PART 2

The Relative Abundance, Distribution, and Instream Flow Relationships of Juvenile Salmon in the Lower Susitna River.

THE RELATIVE ABUNDANCE, DISTRIBUTION, AND INSTREAM FLOW RELATIONSHIPS OF JUVENILE SALMON IN THE LOWER SUSITNA RIVER

Report No. 7, Part 2

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ABSTRACT

Juvenile salmon abundance and distribution were studied in the lower Susitna River (below the Chulitna River confluence) and juvenile salmon rearing habitat was modelled at 20 sites within the reach. Chinook, chum, and sockeye salmon juveniles made use of side channels; however, high turbidity limited use of side channels located in the Chulitna River plume. Coho salmon juveniles were found primarily in tributary mouths; sockeye, chinook, and chum salmon also were present in these areas. Sloughs, which were limited in occurrence, were not used heavily by any of the salmon species.

Both tributary mouths and side channel/slough sites were modelled using one of two habitat models. At tributary mouths, an increase in weighted usable area with a rise in mainstem discharge resulted from the formation of backwater areas which led to lower velocities and an expansion of the area and amount of cover inundated. At side channels, chinook weighted usable area increased after overtopping due to a gain in cover suitability (turbidity), velocity, and area. The weighted usable area response to a rise in mainstem discharge for sockeye and chum salmon juveniles at side channels was also usually positive. Habitat indices at side channels for chinook, chum, and sockeye juveniles at mainstem discharges and side channel flows above the overtopping discharge declined as velocities became unsuitably high. Weighted usable area for these species did not always decline at high discharges, however, because of the compensating effect of a larger surface area.

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1.0 INTRODUCTION

The Susitna River Aquatic Studies Program juvenile anadromous distribution and abundance studies initiated during 1981 and 1982 outlined the general distribution patterns of juvenile salmon and their habitat utilization within the Susitna River (ADF&G 1981a, 1981b, 1983a, 1983b). The 1982 studies also investigated the response of selected areas to mainstem discharge changes and demonstrated species differences in the use of "hydraulic zones" (ADF&G 1983c). These zones were subsections of slough and tributary mouth areas. Some zones were affected by mainstem backwater, other zones were above the backwater, and other zones included mixing areas of the mainstem with slough or tributary flow. The relative use of the hydraulic zones by each species of juvenile salmon was analyzed to provide an incremental index of habitat availability at each site for each species. This analysis provided evidence that the relative use by juvenile salmon of these sites was affected by changes in mainstem discharge. Also, the distribution of juvenile salmon suggested certain microhabitat factors within the zone such as turbidity and the amount of instream cover responded to discharge changes at a higher rate than did zone surface area.

Studies conducted during the 1983 open-water season concentrated on the instream flow relationships of juvenile salmon in the middle reach of the Susitna River between the Chulitna River confluence and Devil Canyon (Schmidt et al. 1984). Suitability criteria for juvenile salmon were developed and these were used in two types of habitat models to model the site-specific response of juvenile salmon habitat to variations in mainstem discharge. Additional information was gathered on juvenile salmon abundance and distribution in the middle reach.

The 1983 studies suggested that juvenile chinook salmon made heavy use of mainstem side channels and used the turbid water in these areas as cover. Juvenile coho, chum, and sockeye salmon tended to occupy areas that were less influenced by mainstem flow.

In the Susitna River below the Chulitna River confluence (lower river), the braided nature of the river and lower gradient provides large amounts of potential side channel habitat for juvenile salmon. A study plan was formulated, therefore, to examine juvenile salmon distribution and the usability of different morphological components of the lower Susitna River for juvenile salmon during the 1984 open-water season. The results of these studies, which include the responses of rearing juvenile salmon and their habitat within these morphological components to variations in mainstem discharge, are detailed in this paper. These results will be integrated with responses of side channel and slough complex wetted surface areas to variations in mainstem discharge in order to estimate the response of juvenile salmon habitat in the lower river to flow regulation.

Large scale aerial mapping of lower Susitna River side channel and slough complex changes in area with variations in mainstem discharge has been done by Ashton and Klinger-Kingsley (1985). Habitat types identified in the mapping included tributaries, tributary mouths, side sloughs, primary side channels, secondary side channels, clearwater areas, and turbid backwaters. Tributaries, tributary mouths, and side sloughs were defined as in the middle river by Klinger and Trihey (1984). Primary side channels have characteristics similar to the mainstem in the middle river and therefore offer little potential habitat for juvenile salmon and are not discussed in this report. Turbid backwaters are unbreached channels which contain turbid water from being overtopped at higher mainstem discharges and therefore are a transitional habitat type between secondary side channels and side sloughs or clearwater areas. Turbid backwaters are not addressed in this report but their habitat values are probably similar to barely breached side channels. Clearwater areas were also not sampled but are thought to have habitat value similar to that of side sloughs.

The major emphasis of this report is the evaluation of juvenile salmon use of secondary side channels and their related habitat values. Some of the larger secondary side channels are considered primary side channels at higher mainstem discharges. Juvenile salmon use of tributary mouths and side sloughs was also evaluated. The macrohabitat evaluation data presented here will be integrated with the aerial mapping data contained in Ashton and Klinger-Kingsley (1985) in later reports to formulate the reach-wide response of juvenile salmon habitat to discharge variations.

2.0 METHODS

2.1 Field Sampling Design

Three Juvenile Anadromous Habitat Study (JAHS) field crews, composed of two biologists, examined rearing habitats used by juvenile salmon at selected side channels, tributary mouths, sloughs, and mainstem sites of the Susitna River between the Yentna River confluence (RM 28.5) and Chulitna River confluence (RM 98.5). JAHS sampling was conducted from river boats during the open-water season, with helicopter support enlisted as needed. The crews operated out of camps located on the Susitna River at the Deshka River (RM 40.6), Sunshine Station (RM 79.0), and Talkeetna (RM 97.5).

The JAHS field crews sampled three categories of sampling sites. Most of the sampling occurred at Resident Juvenile Habitat (RJHAB) model sites where the response of the site to changes in mainstem discharge was evaluated along with juvenile salmon use of the site. Crews also sampled Instream Flow Incremental Methodology (IFIM) model sites for fish distribution and abundance at which hydraulic habitat models were developed. The third category of sites, at which further data on fish distribution and habitat were gathered, were known as "opportunistic" sites. Further details on specific sampling techniques and methods used in the JAHS studies are given in earlier reports (ADF&G 1984a, 1984b).

2.1.1 Study locations and selection criteria

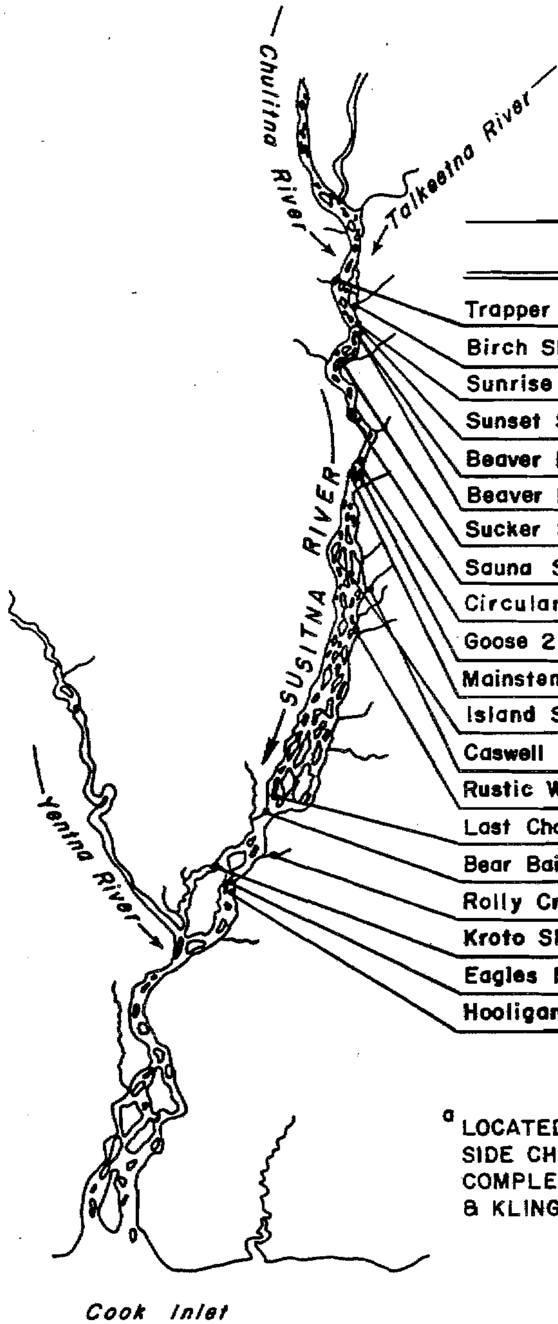
The sampling sites modelled were chosen from side channels, tributary mouths, and side sloughs, which met the following basic criteria:

A. The effects of mainstem discharge (stage and flow) on the sites are measurable.

B. The sites are documented or thought to contain potential habitat for rearing juvenile salmon. Sites with extremely high (>3 feet/sec) velocities were assumed to have little value and were not evaluated.

C. The sites are accessible by boat at normal mainstem discharges during the open-water season.

The 20 sites modelled with RJHAB and IFIM models were distributed between the Yentna River confluence and Talkeetna (Figure 1). Fourteen of the sites were modelled only with the RJHAB model, four with only IFIM models, and two with both RJHAB and IFIM models. Eight of the sites are located within slough or side channel complexes which were picked by R&M Consultants and E.W. Trihey and Associates as representative of lower Susitna River slough or side channel complexes for extrapolation purposes. For purposes of extrapolation, the side channel complex area data need to be integrated with the habitat modelling data by comparing breaching flows and channel size and type between modelled sites and individual channels within the representative complexes.



SITE	RIVER MILE	MODEL	
		RJHAB	IFIM
Trapper Creek S.C.	91.6	X	X
Birch Slough[a]	88.4	X	
Sunrise S.C.[a]	87.0	X	
Sunset S.C.[a]	86.9		X
Beaver Dam Slough[a]	86.3	X	
Beaver Dam S.C.[a]	86.3	X	
Sucker S.C.[a]	84.5	X	
Sauna S.C.	79.8		X
Circular S.C.	75.3		X
Goose 2 S.C.	74.8	X	
Mainstem West Bank	74.4		X
Island S.C.	63.2	X	X
Caswell Creek Mouth[a]	63.0	X	
Rustic Wilderness S.C.	59.5	X	
Last Chance S.C.	44.4	X	
Bear Bait S.C.	42.9	X	
Rolly Creek Mouth	39.0	X	
Kroto Slough Head	36.3	X	
Eagles Nest S.C.[a]	36.2	X	
Hooligan S.C.[a]	35.2	X	

[a] LOCATED WITHIN REPRESENTATIVE SIDE CHANNEL OR SLOUGH COMPLEXES MAPPED BY ASHTON & KLINGER-KINGSLEY (1985).

Figure 1. Location of study sites on the lower Susitna River at which juvenile salmon habitats were modelled, June through October 1984.

Proportionately more sampling effort was expended within smaller side channels in this study because that is where potential habitat is greatest. Only a portion of the habitat modelling sites were selected to occur within the representative complexes because further data on distribution of juvenile salmon at locations throughout the lower river were desired.

Four of the sites were normally clear-water sloughs or tributary mouths while the other sites were turbid secondary side channels at normal summer flows. Secondary side channels selected for sampling ranged greatly in size, shape, and overtopping discharge. The majority of the habitat model sites selected were secondary side channels because most of the potential habitat for juvenile fish in areas of the lower Susitna River affected by the mainstem is composed of secondary side channels. Primary side channel and mainstem velocities were so high that they were not considered viable habitat.

Opportunistic sampling sites were selected by sampling crews as potential habitat which upon sampling might provide for a better analysis of fish abundance and distribution. Sites sampled were more diverse than the RJHAB and IFIM model sites and included areas within alluvial island complexes.

2.1.2 Field data collection

2.1.2.1 Resident Juvenile Habitat (RJHAB) model sites

Two types of data were collected at RJHAB model sites. Habitat data were collected for the purpose of modelling the response of the site to changes in mainstem discharge. Fish distribution data were collected for use in verifying the habitat model data, documenting abundance and distribution, and modifying suitability criteria, if necessary. A discussion of the techniques used in the collection of habitat modelling data will be followed by a discussion of methodology used in the collection of fish sampling data.

Each of the RJHAB sites was sampled within a grid consisting of a series of transects with associated sampling cells which intersect the channel of the study site at right angles (Figure 2). Grids were located so that water quality within them was uniform and so that they encompassed a variety of habitat types. Survey stakes and orange flagging were used to mark each transect within a grid. Initial measurements within each grid included distances and angles between transect bench marks. Transects were spaced from 50 to 300 feet apart in order to encompass a variety of habitat types within each grid. Aerial photos of all the RJHAB sites showing placement of all transects within each site are presented in Quane et al. (1985).

Up to four 6-by-50 foot rectangular sampling cells extending upstream from every transect within each grid were characterized by habitat measurements (Figure 2). If the top width of the wetted channel was greater than 42 feet, two of the four cells paralleled both edges of the channel and the third and fourth cells were located parallel to the shoreline cells so as to split the channel into thirds. If the channel

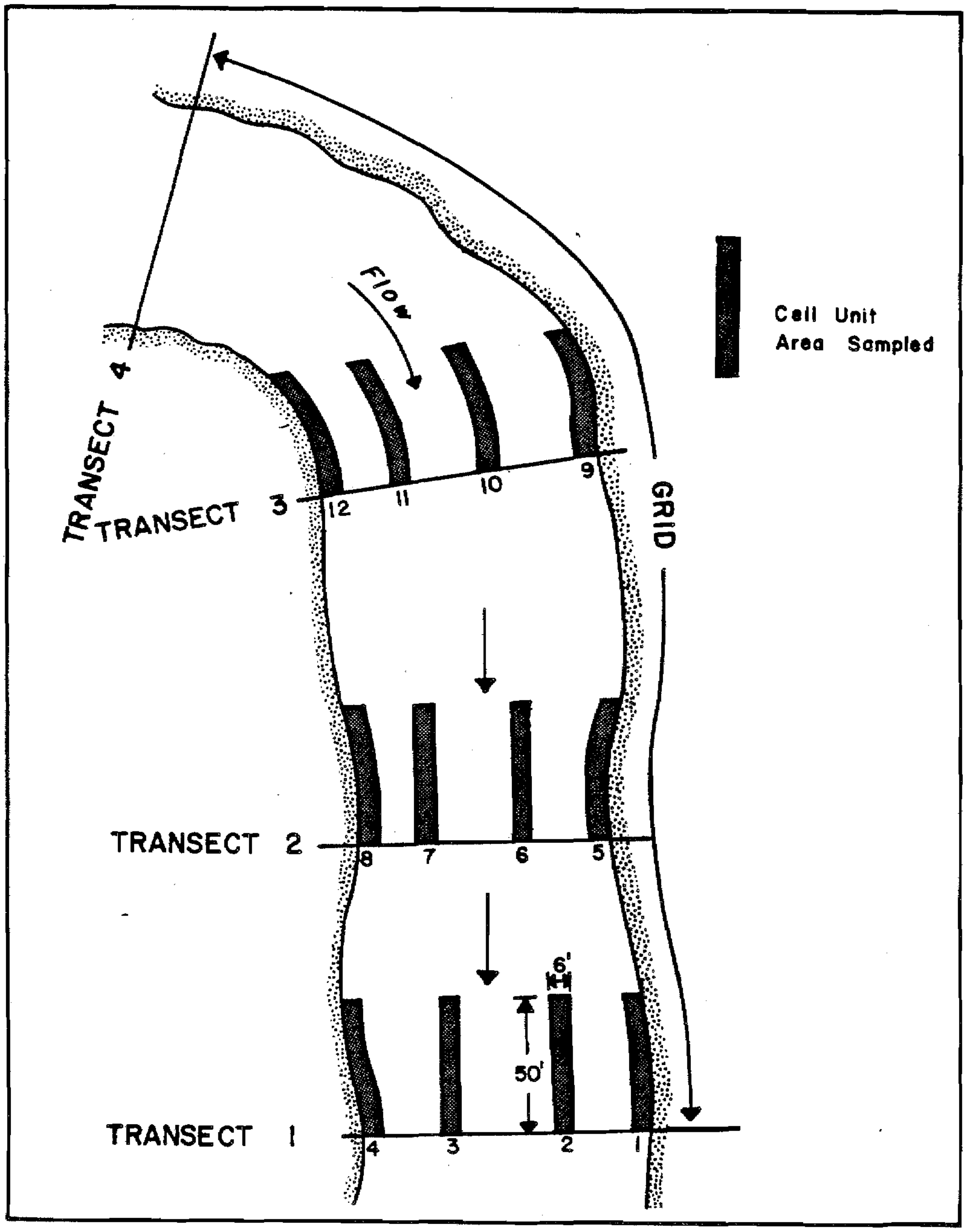


Figure 2. Arrangement of transects and sampling cells within a grid at a hypothetical RJHAB modelling site.

measured 30 to 41 feet in width at the transect, there was a cell on each shoreline of the channel and one cell located approximately mid channel. If the wetted edge was 18 to 29 feet in width, there was one cell on each side of the channel parallel with the bank. If the channel was less than 18 feet in width, there was only one cell.

