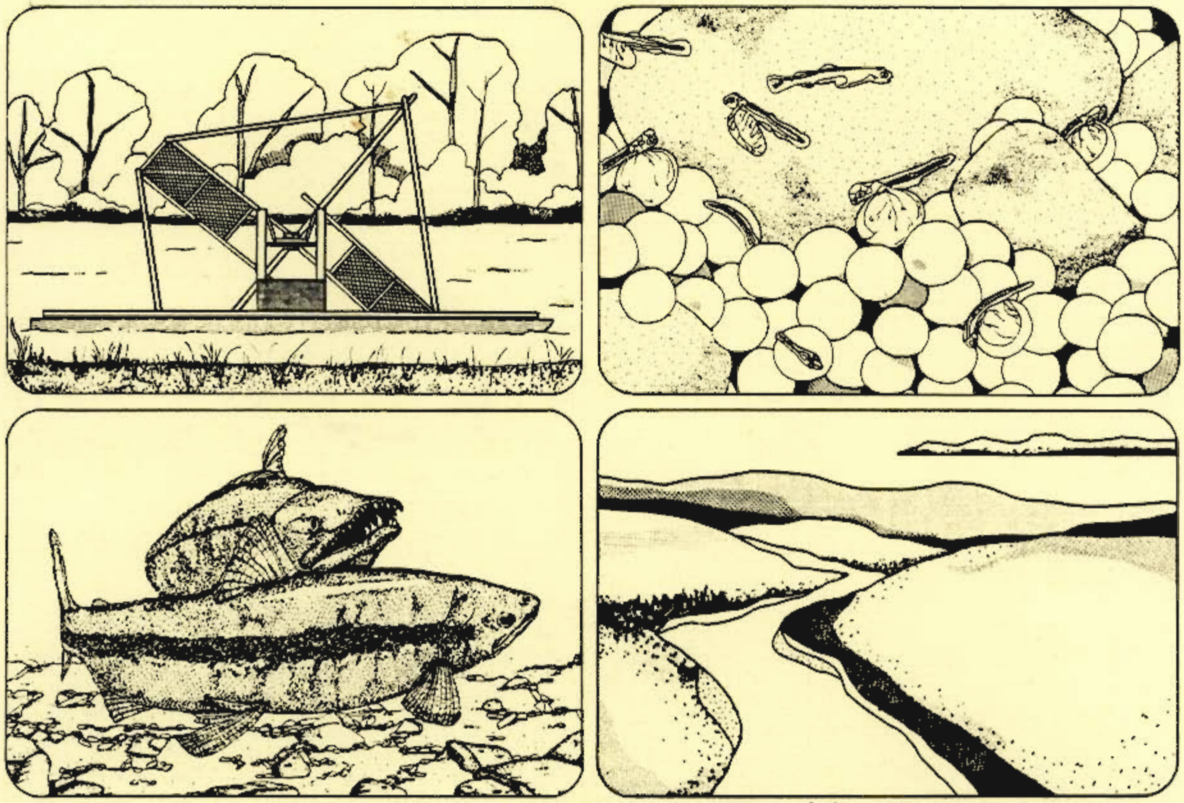
1784d

ARLIS
3 3755 000 44766 4



REPORT No 2
(RESIDENT AND JUVENILE
ANADROMOUS FISH - - -)

Merged With
A.R.L.I.S.
ANCHORAGE, ALASKA
Est. 1997

UNIVERSITY OF ALASKA
ARCTIC ENVIRONMENTAL INFORMATION
AND DATA CENTER
707 A STREET
ANCHORAGE, AK 99501

PART 7

MODELLING OF JUVENILE SALMON
AND RESIDENT FISH HABITAT

ADF&G/SU HYDRO
PROVISIONAL DATA
DATE MAY 0 8 1984

ALASKA DEPARTMENT OF FISH AND GAME
SUSITNA HYDRO AQUATIC STUDIES REPORT SERIES

TK
1425
.S8
A68
no.1784d
pt.7

TK
1425
.S8
A68
no.1784d
pt.7

DRAFT

MAY 14 1984

PART 7

MODELLING OF JUVENILE SALMON AND RESIDENT FISH HABITAT

DRAFT

PROVISIONAL DATA

UNIVERSITY OF ALASKA
ARCTIC ENVIRONMENTAL INFORMATION

ARLIS
Alaska Resources
Library & Information Services
Anchorage, Alaska

DRAFT

MAY 14 1984

MODELLING OF JUVENILE SALMON AND RESIDENT FISH HABITAT

Report Series No. 2, Part 7

by Stephen S. Hale, Paul Suchanek, and Dana C. Schmidt

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

DRAFT

ABSTRACT

Output from the Instream Flow Group hydraulic models of rearing habitat for juvenile salmon and resident species at seven sites in the Chulitna River confluence to Devil Canyon reach of the Susitna River leads to similar conclusions as those drawn from a habitat model developed by the Susitna Hydro Aquatic Studies group for six additional sites. Rearing habitat for chinook salmon at the study sites is maximized when the head of the site is slightly overtopped, thus providing turbid water for cover and moderate water velocities. The portions of this reach which are directly influenced by the mainstem provide only limited rearing habitat for coho and sockeye salmon during the open water season, but are likely to be of major importance for all overwintering species.

PROVISIONAL DATA

3 3755 000 44766 4

DRAFT

MODELLING OF JUVENILE SALMON AND RESIDENT FISH HABITAT

PROVISIONAL DATA

Table of Contents

7.0 LITERATURE CITED

8.0 APPENDICES

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDIX TABLES

1.0 INTRODUCTION

PROVISIONAL DATA

The effects of flow regulation on downstream fisheries have long been the subject of investigations whose goal was to predict the status of future fisheries after development of hydro power or other types of instream flow regulation. The incremental analysis approach has gained wide acceptance as the "state of the art" in prediction of the future of effects of hydro development on downstream fisheries. Bovee (1982) has presented the fundamentals of this approach, the method most often applied to these types of studies. We have used this approach for quantifying the response of habitat to discharge for the various life phases and species within the Susitna River reach most directly affected by the proposed development of two dams on this river. When the flow regime is to be altered from the natural range, hydraulic models have been a logical and commonly used method for this analysis (Estes et al. 1980; Wilson et al. 1981;Bovee 1982; ADF&G 1983a). The Instream Flow Group (IFG) models developed by the U. S. Fish and Wildlife Service have been used by the Susitna Hydro Aquatic Studies for two seasons to simulate changes in available spawning habitat of chum and sockeye salmon as a function of mainstem discharge.

Beginning in the open water season of 1983, we used these IFG hydraulic models and another habitat model developed by ourselves (RJHAB) to calculate the effects of mainstem discharge variations on rearing habitat for juveniles of four species of salmon and juveniles and adults of several resident fish species.

This paper presents the results of the IFG model habitat simulations for juvenile salmon and resident fishes, compares the IFG models with the RJHAB model, (which was presented in Part 4 of this report), and discusses in general the usefulness and implications of these habitat models in understanding and predicting the effects of discharge changes on rearing habitat.

2.0 METHODS

2.1 Study Locations

Seven IFG model sites and six RJHAB sites located on the Susitna River reach extending from the Chulitna River confluence to Devil Canyon were modelled (Figure 1). Criteria used in IFG model site selection are detailed in Estes and Vincent-Lang (1984). Sloughs 8A, 9, and 21 were selected in 1982 to quantify the response of salmon spawning habitat in sloughs to variations in mainstem discharge. These sloughs are representative of side sloughs in general and also contain critical spawning habitat. In 1983, the four IFG side channel study sites were selected as representative sites for study of responses of mainstem salmon spawning and rearing habitat to variations in mainstem discharge. The RJHAB sites were selected as representative or important juvenile salmon rearing sites. (Part 4 of this report).

Figure 2 shows the sites ordered by the mainstem discharge required to overtop the head of the sites. The two upland slough sites (Slough 5 and Slough 6A) are not included on this figure. It can be seen that, generally, sites which have heads overtopped more than 60% of the time have been named side channels; sites with less frequent overtopping have been called side sloughs. The mainstem discharge required to overtop the head of the sites is as follows:

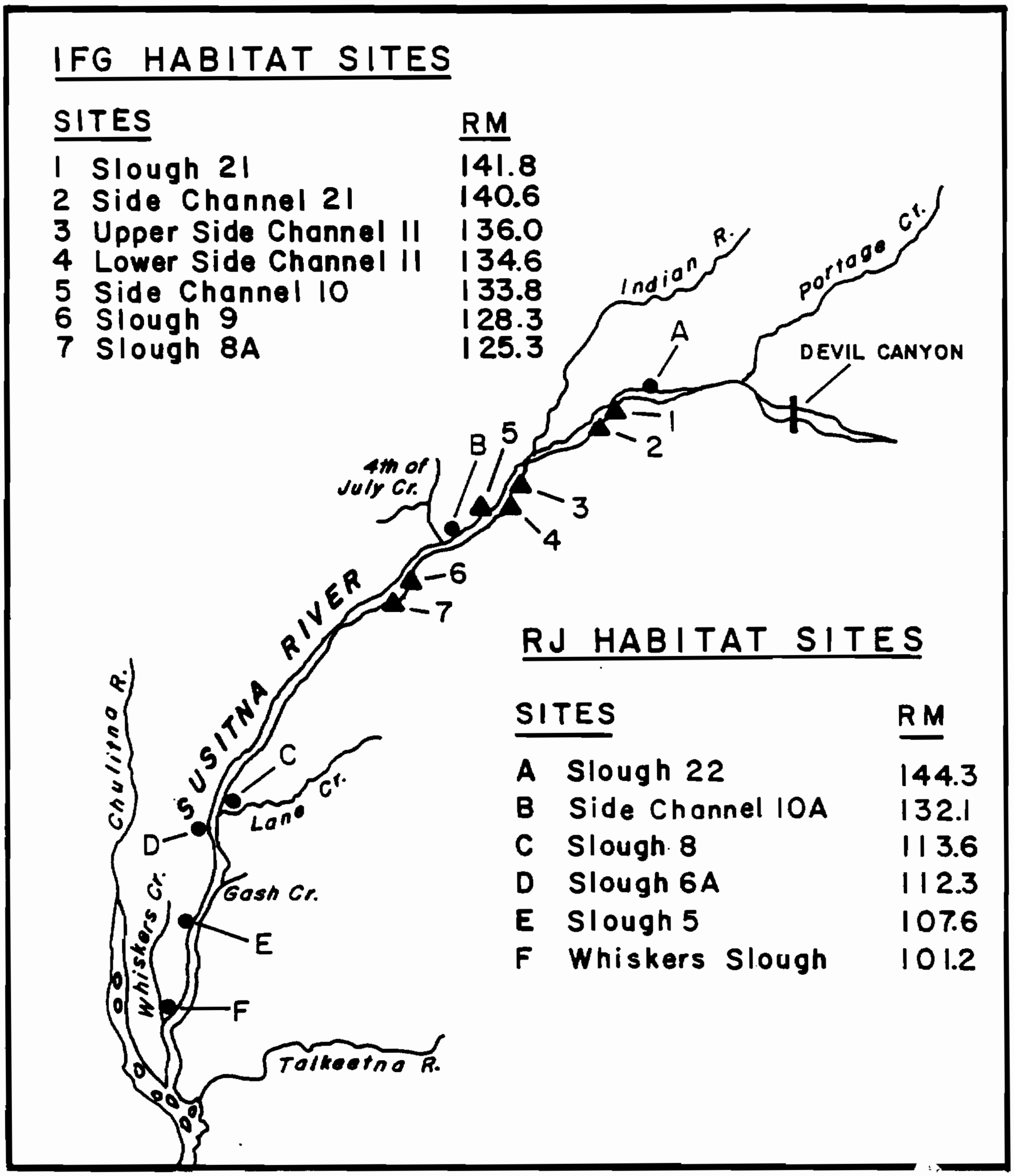


Figure 1. Location of IFG and RJHAB modelling sites.

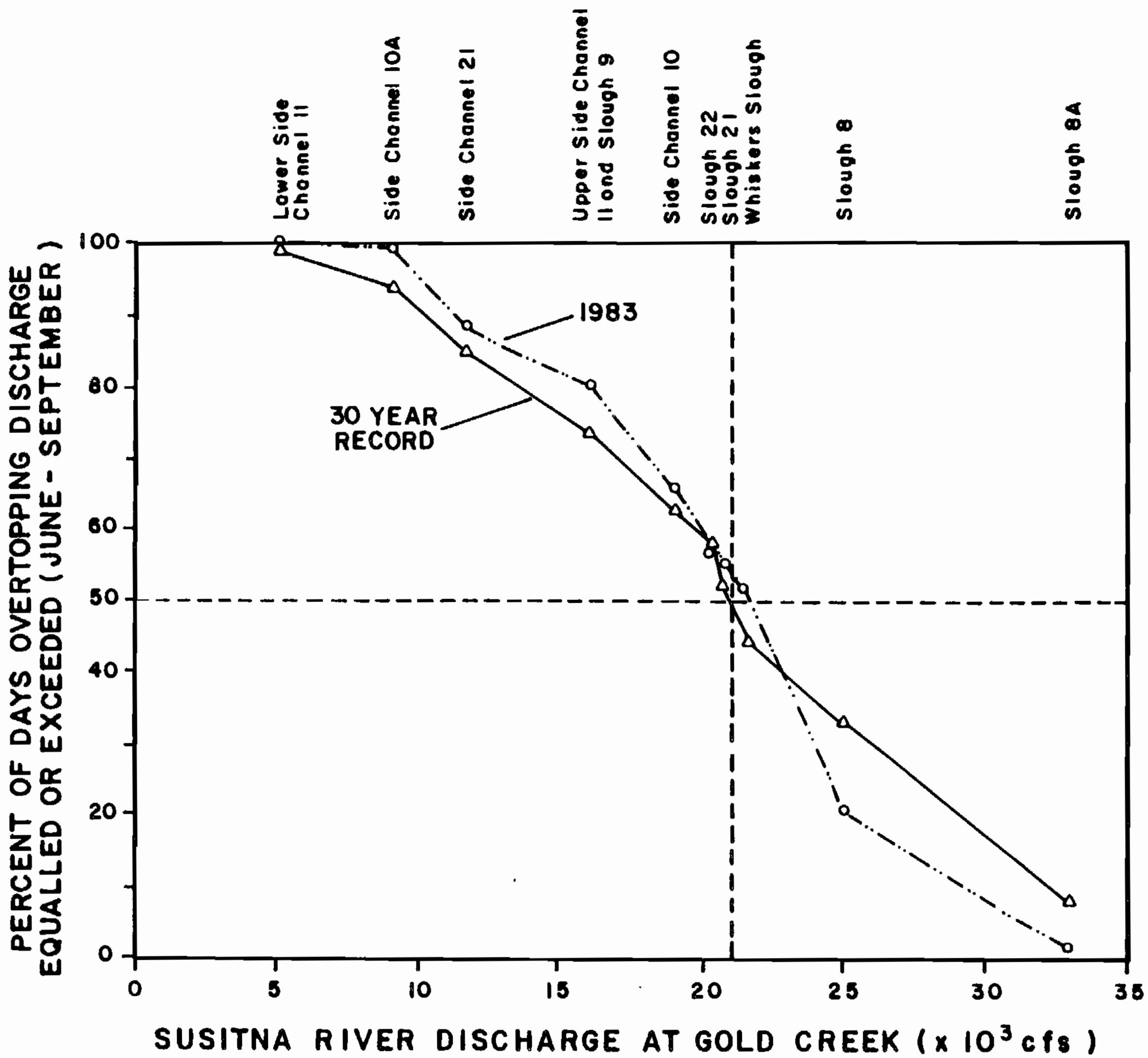


Figure 2. Percent of time that the heads of study sides were overtopped by mainstem discharge.
Sources: 30 year record – Bredthauer and Drage (1982);
1983 discharges – USGS provisional data.

Site	Model	Overtopping Discharge [a/]
Lower Side Channel 11	IFG-2	< 5,000
Side Channel 10A	RJHAB	9,000
Side Channel 21	IFG-4	11,600
Upper Side Channel 11	IFG-4	16,000
Slough 9	IFG-4	16,000
Side Channel 10	IFG-4	19,000
Slough 22	RJHAB	20,200
Slough 21	IFG-4	20,900
Whiskers Slough	RJHAB	21,600
Slough 8	RJHAB	25,000
Slough 8A	IFG-4	33,000
Slough 5	RJHAB	upland slough
Slough 6A	RJHAB	upland slough

[a/] Source: Estes and Vincent-Lang (1984)

2.2 Physical Habitat Modelling

The models used have been described in other reports (see below) and will only be summarized here. Basically, transects are established at a site and then measurements of depth, mean water column velocity, and cover are made across the transects. Also, the top width of the wetted surface at each transect is measured so that wetted area may be calculated. This is done on three or four different occasions over a range of flows and the information is then input to the models. Output from the models provides either simulated physical parameters and habitat values (IFG) or extrapolated habitat values (RJHAB) for any level of discharge over a wide range of discharge.

2.2.1 Instream Flow Group (IFG) Hydraulic Models

Two hydraulic models were used by the Aquatic Habitat section and Trihey and Associates during the 1983 open water season (Estes and Vincent-Lang 1984). The IFG-4 model simulates depth and mean water column velocity across horizontal transects at a site over a discharge range from 40% of the lowest calibration flow to 250% of the highest calibration flow (Bovee and Milhous 1978). The IFG-2 model is a water surface profile model that provides the same information as the IFG-4 model but which requires less field data. The IFG-4 model was used for all of the sites except for Lower Side Channel 11, where the IFG-2 model was used.

The models also allow the input of substrate data. However, cover data rather than substrate information were input because we had determined that cover was more important than substrate in influencing the distribution of juvenile salmon (see Part 3 of this report). Substrate was frequently the primary cover type in the cover coding. Consistently good cover data were not obtained at the IFG model sites because the sites were primarily intended to be used for simulating habitat for adult spawners. Consequently, cover for some of the transects had to be estimated in the office and may, therefore, lead to some error in the weighted usable area predictions. The cover values on these transects will be calibrated this spring and the output will be modified accordingly.

2.2.2 RJ Habitat Model (RJHAB)

The RJ Habitat Model, which modelled juvenile salmon habitat at six sites, was presented in Part 4 of this report. Transects were established at these sites but, rather than using detailed depth and mean column water velocity measurements across each transect, as do the IFG models, these models use the average depth and average mean water column velocity of 300 sq. ft. (6 ft. wide by 50 ft. long) cells which were established along the transect. Usually, there were three cells per transect, but sometimes only two when the channel became too narrow (less than 18 ft. in width). This model does not simulate hydraulic characteristics of the site as do the IFG models. It generates WUA estimates for shoreline and mid-channel portions of the site for those discharge levels when physical habitat attributes were measured. Estimates of WUA for other discharges are then extrapolated.

2.3 Suitability Criteria

The suitability criteria for juvenile salmon input into the models were developed in Part 3 of this report. Suitability indices for cover, velocity, and depth input into the IFG models are presented in Appendix Table 1. The IFG PHABSIM models linearly interpolate between the point values for depth and velocity input. The cover suitability indices were put into the IFG model in place of substrate and these indices reflect both amount and type of cover. Velocity criteria were taken directly from Part 3 and curves were fit to the midpoint of velocity value intervals with an envelope of the optimum suitability interval. Depth was not thought to be as important as cover and velocity in affecting distribution and suitability for depth was fixed at 1.00 (i.e., it had no effect on the results) except when depth was less than 0.14 ft. and then suitability was fixed at 0.00. This depth was thought to physically limit juvenile salmon distribution.

Depth and velocity criteria input into the RJHAB models were slightly different. Suitability indices were constant over an interval of 0.5 ft. for depth and 0.3 ft/sec for velocity. This grouping was made because the limited number of measurements was only an index to hydraulic conditions present and finer resolution was deemed unnecessary. Depth suitabilities input into the RJHAB models were also fit to data presented in Part 3 of this report.

