.

8) Evaluate trends shown by these scatter plots to determine if temperature and/or upwelling are limiting. If they are limiting, proceed to step II-A-9 and if not, continue to II-B.

9) Evaluate whether a portion or all of the:

a) temperature, upwelling, velocity, depth and substrate spawning habitat utilization data are adequate;

b) whether temperature and upwelling availability data are required; and

c) whether to continue to the combined step II-A-10 and I-D or to II-B.

10) Collect FY85 spawning habitat utilization data if required:

a) velocity, depth and substrate;

b) surface and intragravel water temperature; and

c) upwelling presence or absence.

B. Evaluate Whether the Following Approaches or a Combination of Them Can or Should Be Used to Develop Spawning Habitat Curves:

- Standard U.S. Fish and Wildlife Service IFG approach (Bovee and Cochnauer 1977);
- Baldrige and Amos (1981);
- Voos (1980);
- Prewitt (1982);
- ADF&G (1983) AH technique; and
- Other possible approaches or combinations of the above.

C. If data base appears adequate continue to step II-D; if data are inadequate, proceed to step II-A-5 following solid line process only. This only applies if II-A-5 and II-A-6 were not incorporated into development of curves at step II-A-4.

D. Develop Spawning Habitat Curves.

E. If data from II-A-5 and II-A-6 Were Not Incorporated Into Initial Development Of Curves Proceed to Step II-A-5 Following Dashed Line Processes Only To Determine If These Data Can Be Used To Refine Curves. If Previously Used Or If It Is Determined That These Data Should Not Be Used For This Purpose, Continue To Step III-A.

FLOW CHART ATTACHMENT

III. Habitat Model [Combination of Spawning Habitat Curves and Calibrated Hydraulic Models To Determine Weighted Usable Area (WUA)]

A. Evaluation of Linkage Approaches of Spawning Habitat Curves with Hydraulic Models.

1) WUA Calculation Technique Evaluation

a) IFG WUA calculations:

i) standard calculation with three matrices

ii) lowest limiting factor

iii) Geometric mean

b) Multi-variate calculation

2) Consider calculation of WUA using optimum, preferred, utilized, and available categories of ADF&G AH, 1983 analysis.

B. Use Habitat Model to Generate WUA.

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IV. Miscellaneous (These Items Are Not Included In Flow Chart.)

1) Assess whether spawning habitat utilization behavior criteria can be evaluated and combined with other spawning habitat utilization data, i.e., Fanning (F), Quivering (Q), Aggression (A) and Holding (H). This task has been assigned a low priority but may be useful for determining "outliers" in spawning habitat utilization data sets (II-A-3).

2) Availability data sets for temperature and upwelling are not available. Cost effective methods for collecting and analyzing these data are being evaluated in the event it is necessary to input these data into the model in the future.

3) The evaluation of tributary mouth hydraulic and spawning habitat availability and utilization data will be treated independently of this analysis.

4) Develop changes in hydraulic and habitat models to enable the RJ staff to incorporate juvenile habitat data for their analysis.

FLOW CHART ATTACHMENT

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