Transects were numbered consecutively beginning with the transect furthest downstream within the site. Cells were also numbered consecutively from right to left looking upriver. If there were less than four cells within a transect, cells were numbered as if the missing cells were present.

One or more staff gages were installed by Aquatic Habitat and Instream Flow Project (AH) personnel at each site to document changes in the stage at each site with changes in mainstem discharge. These gages provided an index to the changes in habitat and hydraulic conditions at the site between sampling occasions. AH staff also developed mainstem stage and site flow relationships and mapped the thalweg at selected sites.

Habitat modelling data were collected over a broad range of mainstem discharges. Emphasis was placed on data collection at mainstem discharges of 30,000 to 60,000 cfs as measured at the Sunshine USGS gaging station. When staff gage readings and observations indicated that the stage at the site had changed little from a previous sampling occasion, no habitat data were taken.

Habitat data taken at each grid on a modelling occasion included the following. At each transect, the distance between the left and right edge of water and the left bank transect marker was measured. If the water quality within the grid or grids was uniform, one measurement of water pH, temperature, conductivity, and dissolved oxygen was taken. A turbidity sample was collected in a 250 ml plastic bottle and stored in a cool dark location for up to two days prior to analysis. Turbidity was measured in nephelometric turbidity units (NTU) with an HF Instruments Model No. DRT-15B field turbidometer. If the water quality within the grid appeared to vary because of mixed water sources, additional water quality and turbidity measurements were taken as necessary to describe these within grid variations.

In addition to the above measurements, each sampling cell within the grid was characterized by several habitat measurements. A representative depth and velocity were measured by taking one or more point measurements along the midline of each cell. The entire cell was walked so measurements taken were representative. A velocity measurement was taken at 0.6 of the distance from the top of the water column at one representative location for the entire cell.

Additionally, cover type and amount were estimated in each cell and coded into categories (Table 1). Aquatic vegetation was defined as aquatic plants which are normally completely submerged and do not stand upright. Emergent vegetation consisted of plants such as <u>Equisetem</u> sp. which normally are only partially submerged and stand upright. Overhanging riparian vegetation consisted of vegetation whose roots are submerged only at flood stage and which typically grow in moist or dry soil. Initially, the total amount of cover of all types was estimated for the entire cell. Next, the primary and secondary cover type was recorded along with a percentage of the total for each. Cover was defined as hiding or escape locations for fish less than or equal to 100 mm in total length.

Table 1. Percent cover and cover type categories.

Group #	% Cover	Group #	Cover Type
1	0-5%	1	No object cover
2	6-25%	2	Emergent vegetation
3	26-50%	3	Aquatic vegetation
4	51-75%	4	Debris or deadfall
5	76-96%	5	Overhanging riparian vegetation
6	96-100%	6	Undercut banks
		7	Gravel (1"to 3" diameter)
		8	Rubble (3" to 5" diameter)
		9	Cobble (larger than 5" diameter)

In September, when the water levels in the Susitna River were low, the cover on all the transects within each site was systematically recorded. One person did the systematic cover coding for all the sites so that between site observer bias was minimized. The cover was recorded by distance from the left bank transect marker along the transect line.

Fish distribution data were normally collected from a minimum of seven cells within each RJHAB site during each sampling occasion. Cells to be sampled were selected randomly by using a random numbers table (ADF&G 1985). If a cell was missing or could not be sampled due to high velocities or large depths, an additional cell was randomly chosen for sampling. Consequently, the sampling was not totally random. Each cell selected was then sampled for fish with one pass through the entire cell with a backpack electroshocker or beach seine. The gear type used was considered the most efficient for sampling the cell. Typically, beach seines are more efficient in turbid water while electrofishing gear is most efficient in clear water (Dugan et al. 1984). The area of the cell was recorded so that catches in cells with areas different than 300 ft^2 could be adjusted to this standard cell size. Sampling efficiency of electrofishing and beach seining was assumed to be equal.

Additional selected cells were occasionally fished at the site if sampling of the random cells failed to capture many fish because the cells had high water velocities. In this case, the sampling crew fished areas which had more suitable water velocities. Areas fished were not limited to cells on the transects. These data were pooled with the randomly selected cell data for analysis.

After each cell was sampled, juvenile salmon captured were identified to species and then released. The total length of each of the first 50 fish of each species in each size class was measured in millimeters.

If staff gage readings indicated the stage at the site had not changed from a previous sampling period only limited habitat measurements were taken. These included water chemistry data and a turbidity sample. Fish distribution data were taken during each visit to the site, however. Each cell sampled for fish was also characterized by a representative velocity, depth, and estimate of cover type and abundance.

2.1.2.2 Instream Flow Incremental Methodology (IFIM) sites

In addition to the RJHAB model sites, there were also six sites modelled for juvenile fish using the "instream flow incremental methodology" (IFIM) (Bovee 1982). A summary of this methodology and specific data collection and modelling techniques are presented in Appendix D of this report. All habitat data used in the IFIM models were collected and analyzed by Aquatic Habitat (AH) personnel. Two of the IFIM sites were also modelled with RJHAB models using the same transects in order to compare output from the two modelling methods. At these two sites, RJ personnel collected the RJHAB and fish distribution data and AH personnel collected the IFIM data, so the two models were independent.

Fish abundance and distribution data were also collected at the other four IFIM model sites. Sampling effort at these sites was secondary in importance to the sampling of the RJHAB sites. Cells were sampled for fish using the transects placed for the IFIM models. Cells were randomly selected and then sampled with the same procedures used at RJHAB sites. Cell numbering was the same as that used in the RJHAB studies. The distance from the transect end markers to the cell edge was measured, however, so that the location of the cell on the transect was specified. Other data collected at each cell fished included amount and type of cover, water depth, and water velocity. Water chemistry measurements and a turbidity sample were also taken at a selected location within the site.

2.1.2.3 Opportunistic sites

In addition to the RJHAB and IFIM sites, other sites were sampled for fish as time permitted to gather juvenile abundance and distribution information at a wider variety of sites and to obtain further data for juvenile suitability criteria. Selected 6-by-50 foot cells were sampled for juvenile salmon at opportunistic sites but no permanent grids or transects were marked. Water chemistry was measured at mid-site. If time permitted, each cell sampled for fish was characterized to amount and type of cover, water depth, and water velocity as were cells sampled at RJHAB and IFIM sites.

Early in the sampling season, large differences in turbidity were noted between sites located on the east and west banks of the Susitna River mainstem below the Chulitna River confluence. In order to better understand the reason for these differences, turbidities were taken within the Talkeetna and Chulitna rivers just above their respective confluences with the Susitna and also in the middle Susitna River above its confluence with the Chulitna River. The turbidity measurements were then repeated in the lower Susitna River below the Chulitna River on the left (west) bank channel, center channel, and right (east) bank channel at several locations from RM 92.7 downstream to RM 60.6. Blueline maps detailing the precise sampling locations are available at the Susitna Aquatic Studies office. Two sets of measurements were taken, on July 19 and on August 16. The measurements were recorded within a four hour period on each date. Turbidity samples were taken at least 30 feet off shore near the middle of the channel.

2.1.3 Schedule of activities and frequency of sampling

Field sampling trips, lasting approximately 7-10 days, were conducted bimonthly from June through mid-October. Each RJHAB site was sampled for fish on each sampling occasion if fish habitat was present. Habitat data were collected on at least three occasions when staff gage readings or observations suggested a change in the habitat within a site. The collection of habitat data was therefore dependent upon mainstem discharge.

The IFIM sites were sampled at least once a month during the open-water season. Opportunistic sites were sampled as time permitted and some were only sampled once. Opportunistic sites were sampled mainly in September and early October when many of the RJHAB and IFIM sites were dewatered.

2.2 Data Analysis

All field data were recorded on the appropriate data forms and transmitted to the office where the fish distribution data and much of the habitat data were entered into a mainframe computer data base. Data sorts, summary retrievals, and selected computer files were extracted from this data base as needed. Other habitat data were entered directly into basic programs or commercial software on a personal computer.

2.2.1 Physical data

Overtopping flows at the study sites were observed or estimated from staff gage measurements and flow observations. Data were grouped into nine half-month sampling periods from early June (June 1 - June 15) to early October (October 1 - October 15). Due to logistical constraints, the actual sampling periods did not always run from the 1st to the 15th and 16th through the end of the month.

An index to the amount and type of cover within the RJHAB and IFIM model sites was calculated by totalling the linear feet of all the cover types along the transects at a mainstem discharge within the range of 49,000 to 57,000 cfs. In addition, at Rolly Creek mouth, Caswell Creek mouth, and Beaver Dam Slough, the response of physical cover to changes in mainstem discharge was plotted by totalling the cover along the transects at all measured discharges.

The response of RJHAB site wetted areas to mainstem discharge was plotted using a BASIC language geometry program to calculate wetted area at each transect within a site on each modelling occasion. After fitting these points by hand using professional judgement, site areas at 3000 cfs increments were measured on the graphs with a digitizer. The IFG HABTAT program calculated wetted areas at the six IFIM sites as a function of side channel flow, and these were also plotted using a mainstem discharge-side channel flow relationship.

2.2.2 Abundance and distribution

The same classification of macrohabitats was used to examine differences in fish distribution among the sites as that discussed in Dugan et al. (1984). The sites were classified as tributary mouths, side sloughs, and side channels. Tributary mouths are sites which are influenced by tributary flows and backwater effects from the mainstem. Side channels are channels whose upstream berms (heads) are breached by the mainstem while side sloughs are channels whose heads are not breached and whose water sources are upwelling, local runoff, or small tributaries. Side sloughs transform to side channels when their heads are breached by the mainstem. Birch Creek Slough was classified as a tributary mouth in 1984 because road building activities in the upper part of the slough closed the head off from the mainstem. Beaver Dam Slough was also classified as a tributary mouth because it only overtops at discharges greater than 80,000 cfs and normally runs clear. Beaver Dam Slough is much more similar to Rolly Creek mouth than to any of the other side sloughs in the lower reach.

Catches within cells with areas other than the standard 300 ft^2 were adjusted to correspond to this standard cell area. The analysis was then based on the adjusted mean catch per cell.

2.2.3 Habitat modelling of rearing salmon

2.2.3.1 Suitability criteria development

Suitability criteria have been developed to model the response of juvenile salmon habitat to variations in mainstem discharge at sites located in the middle reach of the Susitna River (Suchanek et al. 1984). As habitat data collection techniques used in the lower river in 1984 were similar to those used during 1983, the middle river suitability criteria were compared to the lower river distribution data and modified, if necessary, in Appendix A. The suitability criteria developed in Appendix A are used in all subsequent habitat modelling for the lower river.

2.2.3.2 Instream Flow Incremental Methodology (IFIM) models

The IFIM PHABSIM system of computer programs was developed by the U.S. Fish and Wildlife Service as a means of describing the mosaic of physical features of a stream which includes hydraulic variables such as depth and velocity and other features such as substrate or cover (Bovee 1982). A hydraulic model is first calibrated which describes the response of hydraulic variables such as depth and velocity to stream flow (Milhous et al. 1981). The HABTAT program is then used to incorporate output from the hydraulic model and substrate data with the suitability criteria to produce estimates of the habitat potential (weighted usable area) for a given life stage of a species. Weighted usable area (WUA) is calculated as follows (Bovee 1982):

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

where: $C_{i,s}$ = the composite weighting factor (sometimes called the joint preference factor) for cover, velocity, and depth of the cell (i) for the species and life stage (s)

A_i = the surface area of the cell

Each cell is a small section of the study channel which is bounded by other cells or the shoreline and extends midway between transects. The WUA for the study site at a given discharge was calculated by totalling all the individual cell WUA's. The composite weighting factor 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 flows which corresponded to 3,000 cfs increments of mainstem discharge as measured at Sunshine gaging station.

Much more detailed descriptions of the IFIM data analysis methods and hydraulic simulation results are presented in Appendix D. Only selected WUA results as a function of mainstem discharge are presented here. All species and site combinations were run and are available on request but space limitations prevent presentation here. Site/species combinations presented were selected on the basis of fish catches at the site.

2.2.3.3 Resident Juvenile Habitat (RJHAB) models

The original RJHAB model was designed to calculate weighted usable areas for the habitat within a site without using hydraulic models (Marshall et al. 1984). The model divided the site into shoreline and mid-channel sections, and calculated weighting factors for cover and velocity for each section which were then multiplied together with area to produce a weighted usable area estimate at each of the discharges measured.

The original RJHAB model was greatly modified for the 1984 analyses. These changes were made so that the RJHAB model calculates weighted usable areas similarly to the HABTAT program described by Milhous et al. (1981) that is used in IFIM analysis. Also the cover coding has been standardized so that observer variations in rating cover at different discharges do not lead to variations in cover estimates unrelated to changes in wetted area.

The current RJHAB model is a spreadsheet developed on commercial software. Though no hydraulic model is developed, the current RJHAB model closely resembles the HABTAT model in its procedures for calculating weighted usable areas within a site. Instead of calculating weighting factors for cover and velocity in shoreline and mid-channel sections on a given sampling occasion as did the original RJHAB model, each site is partitioned into "stream cells" each with a unique area, cover type, cover percentage, velocity, and depth. The site weighted usable area (WUA) is then the sum of the "stream cell" WUA's which are calculated by multiplying the area, cover, velocity, and depth suitabilities together.

The velocity and depth measurements of the 6' x 50' sampling cells are assumed to represent a much larger stream cell. The wetted surface area between transects was partitioned into one to four stream cells dependent upon wetted transect width (Table 2).

Table 2. Partitioning of wetted channel width into stream cells.

Wetted Channel Width	No. of Stream Cells	How Area Partitioned
> 42 ft	4	Cell on each shoreline 6 ft in width, two center cells split the difference.
30-41 ft	3	Cell on each shoreline 6 ft in width, middle cell is the rest.
18-29 ft	2	Each cell with half the width.
< 18 ft	1	Entire width.