Data presented in Part 6 of this report were used to generate suitability criteria for resident fish. Depth and velocity criteria used for juvenile round whitefish were taken directly from Part 6 and are presented in Appendix Table 2. Cover suitability was 1.00 for juvenile round whitefish unless the slough was not overtopped and then cover suitability was set to 0.00 as round whitefish do not often occur in clear side sloughs (Part 6 of this report). Preliminary adult Arctic grayling, longnose sucker, rainbow trout, and round whitefish suitability criteria were fit to data presented in Part 6 (Appendix Table 2). Cover type and velocity criteria were fit to the data using professional judgement. Depth suitability was set to 1.00 except when shallower than 0.5 ft. when the suitability was set to 0.00. We felt that this depth may limit adult resident fish distribution. Wesche (1976) reported that adults of three trout species preferred depths greater than 0.5 ft. Percent cover was not incorporated into the resident cover suitability indices. The data for resident fish are only preliminary estimates of suitability functions.

2.4 Weighted Usable Area Projections

For each cell in a transect of an IFG site, the habitat potential for a given life stage of a species is called the weighted usable area (WUA) and calculated (Bovee 1982) by:

$$WUA = C_{i,s} \times A_i$$

where: $C_{i,s}$ = the combined suitability index for cover, velocity, and depth of the cell (i) for the species and life stage (s)

A_i = the surface area of the cell

The WUA for the study site at a given discharge was calculated by totalling all the individual cell WUA's. The combined suitability index ($C_{i,s}$) was calculated by multiplying the suitability indices for cover, velocity, and depth of the cell together. WUA's at each study site were calculated at 10 to 40 incremental flows at each site over the recommended extrapolation range of the hydraulic model.

At RJHAB sites, WUA's were calculated for shoreline and mid-channel portions of the site each time the site was measured. Data were pooled over a number of cells for WUA calculations instead of calculating by cell as in the IFG PHABSIM models. WUA's calculated for the RJHAB sites are generated from habitat measurements which provide an index to conditions at the site. The IFG WUA is standardized to a 1000 ft reach while the RJHAB WUA is dependent on the size of the site.

The output from the IFG models consists of weighted usable area and total surface area predictions for incremental levels of discharge. RJHAB provides the same information at measured flows and then plots WUA as a function of discharge. All of the output from RJHAB was presented in Part 4 of this report.

We entered the output of the IFG models into a microcomputer worksheet program so we could perform additional manipulations of the data. First, plots were constructed of WUA as a function of mainstem discharge. Then, we matched predictions of WUA with each of the mean daily discharge levels observed from June 1 to September 30, 1983 by interpolating from the simulated discharge/WUA output so that we could obtain a time series of WUA at each of the sites during the open water season. This time series was then compared with the catch data at these sites and the outmigration timing data from the downstream migrant traps.

Not all possible site/species combinations are presented in this paper. With a few exceptions, the basic criterion used was that mean catch per cell for the species for the entire season at the site had to be greater than the mean catch per cell at all sites (Table 1). Hence, we are not predicting weighted usable area for a species at those sites where very

Table 1. Total catch and catch per unit effort of juvenile salmon at the IFG sites, open water season, 1983.

IFG Site	No. of Cells	Catch (catch/cell) Chinook 0+	Coho 0+	Chum	Sockeye 0+
Slough 21	86	91(1.1)*	1(0.0)	417(4.8)*	23(0.3)*
Side channel 21	23	38(1.6)*	0(0.0)	0(0.0)	0(0.0)
Upper side channel 11	21	101(4.8)*	0(0.0)	0(0.0)	0(0.0)
Lower side channel 11	21	39(1.9)*	0(0.0)	0(0.0)	0(0.0)
Side channel 10	62	279(4.5)*	0(0.0)	2(0.0)	0(0.0)
Slough 9	123	227(1.8)*	0(0.0)	74(0.6)*	30(0.2)*
Slough 8A	66	6(0.1)	26(0.4)	129(2.0)	24(0.4)
Sum of IFG sites	402	781	27	205	77
Mean of IFG sites		112(1.9)	4(0.1)	29(0.5)	11(0.2)
Mean of all sites sampled					
Backpack electrofishing		(3.4)	(2.3)	(1.3)	(0.9)
Beach seining		(3.4)	(0.3)	(0.0)	(0.5)

* = Site/species combination selected for presentation.

few individuals of the species were captured. There are some exceptions to this practice for resident species because the sampling methods used at the modelling sites were not effective at capturing adult resident fish. The species for which weighted usable area predictions are presented include juveniles of the four salmon species (chinook, coho, chum, and sockeye), juvenile and adult round whitefish, and adult rainbow trout, Arctic grayling, and longnose suckers.

To make comparisons among sites which would be independent of the size of the site, we divided the weighted usable areas at all levels of discharge at each IFG site by the total surface area of the site when the discharge was 23,000 cfs. The resulting habitat index is the same as the habitat index calculated for the RJHAB sites in Part 4 of this report.

2.5 Model Verification

Data on fisheries abundance and distribution were collected at the sites; however, time constraints prevented intensive sampling efforts. Combined suitability indices or weighting factors were calculated for each 6 ft X 50 ft cell sampled for fish and this index was then correlated with fish catch in the cell. If cells with large combined suitability indices are associated with higher densities of fish, then it can be assumed that WUA does reflect habitat potential.

Correlations or associations between catch and combined suitability indices at the RJHAB sites have been presented in Part 4 of this report.

No data are available at the IFG sites for verification of adult resident combined suitability indices; however, some data were available for verification of juvenile salmon and round whitefish combined suitability indices.

The specific hypothesis tested was that the correlation between a combined suitability index and fish catch [transformed by natural log (x+1)] was greater than zero (in other words, there was a positive relationship). For sockeye and chum salmon, the null hypothesis was that there was no association between the combined suitability index and fish presence. Sampling occasions when less than three fish were captured were deleted from the analysis because the low catches were assumed to be a function of seasonal variation in numbers. Specific statistical methodology is presented in Part 4 of this report.

2.6 Index of Available Habitat

The report on total surface area of macrohabitat types at four levels of mainstem discharge in the Susitna River reach between the Chulitna River confluence and Devil Canyon (Klinger and Trihey 1984) arrived too late to be completely assimilated in this draft report. We did, however, try to make some preliminary habitat assessments to obtain an idea of the rearing capacity of the reach.

Of the six macrohabitat types for which total surface area information is available, four are directly influenced by mainstem discharge. These four are the mainstem itself, side channels, side sloughs, and upland sloughs. We did not include the mainstem (defined as the area that conveys over 10% of the total flow at a given site) in this analysis because we have no data on fish usage of this area. The total surface area of the three remaining macrohabitat types given by Klinger and Trihey (1984) at four levels of discharge (9,000, 12,500, 16,000, and 23,000 ft^3/sec) was converted to square feet of actual terrain. The discharge levels at which surface area was mapped are all on the low side of the normal open water season discharge levels as a discharge of 23,000 ft^3/sec is considered to be a typical mid-summer discharge level (Klinger and Trihey 1984). The square feet of a particular macrohabitat type at a given level of discharge was multiplied by the percent use of that macrohabitat type by each species as determined in Part 2 and Part 6 of this report. For chum juveniles, the percent usage data of 1982 (ADF&G 1983b) were used because there was little effort in 1983 in side channels when chum salmon were present (May through early July). Next, the product was summed for all macrohabitat types at each level of discharge. The equation for each species at each level of discharge is:

$$\text{Index of Available Habitat} = \sum_{i=1}^{n} \left[(\text{Area})_i \times (\text{Percent Use})_i \right]$$

where: i = each macrohabitat type

n = total number of macrohabitat types

We named this the Index of Available Habitat (IAH) and made it unit-less because the analysis is not sophisticated enough to provide confidence in giving actual units of rearing habitat area.

This preliminary analysis required several assumptions: (1) change in surface area is the only effect of a varying level of discharge; (2) a side channel at 9,000 ft^3/sec is of equal quality to a side channel at 23,000 ft^3/sec; (3) proportional fish usage of macrohabitat types does not change as the availability of the types changes; (4) there are no seasonal changes in proportional fish usage macrohabitat types; and (5) the areas mapped for each macrohabitat type are similar to the areas in which fish usage data were collected. The degree to which these assumptions were met are discussed later. A more sophisticated analysis of available habitat in the reach, based on available rearing habitat at the IFG and RJHAB model sites, will be presented in the final version of this report.

3.0 RESULTS

3.1 IFG Model Weighted Usable Area

Juvenile salmon catches and catch per unit efforts (CPUE's) varied greatly at the seven IFG modelling sites (Table 1). Slough 8A is only overtopped by mainstem discharges of more than 33,000 cfs and therefore was not modelled for any species. Juvenile salmon at this slough were primarily caught below the modelling site. The Slough 8A IFG modelling site harbored few juvenile fish because access was restricted from below by several beaver dams and access was restricted from above because the head was only infrequently overtopped.

Juvenile coho catches and CPUE's were very low and, therefore, no results for coho WUA's are presented here. In general, calculated WUA's for coho salmon at the sites were less than 2% of the total surface area of the site. The primary reason for low coho density was the preference of cohos for non-turbid water (see Parts 2 and 3 of this report). All of the IFG modelling sites with the exception of Slough 8A, harbored significant numbers of chinook salmon and, therefore, results from six IFG sites are presented. Sockeye and chum WUA's are presented for sloughs 21 and 9 as these were the only two sites where these species were relatively numerous. Unfortunately, the four mainstem side channel sites were not sampled until July and most chum and large numbers of sockeye had moved down river by this time (see Part 1 of this report).

In the time series plots that follow, if a mean daily discharge exceeded the calibration range of the model, no WUA value was plotted. If the discharge was less than the calibration range, then the WUA was set equal to the WUA value for the lowest discharge in the calibration range. Five of the sites were calibrated to some point below the overtopping flow and therefore WUA did not change very much once the head of the site is no longer overtopped. At these sites however, because of mainstem backwater effects at the lower end of some of the sites and because of local hydrology, it may be assumed that WUA is overestimated for those days on which the discharge level was below the calibration range of the site. Slough 21, the head of which is not overtopped at a discharge level less than 20,900 cfs was calibrated only as low as 22,700 cfs. Lower Side Channel 11 is overtopped at a discharge less than 5000 cfs.

3.1.1 Chinook salmon

Weighted usable areas for six IFG modelling sites as a function of mainstem discharge and as projected over the June 1 to September 30 time period are presented in Figures 3 through 8. There were two different sets of suitability criteria for chinook salmon; one for a low turbidity level and one for a high turbidity level (Part 3 of this report). Chinook juveniles preferred the high turbidity condition when other cover types were not abundant. Therefore, the weighted usable area for chinooks drops sharply when discharge levels become low enough so that the head of the site is no longer overtopped by turbid mainstem water. At mainstem discharges less than those required to overtop the head of

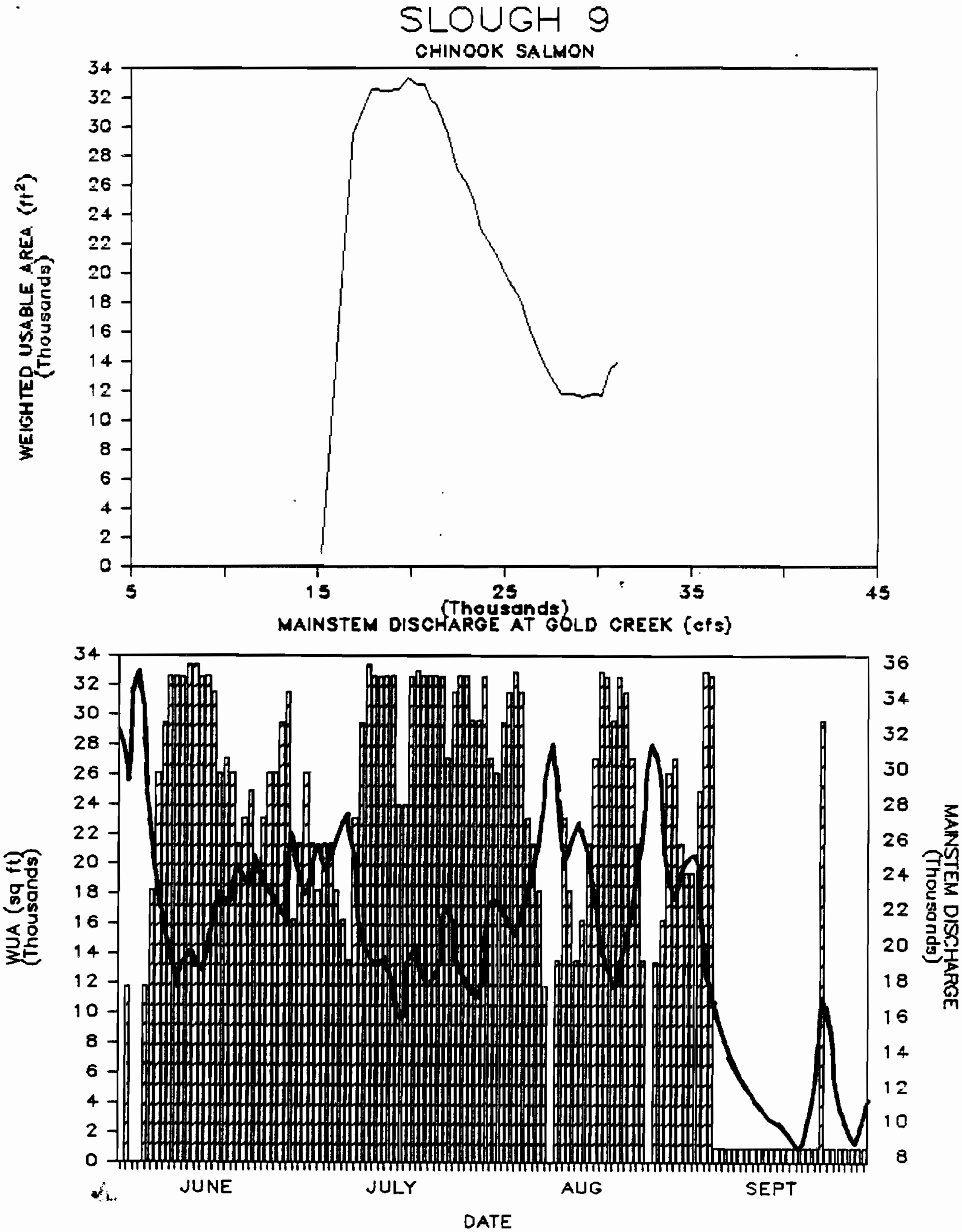
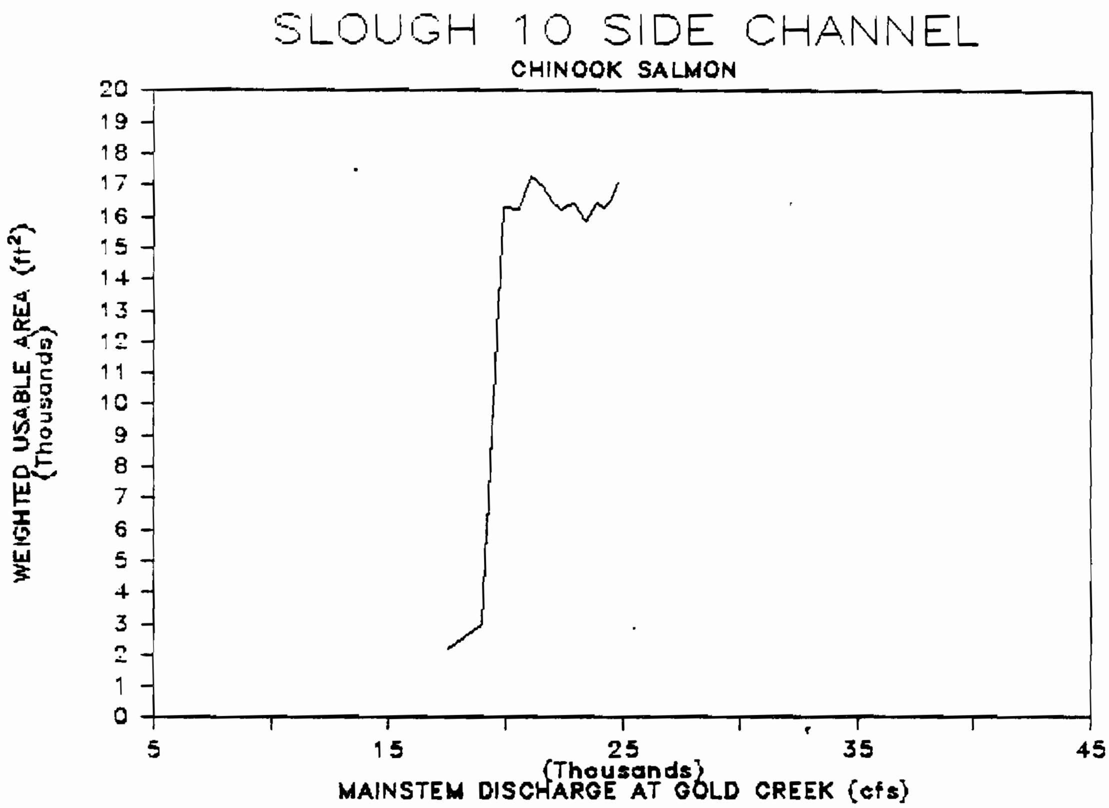


Figure 3. Weighted usable area for chinook salmon at Slough 9 by level of mainstem discharge and by date, 1983. No WUA value is plotted if the mean daily discharge exceeded the calibration range of the model.



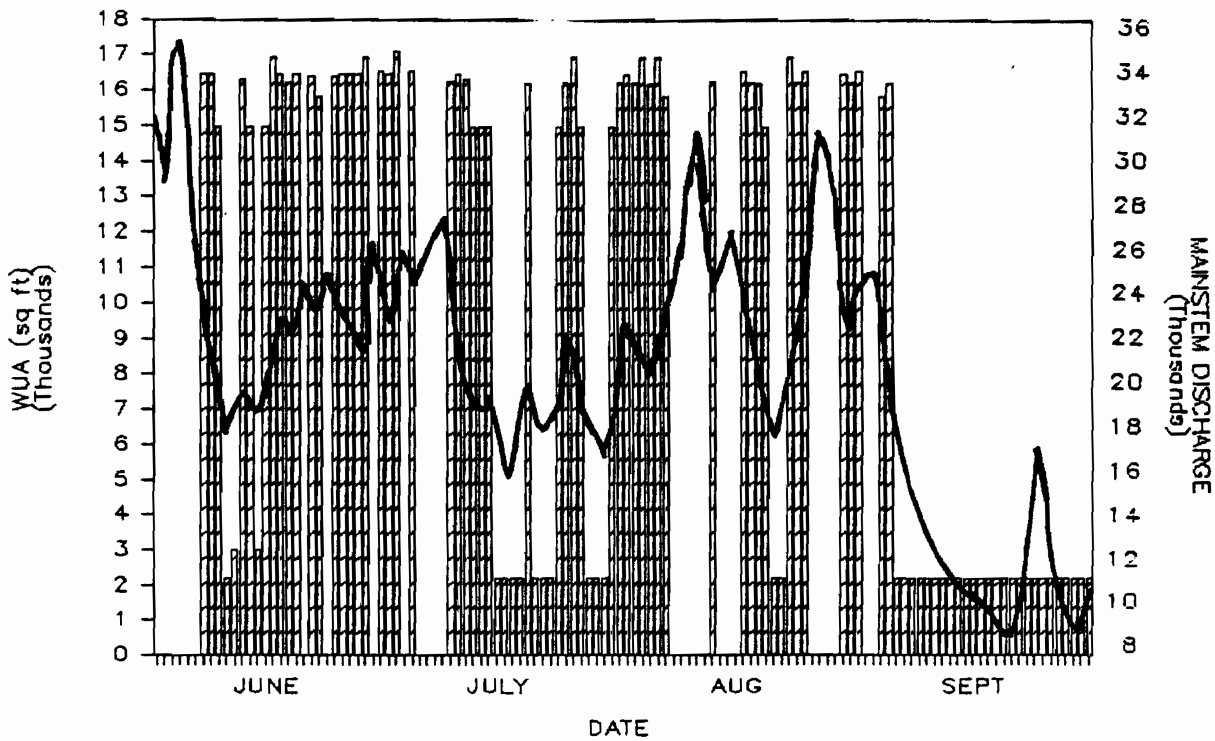


Figure 4. Weighted usable area for chinook salmon at Slough 10 Side Channel by level of mainstem discharge and by date, 1983.