Occasionally, islands prevented a simple partitioning of the site but in each case, areas were partitioned so that sampling cells best represented a given stream cell. Once the wetted width of stream cells was partitioned, a computer program written in BASIC was used to calculate the surface area of each stream cell on each sampling occasion. The areas of islands were estimated from width measurements, observations, and sketch maps and then subtracted from the area of each stream cell.

Cover suitabilities for each stream cell were calculated with a BASIC program which integrated the standard cover data taken on each transect with the partitioned wetted width of each stream cell. The cover suitability of each cover type on the stream cell wetted width was averaged with the other cover suitabilities present (proportional to their occurrence) to give an average cover suitability. For example, if the stream cell was 15 feet in width and ten feet of the width was a cover type with a suitability of 0.5 and the other five feet was a cover type with a suitability of 1.0, the average cover suitability for the cell would be : $[(10 \times 0.5)+(5 \times 1.0)]/15 = 0.67$.

The RJHAB spreadsheet then took the stream cell areas and cover suitabilities, and multiplied these with the depth and velocity suitabilities which it assigned to the sampling cell depth and velocity measurements. The products of these calculations (stream cell WUA's) are then totalled to calculate site WUA's for each sampling occasion. Weighted usable areas for chinook salmon in turbid and clear water and chum, coho, and sockeye salmon were all calculated concurrently.

Weighted usable areas were plotted over the range of mainstem discharges sampled. Since initial overtopping flows were estimated for each side channel, WUA response was extrapolated in the range around breaching using this information. Habitat indices were calculated by dividing the WUA of the site at a given discharge by the site area at the same discharge and these were also plotted. Only selected site and species combinations are presented here, all other WUA calculations are available upon request. Individual sampling cell measurements are also available upon request.

In order to compare output from the RJHAB model with that of the IFIM methodology, two sites (Island and Trapper Creek side channels) were modelled with both techniques. Output from both techniques were graphed as a function of mainstem discharge and then correlated with each other at the measured RJHAB discharges.

2.2.3.4 Model verification

Fish abundance data were collected at all of the IFIM and RJHAB sites. High mean catches per cell (CPUE's) should reflect high densities of fish within the site. Since WUA on a per site basis reflects the size of a site, WUA/site is not an index to habitat quality of a site. The habitat index calculated by dividing WUA by site area (at any given discharge), however, does reflect site habitat quality, independently of site area.

Variations in mainstem discharge cause fluctuations in the habitat value of a given site. Fish populations within a site may not respond immediately to such variations in habitat value but should adjust after a period of time. Over a season, average densities of fish (as expressed by CPUE) should be positively correlated to the average seasonal habitat index if there is a relationship between the two. A test of the significance of the correlation between mean seasonal habitat indices and mean catch per cell by species was used to verify the habitat modelling efforts.

Mean seasonal habitat indices for each site were calculated for each species with the following procedure. Mean daily discharges for each day between May 15 and October 15 were rounded to the nearest 3,000 cfs increment in the range from 12,000 to 75,000 cfs. The season for chum salmon ran from May 15 to July 15. If the discharge was greater than 75,000 cfs, the discharge was assumed to be 75,000 cfs because WUA's were calculated only up to 75,000 cfs. Corresponding WUA's and site areas corresponding to these discharges were then totalled to find the total WUA and site area for the season. The mean seasonal habitat index was then calculated by dividing the total WUA by the total site area. For chinook and chum salmon, WUA's were adjusted by a turbidity factor before the habitat index was calculated. The turbidity factor was calculated by fitting a suitability index from 0 to 1.0 on the distribution of mean chum and chinook juvenile salmon catch by 50 NTU turbidity increments. Site mean CPUE's were regressed against site habitat indices at each site.

3.0 RESULTS

3.1 Seasonal, Spatial, and Discharge Related Variations in Habitat

3.1.1 Macrohabitat type classifications of study sites

All the study sites were classified into one of three macrohabitat types: tributary mouths, side channels, or side sloughs. Classification and habitat characteristics of the twenty modelled study sites are given in Table 3. Initial breaching discharges for the side channels ranged from approximately 14,000 to 46,000 cfs with flows controlled by the mainstem at least 50% of the time. Channels with input into the tributary mouth sites were never breached at flows less than 54,100 cfs and site flows were controlled by the mainstem less than 5% of the time. Backwater effects were the only effects attributable to mainstem discharge at the tributary mouths on all sampling occasions except at Beaver Dam Slough where discharges greater than 75,000 cfs caused the head to overtop and flow to increase through the site. Even at discharges greater than 75,000 cfs however, the major effect of mainstem discharge on Beaver Dam Slough was a backwater response.

The side slough macrohabitat type was not represented by any of the sites when mainstem discharges were highest during the period from late June through early August. Side slough habitat increased with decreases in mainstem discharges.

Major object cover differences among the modelling sites were differentiated by macrohabitat type. An index of cover for each site at a discharge of approximately 52,000 cfs (range 45,500 to 58,800 cfs) was calculated for between-site comparisons of cover (Table 4). The percentage of the site with the primary cover type, submerged aquatic vegetation, varied from 8.5% to 68.5% for the tributary mouths, while none of the side channel/sloughs had any submerged aquatic vegetation. Substrate in the form of large gravel (1-3" diameter) and rubble (3-5" diameter) was the primary cover type and averaged 62% of the side channel area while these two cover types only covered an average of 14% of the area of tributary mouth sites. The density of cover at tributary mouths was almost three times that of side channels also. Side sloughs, which by definition are unbreached side channels, typically have less object cover than side channels.

Cover, in the form of turbidity was much more frequent within side channels than at tributary mouths and side sloughs. Turbidities were consistently higher in the side channels than in the tributary mouths during the open-water season (Figure 3). A few turbidities of 100 to 150 NTU were recorded at Rolly Creek mouth and Beaver Dam Slough due to rapid increases in mainstem stage which caused turbid water to intrude into the sites, or in the case of Beaver Dam Slough, by a slight overtopping of the channel head by mainstem water. Turbidities within the side sloughs ranged from 1 to 19 NTU with a mean of 5.2 NTU.

Table 3. Classifications and habitat characteristics of study sites on the lower Susitna River at which juvenile salmon habitat was modelled, June through October 1984.

Site	River Mile	Initial Breaching Discharge (cfs)	Percent of Time Flow Controlled by Mainstem in 1984[1]	Non-mainstem Water Sources
Side Channels (head open)/ Sloughs (head closed)				
Hooligan Side Channel	35.2	23,100	80	Pools only
Eagles Nest Side Channel	36.2	14,000	94	Unknown
Kroto Slough Head	36.3	36,000	62	Minor upwelling
Bear Bait Side Channel	42.9	35,000 (Est.)	64 (Est.)	Pools only
Last Chance Side Channel	44.4	22,700	79	Pools only
Rustic Wilderness Side Channel	59.5	19,000	86	Pools only
Island Side Channel	63.2	34,000	64	Major upwelling
Mainstem West Bank	74.4	19,000	86	Major upwelling
Goose 2 Side Channel	74.8	30,000	68	Minor upwelling
Circular Side Channel	75.3	36,000	64	Major upwelling
Sauna Side Channel	79.8	37,000	62	Minor upwelling
Sucker Side Channel	84.5	27,500	71	Minor upwelling
Beaver Dam Side Channel	86.3	46,000	50	Unnamed tributary
Sunset Side Channel	86.9	31,000	68	Major upwelling
Sunrise Side Channel	87.0	34,300	64	None
Trapper Creek Side Channel	91.6	43,000	57	Cache Creek
Tributary Mouths				
Rolly Creek Mouth	39.0	-	0	Rolly Creek
Caswell Creek Mouth	63.0	-	0	Caswell Creek
Beaver Dam Slough	86.3	75,000+	< 5	Unnamed tributary
Birch Creek Slough[2]	88.4	54,100	< 5	Birch Creek

1 These percentages based on controlling breaching discharges presented in Quane et al. (1985) for the period from May 15 to October 15, 1984.

2 A culvert at the head of this slough is frequently blocked and therefore little mainstem water flows into the slough, even if the slough head is breached. The effect of mainstem discharge on this site is minimal for this reason.

Table 4. Percentages of lower river habitat modelling sites associated with nine cover-type categories. Percentages are based on the width of transect with each cover type. Cover index calculated by dividing total cover by total area of site.

Side Channels/Sloughs	River Mile	Date	Discharge (cfs)	Percentage of Site With Primary Cover Type: No Cover	Emergent Veg.	Aquatic Veg.	Large Gravel	Rubble	Cobble	Debris	Overhang. Riparian Veg.	U.C. Banks	Total	Cover Density[1] (%)
Hooligan Side Channel	35.2	7/14	52400	18.9	0.0	0.0	72.0	0.0	0.0	8.5	0.6	0.0	100.0	13.7
Kroto Slough Head	36.3	7/17	49600	56.4	0.0	0.0	8.6	0.0	0.0	33.5	1.6	0.0	100.1	1.8
Bear Bait Side Channel	42.9	7/13	52400	0.0	0.0	0.0	66.8	0.0	0.0	28.1	3.7	1.4	100.0	11.5
Last Chance Side Channel	44.4	7/12	54100	23.5	0.0	0.0	63.5	0.0	0.0	12.3	0.8	0.0	100.1	5.9
Rustic Wilderness Side Channel	59.5	8/12	52900	0.0	0.0	0.0	60.9	30.0	0.0	7.8	0.8	0.5	100.0	13.7
Island Side Channel	63.2	7/19	51600	13.4	0.0	0.0	62.0	21.6	0.0	0.0	1.4	1.6	100.0	10.5
Mainstem West Bank	74.4	Extrapolated	54100	1.0	0.4	0.0	43.4	49.3	0.0	2.2	3.4	0.4	100.1	22.7
Goose 2 Side Channel	74.8	7/20	52600	2.0	0.9	0.0	24.3	51.8	13.7	3.5	3.5	0.2	99.9	22.5
Circular Side Channel	75.3	7/24	56600	20.4	0.0	0.0	48.4	21.3	0.0	5.3	4.6	0.1	100.1	9.3
Sauna Side Channel	79.8	7/23	56600	93.4	0.0	0.0	0.0	0.0	0.0	4.3	2.4	0.0	100.1	0.5
Sucker Side Channel	84.5	7/09	55400	80.2	8.4	0.0	6.6	0.0	0.0	3.9	1.0	0.0	100.1	1.1
Beaver Dam Side Channel	86.3	7/08	57100	55.9	0.9	0.0	18.6	5.9	0.0	18.6	0.0	0.0	99.9	1.9
Sunset Side Channel	86.9	7/22	57800	15.0	0.0	0.0	66.8	9.7	0.0	7.7	0.5	0.3	100.0	4.8
Sunrise Side Channel	87.0	7/07	58800	4.0	0.0	0.0	51.4	44.6	0.0	0.0	0.0	0.0	100.0	10.0
Trapper Creek Side Channel	91.6	8/19	57200	2.2	0.0	0.0	39.1	58.8	0.0	0.0	0.0	0.0	100.1	12.3
			MEAN	25.8	0.7	0.0	42.2	19.5	0.9	9.0	1.6	0.3	100.0	9.5
Tributary Mouths														
Rolly Creek Mouth	39.0	7/11	55100	6.9	25.2	46.2	0.0	0.0	0.0	21.5	0.1	0.0	99.9	24.2
Caswell Creek Mouth	63.0	8/18	45400	2.9	5.3	48.2	17.6	0.0	0.0	18.4	1.6	6.1	100.1	19.0
Beaver Dam Slough	86.3	7/08	57100	6.8	9.9	68.5	0.0	0.0	0.0	11.1	3.1	0.6	100.0	57.8
Birch Creek Slough	88.4	7/20	52600	36.8	0.5	8.5	29.2	9.0	0.0	13.6	2.2	0.3	100.1	6.3
			MEAN	13.4	10.2	42.9	11.7	2.3	0.0	16.2	1.8	1.8	100.0	26.8

[1] Cover density is the average density of object cover within the site on a percentage basis.

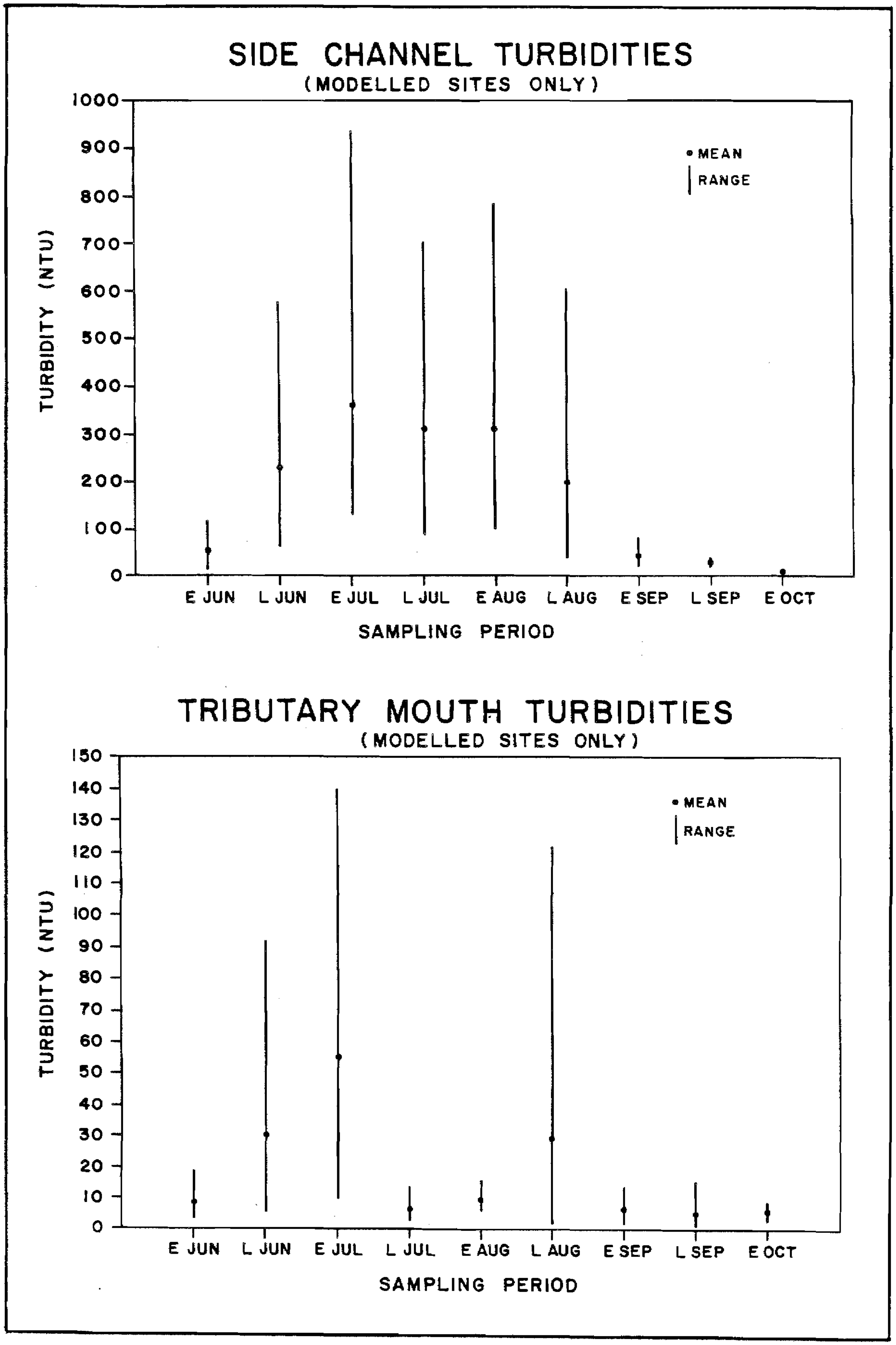


Figure 3. Turbidities of modelled side channels and tributary mouths on the lower Susitna River, June through October 1984.

3.1.2 Chulitna and Talkeetna River plume influences on turbidity of side channels

Turbidity measurements of the lower Susitna River taken in west bank, mid-channel, and east bank portions of the mainstem indicate that plume influences of the Chulitna and Talkeetna Rivers extend at least 20 to 30 miles downriver (Figure 4). On September 2, turbidities at RM 83.8 ranged from 60 NTU on the east bank, to 77 NTU in mid-channel, and 88 NTU on the west bank. West bank turbidities are much higher than on the east bank, because the Chulitna River is three or more times as turbid as the Talkeetna River and middle reach of the Susitna River.

A comparison of turbidities at the modelled side channels located above RM 70 also suggests that the plumes have major effects on turbidities downstream. Mean turbidity at lateral side channels located on the west bank (Mainstem West Bank, Sauna S.C., and Trapper Creek S.C.) during June through late August was 377 NTU. During the same time period, lateral side channels located on the east bank (Goose 2 S.C., Sunset S.C., and Beaver Dam, S.C.) had a much lower mean turbidity of 158 NTU. Mean turbidities for all the side channels modelled with the exception of Eagle's Nest Side Channel have been calculated in Appendix Table B-1.

Many more turbidities would have to be taken to better delineate the Chulitna River and Talkeetna River plumes. The large east bank clear water tributaries such as Montana Creek and Goose Creek make the differences in turbidity between the east and west banks of the lower river even larger, and confound analysis of the extent of plumes from the Chulitna and Talkeetna rivers.

3.1.3 Physical responses of sampling sites to mainstem discharge variations

Variations in mainstem discharge cause the heads of side channels to alternately be overtopped or dewatered, thereby altering macrohabitat classifications due to changes in water quality, flows, wetted areas, and the amount of cover. The relationships between side channel flows and mainstem discharge at the sampling sites are presented in Quane et al. (1985).

Changes in wetted area of sites due to variations in mainstem discharge are important because these changes may directly increase or decrease fish habitat. Areas measured from aerial photos have been compiled for selected side channel and slough complexes by Ashton and Klinger-Kingsley (1985) for a variety of discharges. Mainstem backwater effects at tributary mouths are also important because object cover inundated by backwater is an important component of these sites for juvenile salmon. Discharge related responses of site area for all sites pooled and cover for selected tributary mouths will be presented in the next two sections.

3.1.3.1 Area

The areas of the RJHAB study sites were calculated geometrically at modelled discharges, and then plotted against mainstem discharge by eye. Measurements of area were then read from these graphs in the range

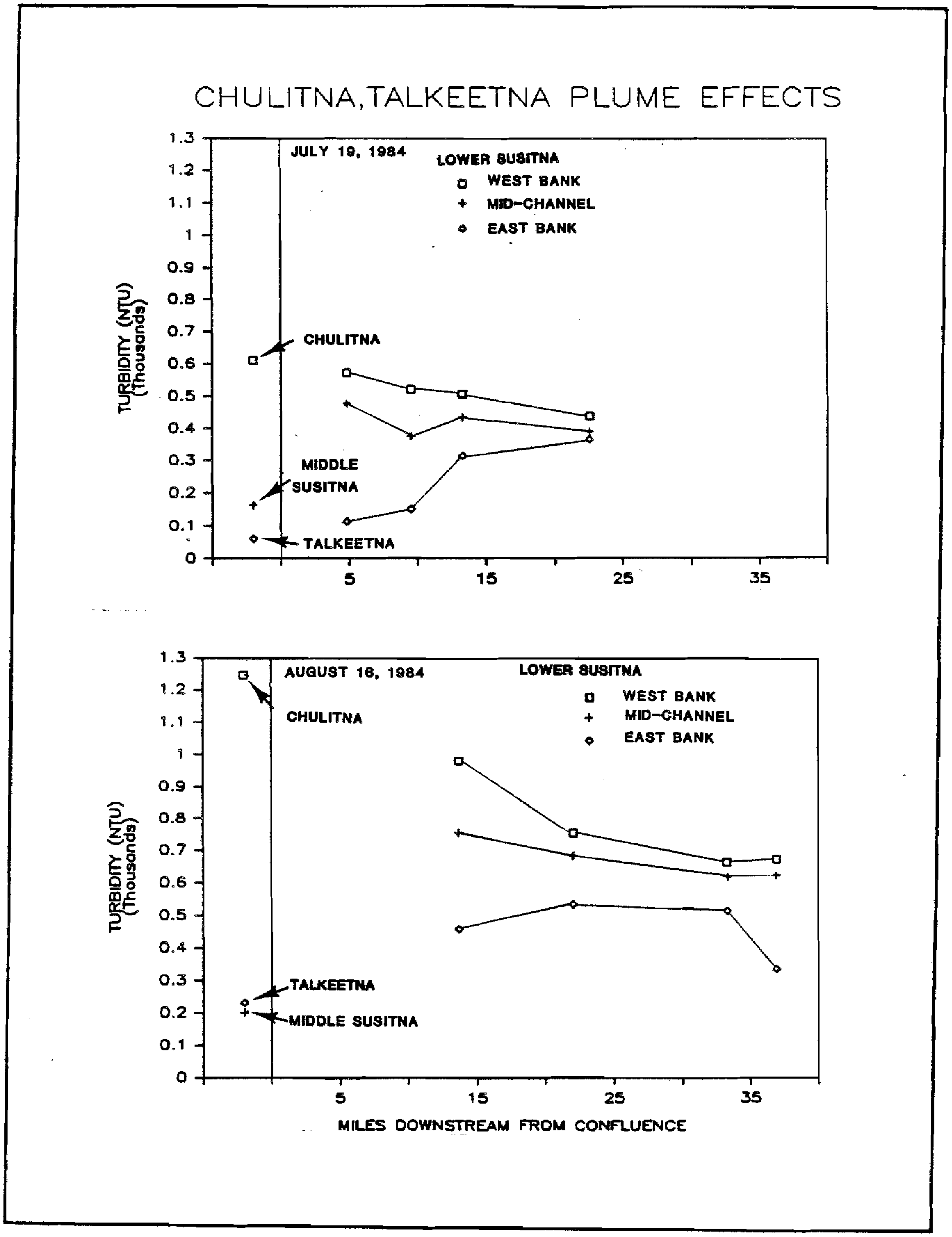


Figure 4. Comparison of turbidities in the lower Susitna River below the Chulitna and Talkeetna River confluences on July 19 and August 16, 1984.

between 12,000 to 75,000 cfs at 3,000 cfs increments. Since Eagles Nest Side Channel was modelled only at discharges less than 20,000 cfs, we did not try to extrapolate values over this range for this site. Similarly, area response at the six IFIM sites were calculated by the IFG program at side channel flows which corresponded to increments of 3000 cfs within the 12,000 to 75,000 cfs mainstem discharge range.

Individual area responses for all the modelling sites have been tabulated in Appendix Table B-4 at 3,000 cfs discharge increments. Also, side channel flows associated with these increments have been tabulated. By summing areas of the sites by macrohabitat type, the response of the pooled sites can be illustrated. The combined area of three tributary mouths increased greatly at discharges greater than 27,000 cfs (Figure 5). Since sloughs transform to side channels at greater discharges, slough habitat decreased with discharge while side channel habitat steadily increased (Figure 6). Slough habitat was broken into two categories: total and accessible. The total category includes ponded water with no access from the mainstem while the accessible sloughs are those with potential access from the mainstem.

3.1.3.2 Cover

Since instream cover is an important component of fish habitat, the response of available cover to mainstem discharge at individual sites is of interest. Increases in instream cover (debris, riparian vegetation) at side channels were often accompanied by large increases in flows and related water column velocities. Therefore, increases in suitable cover at side channels were often offset by increases in velocities which made the site unsuitable. Turbid water in side channels also provides cover for juvenile chinook salmon and therefore, instream object cover may be less necessary for chinook salmon under turbid conditions (Suchanek et al. 1984).

At tributary mouths, on the other hand, tributary flows are independent of mainstem discharge, the water is often clear, and the primary effect of mainstem discharge is the formation of a backwater zone. Increases in mainstem stage typically decrease velocities and inundate cover at tributary mouths.

Cover responses to mainstem discharge at the four tributary mouths varied. At Birch Creek Slough, there were no changes in cover as a result of changes in mainstem stage during 1984 sampling because the sampling site was located high enough (0.7 miles) up the channel that it was not influenced by mainstem stage. At Beaver Dam Slough, increases in total cover caused by rises in mainstem discharge were limited because most of the cover was submerged aquatic vegetation (Figure 7). At Rolly Creek and Caswell Creek mouths, however, the amount of cover increased rapidly at discharges larger than 45,000 cfs. Increases in total cover at Rolly Creek mouth were caused primarily by inundation of emergent vegetation while both emergent vegetation and overhanging riparian vegetation cover became more abundant at Caswell Creek mouth at high mainstem discharges.

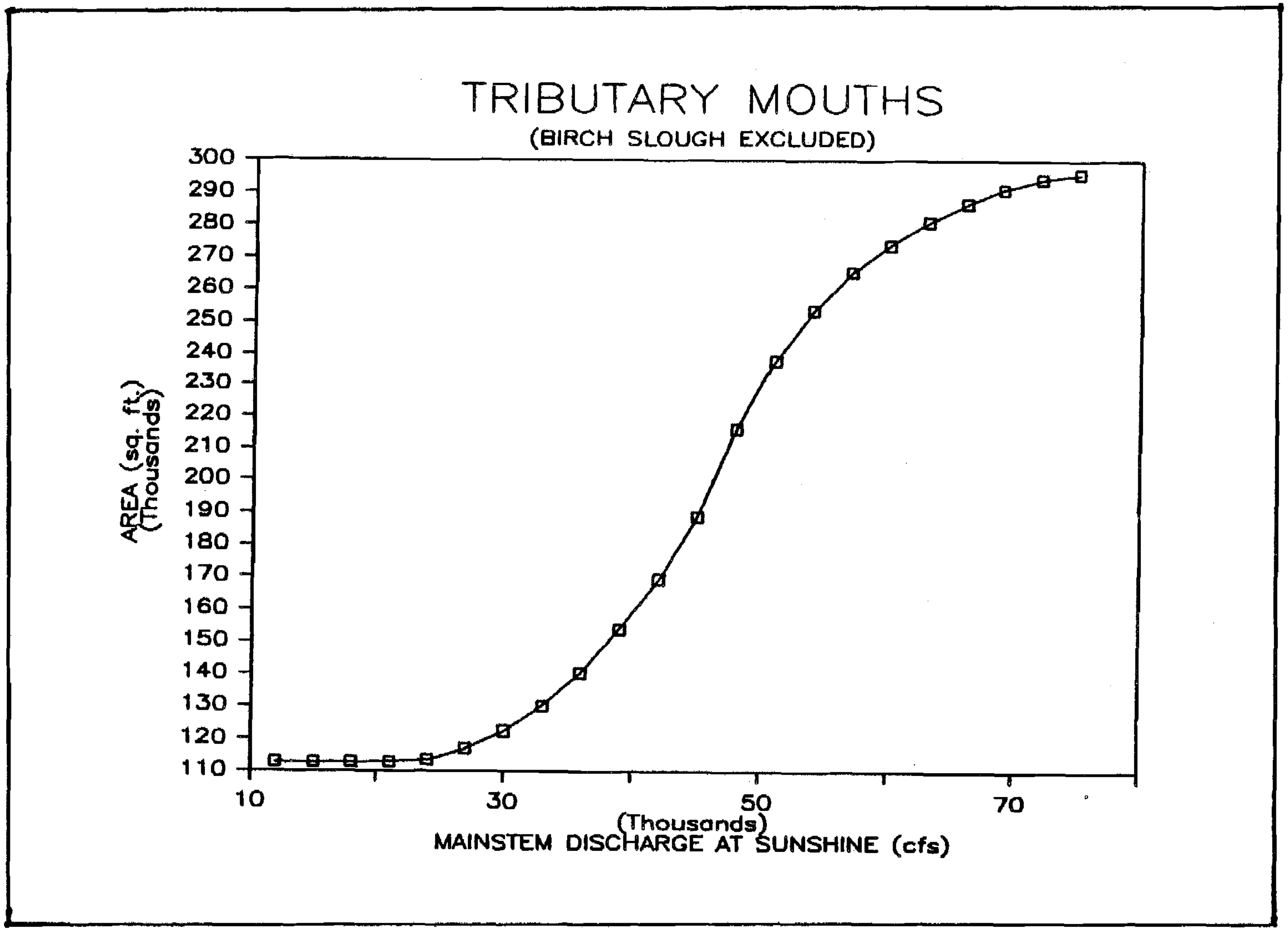


Figure 5. Area within modelled tributary mouths as a function of mainstem discharge at the USGS Sunshine gaging station, 1984. Boundaries of the site were fixed.

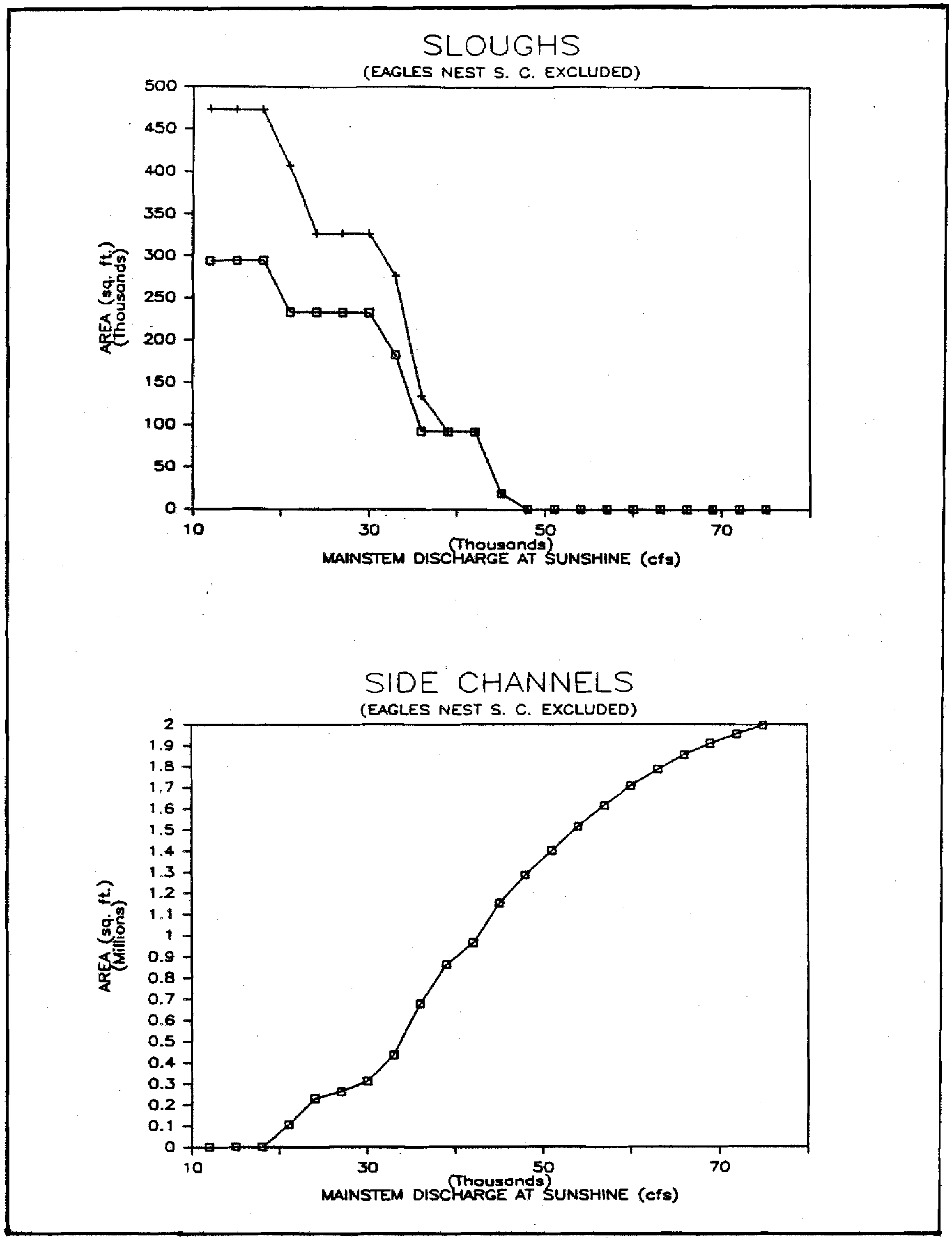


Figure 6. Area within modelled sloughs and side channels as a function of mainstem discharge at the USGS Sunshine gaging station, 1984.