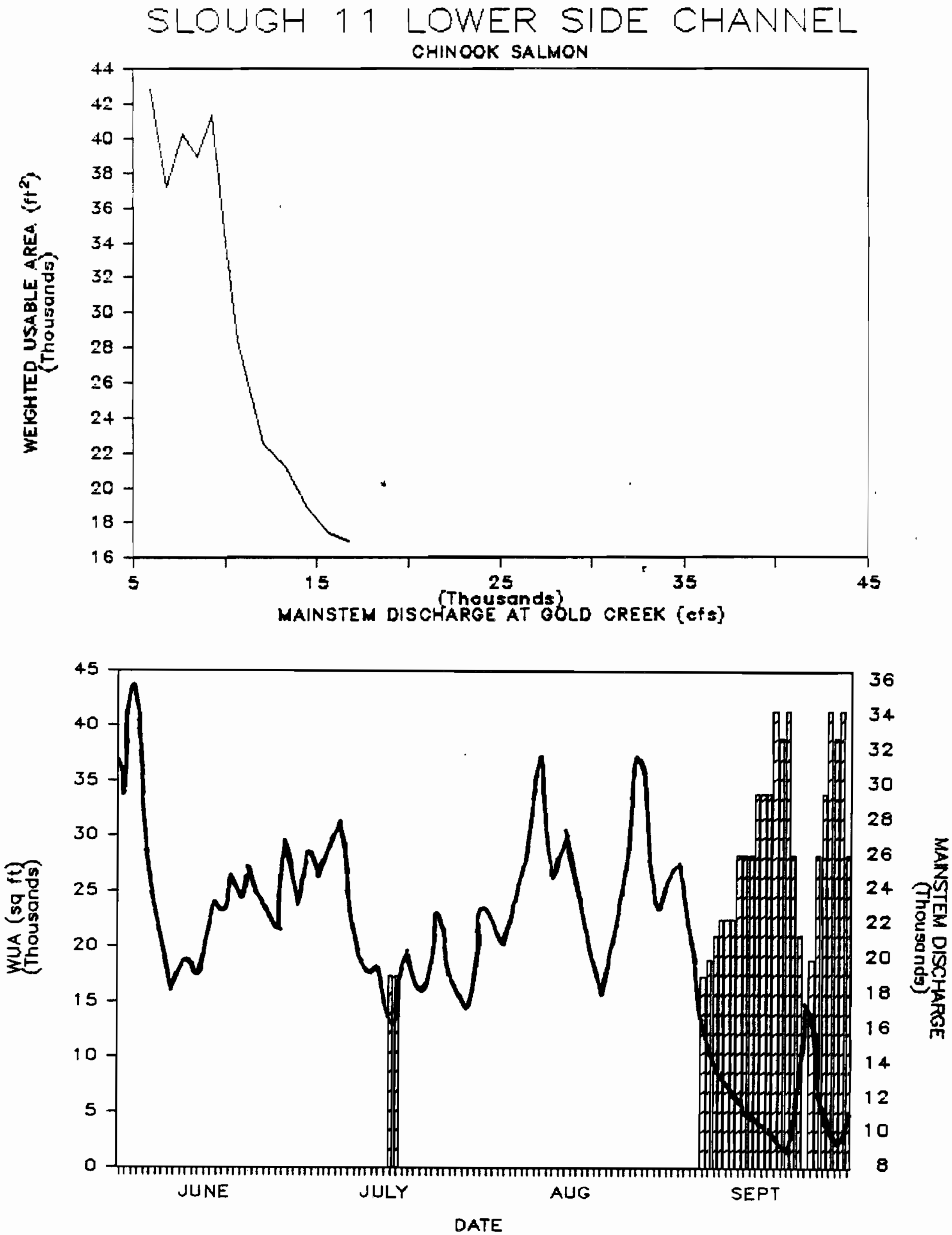


Figure 5. Weighted usable area for chinook salmon at Slough 11 Lower Side Channel by level of mainstem discharge and by date, 1983.

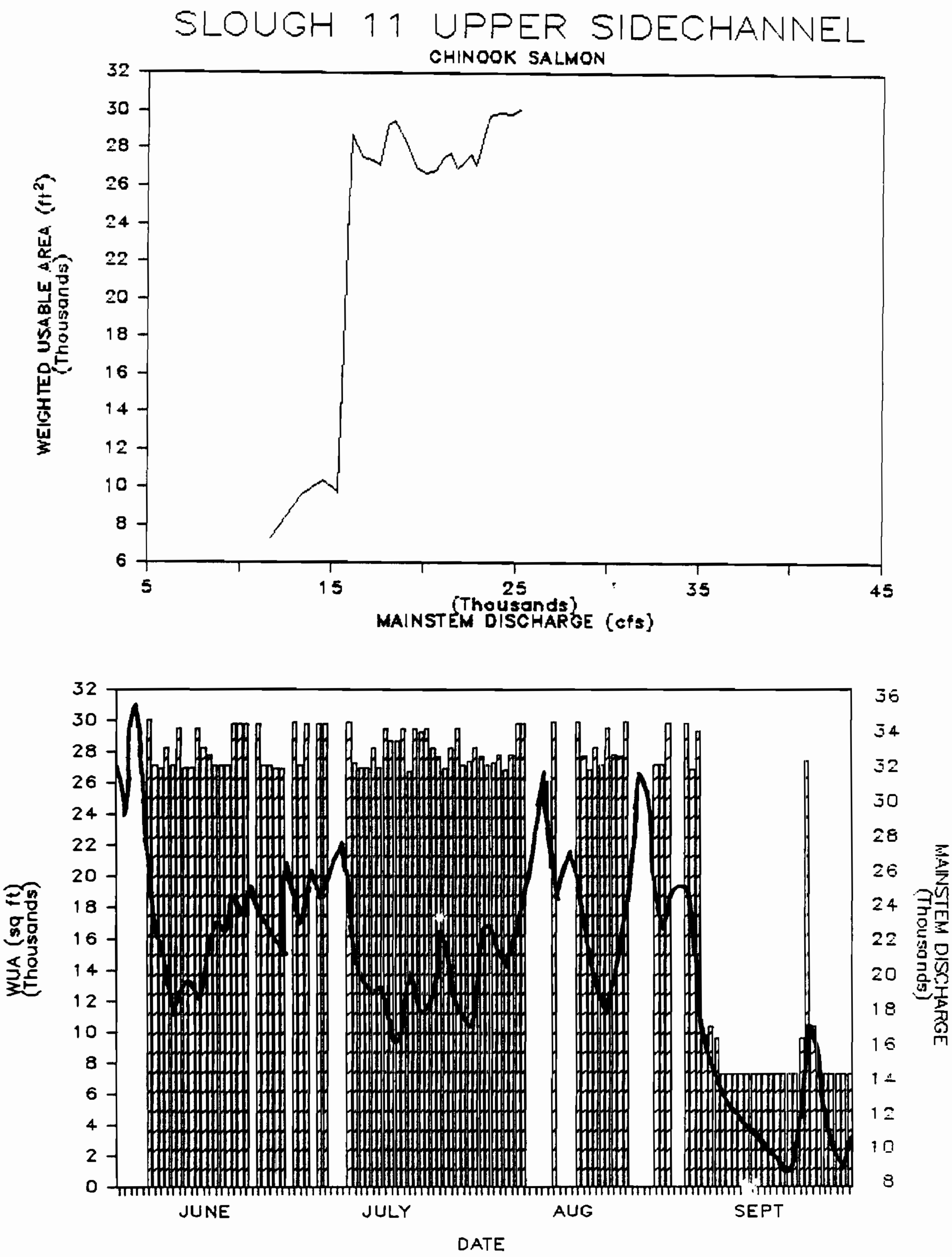


Figure 6. Weighted usable area for chinook salmon at Slough 11 Upper Side Channel by level of mainstem discharge and by date, 1983.

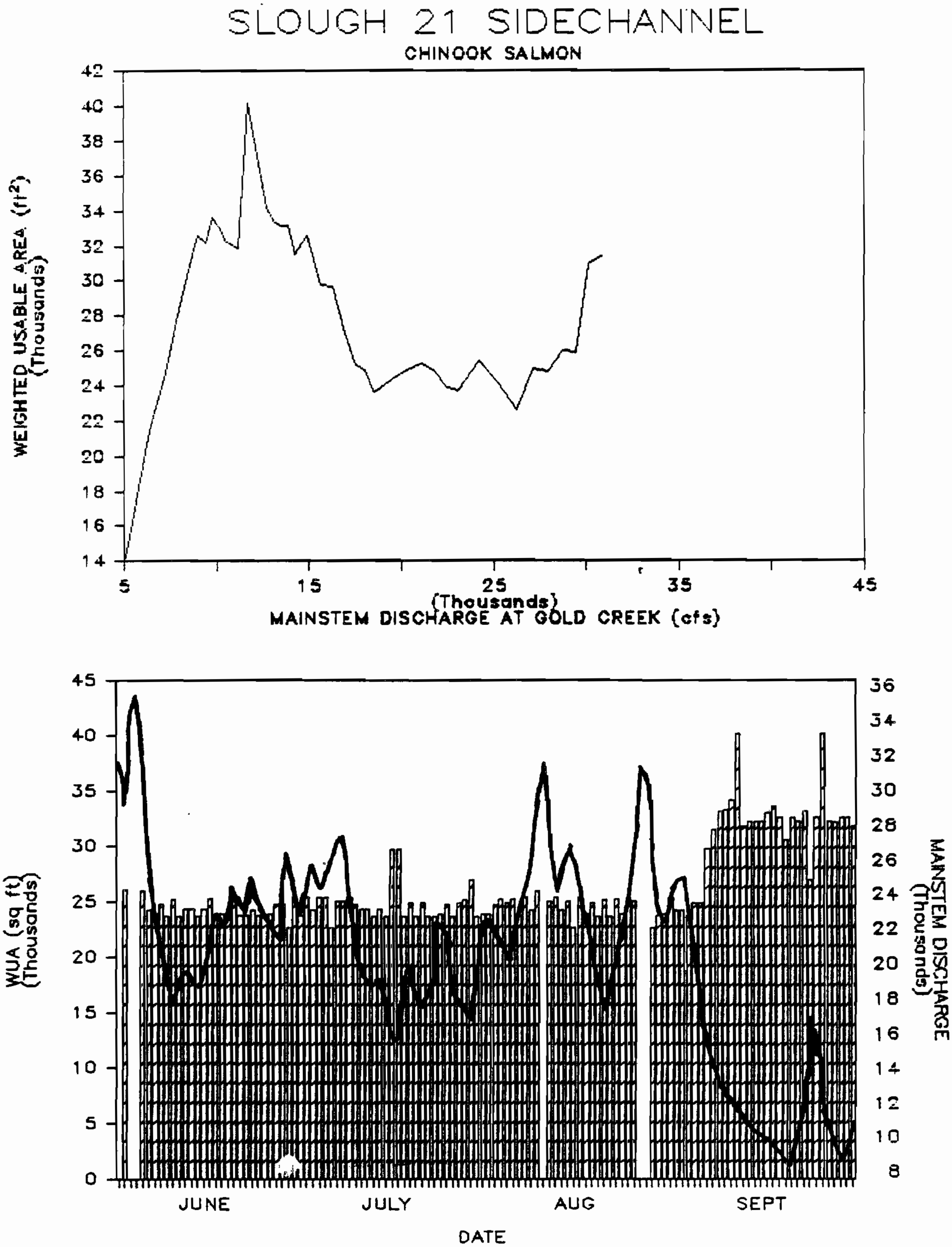


Figure 7. Weighted usable area for chinook salmon at Slough 21 Side Channel by level of mainstem discharge and by date, 1983.

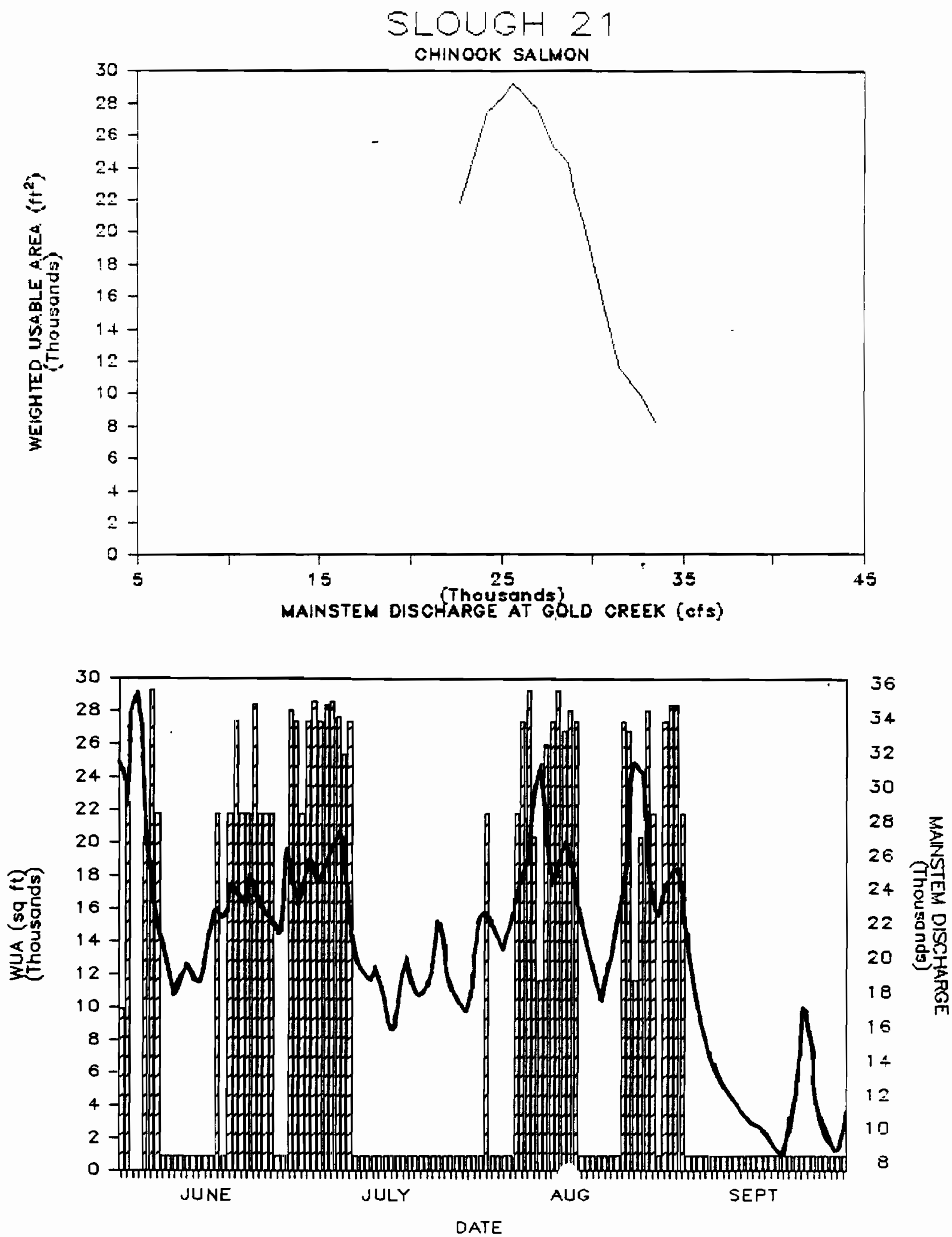


Figure 8. Weighted usable area for chinook salmon at Slough 21 by level of mainstem discharge and by date, 1983.

the site, there is no strong relationship between slough flow and mainstem discharge unless groundwater flow is significantly related to discharge. Calibration ranges of the model at many of the sites limited the calculated responses of WUA to a small range of mainstem discharges. The three peak discharges which occurred in early June and in early and late August exceeded the calibration range of all the sites except for Slough 21.

Typically, peaks in weighted usable area were found at mainstem discharges slightly greater than the overtopping discharges. When these peaks occurred and, hence, when the site was theoretically able to support the maximum number of fish of the species, can be seen from the time series plots. In general, sites at which the overtopping flow occurred at a middle level of discharge provided more habitat during the open water season of 1983 than sites which had either a relatively low overtopping flow (Lower Side Channel 11) or a relatively high overtopping flow (Slough 21).

3.1.2 Chum and sockeye salmon

Plots of WUA's for chum sockeye salmon as a function of mainstem discharge showed very similar trends (Figures 9 through 12). Chum and sockeye WUA plots were almost identical at both Slough 9 and Slough 21. At both sites, WUA's for chum and sockeye peaked rapidly with small increases in discharge, held constant over a range of approximately 5,000 cfs in mainstem discharge, and then decreased rapidly with further increases in mainstem discharge. At a given site, sockeye WUA's peaked

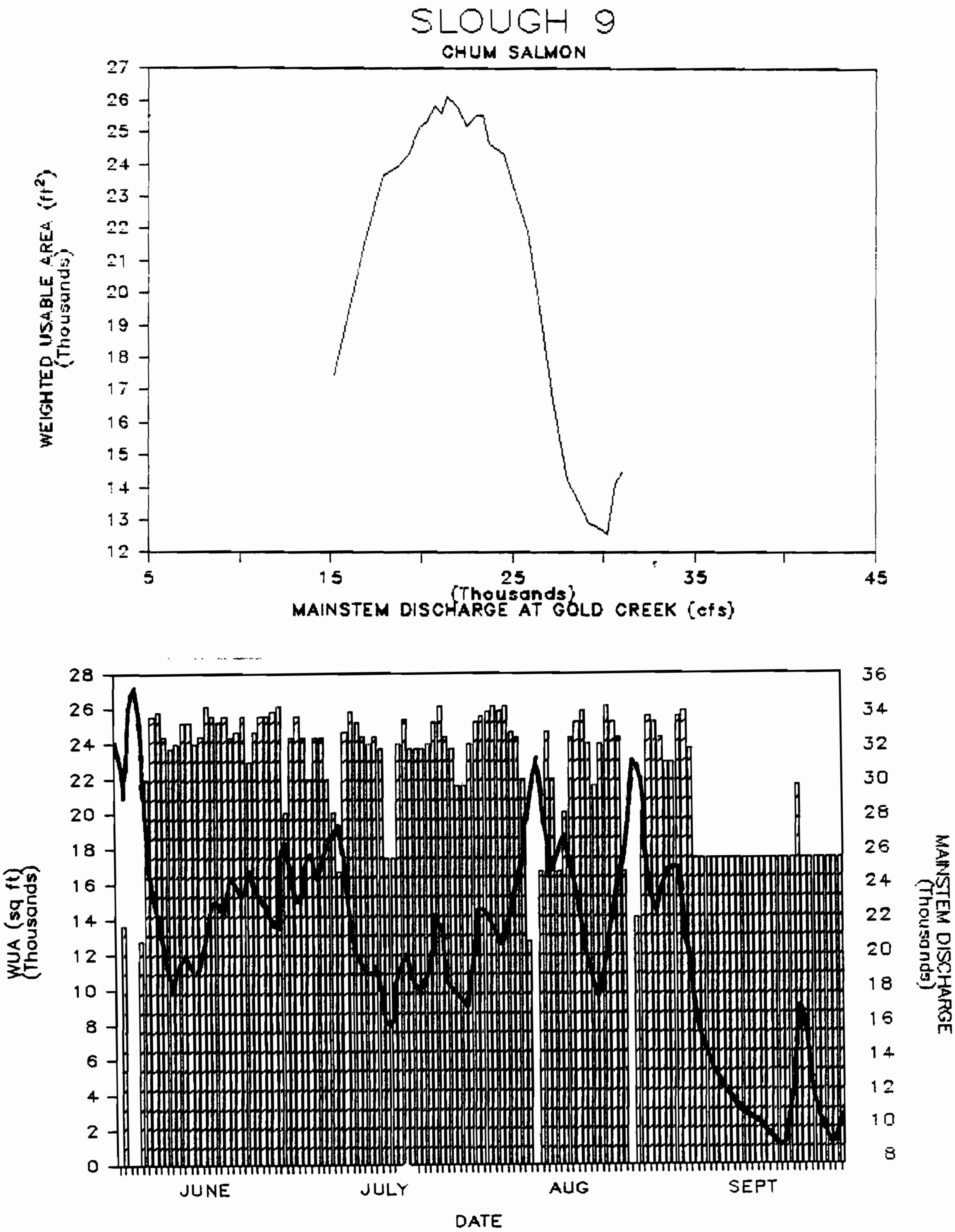


Figure 9. Weighted usable area for chum salmon at Slough 9 by level of discharge and by date, 1983.