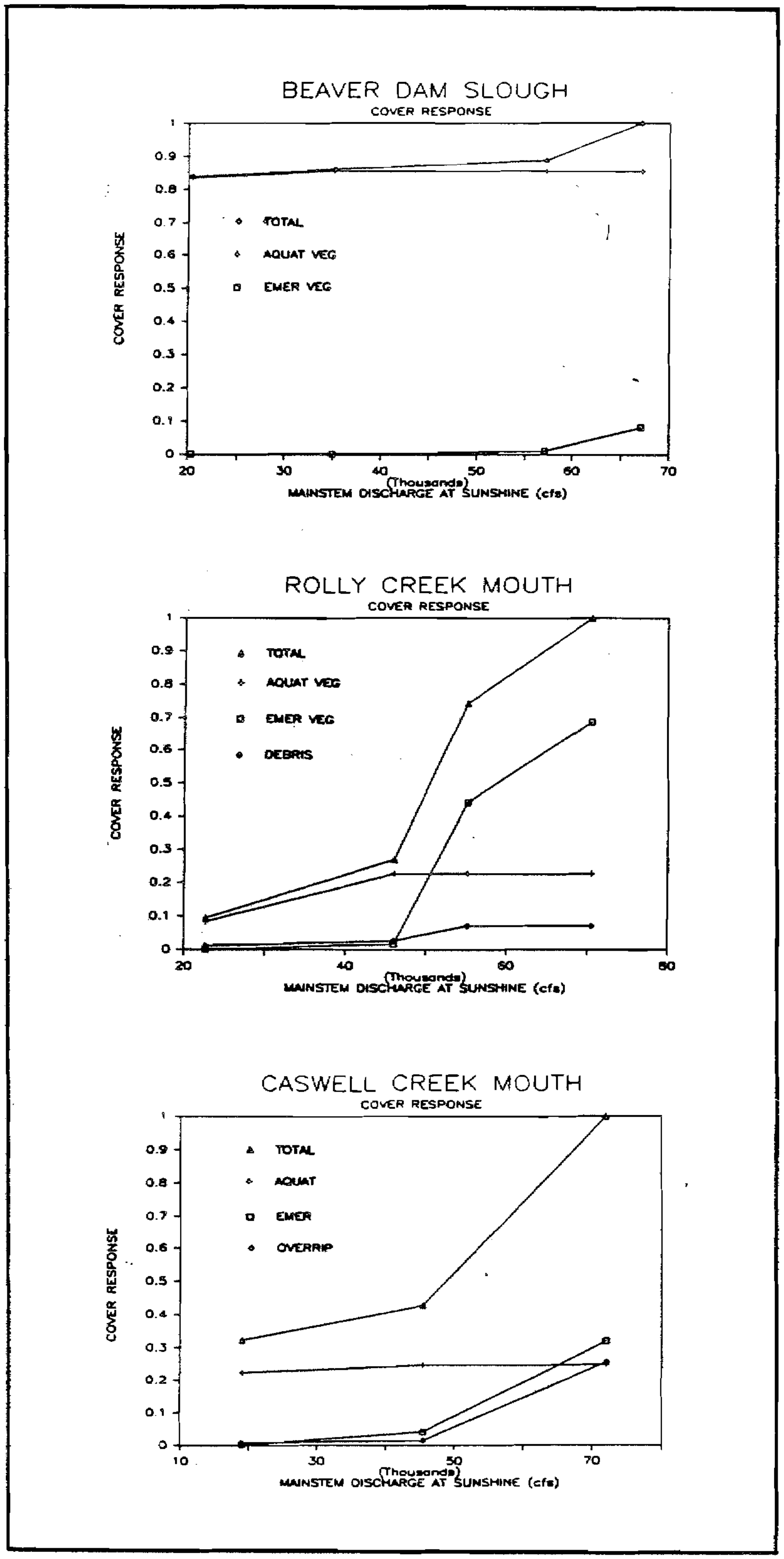


Figure 7. Instream cover response at Beaver Dam Slough, Rolly Creek, and Caswell Creek mouths as a function of mainstem discharge at the USGS Sunshine gaging station, 1984.

3.2 Distribution and Abundance of Juvenile Salmon

Chinook, coho, chum, and sockeye salmon juveniles were captured at the twenty habitat model sites, but only one pink salmon fry was captured. Pink salmon outmigrate early and our methods are not effective at capturing them. A summary of the juvenile chinook, coho, chum, and sockeye salmon catch and catch per cell (CPUE) data by site is given in Appendix Table B-2.

3.2.1 Chinook salmon

Fourteen hundred fifty-eight juvenile chinook salmon were collected in the lower reach of the Susitna River from June through early October. Approximately 83% of these fish were captured at the 20 habitat model sites. Age 0+ fry accounted for 93% of the chinook salmon juveniles captured. The percentage of 0+ fry increased from 66% in late June to 99% in early August. All chinook fry captured after early August were 0+ fish, indicating that 1+ chinooks had outmigrated from the study reach prior to August 15.

Chinook fry were widely distributed at the modelling sites from early June through late August (Figure 8). Last Chance Side Channel was the only site where no chinook juveniles were captured. Chinook juveniles were captured at 80% or more of the sites sampled in early June and late August. In September and early October, the proportion of sites where chinook salmon were captured decreased.

Mean juvenile chinook CPUE was highest at tributary mouths, where 1.5 fish per cell (fpc) were captured. At side channels, the mean CPUE for juvenile chinook was 0.8 fpc. Slough catch rates were consistently low (0.1 fpc). Mean catch rates at side channels were relatively constant throughout the season, while tributary mouth CPUE's peaked in August (Figure 9). The peak CPUE for tributary mouths occurred in late August at Caswell Creek mouth (20.2 fpc). The peak CPUE at a modelled side channel (4.4 fpc) occurred at Sunset Side Channel. CPUE's within the side channels peaked at turbidities of 100 to 150 NTU (Figure 10). The correlation (r) between mean turbidity of the modelled side channels and mean catch per cell of chinook salmon was -0.63 ($p < 0.05$).

Catches at Trapper Creek Side Channel appeared to reflect the effect of turbidity upon chinook fry use. This west bank site, located below the Chulitna River, had a high CPUE in early June (2.7 fpc) when turbidity was low but then no chinook were captured in late June and early July when turbidities were above 550 NTU. Chinook fry catches increased slightly on subsequent trips when turbidities began to decrease.

3.2.2 Coho Salmon

Four hundred forty-two juvenile coho salmon were captured within the lower Susitna River study areas of which only five were not captured within the habitat model sites. Three age classes of juvenile coho salmon were captured. Eighty-six percent of the juvenile coho captures were age 0+ and 14% were age 1+. Only one age 2+ juvenile was captured.

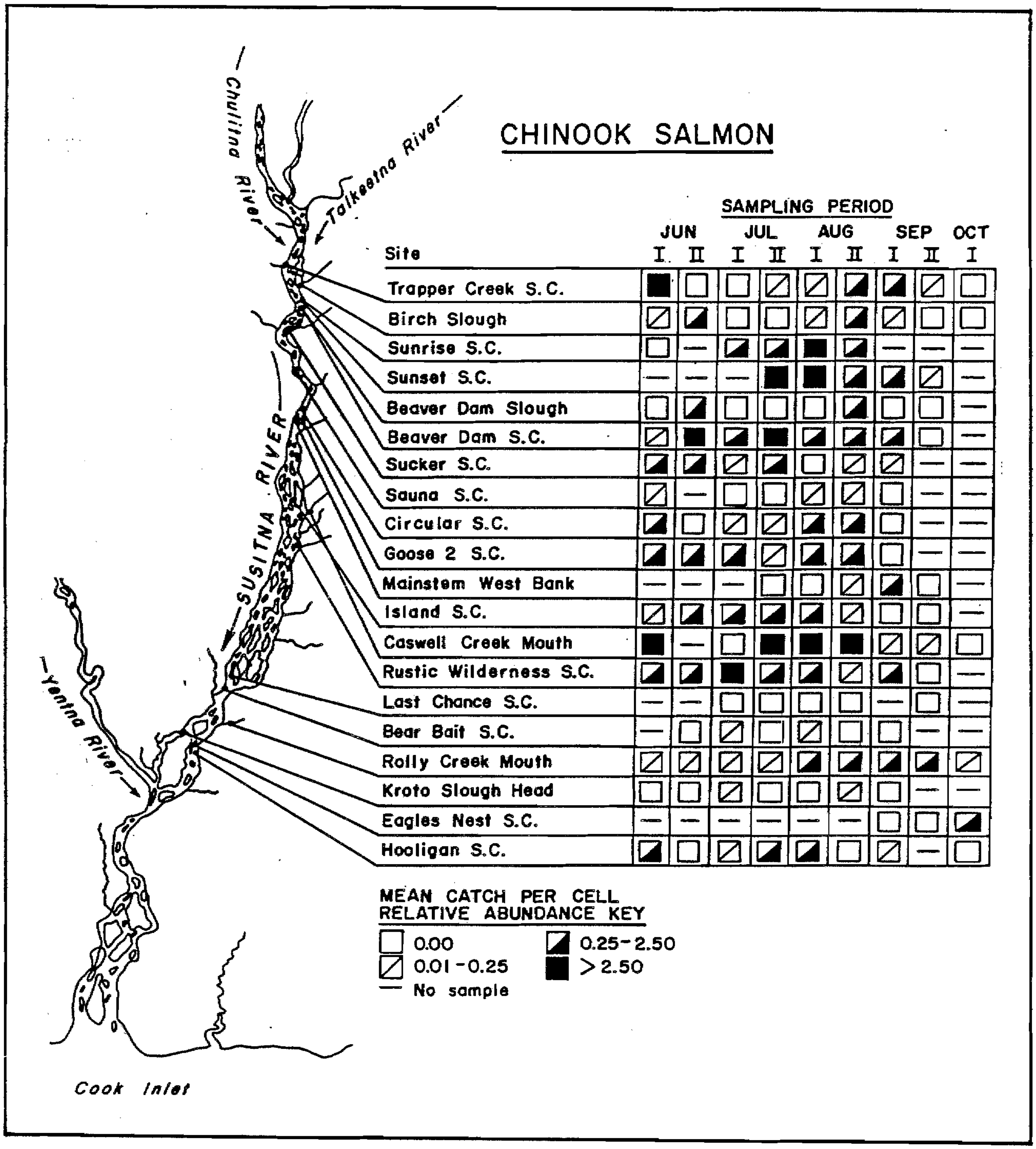


Figure 8. Seasonal distribution and relative abundance of juvenile chinook salmon on the lower Susitna River, June through mid-October 1984.

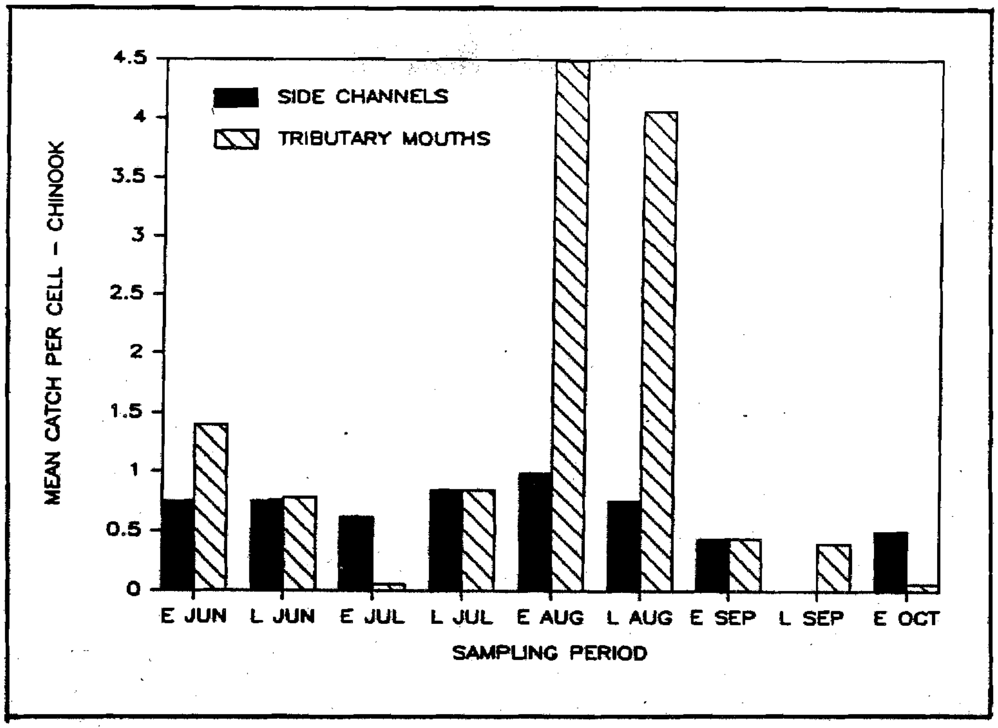


Figure 9. Juvenile chinook salmon mean catch per cell at side channels and tributary mouths on the lower Susitna River by sampling period, June through mid-October 1984.

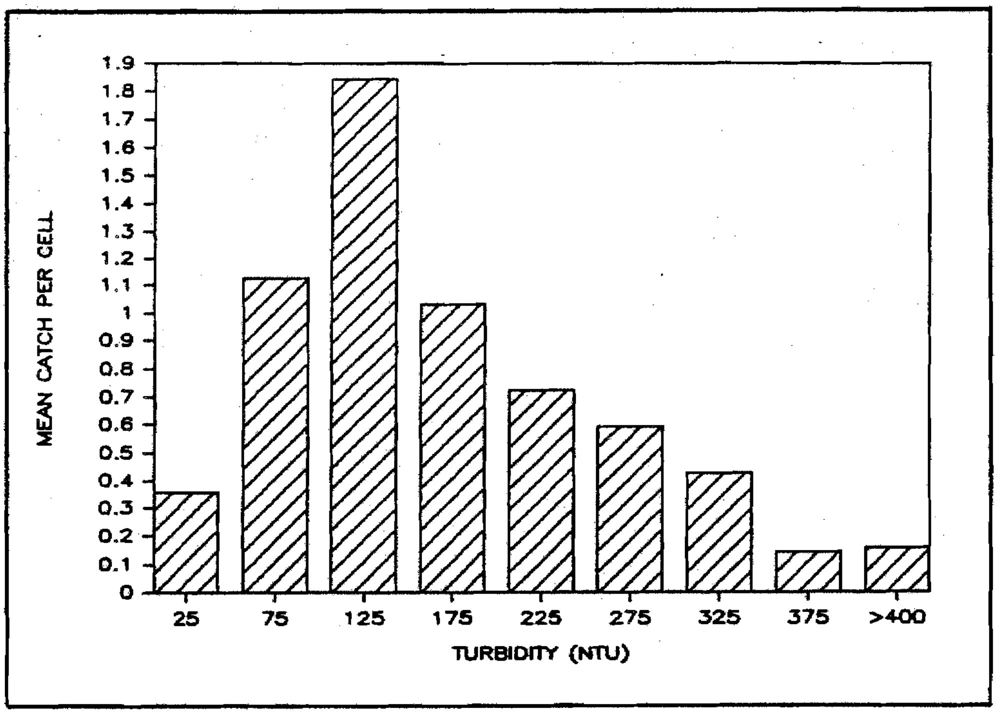


Figure 10. Juvenile chinook salmon mean catch per cell at modelled side channels on the lower Susitna by turbidity increment, June through mid-October 1984.

The percentage of age 1+ fry captured decreased from approximately 50% in early June to 2% in early October.

Juvenile coho salmon were unevenly distributed in the study area, being captured at only 50% of the 20 modelled sites (Figure 11). Only one coho was captured at four of these sites. In most instances, juvenile coho CPUE's tended to be higher in late summer.

Juvenile coho salmon catches varied greatly among the three macrohabitat types. Tributary mouths had a mean juvenile coho CPUE of 1.2 fpc while sloughs and side channels had CPUE's of 0.02 and 0.01 fpc, respectively. Juvenile coho were captured at all four tributary mouths, five of the 16 side channels (31%) and two of the 14 sloughs (14%) sampled. Over half of the juvenile coho were captured at Caswell Creek mouth, with the majority in mid to late August. The juvenile coho catch rate at tributary mouths ranged from near ten juveniles per cell at Caswell Creek in late August to zero fish per cell at several sites during various sampling periods throughout the open-water season (Figure 12). With the exception of Birch Creek Slough, coho CPUE's were higher during late summer and fall than during early summer sampling periods.

3.2.3 Chum salmon

Six hundred eight juvenile chum salmon were collected in the lower Susitna River of which only ten were captured at opportunistic sites. In early June, chum fry were captured at 13 of 15 (87%) modelling sites sampled (Figure 13). By late July, chum were only captured at six of 19 (32%) sites sampled. Over 99% of the total catch was made prior to August and no chum salmon fry were captured after August 15. The majority of sites with high CPUE's were located in the reach from Island Side Channel (RM 63.2) to Sucker Side Channel (RM 84.5).

Chum fry CPUE's declined steadily from early June to mid-August (Figure 14), reflecting outmigration of juvenile chum salmon from the Susitna system. In a pre-study trip in late May, chum fry were collected at a number of lower river sites and appeared widely distributed in the river.

Juvenile chum CPUE's were highest in side channels (0.6 fpc) and tributary mouths (0.1 fpc). Slough CPUE's of juvenile chum were low (0.01 fpc), however, sampling effort at sloughs was limited from early June through early July. Tributary mouth densities were unequally distributed by a single site catch of 39 fry at Birch Creek Slough in late June. Juvenile chum catches at side channels were affected by turbidity. Peak chum catches were made in side channels with a turbidity of less than 50 NTU (Figure 15).

3.2.4 Sockeye salmon

Four hundred twelve juvenile sockeye salmon were captured in the lower Susitna River study reach. Ninety percent (369) of these fish were captured at the habitat modelling sites. Age 0+ sockeye comprised 99% of the catch. Age 1+ sockeye were found in early June at Hooligan Side Channel, a site which produced no further sockeye juveniles all season,

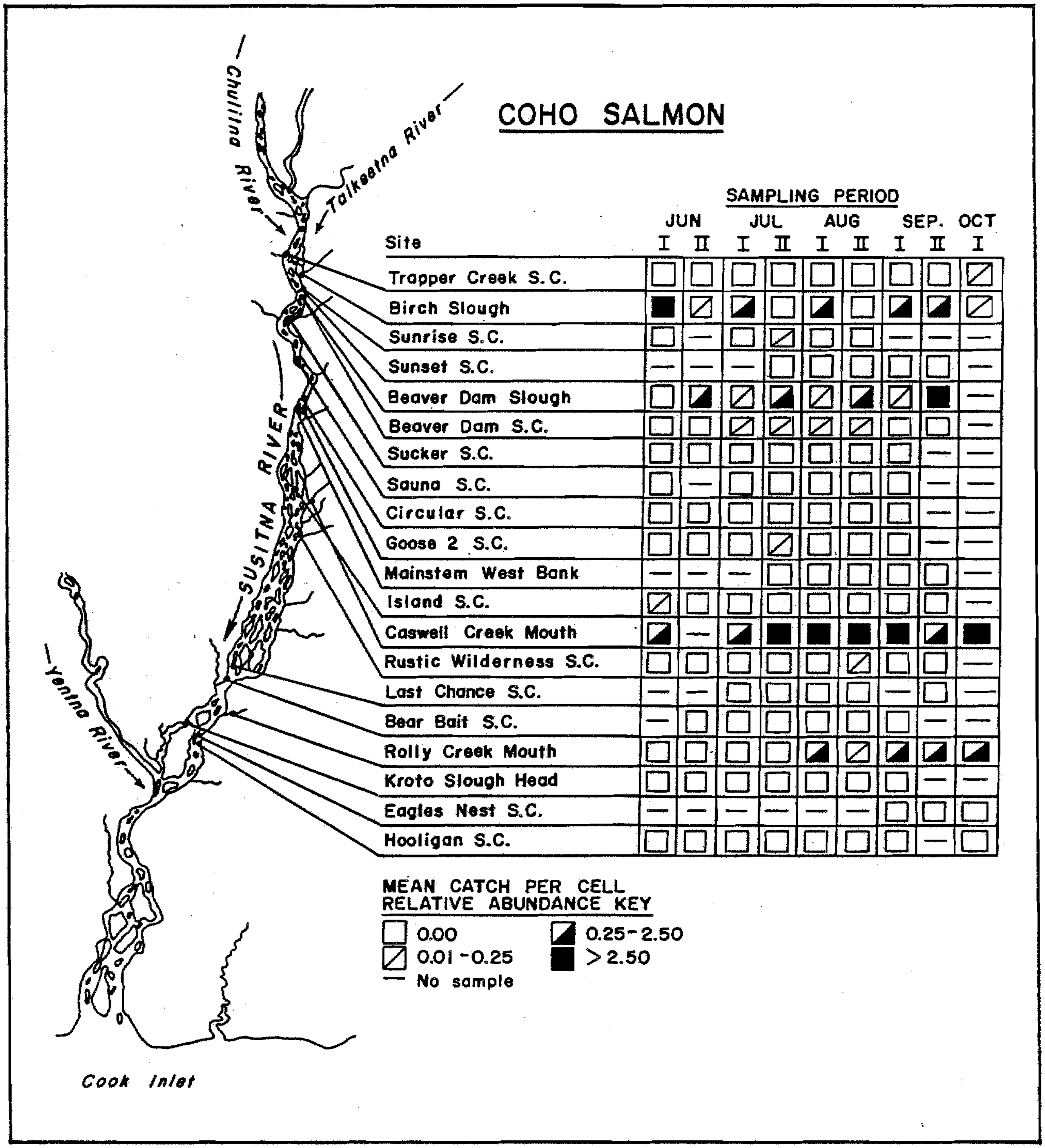


Figure 11. Seasonal distribution and relative abundance of juvenile coho salmon on the lower Susitna River, June through mid-October 1984.

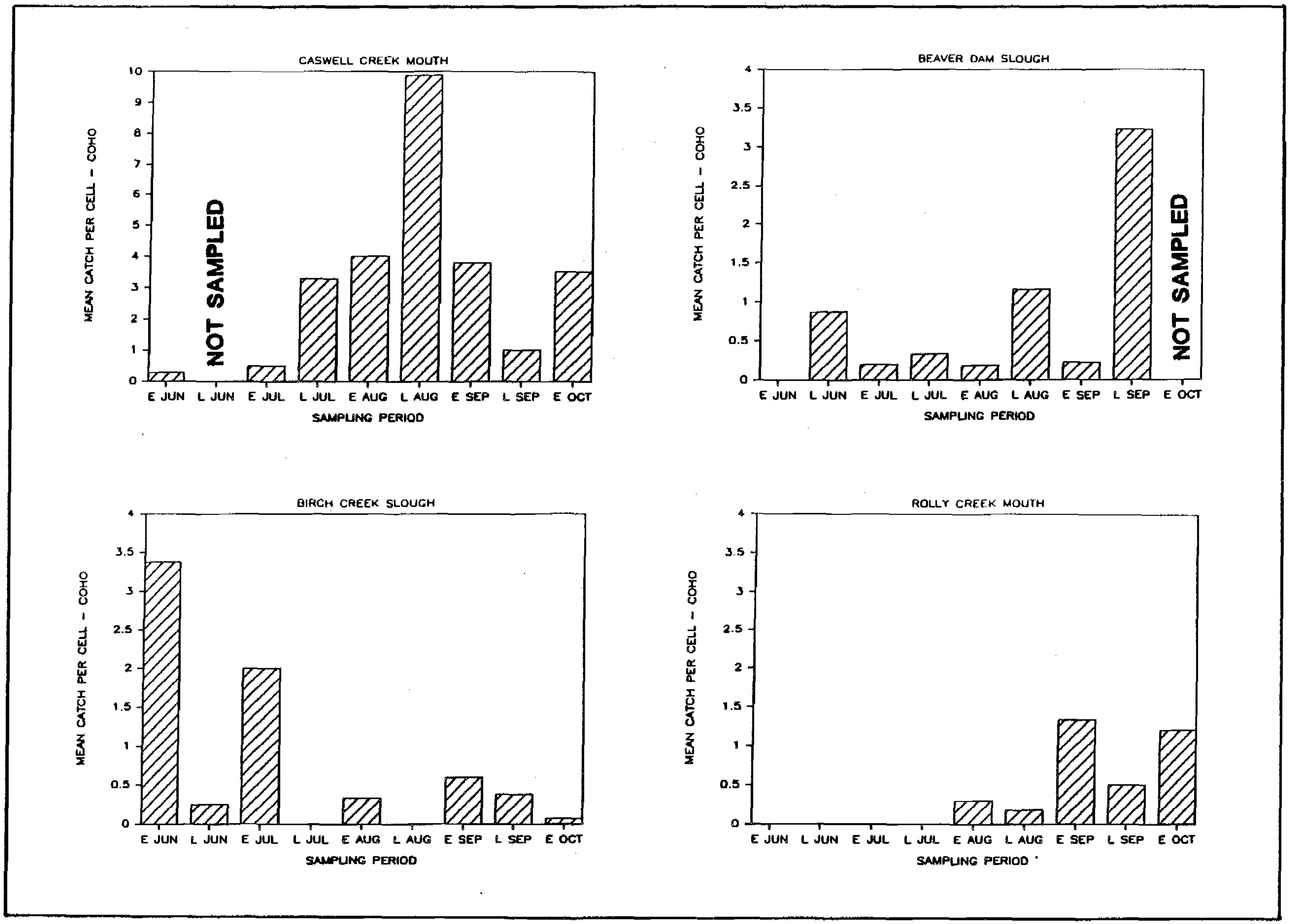


Figure 12. Juvenile coho salmon mean catch per cell at four tributary mouths on the lower Susitna River by sampling period, June through mid-October 1984.

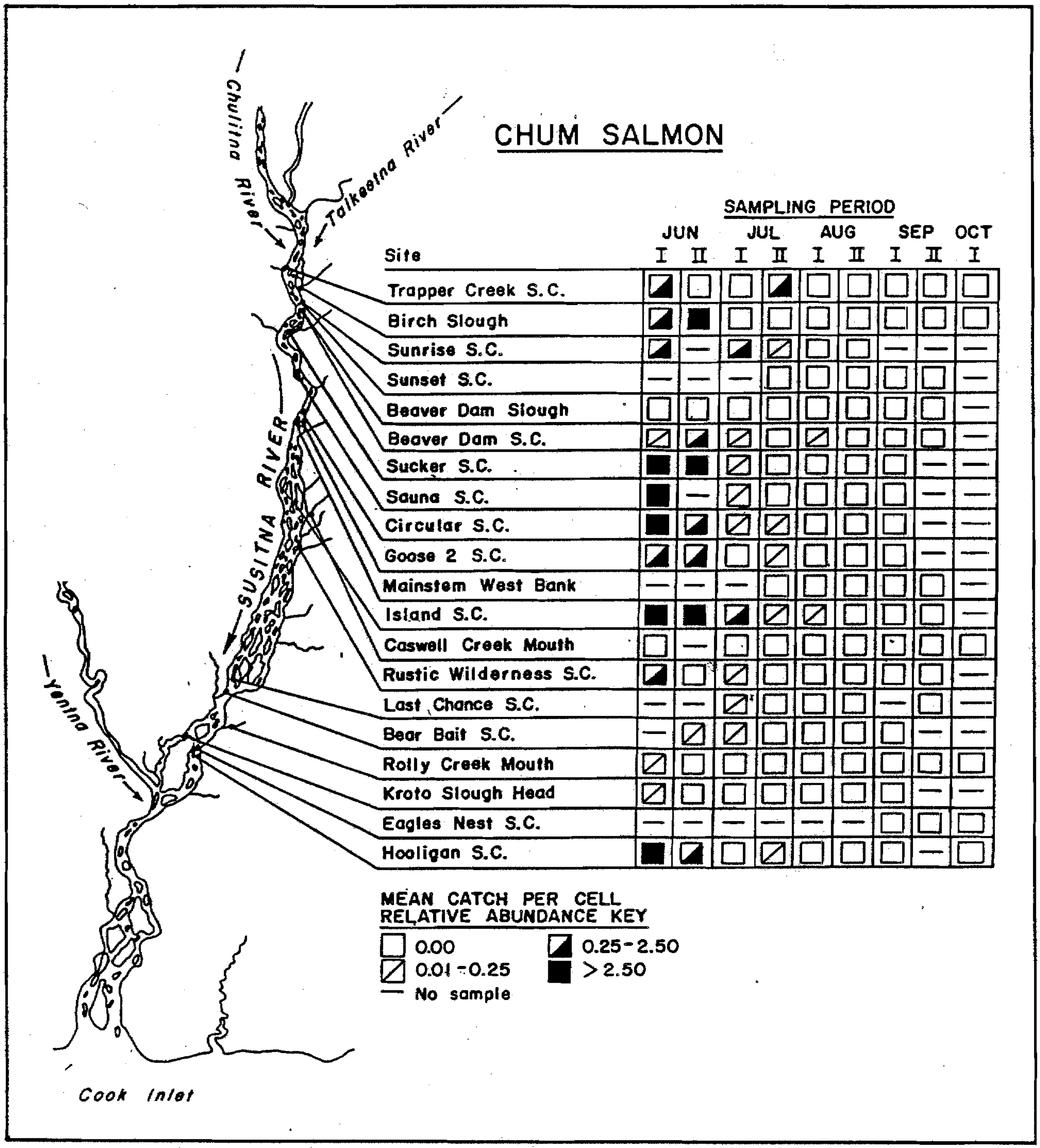


Figure 13. Seasonal distribution and relative abundance of juvenile chum salmon on the lower Susitna River, June through mid-October 1984.