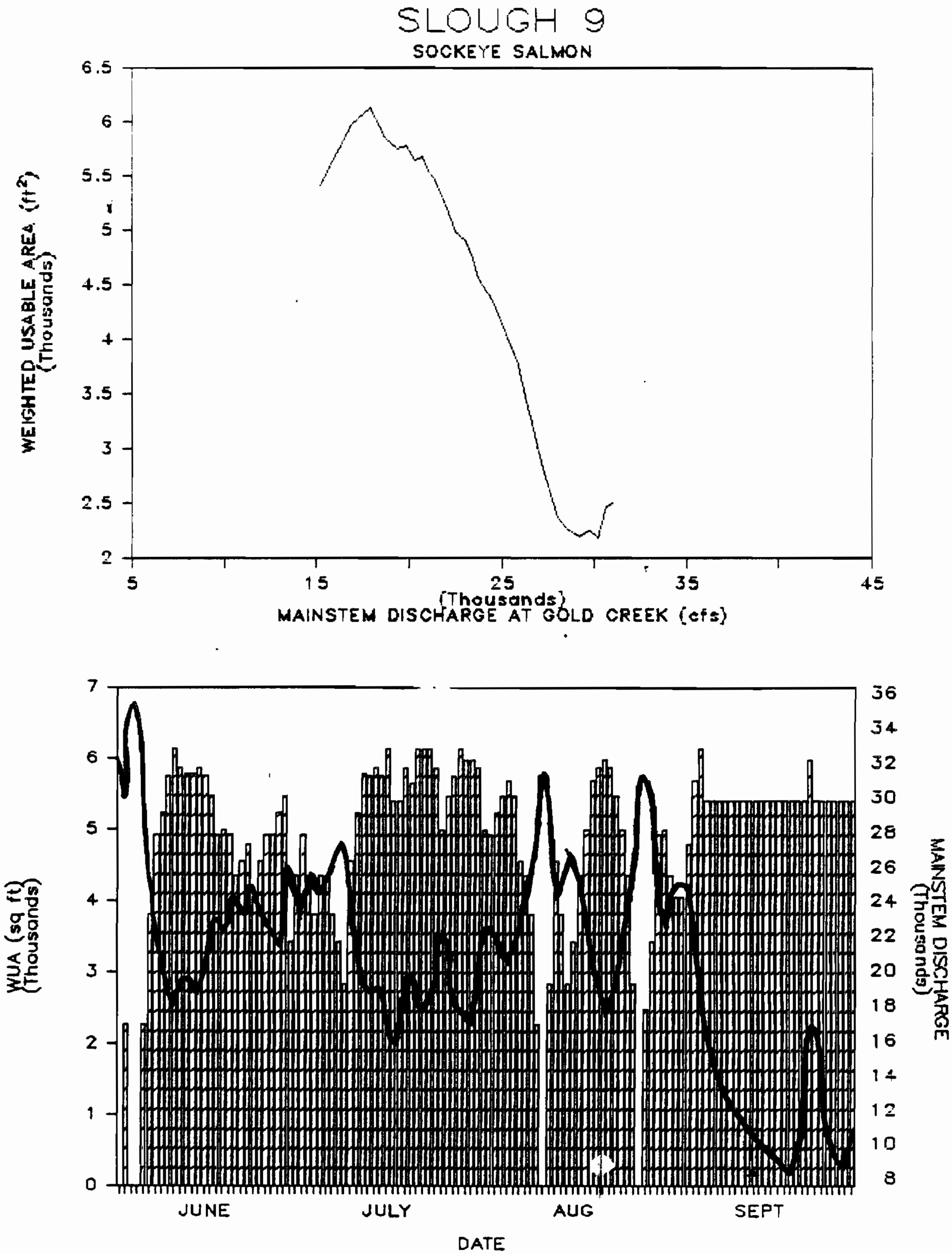


Figure 10. Weighted usable area for sockeye salmon at Slough 9 by level of discharge and by date, 1983.

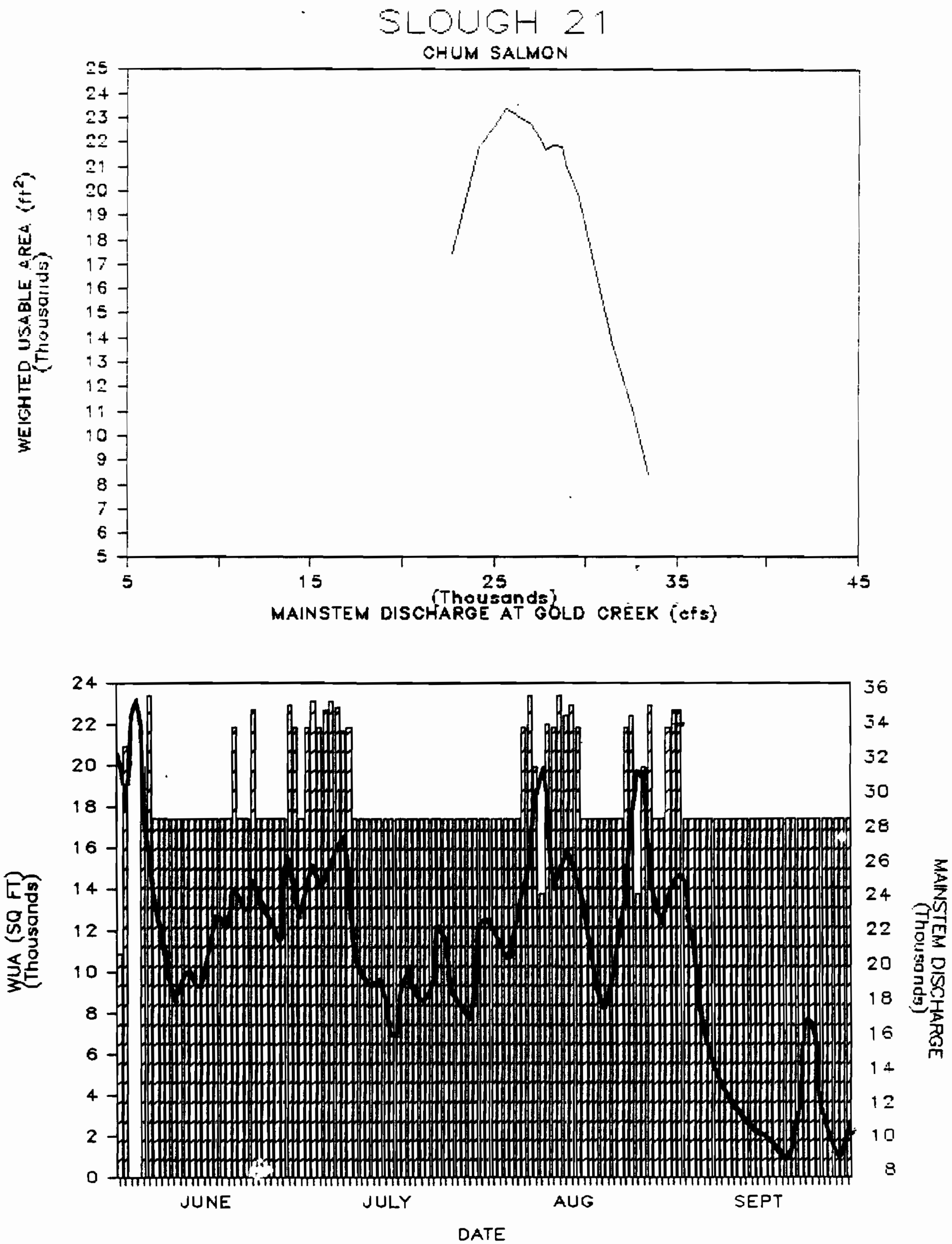


Figure 11. Weighted usable area for chum salmon at Slough 21 by level of discharge and by date, 1983.

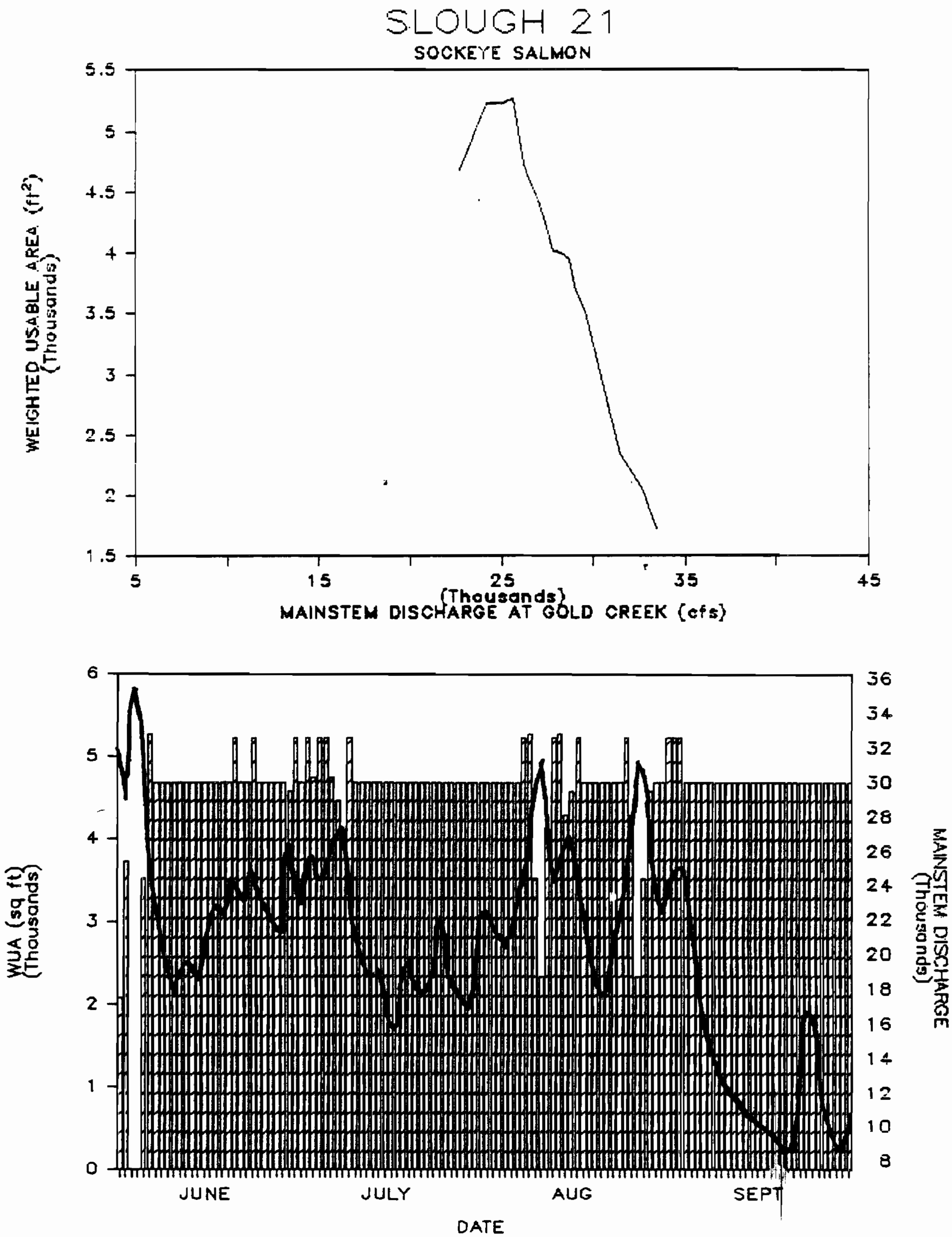
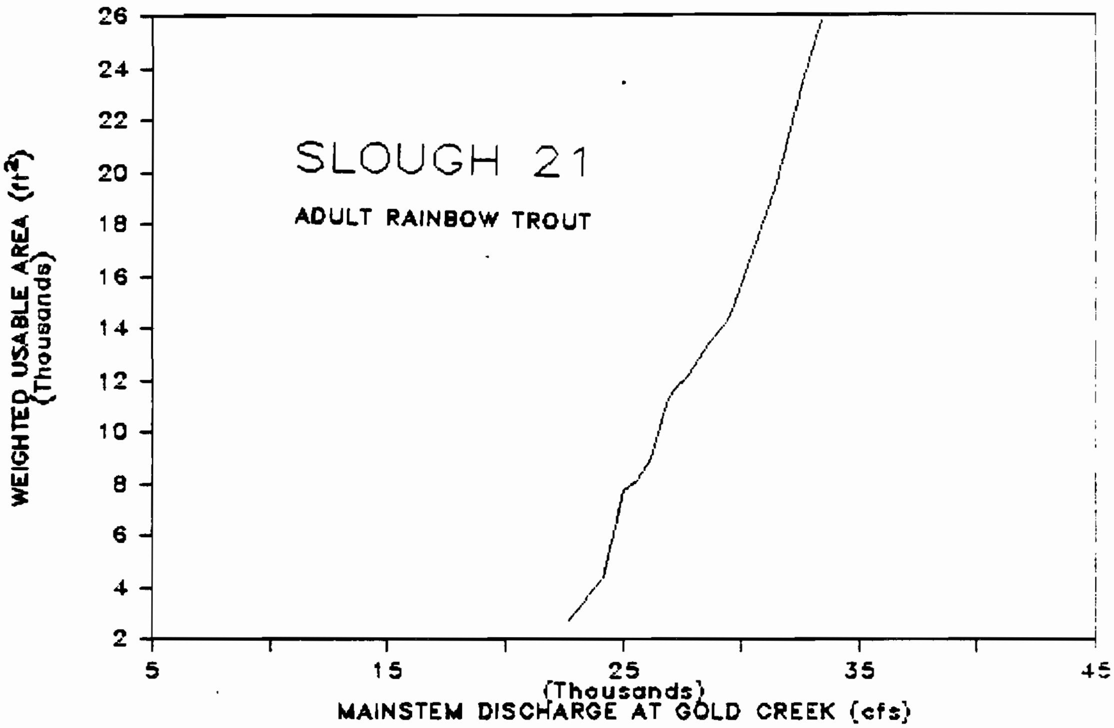


Figure 12. Weighted usable area for sockeye salmon at Slough 21 by level of discharge and by date, 1983.

slightly before chum WUA's because slightly lower velocities were more suitable to the sockeye salmon juveniles. Because the head of Slough 21 was not overtopped for a large number of days in the 1983 open water season, the weighted usable area for each species is not affected by mainstem discharge and stayed relatively constant. When the head of Slough 21 was overtopped, the WUA for sockeye and chum increased slightly but was not nearly as dramatic as the increase in chinook WUA (Figure 8).

3.1.3 Resident Fish Weighted Usable Area

Only limited sampling for resident fish was conducted at the IFG modelling sites and, therefore, no site specific data on adult resident use of the sites are available. Many of the sites are inaccessible to electrofishing boats except during high mainstem discharges. Slough 21 was picked as a representative site to present responses of adult resident fish. WUA's and the relationships between WUA and mainstem discharge for adult rainbow trout, Arctic grayling, round whitefish, and longnose suckers are presented in Figures 13 and 14. Since Arctic grayling, an important sportfish, are frequently found in sloughs and side channels during the ice-free months, responses of WUA to mainstem discharge for Arctic grayling at Slough 9 and Side Channel 21 are also presented (Figure 15). Within the extrapolated flow ranges of the site or sites, WUA's for adult rainbow trout, Arctic grayling, and round whitefish increased with flow. WUA for longnose suckers, which prefer low velocities, peaked with the overtopping of the site by mainstem



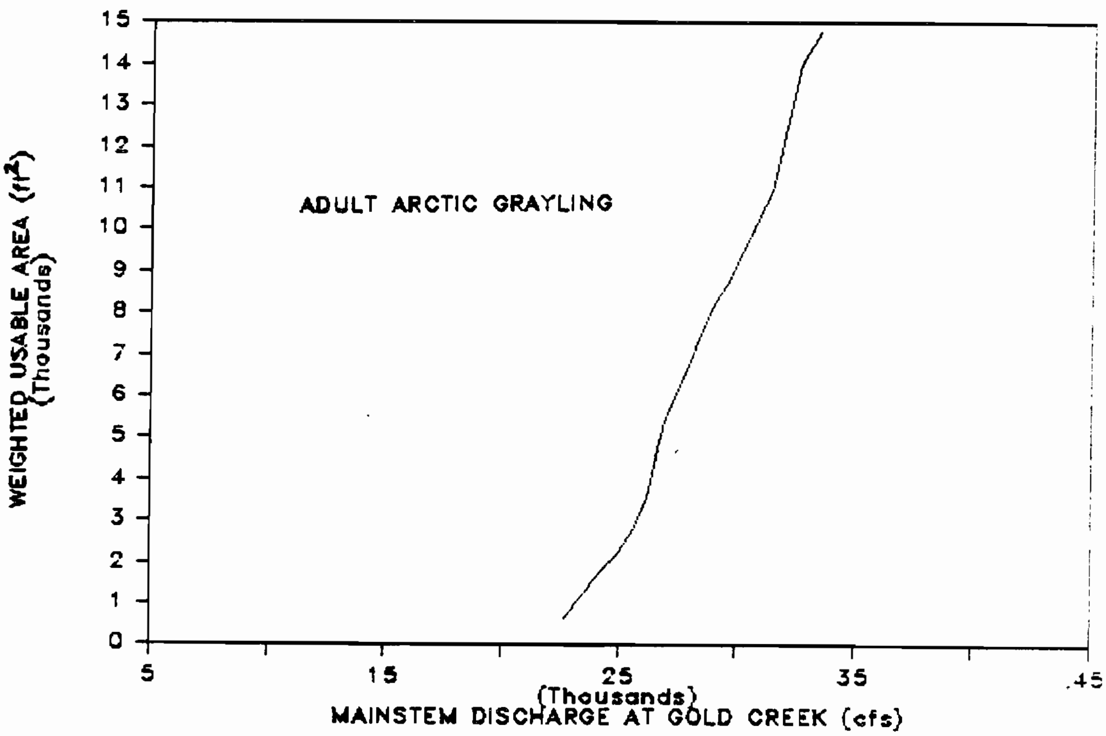
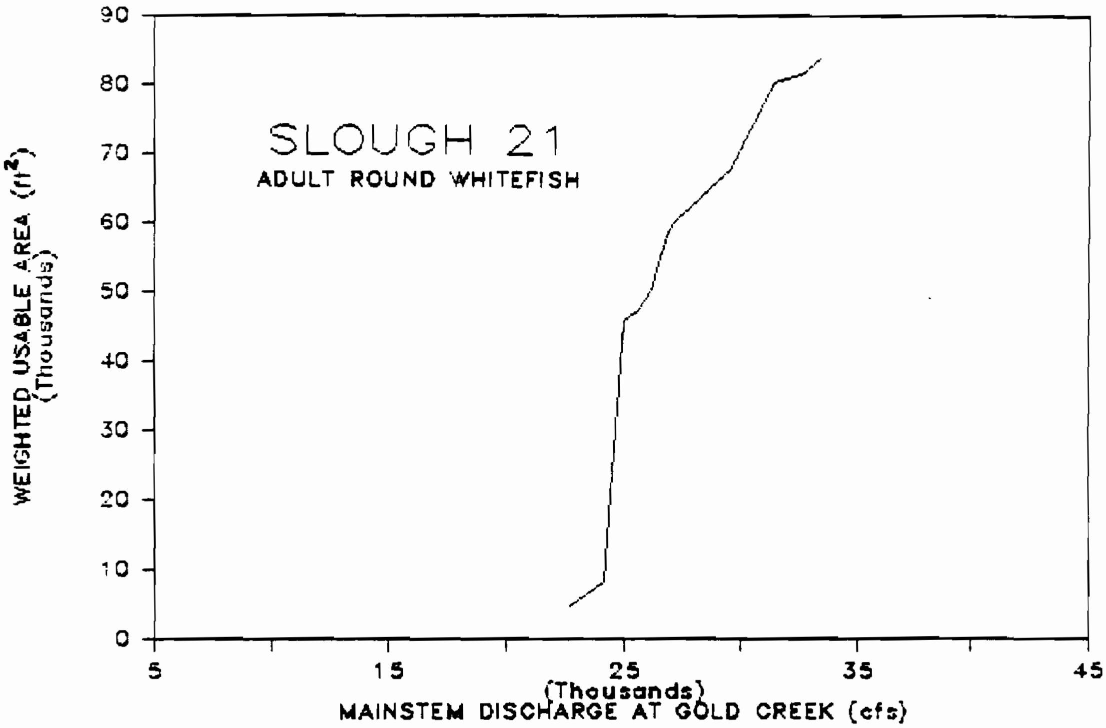


Figure 13. Weighted usable area for adult rainbow trout and Arctic grayling at Slough 21.