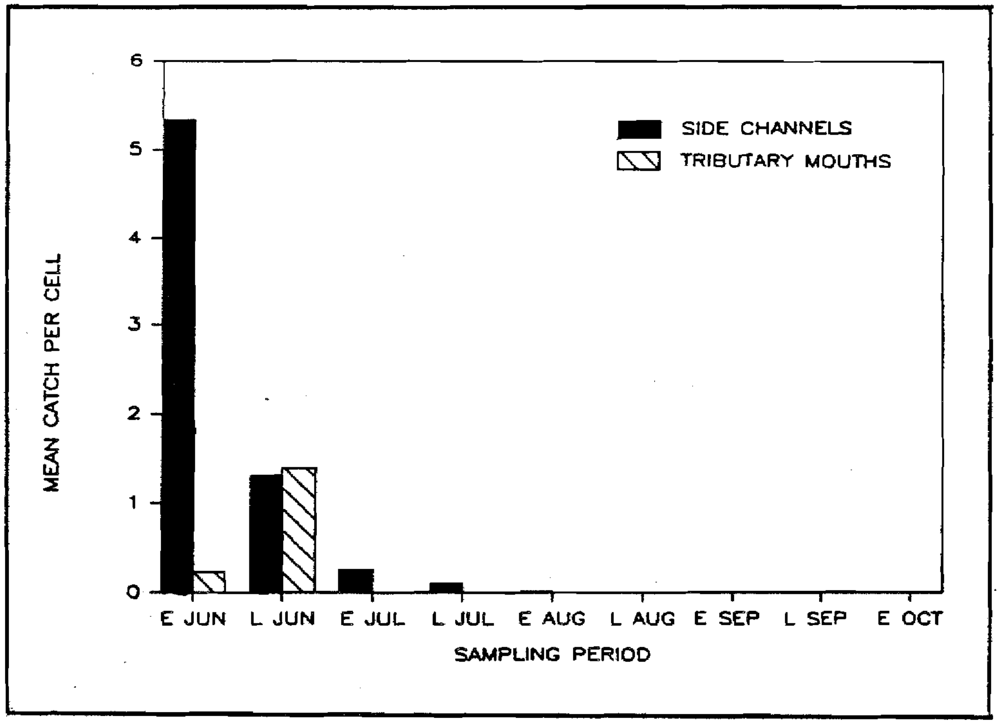


Figure 14. Juvenile chum salmon catch per cell at modelled side channels and tributary mouths on the lower Susitna River by sampling period, June through mid-October, 1984.

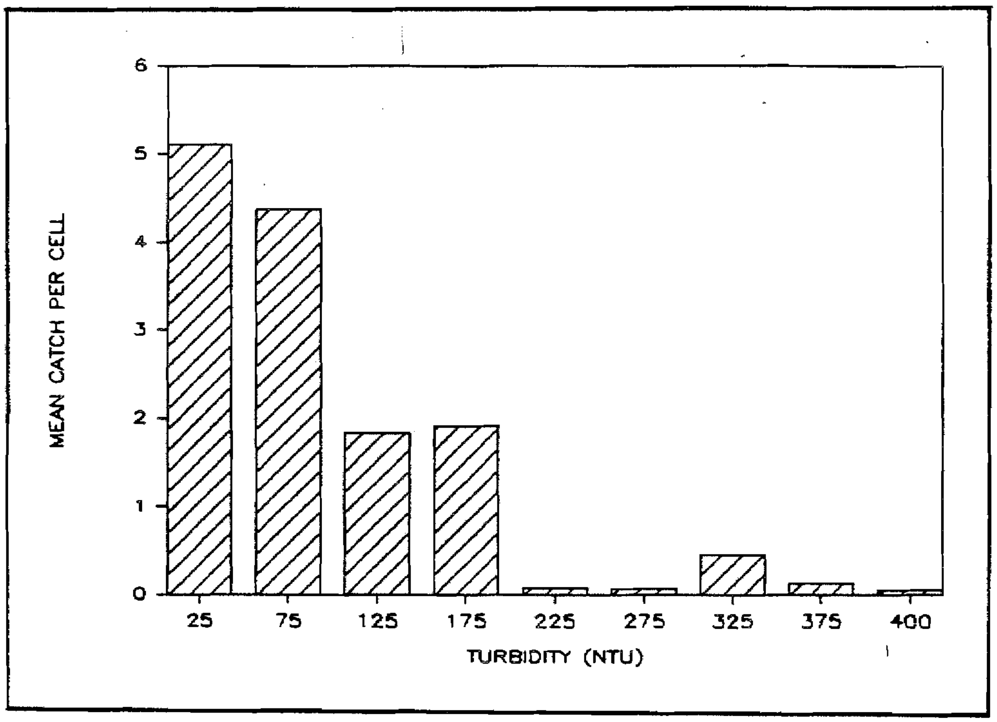


Figure 15. Juvenile chum salmon mean catch per cell at modelled side channels on the lower Susitna River by turbidity increment, June through mid-July 1984.

and in late June at Beaver Dam Slough. Sockeye juveniles were most widely distributed within modelled sites upstream of Goose 2 Side Channel (Figure 16).

Tributary mouths had the greatest densities of juvenile sockeye salmon with a mean catch of 0.7 fpc. The highest CPUE for juvenile sockeye at a tributary mouth was 1.2 fpc at Beaver Dam Slough. Side channels had a mean sockeye CPUE of 0.1 fpc. Beaver Dam Side Channel had the highest CPUE for a side channel of 0.7 fpc. Side slough CPUEs of sockeye juveniles were minimal (0.03 fpc). Side channel CPUE's remained at low levels through August in comparison to tributary mouth CPUE's which varied greatly (Figure 17). No sockeye juveniles were captured in side channels after August, however, sampling was limited.

Sockeye fry CPUEs were highest in side channels where turbidities ranged between 100 and 150 NTU (Figure 18). The numbers of sockeye juveniles captured in Beaver Dam Side Channel, immediately below and contiguous with Beaver Dam Slough, may have been enhanced by site to site movement. With Beaver Dam Side Channel captures excluded, the peak CPUE for juvenile sockeye in side channels occurred at turbidities between 50 and 100 NTU.

Catches at Beaver Dam Slough and Beaver Dam Side Channel show the effects of turbidity as cover on the distribution of sockeye juveniles (Figure 19). From late June through August, Beaver Dam Side Channel was breached by the mainstem, the water was turbid, and sockeye CPUE's were high. In early June and September, however, the head of the channel was not breached, the water was clear, and few sockeye juveniles were caught in this environment with little cover. In contrast, Beaver Dam Slough, which had abundant aquatic vegetation cover, had high CPUE's of sockeye juveniles in late August and September. Catches at Rolly Creek also increased in late August and remained fairly high through early October (Figure 19).

3.3 Habitat Modelling of Rearing Juvenile Salmon

The response of juvenile salmon habitat to variations in mainstem discharge was modelled using two techniques: (1) the RJHAB model developed in Marshall et al. (1984) and (2) the IFIM hydraulic models discussed by Bovee (1982). Suitability criteria for important microhabitat variables are necessary as inputs to both models and criteria specific to the lower reach of the Susitna River for juvenile chinook, coho, chum, and sockeye salmon have been developed in Appendix A.

In the following discussion, results are presented by species. Each presentation includes modelling results from selected sites using the RJHAB or IFIM models, pooled results from all the sites modelled, and a test of model verification.

No results from the Birch Creek Slough and Eagles Nest Side Channel modelling sites are presented here. At Birch Creek Slough, there was no measurable effect of mainstem discharge upon the site as mainstem backwater at discharges less than 75,000 cfs did not extend to the site and a blocked culvert at the head of the slough stopped mainstem water

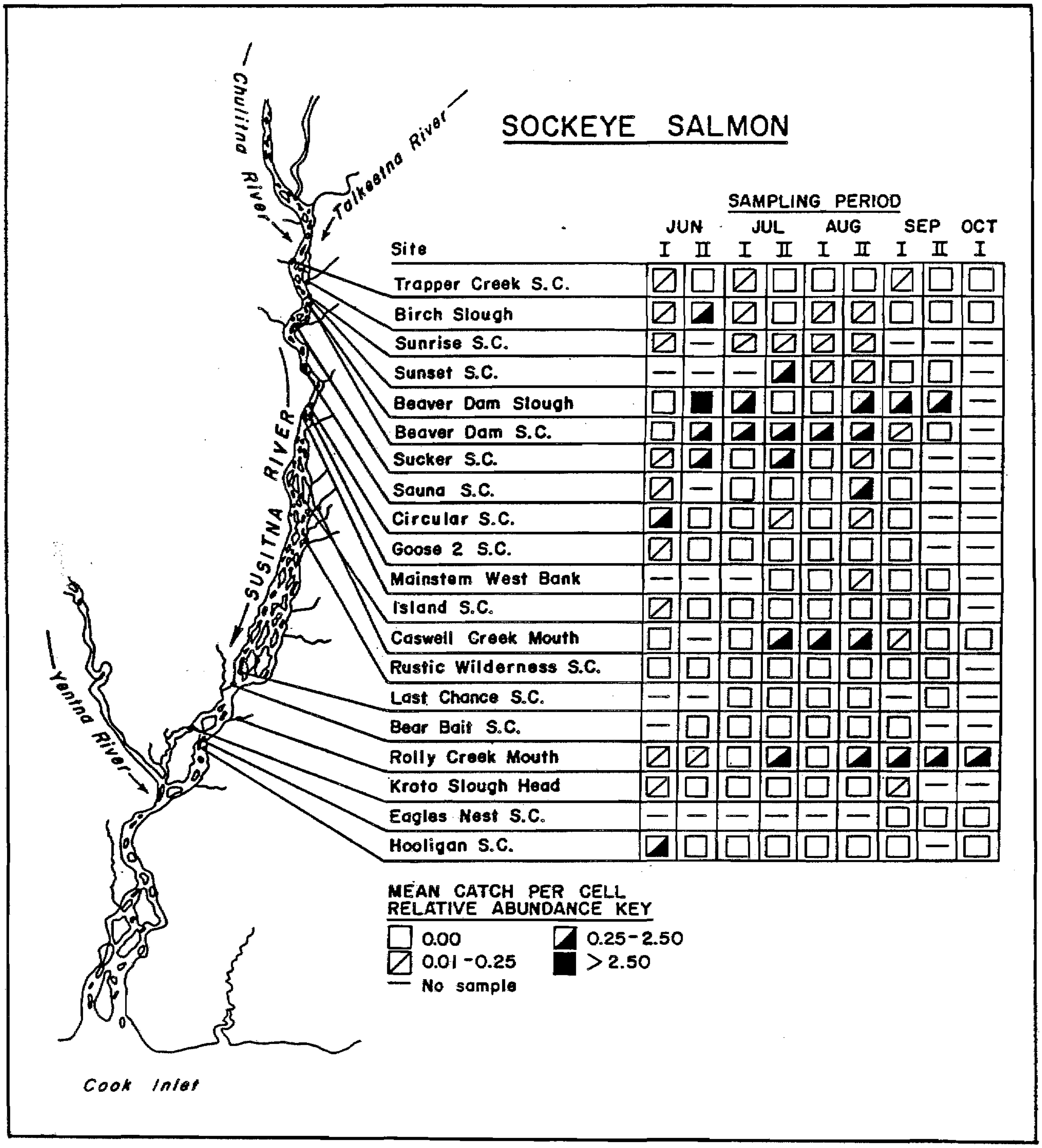


Figure 16. Seasonal distribution and relative abundance of juvenile sockeye salmon on the lower Susitna River, June through mid-October 1984.

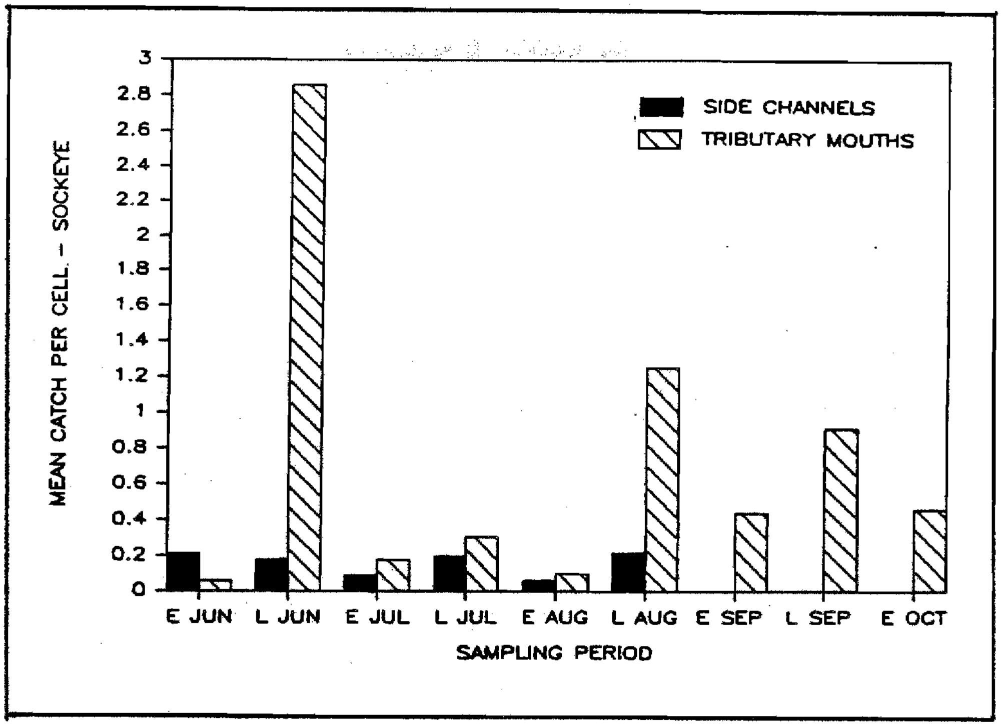


Figure 17. Juvenile sockeye salmon mean catch per cell at side channels and tributary mouths on the lower Susitna River by sampling period, June through mid-October 1984.

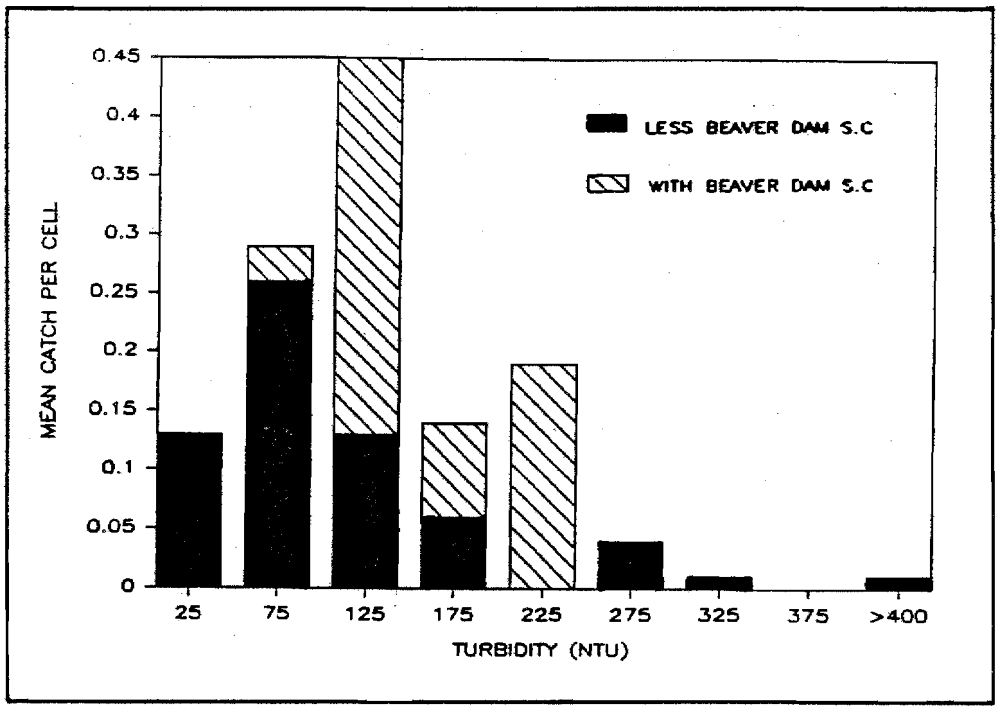


Figure 18. Juvenile sockeye salmon mean catch per cell at modelled side channels on the lower Susitna River by turbidity increment (with and without Beaver Dam Side Channel), June through mid-October 1984.