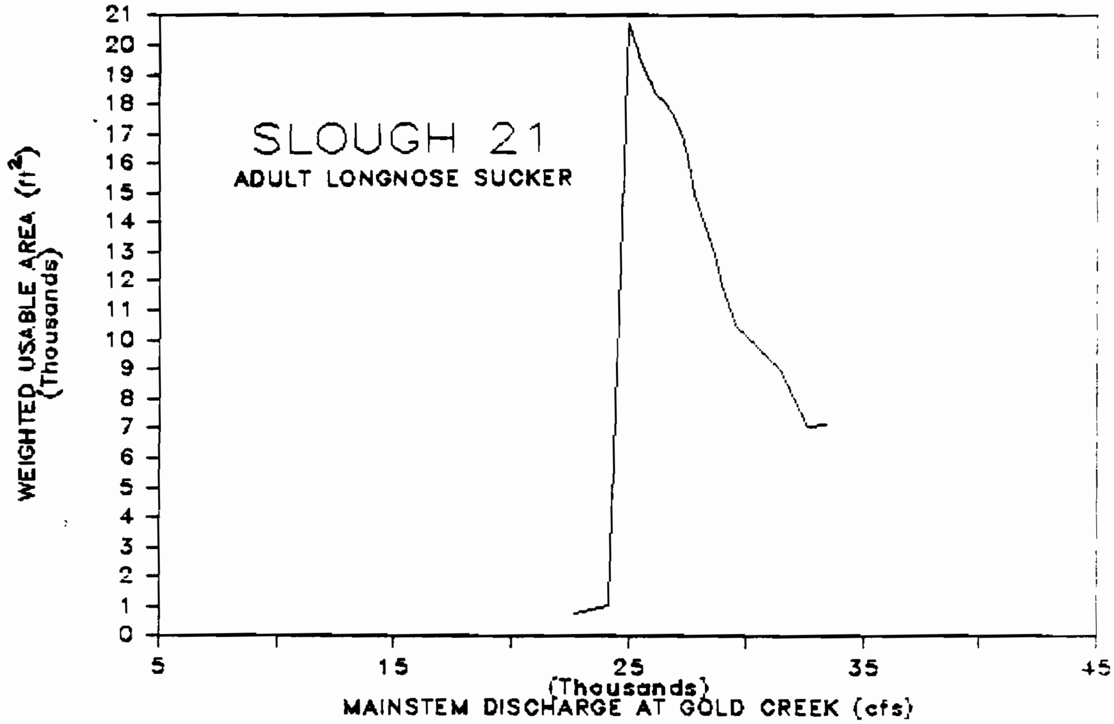


Figure 14. Weighted usable area for adult round whitefish and longnose suckers at Slough 21.

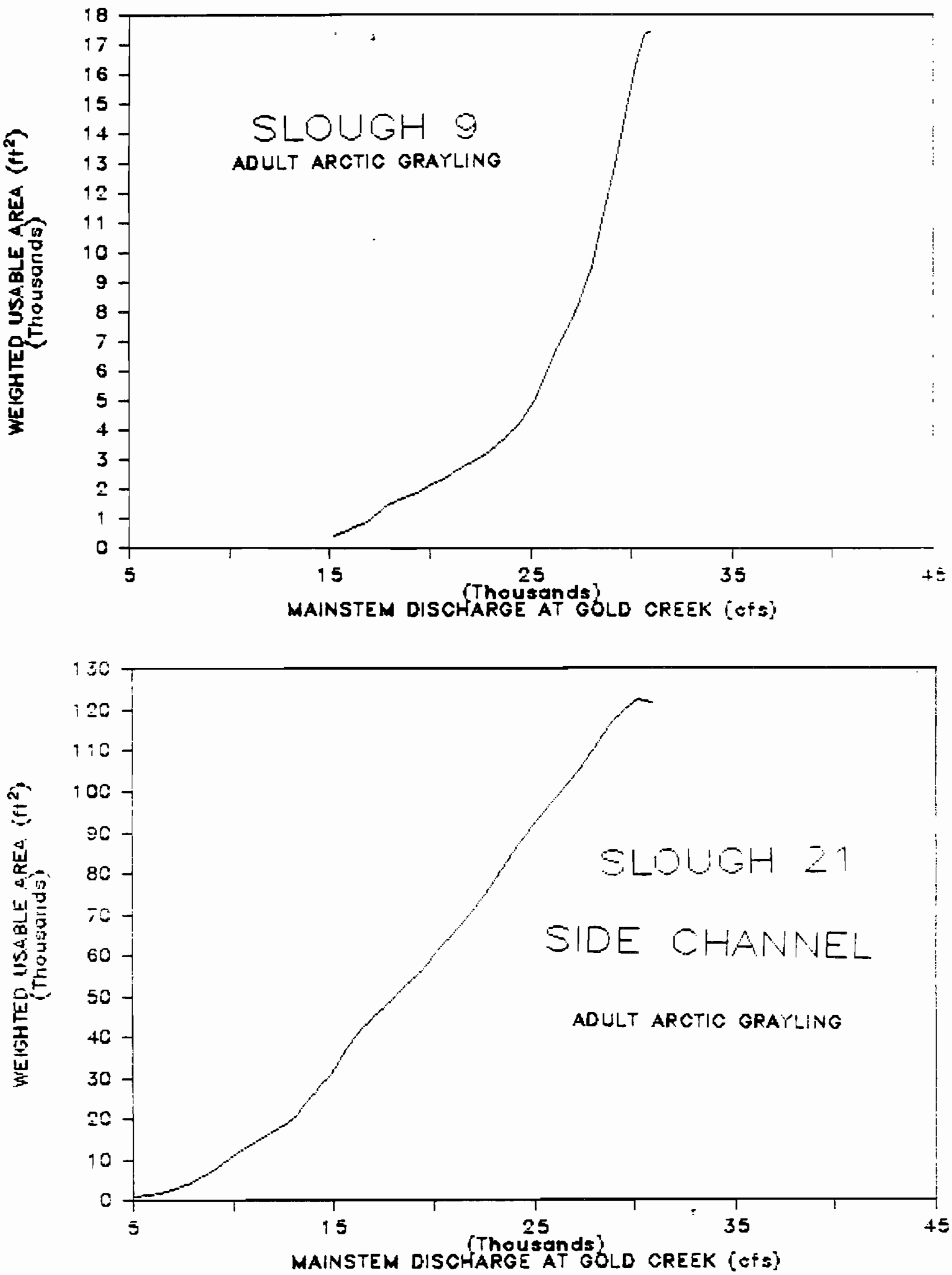


Figure 15. Weighted usable area for adult Arctic grayling at Slough 9 and Slough 21 Side Channel.

discharge and then rapidly decreased with further increases in discharge.

At least 16 juvenile round whitefish were captured at every site with the exception of Slough 8A where none were captured. Results from WUA calculations for juvenile round whitefish are presented for six sites in Figures 16 to 18.

3.2 Model Verification

Slough 9 and Side Channel 10 were the only two IFG sites where both a relatively large amount of sampling and catch of juvenile chinook occurred. Correlations between chinook catch and combined weighting factor at Slough 9 and for all seven sites pooled for both clear and turbid conditions were significantly greater than 0.0 (Table 2). At Side Channel 10, however, there was no significant correlation between chinook catch in turbid water and combined weighting factor interval.

Data from Sloughs 8A, 9 and 21 were pooled for chi-square contingency tests of chum and sockeye proportional presence by combined weighting factor interval (Table 3). Chum salmon presence was associated with larger combined weighting factors; however, sockeye salmon presence was not.

Correlations between round whitefish catch in turbid ($>$ 30 NTU) water and combined weighting factors were all significantly greater than 0.0 at the 0.01 level. The correlations were 0.35 (n = 54) at Side Channel

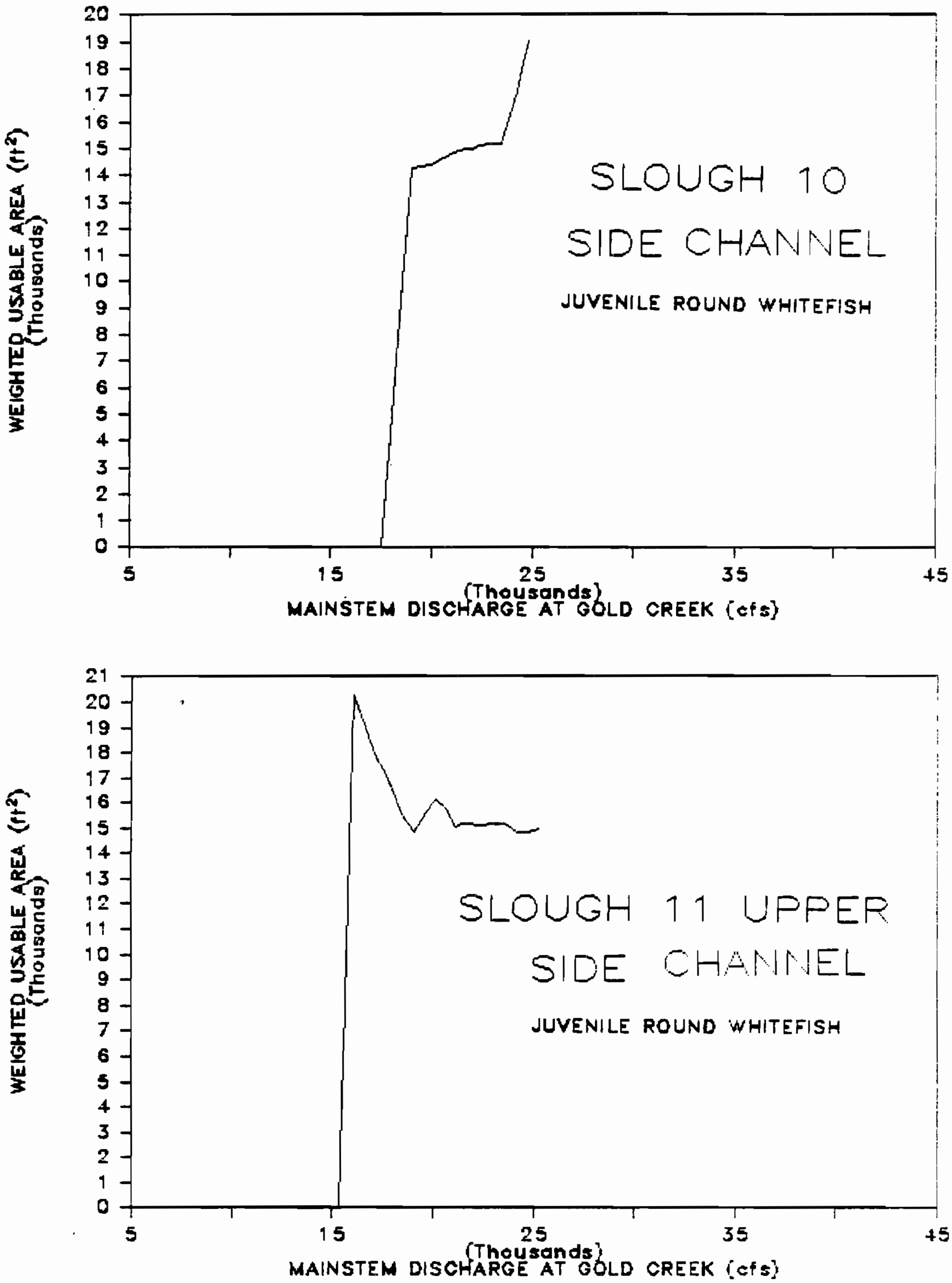


Figure 16. Weighted usable area for juvenile round whitefish at Slough 10 Side Channel and Slough 11 Upper Side Channel.

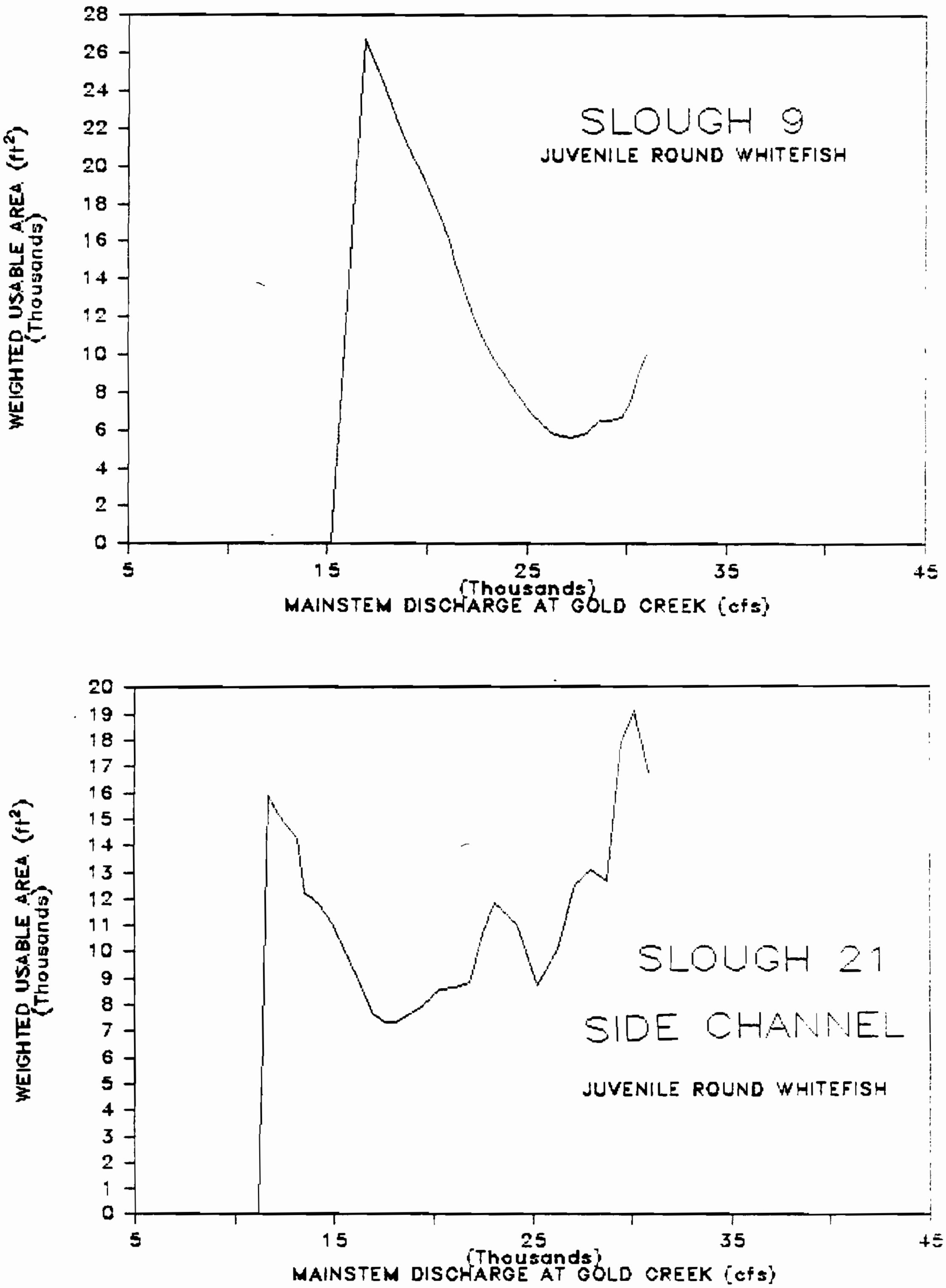


Figure 17. Weighted usable area for juvenile round whitefish at Slough 9 and Slough 21 Side Channel.

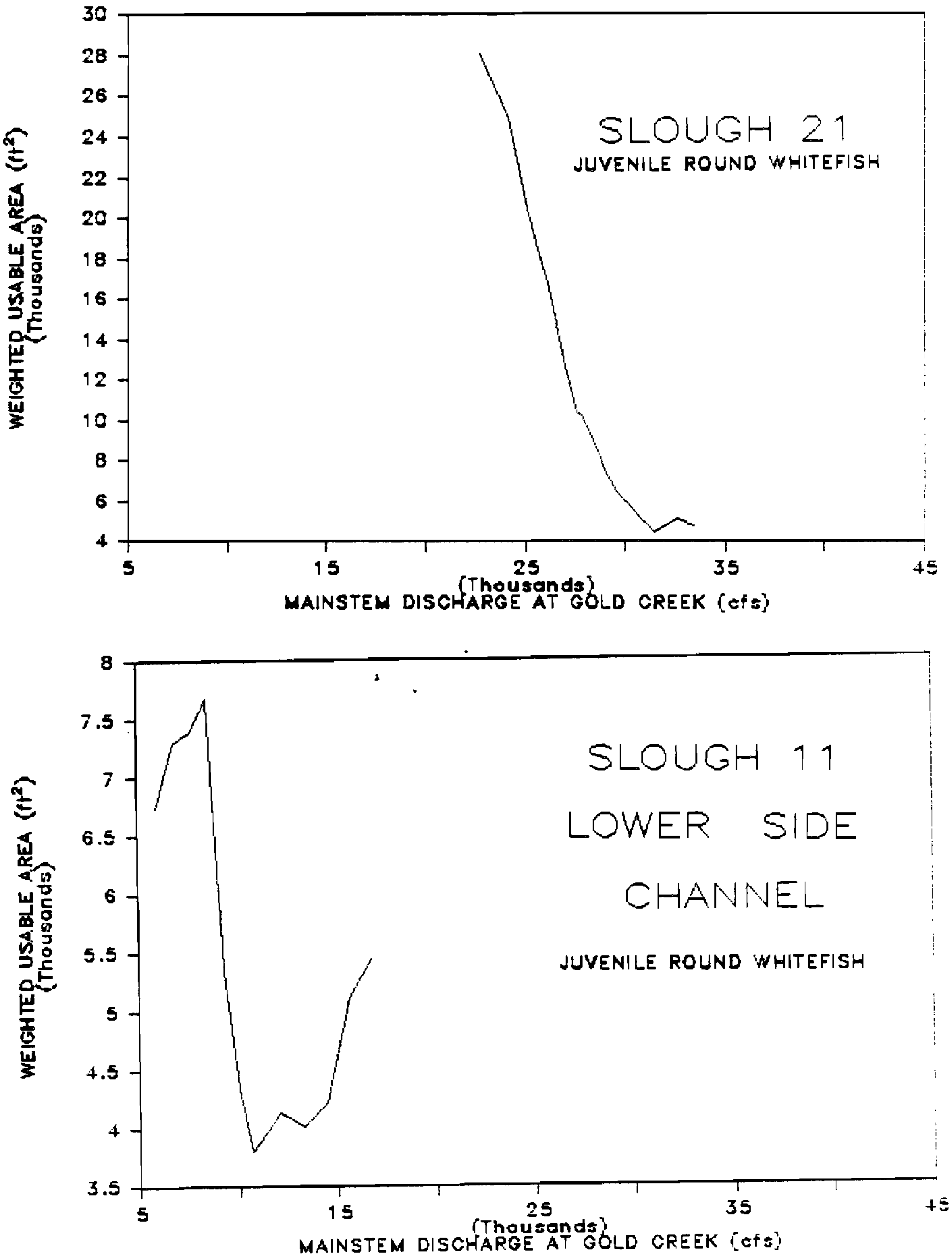


Figure 18. Weighted usable area for juvenile round whitefish at Slough 21 and Slough 11 Lower Side Channel.

Table 2. Correlations between combined weighting factors and catch transformed by natural log (X+1) for juvenile chinook salmon by selected sites and by all sites pooled.

	Chinook					
	Low turbidity (≤ 30 NTU)			High turbidity (> 30 NTU)		
Site	n	r	Sig [a/]	n	r	Sig
Slough 9	48	0.35	0.008	63	0.48	< 0.001
Slough 10 Side channel	(Insufficient data)			54	-0.08	0.28
All 7 sites pooled	99	0.40	<0.001	192	0.25	< 0.001

[a/] Significance level for rejection of hypothesis that there is no positive correlation between combined weighting factors and catch.

Table 3. Chi-square contingency tests of chum and sockeye salmon proportional presence by combined weighting factor intervals. Data from Sloughs 9, 21, and 8A pooled.

Chum

Combined weighting factor interval	No. of Cells Present	Absent	Total	Proportion Present
0.00-0.28	13	28	41	0.32
0.29-0.44	15	21	36	0.42
0.45-0.55	14	21	35	0.40
0.56-1.00	33	10	43	0.77

$\chi^2 = 20.05$ df = 3
$p < 0.001$

Sockeye

Combined weighting factor interval	No. of Cells Present	Absent	Total	Proportion Present
0.00-0.07	9	25	34	0.26
0.08-0.14	7	28	35	0.20
0.15-0.38	11	26	37	0.30

$\chi^2 = 0.92$ df = 2
$p < 0.37$

10, 0.46 (n = 63) at Slough 9, and 0.52 (n = 188) for all seven IFG sites pooled.

3.3 Habitat Indices

In order to compare sites with one another and to compare IFG model results with RJHAB model results, habitat indices were calculated. These habitat indices were calculated by dividing WUA by the total surface area of the site at a mainstem discharge of 23,000 cfs. This discharge level was chosen because it represents typical mid-summer discharge conditions in this reach (Klinger and Trihey 1984).

3.3.1 Juvenile Salmon

The response of chinook salmon habitat indices to mainstem discharge varied greatly by site (Figure 19). Habitat indices for juvenile chinook salmon in Sloughs 9 and 21 showed prominent peaks in habitat indices while Side Channel 10 and Upper Side Channel 11 chinook salmon habitat indices increased greatly after the heads were overtopped and then remained fairly constant. Chum salmon habitat indices at Sloughs 9 and 21 were very similar and showed distinct peaks. Sockeye salmon habitat indices were very low and decreased slowly with discharge.

3.3.2 Resident Species

The response of resident fish habitat indices to changes in discharge varied greatly by species. Juvenile round whitefish habitat indices

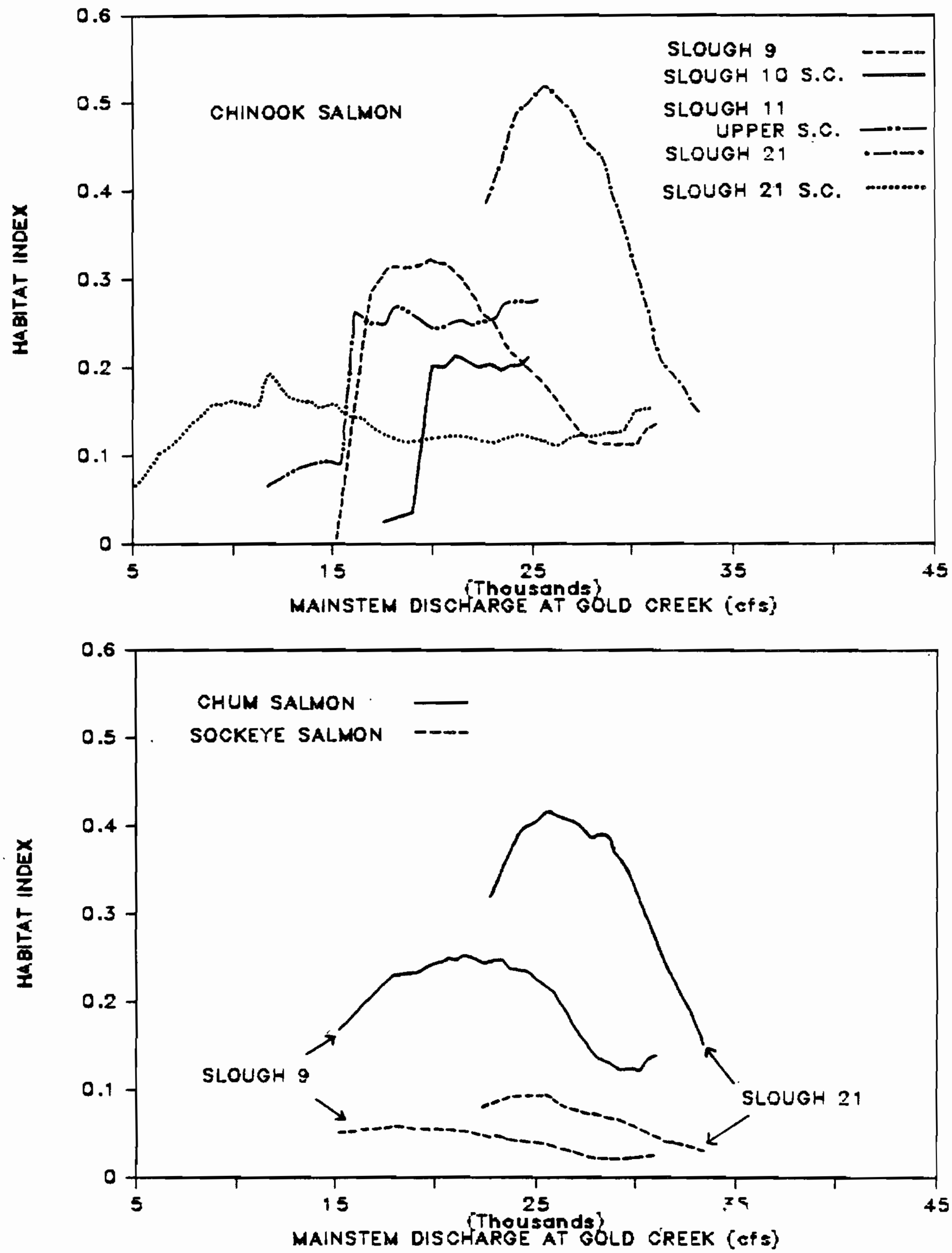


Figure 19. Habitat indices for juvenile salmon at IFG modelling sites.

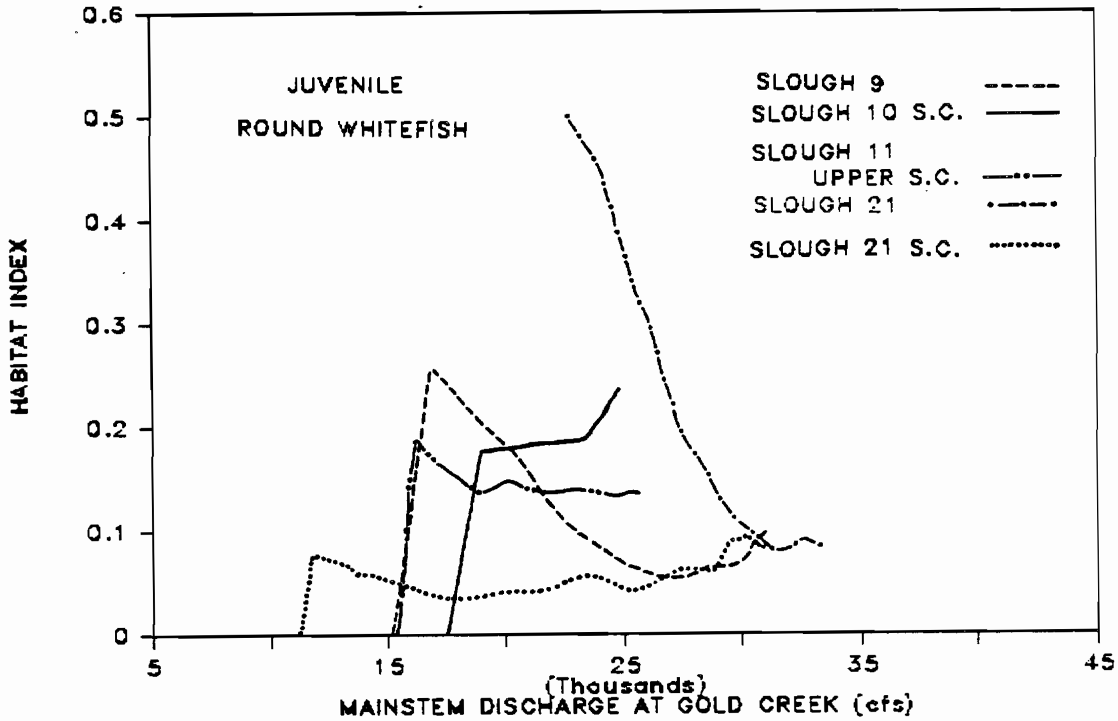
changed in a similar way to chinook salmon habitat indices while Arctic grayling habitat indices increased greatly with discharge (Figure 20). Rainbow trout habitat indices at Slough 21 increased with mainstem discharge while adult longnose sucker habitat indices steadily decreased with mainstem discharge (Figure 21).

3.4 Index of Available Habitat

The index of available habitat for juveniles of the four species of salmon is plotted in Figure 22. There was approximately an order of magnitude increase in surface area between upland sloughs and side sloughs and again between side sloughs and side channels (Klinger and Trihey 1984). Therefore, species which show a moderate or greater preference toward side channels will have a much higher index of available habitat (IAH) than those species that do not and will parallel the increase shown by side channel area as discharge increases. This effect is shown by chinooks (side channel use = 58.1%) and chums (side channel use = 25.5%). Percent use of macrohabitat types affected by the mainstem which were used in the calculations are as follows:

Macrohabitat Type	Chinook	Coho	Chum	Sockeye
Side Channel	58.1	7.0	25.5	8.5
Side Slough	24.9	20.7	56.9	41.5
Upland Slough	17.0	72.4	17.7	49.9

Cohos and sockeyes, which show a propensity to use upland sloughs, do not have a very high IAH because there is little surface area of upland slough available in the reach.



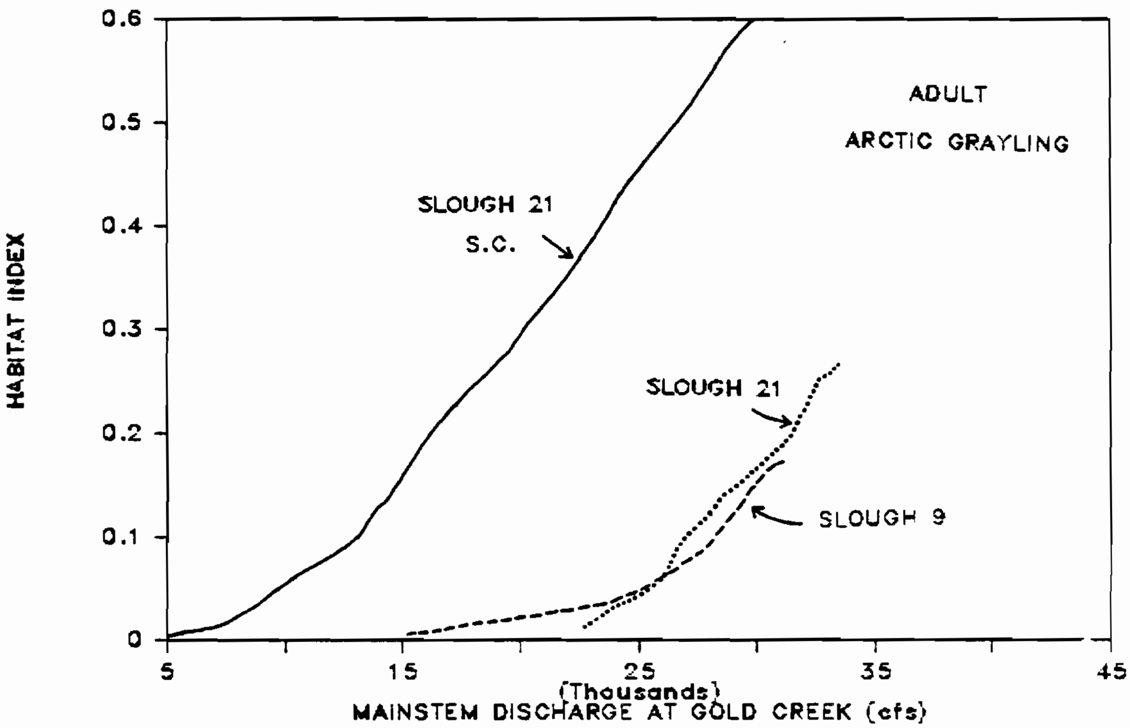


Figure 20. Habitat indices for juvenile round whitefish and adult Arctic grayling at IFG modelling sites.

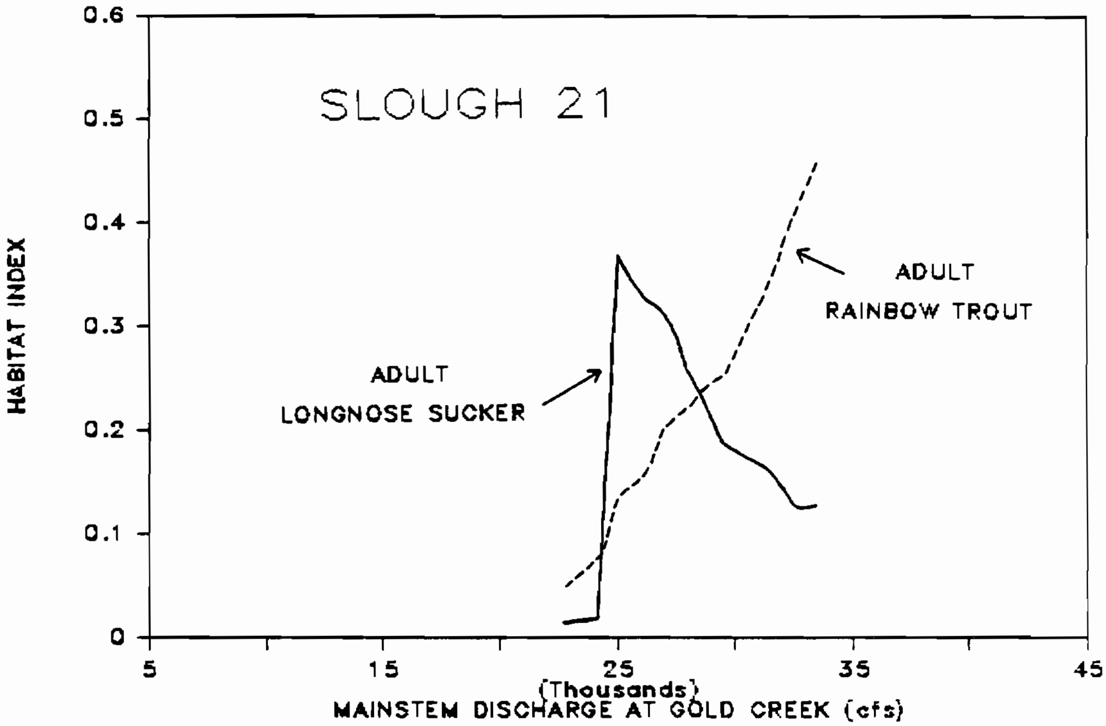


Figure 21. Habitat indices for adult rainbow trout and longnose suckers at IFG modelling sites.

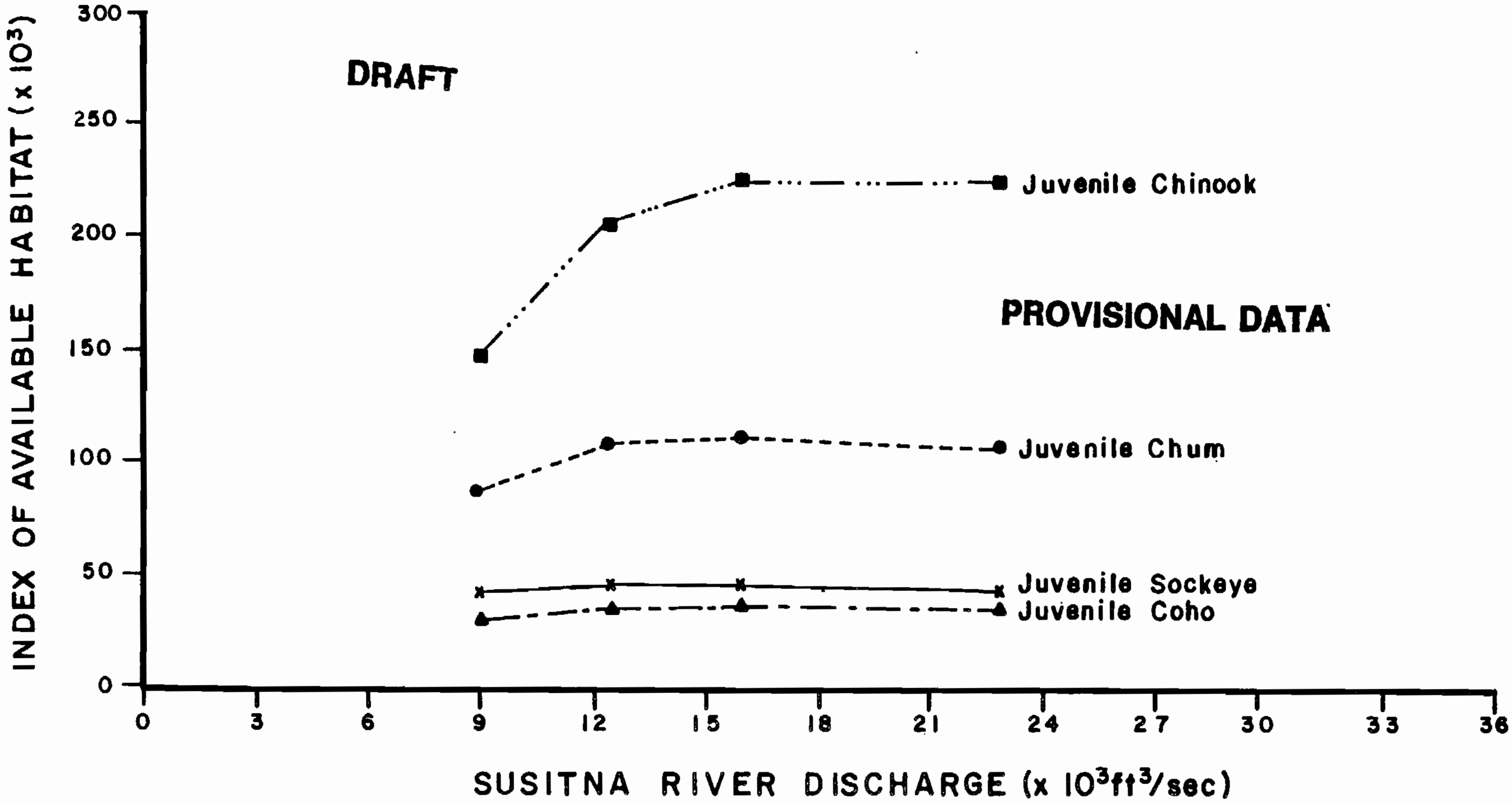


Figure 22. Index of available habitat for juvenile salmon in the Susitna River reach between the Chulitna River confluence and Devil Canyon.

DRAFT

The IAH plots for chum and sockeye and for chinook and chum in the discharge range 16,000 - 23,000 ft^3/sec appear to be relatively flat. This occurs in part because the surface area of side channels and upland sloughs increases with an increase in discharge while the surface area of side slough decreases (Klinger and Trihey 1984). The three tend to balance and the net effect is a flat line.

The index of available habitat for juvenile round whitefish (Figure 23) reflects the strong preference of this fish for side channels. The percent usages for this species were (side channels - 88.6%, side sloughs - 1.0%, and upland sloughs - 10.4%).

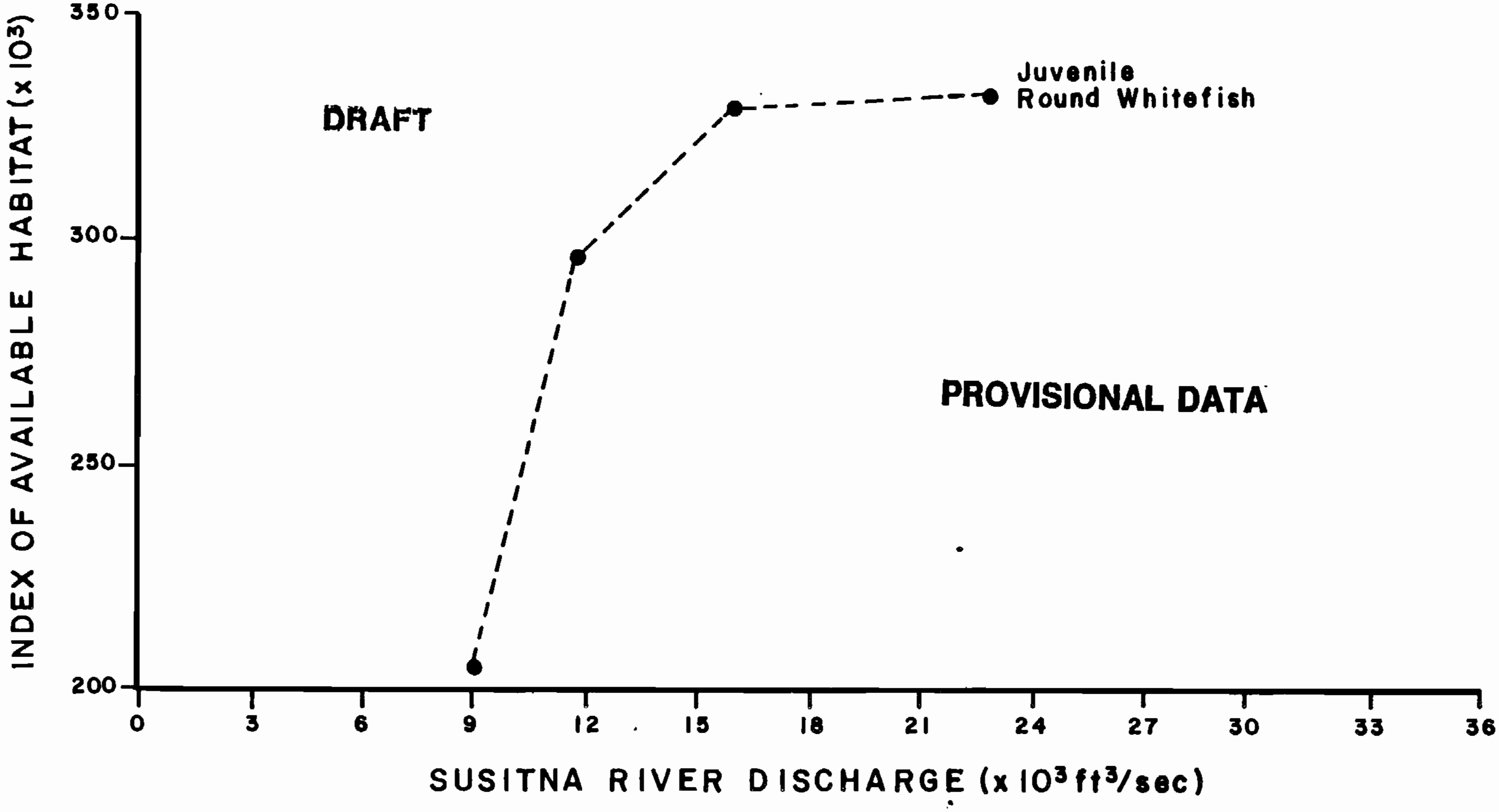


Figure 23. Index of available habitat for juvenile round whitefish in the Susitna River reach between the Chulitna River confluence and Devil Canyon.

4.0 DISCUSSION

4.1 Limitations of the Data

The assumptions of the incremental method of habitat analysis by calculating weighted usable areas have been outlined by Orth and Maughan (1982). As applied here, these assumptions are (1) cover, velocity, and depth are the most important variables affecting fish abundance when flow regime changes are considered; (2) the stream channel is not altered by changes in flow; (3) cover, velocity and depth are independent in their influence on habitat selection by juvenile salmon; (4) the reach can be modelled by reference to a few study areas; and (5) there is a positive relationship between weighted usable areas and habitat use.

The initial assumption is a difficult one to evaluate as changes in flow regime may have important effects on such factors as the food supply by affecting water quality. Turbidity is a factor which may have major direct and indirect effects on fish distribution but which was addressed only for chinook salmon indirectly by its use as cover. Analysis is also specific to the ice-free months and no analysis for effects of winter processes has been made. The importance of bank area cover to the suitability of offshore areas for rearing juvenile coho, for instance, is similarly unknown.

Channel morphometry of the sites studies appeared to be stable during the period of study. At Slough 9, however, an IFG-4 modelling site, large amounts of silt were deposited during a flood event in September 1982 (Estes and Vincent-Lang 1984). Long term changes in channel morphometry are therefore possible.

Cover, velocity, and depth are probably not independent in their influence on habitat selection by young salmonids. Analysis of variance indicated that there is a significant interaction between depth and velocity for juvenile chinook and coho salmon catch (Part 3 of this report). Since depth was set to 1.0 over most of the range, this interaction became of little importance. Other interactions between cover and velocity are also likely. Hopefully, the effects of these interactions on WUA projections are not large.

The fourth assumption of the representativeness of the sites studied was probably not met because of several reasons. The sites studied showed large variations in response to discharge and this variation in response makes the concept of a representative site difficult to formulate. The two upland sloughs, in particular, showed huge differences in response to changes in mainstem discharge (Part 4 of this report). The Susitna River reach under consideration is a vast mosaic of sidechannels, side sloughs, and upland sloughs which overtop at many different discharges. The thirteen sites modelled are representative of a large part of the habitat in this reach but do not include the mainstem or the mid river side channels.

The correlations and proportional presence by weighting factor interval for the four species suggest that there is a positive relationship between the weighted usable area and habitat use at the cell level and, by inference, at the site level. Such factors as season and site are also very important, however, (see Part 2) and much of the variation in catches of fish are not explained by the combined weighting factors.

In summary, some of the assumptions of incremental analysis of habitat may be violated but the effects of these violations on the analysis are difficult to evaluate. The correlation and contingency table analysis, however, suggest that the simulations are related to actual fish use of the sites.

When interpreting the results of the habitat models presented in this paper, it is helpful to consider how close the discharge regime of the open water season of 1983 was to a typical year. Figure 24 shows that June, July, and September discharges were a little lower than the 30 year mean and that the August discharge was higher.

4.2 Comparison of IFG Models with RJHAB

4.2.1 Model Characteristics

A comparison of the characteristics of the IFG models and RJHAB is summarized in Table 4. The IFG models are based on an underlying theory of hydraulics which enables a simulation of conditions that were not actually measured. RJHAB can not simulate physical conditions because cell measurements were not taken in exactly the same physical location each time, and therefore can not be used to project velocities or depths

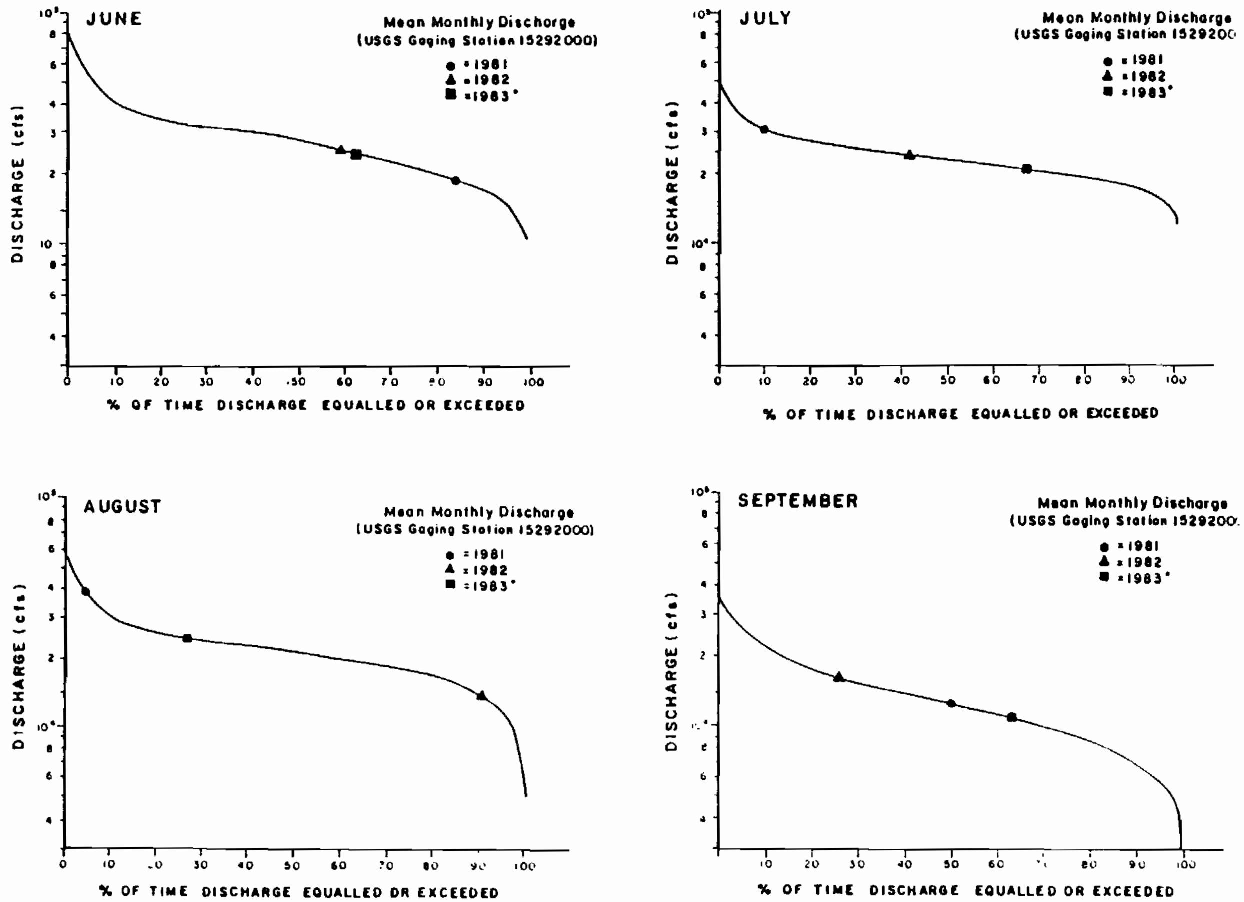


Figure 24. Time duration curves and mean monthly discharges for June, July, August, and September based on the 30 year record of Susitna River discharge at Gold Creek.
Sources: time duration curves - Bredthauer and Drage (1982); mean monthly discharges - USGS (1982), Lamke et al. (1983), and USGS provisional data.

Table 4. Comparison of model characteristics of IFG models and RJHAB.

Parameter	IFG Model	RJHAB
Transects	4 to 11	8 to 9
Measurements	point specific	300 sq ft cells
Data collection	intensive	less intensive
No. of calibration measurements	1 to 4	4 to 6
Extrapolated range	40-250% of calibration range	5,000 to 45,000 cfs
Total surface area	yes	yes
Physical simulation	yes	no
Resolution	fine	coarse
Computer	mainframe	micro
Cost	more	less
Upland sloughs	no	yes
WUA	standardized to 1,000 ft reach	depends on size of site but could be standardized to a 1,000 ft. reach

at a study site. It does, however, model habitat which is based on physical measurements and this habitat can be interpolated between actual measurements.

The results and the verification tests show that RJHAB produces a product which is similar to, and as credible as, the IFG models. The enormous capacity of the IFG models to predict detailed information on depths and velocities is perhaps overkill when the question to be answered is the availability of rearing habitats. Juvenile salmon and resident fish do not necessarily respond to increments of velocity and depth on the order of 0.1 ft/sec or 0.1 ft. Fish will select an area that has a general range of velocities or depths. Further, factors other than the variables simulated by the IFG models, such as food availability, override small differences in depth or velocity in influencing fish density. Restricted access into Slough 8A, for example, caused by beaver dams and lack of overtopping flows limited juvenile chinook use of the site. The IFG models are probably more useful in modelling salmon spawning habitat, where the variables which the IFG model is good at simulating (depth, velocity, substrate) are also important to the fish. The IFG models in 1983 were primarily used to model salmon spawning habitat; hence, the quality of cover data obtained was lower than would have been desirable from the standpoint of rearing habitat. RJHAB was specifically designed to consider the effect of discharge on cover.

Another benefit of RJHAB is that the field data collection effort required is considerably less than of the IFG models. This enabled us to sample a larger range of habitat types in the reach.

4.2.2 Model Output

The output from the IFG models and RJHAB can be directly compared in at least two different ways: 1) compare percent change in weighted usable area over similar increments of mainstem discharge, and 2) compare the habitat index plots. The actual values of WUA are not comparable because the IFG WUA's are standardized to 1,000 ft reaches while RJHAB WUA depends on site size. Also, water depth was used as a factor in RJHAB but not in the IFG models.

Percent changes in weighted usable areas for chinook, chum, and sockeye salmon are shown in Tables 5 to 7. The WUA for the IFG models can be extrapolated down to about 8,000 ft3/sec. The WUA below the overtopping flow is dependent on local hydrology and object cover abundance and is relatively constant at most sites. Therefore, the percent change in WUA for the IFG sites in the range of 8,000 ft^3/sec to the overtopping flow is zero.

The sharp increases in WUA for chinook salmon when the head of the site overtops can be seen in Table 5 for both the IFG models and RJHAB. Changes are less radical for chum and sockeye. The two upland sloughs show a steady increase in WUA as discharge increases. The

Table 5. Status and percent change[a/] in juvenile chinook salmon weighted usable area at IFG and RJHAB sites over 2,000 ft^3/sec increments of mainstem discharge.

Site	Model	Mainstem Discharge ($X10^3$ ft^3/sec)													
		6	8	10	12	14	16	18	20	22	24	26	28	30	32
Lower Side Channel 11	IFG-2	SC	SC -6	SC -15	SC -33	SC -13	SC -13								
Side Channel 10A	RJHAB				SC	SC -8	SC -7	SC -6	SC -6	SC -6	SC -7	SC -11	SC -18	SC -30	
Side Channel 21	IFG-4	SS	SS 46	SS 17	SC 15	SC -15	SC -9	SC -16	SC -1	SC -1	SC 2	SC -8	SC 8	SC 19	
Upper Side Channel 11	IFG-4				SS	SS 30	SC 186	SC 2	SC -8	SC 1	SC 1				
Slough 9	IFG-4						SC	SC 22	SC 2	SC -11	SC -24	SC -22	SC -33	SC 0	
Side Channel 10	IFG-4							SS	SC 560	SC 1	SC -1				
Slough 22	RJHAB								SS	SC 357	SC 156	SC 29	SC -10	SC -48	
Slough 21	IFG-4										SC	SC 7	SC -13	SC -27	SC -41
Whiskers Slough	RJHAB				SS	SS 0	SS 0	SS 0	SS 0	SC 262	SC 145	SC -1	SC -10		

[a/] Status:

SS = Side slough
SC = Side channel

$$\text{Percent change} = \frac{WUA(Q) - WUA(Q-1)}{WUA\ (Q-1)}$$

where: WUA = Weighted usable area
Q = discharge

Table 6. Status and percent change[a/] in juvenile chum salmon weighted usable area at IFG and RJHAB sites over 2,000 ft^3/sec increments of mainstem discharge.

		Mainstem Discharge ($X10^3$ ft^3/sec)													
Site	Model	6	8	10	12	14	16	18	20	22	24	26	28	30	32
Slough 9	IFG-4						SC	SC 22	SC 6	SC 2	SC -5	SC -13	SC -33	SC -11	
Slough 21	IFG-4										SC	SC 8	SC -6	SC -15	SC -33
Slough 8	RJHAB		SS	SS 0	SS 0	SS -1	SS -4	SS -3	SS -4	SS -3	SS -2				

[a/] Status:

SS = Side slough
SC = Side channel

$$\text{Percent change} = \frac{WUA(Q) - WUA(Q-1)}{WUA\ (Q-1)}$$

where: WUA = Weighted usable area
Q = discharge

Table 7. Status and percent change[a/] in juvenile sockeye salmon weighted usable area at IFG and RJHAB sites over 2,000 ft^3/sec increments of mainstem discharge.

		Mainstem Discharge (X10^3 ft^3/sec)													
Site	Model	6	8	10	12	14	16	18	20	22	24	26	28	30	32
Slough 9	IFG-4						SC	SC 7	SC -6	SC -9	SC -14	SC -18	SC -35	SC -6	
Slough 21	IFG-4										SC	SC -5	SC -18	SC -19	SC -32
Slough 8	RJHAB		SS	SS 0	SS 1	SS 11	SS 15	SS 17	SS 20	SS 20	SS 20				
Slough 5	RJHAB		US	US 34	US 26	US 23	US 19	US 17	US 15	US 16	US 17	US 12	US 12		
Slough 6A	RJHAB				US	US 4	US 4	US 5	US 4	US 2					

[a/] Status:

US = Upland slough
SS = Side slough
SC = Side channel

$$\text{Percent change} = \frac{WUA(Q) - WUA(Q-1)}{WUA\ (Q-1)}$$

where: WUA = Weighted usable area
Q = discharge

shallow-banked Slough 5 responds more to a given increment of discharge than does the steep-banked Slough 6A (Table 7).

The results of the IFG models and RJHAB may also be directly compared by examining the habitat index plots. These are the weighted usable areas at a site for incremental levels of mainstem discharge divided by the total surface area of the site at a discharge of 23,000 cfs.

Generally, the shape of the habitat index curves for chinook salmon juveniles are similar for side sloughs and side channels modelled by the IFG models and RJHAB. The habitat index curves in RJHAB are split into side sloughs (heads not overtopped) and side channels (heads over-topped). The habitat index for chinook juveniles is the highest at a discharge level which is slightly higher than that required to overtop the head of the site. This is because chinooks prefer moderate flows and moderately turbid water. As the discharge levels increase further, the velocity at the sites becomes too great and the habitat index decreases.

The habitat indices calculated for coho salmon from RJHAB are generally low. The same would be true from the IFG models, had we calculated them. The highest habitat indices are from the two upland slough sites, Slough 5 and Slough 6A. This is in agreement with the observed distribution of coho salmon; this species is found in low density in turbid waters (see Part 2 of this report).

Chum habitat indices were similar to those for chinook in that a discharge slightly over the overtopping point produced the maximum habitat index.

Sockeye habitat indices were generally low. The highest indices were for upland sloughs, which are the most lake-like of all the macrohabitat types. Generally, this reach of river is not prime sockeye rearing habitat (see also discussion in Part 1 and Part 2 of this report). There are not very many upland sloughs available. Neither the IFG model or RJHAB successfully predicted the heavy use of side sloughs by sockeye juveniles. This use is more a result of the fact that side sloughs are the dominant sockeye spawning grounds in this reach of river than the quality of the rearing habitat available in side sloughs.

Sockeye habitat indices increased in side sloughs with increasing discharge as surface area increased. After the heads of the sites were overtopped by mainstem water, the habitat index started to decline sooner than did the habitat indices for chinooks and chums. This reflects the preference of sockeye juveniles for lower velocity water than the other two species.

Habitat indices for all species in upland sloughs increase steadily as mainstem discharge increases. This is strictly a function of increased surface area attributable to the backwater effect of mainstem stage at the mouth of these sites. Similar results were obtained by the 1982 study that specifically examined the effect of the backwater phenomenon on rearing habitat (ADF&G 1983c).

4.3 Available Habitat in the Middle River Reach.

A cursory glance at the plots of the Index of Available Habitat (Figure 22) indicates that the mainstem influenced habitat in this reach during the open water season provides the best rearing habitat for chinook juveniles followed by chums. Sockeye and coho rearing habitat is limited. This agrees with the present information available about the reach. There are some unresolved questions about the viability of sockeye rearing in the reach. Most sockeye fry outmigrate from this area during their first summer. Coho juveniles apparently rear primarily in tributaries, but will take advantage of the upland slough habitat that is available. If the trends shown continue below a discharge level of 9,000 ft^3/sec, then chinook and chum habitat would approach the level of sockeye and coho at a mainstem discharge of around 6,000 ft^3/sec.

The index of available habitat (IAH) does not include the habitat in tributaries, so in fact the available rearing habitat in the Susitna basin above the Chulitna confluence is substantially larger for chinook, coho, and chum than the index indicates. Sockeyes do not use tributaries for rearing to any great extent, so their available habitat is as low as is indicated.

One problem with the side channel macrohabitat as defined by Klinger and Trihey (1984) is that this habitat type occupies a large part of the river, including channels out in the middle which were essentially devoid of any cover besides substrate and which had no clear water input. These sites were also much wider channels with larger flows than the sites modelled, with the exception of Lower Side Channel 11. The side channels in which fish data were collected in 1982 and 1983 were almost always near the shore, less than 100 ft wide, and with bank and overhanging cover. The model sites often had some sort of clear water input, from a small tributary , upwelling, or hillside runoff. The cover and secondary water sources (and associated invertebrates) are important to rearing juvenile salmon. A second problem is that the heads of the side channels where the fish data were collected as a rule tended to overtop at a higher discharge than many of the mid-river side channels. Therefore, the fish collection side channels were actually side sloughs a higher proportion of the time than were many of the mid-river side channels. The effect of these two qualifications on the results is that the index of available habitat in mainstem affected areas is probably overestimated.

As mentioned earlier, the flat response of the coho and sockeye IAH plots over the discharge range 9,000 to 23,000 ft^3/sec is in part a result of the balancing of an increase in two macrohabitat types by the decrease in another. If in fact the fish could exactly compensate for the loss of one macrohabitat type by the addition of another, then there would be no net effect on the fish. However, it does not seem likely that it could happen. We suggest that there is a minimal percentage of weighted usable area of a reach of river that is required before any appreciable rearing value is obtained. Therefore, increases of area of low quality habitat may over estimate actual usable habitat.

This index of available habitat is only valid during the open water season. Although few data on winter distribution are available, there are strong indications of substantial changes in macrohabitat use during the winter. The discharge regime is much reduced and the mainstem water becomes clear. Many chinook and coho juveniles move out of tributaries to overwinter in the mainstem. There appears to be a trend in the fall that has been noticed for three consecutive years in which chinook and coho move into the deeper slough areas. There may be a thermal attraction produced by upwelling water in the sloughs.

As mentioned previously, a more sophisticated analysis of available habitat in the reach which incorporates the macrohabitat surface area measurements with available habitat at the modelling sites will be included in the final version of this report.

4.4 Summary of Seasonal Habitat Projections for Rearing Salmon and Resident Fish

An examination of the figures in which chinook weighted usable area is plotted versus mainstem discharge and versus time of season shows that some sites provide the most weighted usable area when discharge is low (e.g., Lower Side Channel 11), some when discharge is at an intermediate level (e.g., Slough 9), and some when discharge is high (e.g., Slough 21). The controlling factor is the discharge at which the head of the site is overtopped. Most sites had their maximum weighted usable area at a flow slightly greater than the overtopping flow. Therefore, chinook weighted usable area in the reach of river would theoretically be the highest at the discharge level which just overtops the maximum number of sites. This should be weighted by the wetted surface area of each site.

There is undoubtedly a correlation between a decline in weighted usable area at the rearing sites and re-distribution of juvenile salmon. If a rearing area is essentially saturated by fish and then weighted usable area decreases, some fish are forced to leave. We have observed this at sites such as Slough 22 where chinook juveniles were abundant when the head was overtopped and less abundant when mainstem water no longer entered the slough and the water cleared. Also, we have demonstrated a positive correlation between combined weighting factors and juvenile salmon density.

The fish that are forced out of a certain site will either seek a new rearing site or perhaps, under more extreme conditions, migrate out of that reach of river. In the latter situation, one should be able to see an increase in the capture rate at the downstream migrant traps. It is difficult to see such a relationship with the 1983 data. The outmigration rate of chinook juveniles was relatively low when the weighted usable area at Slough 9 was high and the outmigration rate was high when WUA at Slough 9 was lowest (disregarding the month of September, when discharge was low). However, this relationship was reversed at other sites. Ideally, only the best rearing sites should be considered in this approach. This relationship may also be obscured by major outmigrations from the tributaries which have little to do with changes in mainstem conditions.

There is also the larger question of whether in fact rearing habitat is limiting to salmon. If the number of fry emerging from the gravel is not enough to saturate the available rearing habitat, then there would be more flexibility with regard to varying discharges. In our experience, both saturation and under-utilization of rearing habitat occurs. A partial explanation is that there is no substantial amount of spawning above the upper end of this reach. Therefore, when waves of juvenile chinook and coho migrate out of Portage Creek, they probably saturate a certain portion of the available rearing habitat in the Susitna River downstream of the Portage Creek confluence until they have had sufficient time to re-distribute further downstream. During other periods of time, when few fish are migrating out of Portage Creek, rearing areas in the upper end of the reach may not be saturated. We have observed this at such sites as Slough 22 and Slough 21 when habitat conditions appeared to be relatively good (and weighted usable area was high); yet, few fish were captured.

It seems almost certain that rearing habitat is limiting for sockeye juveniles in this reach of river. The deeper, low velocity, relatively clear water that they prefer does not occur in the reach in large quantities (Klinger and Trihey 1984). A high proportion of the young-of-the-year fish leave this reach (based on downstream migrant trap catch rates, see Part 2). The Age 0+ fish must either rear in the lower river or die, because only a miniscule number of adult sockeyes migrating upstream past the Talkeetna Station outmigrated to the ocean as Age 0+ fish. The majority of adults are 4_2's (Barrett et al. 1984).

It has been conclusively shown (Part 1) that chum salmon rear in this reach of river because they show a substantial increase in length between emergence and outmigration. Rearing habitat for chum salmon, however, is probably not limiting in this reach because almost all chums outmigrate with the discharge peaks which occur in May, June, and early July. The correlation of chum catch per hour at the outmigrant traps and discharge was high (r^2 = 0.79, see Part 2), suggesting that high water events displace or trigger outmigration by chums rather than contribute to suitable habitat. If rearing habitat became restricted because of low discharge, the fish would probably leave this reach later rather than sooner because of the lack of a high water pulse that might trigger outmigration.

Resident fish use of both microhabitat and macrohabitat is closely linked to turbidity (see Part 6 of this report). Juvenile round whitefish, for instance, are almost never found in clear water except perhaps when stranded by rapid decreases in mainstem stage. They are found in the small side channels which have a low flow, and so distribution is tied to discharges at which the heads of these side channels are slightly overtopped. Adult resident fish also make very little use of side sloughs and so increases in side channel habitat with increases in discharge are more favorable for them.

The use of side sloughs by most species of adult resident fish is probably limited by the very small amounts of flow through these sites. As heads are overtopped and flows increase, the sites rapidly become more favorable for adult resident fish. These fish also use portions of the mainstem for rearing. The rearing habitat may be limiting but this is not likely due to lack of suitable open water season cover, depths, or velocities. It is much more likely to be due to other factors such as overwintering mortality or food supply, as densities of residents are low almost everywhere in mainstem influenced sites with the exception of selected tributary or slough mouths where fish may gather to feed on salmon eggs, outmigrating juvenile salmon, or perhaps invertebrates.

The results presented in this part and the data and analysis supplied in parts one through six of this report suggest the following trends:

(1) Of the salmon juveniles rearing in the Susitna River, chinook and chum appear to be most abundant in habitats associated with the mainstem and also have the most abundant adult returns (even year pink salmon excluded) in this reach of the river.

(2) Sockeye salmon appear to be most heavily limited by rearing habitat with highly successful incubation but limited rearing occurring in this reach of river. Apparently, rearing survival is low or takes place in the lower river. Successful rearing does occur within limited portions of some of the upland and clear water sloughs but is apparently minor when compared to the total population of emergent fry.

(3) Of the habitats affected by mainstem discharge, microhabitat within side channels is most affected, primarily by dewatering, lowered turbidity, and lower water veocity after the head is no longer breached by mainstem flows. This habitat is most heavily used by

chinook juveniles who appear to be limited by cover when the sites are not turbid (generally associated with the heads not being breached). Maximum habitat value for chinook salmon is obtained just prior to the head dewatering of the side channels.

(4) Wintering habitat for all rearing species is heavily dependent on mainstem habitats as indicated by spring and fall migratory movements. The models presented have not been designed to evaluate habitat conditions during the winter.

(5) Resident species using mainstem habitat areas are most predictively associated with levels of turbidity and appear limited by food supply. They often associate with the mouths of clear water tributaries or with spawning salmon. The response of primary productivity of the system may be more indicative of the response of resident species than the values generated by habitat simulation based on hydraulic models.

The results and discussion presented in this report do not conclude the analytical effort required to use this information in a decision making process. It remains to integrate these results with the studies conducted on adult anadromous spawning and to further extrapolate our study sites to the entire reach of river from which they were chosen to represent. Further, these results must be weighted with respect to the importance of the harvestable adults of each species. Finally, these results must be portrayed in such a manner as to depict the effects of alternative flow regimes on different species so that the flow requirements of different management goals can be ascertained.

Future reports prepared by other investigators will use this report to ultimately provide the above information.

5.0 CONTRIBUTORS

IFG hydraulic model data collection was done by the Aquatic Habitat Group of the Su Hydro Aquatic Studies. Kim Sylvester of the AH group and Diane Hilliard of E. Woody Trihey and Associates calibrated the hydraulic models. Diane Hilliard input cover data, the suitability criteria, and ran the PHABSIM habitat models which generated weighted usable areas.

Drafting was done by Sally Donovan and the typing was done by Skeers Word Processing.

6.0 ACKNOWLEDGEMENTS

Funding for this study was provided by the Alaska Power Authority.

7.0 LITERATURE CITED

Alaska Department of Fish and Game. 1983a. Susitna Hydro aquatic studies phase II basic data report. Volume 4 (3 parts). Aquatic habitat and instream flow studies, 1982. Alaska Department of Fish and Game Susitna Hydro Aquatic Studies. Anchorage, Alaska.

_____ 1983b. Use of major habitat types by juvenile salmon and resident species. Appendix G to Synopsis of the 1982 aquatic studies and analysis of fish and habitat relationships (2 parts). Alaska Department of Fish and Game Susitna Hydro Aquatic Studies. Anchorage, Alaska.

_____ 1983c. Influence of habitat parameters on distribution and relative abundance of juvenile salmon and resident species. Appendix F to Synopsis of the 1982 aquatic studies and analysis of fish and habitat relationships (2 parts). Alaska Department of Fish and Game Susitna Hydro Aquatic Studies. Anchorage, Alaska.

Barrett, B.M., F.M. Thompson, and S.N. Wick. 1984. Adult anadromous fish investigations: May - October 1983. Alaska Department of Fish and Game Susitna Hydro Aquatic Studies. Report No. 1. Prepared for Alaska Power Authority. Alaska Department of Fish and Game, Anchorage, Alaska.

Bovee, K.D. 1982. A guide to stream habitat analysis using the Instream Flow Incremental Methodology. Instream Flow Information Paper 12. U.S.D.I. Fish and Wildlife Service, Office of Biological Services. FWS/OBS - 82/26.

Bovee, K.D., and R.T. Milhous. 1978. Hydraulic simulation in instream flow studies: theory and techniques. Instream Flow Information Paper 5. U.S.D.I. Fish and Wildlife Service, Office of Biological Services. FWS/OBS - 78/33.

Bredthauer, S., and B. Drage. 1982. Susitna Hydroelectric Project. Appendix B.9. River Morphology. Report prepared for Acres American, Inc. by R&M Consultants, Anchorage, Alaska.

Estes, C., K. Hepler, and A. Hoffman. 1981. Willow and Deception Creeks instream flow demonstration study. Volume 1. Alaska Department of Fish and Game, Habitat Protection and Sport Fish Divisions. Prepared for the U.S. Department of Agriculture, Soil Conservation Service, Interagency Coop. Susitna River Basin Study.

Estes, C.C., and D.S. Vincent-Lang (eds.). 1984. Aquatic habitat and instream flow investigations, May - October, 1983. Alaska Department of Fish and Game Susitna Hydro Aquatic Studies. Report No. 4. Prepared for Alaska Power Authority. Alaska Department of Fish and Game, Anchorage, Alaska.

Klinger, S., and W. Trihey. 1984. Response of aquatic habitat surface areas to mainstem discharge in the Talkeetna to Devil Canyon reach of the Susitna River, Alaska. Report prepared for Alaska Power Authority by E. Woody Trihey and Associates, Anchorage, Alaska.

Lamke, R.D., P.J. Still, B.B. Bigelow, H.R. Seitz, and J.E. Vail. 1983. Water resources data. Alaska. Water Year 1982. U.S. Geological Survey Water - Data Report AK-82-1. USGS, Anchorage, Alaska.

Orth, D.J., and O.E. Maughan. 1982. Evaluation of the incremental methodology for recommending instream flows for fishes. Transactions of the American Fisheries Society. 111: 413-445.

U.S. Geological Survey. 1982. Water resources data. Alaska. Water Year 1981. U.S. Geological Survey Water - Data Report AK-81-1. USGS, Anchorage, Alaska.

Wesche, T.A. 1976. Development and application of a trout cover rating system for IFN determinations. Pages 224-234 in J.F. Orsborn and C.H. Allman, editors. Instream flow needs. Vol. 2. Western Division, American Fisheries Society, Bethesda, Maryland, USA.

Wilson, W.J., E.W. Trihey, J.E. Baldridge, C.D. Evans, J.G. Thiele, and D.E. Trudgen. 1981. An assessment of environmental effects of construction and operation of the proposed Terror Lake hydroelectric facility, Kodiak, Alaska. Instream Flow Studies final report. Arctic Environmental Information and Data Center. University of Alaska, Anchorage.

Appendix Table 1. Suitability indices for juvenile salmon for cover, velocity, and depth.

		Cover Suitability					
Cover type	% Cover	PHABSIM Code	Chinook (high turbidity)	Chinook (low turbidity)	Coho	Sockeye	Chum
No cover	0-5%	1.1	0.45	0.01	0.00	0.11	0.29
Emergent veg	0-5%	2.1	0.57	0.01	0.03	0.18	0.29
	76-100%	2.5	1.00	0.12	0.29	0.47	0.53
Aquatic veg	0-5%	3.1	0.57	0.07	0.07	0.39	0.29
	76-100%	3.5	1.00	0.68	0.65	1.00	0.53
Debris/deadfall	0-5%	4.1	0.57	0.11	0.10	0.19	0.47
	76-100%	4.5	1.00	1.00	0.90	0.49	0.87
Overhanging reparian veg	0-5%	5.1	0.57	0.06	0.04	0.30	0.40
	76-100%	5.5	1.00	0.61	0.38	0.78	0.74
Undercut banks	0-5%	6.1	0.57	0.10	0.12	0.11	0.40
	76-100%	6.5	1.00	0.97	1.00	0.29	0.74
Large gravel (1-3")	0-5%	7.1	0.57	0.07	0.03	0.17	0.37
	76-100%	7.5	1.00	0.63	0.24	0.44	0.68
Rubble (3-5")	0-5%	8.1	0.57	0.09	0.02	0.12	0.54
	76-100%	8.5	1.00	0.81	0.18	0.30	1.00
Cobble or boulder (5")	0-5%	9.1	0.57	0.09	0.02	0.11	0.46
	76-100%	9.5	1.00	0.89	0.18	0.29	0.86

Appendix Table 1 (continued)

VELOCITY

Chinook (Turbid)		Chinook (clear)		Coho		Sockeye		Chum	
Velocity (ft/sec)	Suitability	Velocity (ft/sec)	Suitability	Velocity (ft/sec)	Suitability	Velocity (ft/sec)	Suitability	Velocity (ft/sec)	Suitability
0.00	0.42	0.00	0.18	0.00	0.29	0.00	1.00	0.00	0.86
0.05	1.00	0.20	0.57	0.05	1.00	0.05	1.00	0.05	1.00
0.35	1.00	0.35	1.00	0.35	1.00	0.20	0.71	0.35	1.00
0.50	0.80	0.65	1.00	0.50	0.88	0.50	0.48	0.50	0.87
0.80	0.38	0.80	0.68	0.80	0.55	0.80	0.36	0.80	0.70
1.10	0.25	1.10	0.44	1.10	0.32	1.10	0.27	1.10	0.56
1.40	0.15	1.40	0.25	1.40	0.12	1.40	0.17	1.40	0.37
1.70	0.07	1.70	0.18	1.70	0.04	1.70	0.09	1.70	0.15
2.00	0.02	2.00	0.12	2.00	0.01	2.00	0.02	2.00	0.03
2.30	0.01	2.30	0.06	2.10	0.00	2.10	0.00	2.10	0.00
2.60	0.00	2.60	0.00						

DEPTH ALL SPECIES

Depth (ft)	Suitability
0.00	0.00
0.14	0.00
0.15	1.00
10.00	1.00

Appendix Table 2. Suitability indices for resident species for cover, velocity, and depth.

		Cover Suitability								
		adult rainbow		adult	adult round whitefish		juvenile round whitefish		adult longnose suckers	
Cover type	PHABSIM Code	clear	turbid	grayling	clear	turbid	clear	turbid	clear	turbid
No cover	1.	0	0.33	0.01	0.01	1.00	0	1.00	0.03	0.66
Emergent veg	2.	0	0.33	0.13	0.01	1.00	0	1.00	1.00	1.00
Aquatic veg	3.	0	0.33	0.13	0.01	1.00	0	1.00	1.00	1.00
Debris/ deadfall	4.	0.62	0.62	0.12	0.01	1.00	0	1.00	0.87	0.66
Overhanging reparian veg	5.	0.62	0.62	0.12	0.01	1.00	0	1.00	0.87	0.66
Undercut banks	6.	0.62	0.62	0.12	0.01	1.00	0	1.00	0.87	0.66
Large gravel (1-3")	7.	0	0.33	0.01	0.01	1.00	0	1.00	0.03	0.66
Rubble (3-5")	8.	1.00	1.00	0.87	0.18	1.00	0	1.00	0.04	0.66
Cobble or boulder (>5")	9.	0.70	0.70	1.00	1.00	1.00	0	1.00	0.05	0.66

Appendix Table 2. (Continued)

VELOCITY

Adult					Juvenile	
Velocity (ft/sec)	Rainbow trout suitability	Arctic grayling suitability	Round whitefish suitability	Longnose sucker suitability	Velocity (ft/sec)	Round whitefish suitability
0.00	0.31	0.01	1.00	1.00	0	1.00
0.50	0.31	0.28	1.00	0.23	0.05	1.00
1.50	0.40	0.37	1.00	0.11	0.20	0.52
2.50	0.71	0.47	1.00	0.06	0.50	0.16
3.00	1.00	1.00	1.00	0.04	0.80	0.07
4.00	1.00	1.00	1.00	0.01	1.10	0.04
4.50	0.00	0.00	0.00	0.00	1.40	0.00

DEPTH

Adult		Juvenile	
Depth (ft)	All resident fish suitability	Depth (ft)	Round whitefish suitability
0	0	0	0.00
0.5	0	0.15	1.00
0.6	1.00	0.50	1.00
10.0	1.00	0.75	0.42
		1.25	0.35
		1.75	0.33
		2.50	0.31
		10.0	0.31