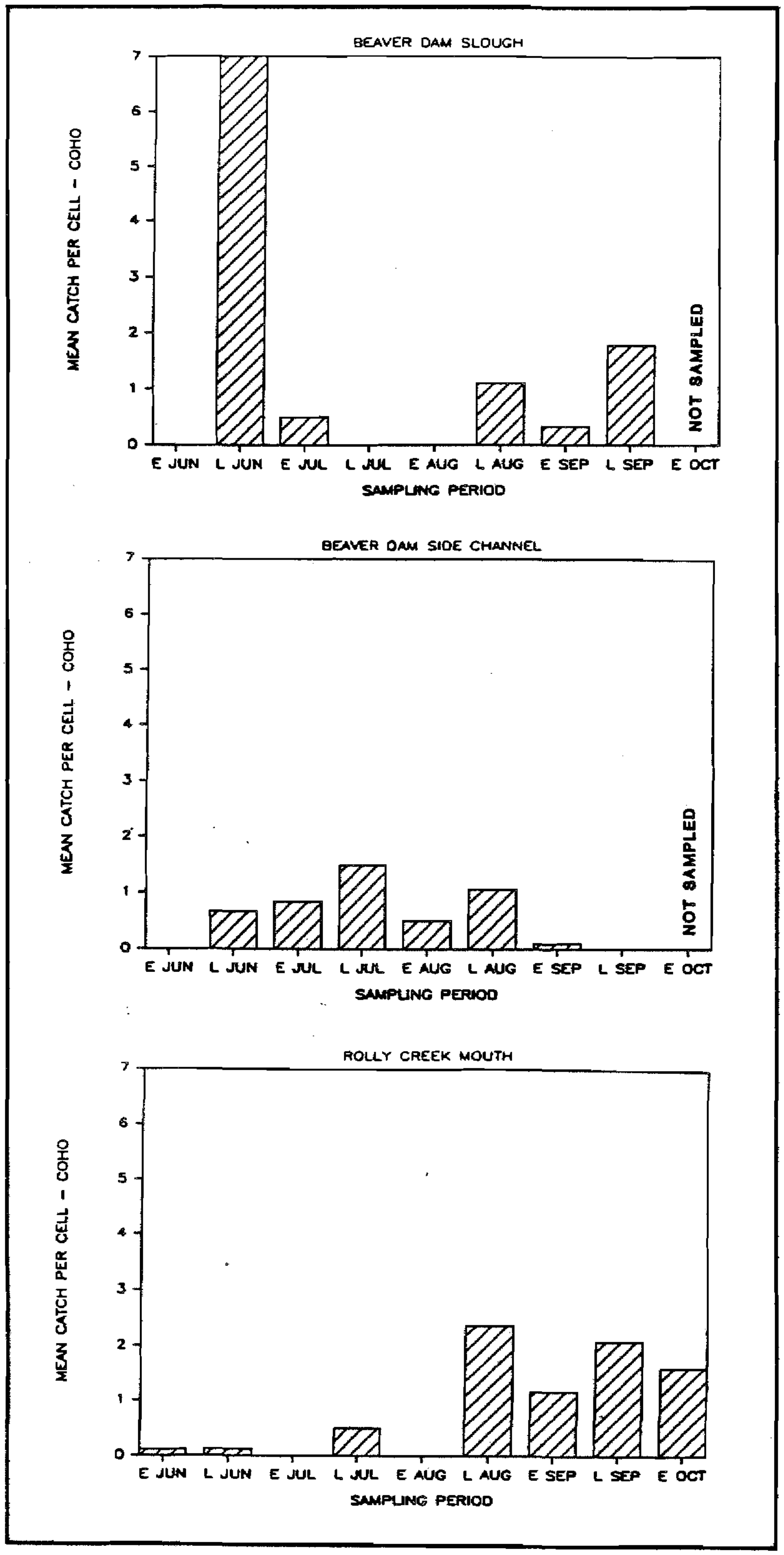


Figure 19. Juvenile sockeye salmon mean catch per cell at Beaver Dam Slough, Beaver Dam Side Channel, and Rolly Creek Mouth by sampling period, June through mid-October 1984.

from flowing through the site. The Eagles Nest Side Channel site was modelled only twice at mainstem flows of 14,900 and 20,400 cfs and therefore could not be readily extrapolated to discharges of 75,000 cfs. All of the other sites were modelled at three or more discharges and results were extrapolated to discharges ranging from 12,000 to 75,000 cfs. The WUAs and site areas at the RJHAB sites were not adjusted to a reach length of 1,000 ft as were the IFIM WUAs. Lengths of all the RJHAB sites are listed in Appendix Table B-3, so that the WUAs could be adjusted if desired.

The instream flow results have been generated only to discharges of 75,000 cfs because it is very difficult to collect data at discharges greater than 75,000 cfs. At 75,000 cfs, most of the side channel sites have very large flows and are poor habitat for juvenile fish. At higher discharges, the entire flood plain becomes full and the flows are barely constrained within the side channels. Refuge for the juvenile fish at these times presumable include large backwater areas and small side channels which are infrequently flooded.

At Island and Trapper Creek side channels, both RJHAB and IFIM models were run on the same transects. Comparative results for these two models are given in Appendix C. The summary figures presented here incorporate data from the RJHAB model at these two side channels.

The ability of the RJHAB models to extrapolate WUA between discharges of 12,000 and 75,000 cfs was rated unacceptable to good (Table 5). Some models were rated fair because there were no habitat measurements taken at discharges just above overtopping of the side channel. Eagle's Nest Side Channel was rated unacceptable because measurements were taken on only two occasions at discharges less than 21,000 cfs.

The IFIM models were evaluated according to hydraulic criteria on the basis of excellent to acceptable (Appendix D). Acceptable ranges of the models usually extend to over 60,000 cfs (Table 6). The models were run and WUAs generated at side channel flows which corresponded to discharges ranging to 75,000 cfs, so reliability at these flows is unknown. At discharges below overtopping, the WUAs of IFIM sites at flows of 5 or 6 cfs were used, except at Trapper Creek Side Channel where a site flow-mainstem discharge rating curve for unbreached conditions developed by Quane et al. (1985) was used to estimate unbreached flows.

Since suitability criteria for chinook salmon juveniles have been developed for both turbid (>30 NTU) and clear (<30 NTU) conditions, several assumptions were made. Tributary mouth sites were assumed to be clear (>30 NTU) at all discharges less than 75,000 cfs. This is not always the case, as occasionally turbid mainstem water may back up into tributary mouths with a rapid increase in mainstem stage. Also spring runoff or large storms may increase turbidities at tributary mouths to over 30 NTU. Available data, however, have indicated turbidities at tributary mouths are normally less than 30 NTU (Figure 3). At side channel/slough sites, turbidities were assumed to be greater than 30 NTU when the site was breached and less than 30 NTU when the site was not breached. In early June, September, and early October, turbidities in side channels were sometimes less than 30 NTU (Figure 3). Many of the

Table 5. Evaluation of RJHAB model quality for extrapolating WUAs over the range of 12,000 to 75,000 cfs as measured at Sunshine gaging station, 1984.

Site	Number of Habitat Measurements	Model Quality[1]
Hooligan Side Channel	5	Good
Eagle's Nest Side Channel	2	Unacceptable
Kroto Slough Head	4	Fair
Rolly Creek Mouth	4	Good
Bear Bait Side Channel	4	Fair
Last Chance Side Channel	5	Fair
Rustic Wilderness Side Channel	5	Good
Caswell Creek Mouth	3	Fair
Island Side Channel	5	Good
Goose 2 Side Channel	4	Fair
Sucker Side Channel	4	Good
Beaver Dam Slough	4	Good
Beaver Dam Side Channel	3	Good
Sunrise Side Channel	4	Fair
Birch Creek Slough	3	Good
Trapper Creek Side Channel	4	Good

[1] Model quality definitions:

1. Good - Side Channels: Measurements spaced so as to cover the range of mainstem discharges above breaching to 75,000 cfs. Models include information about unbreached, barely breached, and a minimum of two other breached flows, one near 75,000 cfs.

   Tributary Mouths: Models include information when no backwater, moderate backwater, and high backwater present.

2. Fair - Side Channels: Model missing information concerning habitat when channel is barely breached, or other flows given above.

   Tributary Mouths: Not enough measurements to accurately describe amount of backwater effect.

3. Unnacceptable - Less than three data points - cannot describe a curve.

Table 6. Discharge ranges of IFIM models at lower Susitna River sites for which hydraulics are rated acceptable, 1984. Data taken from Appendix D.

Site	Acceptable Range
Island Side Channel	35,000 to 70,000 cfs
Mainstem West Bank	18,000 to 48,000 cfs
Circular Side Channel	36,000 to 63,000 cfs
Sauna Side Channel	44,000 to 63,000 cfs
Sunset Side Channel	32,000 to 67,000 cfs
Trapper Creek Side Channel	20,000 to 66,000 cfs

model sites were not breached during these periods of low mainstem discharge. Turbidities in side sloughs were usually less than 10 NTU.

3.3.1 Chinook Salmon

Chinook salmon juveniles were captured at all of the study sites with the exception of Last Chance Side Channel (Figure 8). Since chinook juveniles were widely distributed, results from all sites modelled with RJHAB and IFIM techniques will be presented.

Graphs of the weighted usable area responses to mainstem discharges for all sites not presented here are included in Appendix B. Appendix B also contains the tabulated values of weighted usable areas at 3,000 cfs increments as digitized from these graphs (including site graphs presented here). Also tabulated are habitat indices which were calculated by dividing the weighted usable area at a given discharge by the site area at the same discharge.

At the Rolly Creek, Caswell Creek, and Beaver Dam Slough tributary mouth sites, the responses of weighted usable area to mainstem discharge were very similar. The Rolly Creek mouth weighted usable area response to discharge is presented here as an example (Figure 20). The great increase in weighted usable area with discharge above approximately 45,000 cfs is due to the effect of mainstem backwater causing large increases in area, depth, and amount of cover.

At side channel/slough sites, the responses of weighted usable areas to mainstem discharge was varied. Normally, the weighted usable area increased greatly after overtopping and then decreased with further increases in mainstem discharge as at Kroto Slough Head (Figure 20). The increase in weighted usable area after overtopping is due to increases in area and also increases in cover suitability as turbidity improves cover. As discharge increases with site flow, velocities initially become more suitable, but then as flows continue to rise, velocities become unsuitable and WUA decreases.

At Sucker Side Channel, backwater effects buffer the velocities from becoming too high and so weighted usable area increases after overtopping and then remains nearly the same to a discharge of 45,000 cfs after which it rapidly increases (Figure 20). At approximately 60,000 cfs, WUA's begin to decline at this site, however, as velocities and depths become unsuitable. At other sites, WUA held quite constant after overtopping or slowly increased (see Appendix B).

When WUA's from three tributary mouths are pooled there is no large change in WUA until approximately 45,000 cfs when the WUA increases greatly with discharge (Figure 21). By dividing the WUA at 3,000 cfs increments by pooled area for the three sites and plotting the habitat index, it becomes apparent that the change in WUA is not simply due to increases in site area. Increases in habitat indices are due to increases in the amount of instream cover, more suitable velocities, and deeper water which may also provide cover.

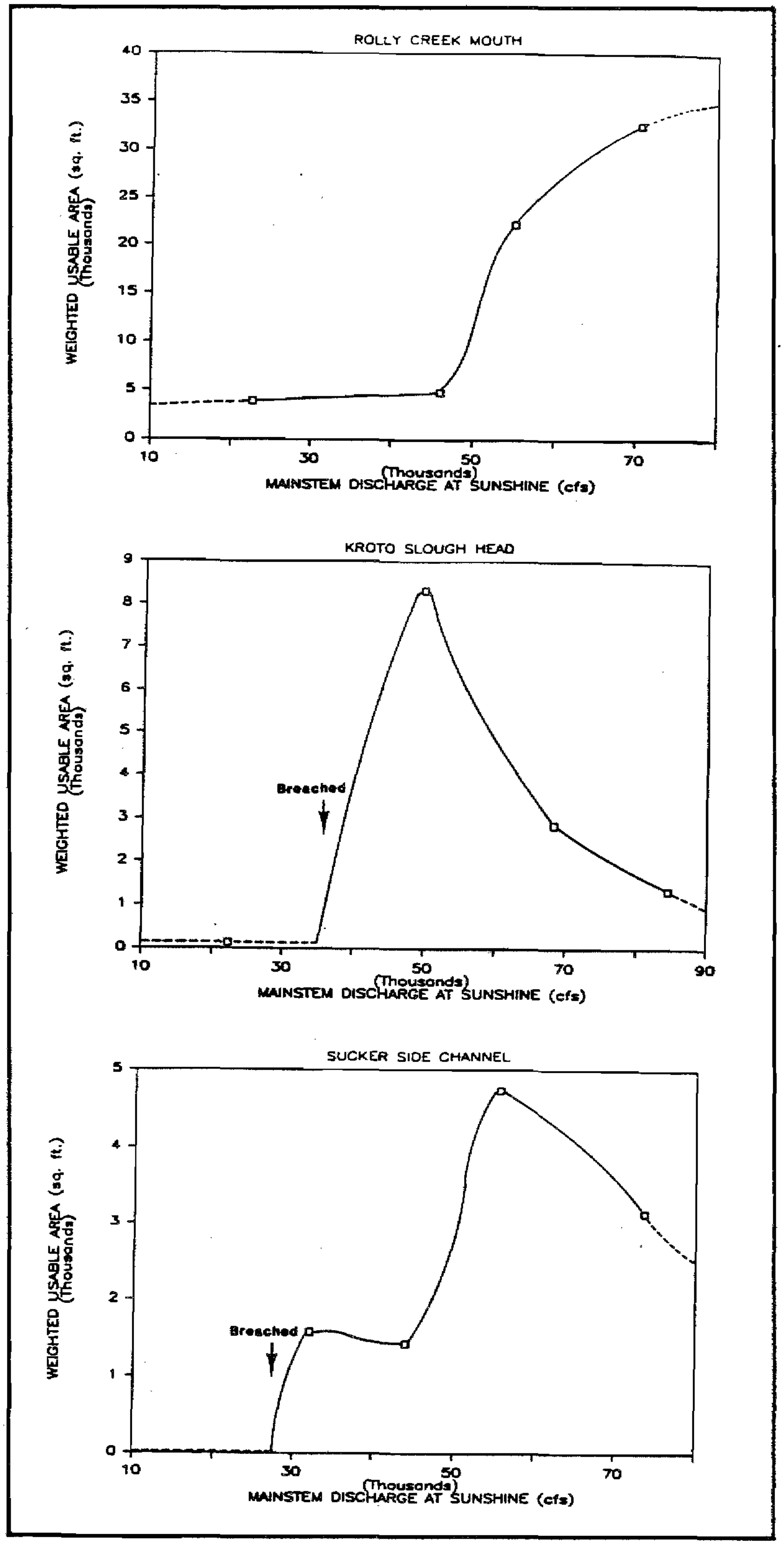


Figure 20. Weighted usable area for juvenile chinook salmon at Rolly Creek Mouth, Kroto Slough Head, and Sucker Side Channel study sites as a function of mainstem discharge, 1984.

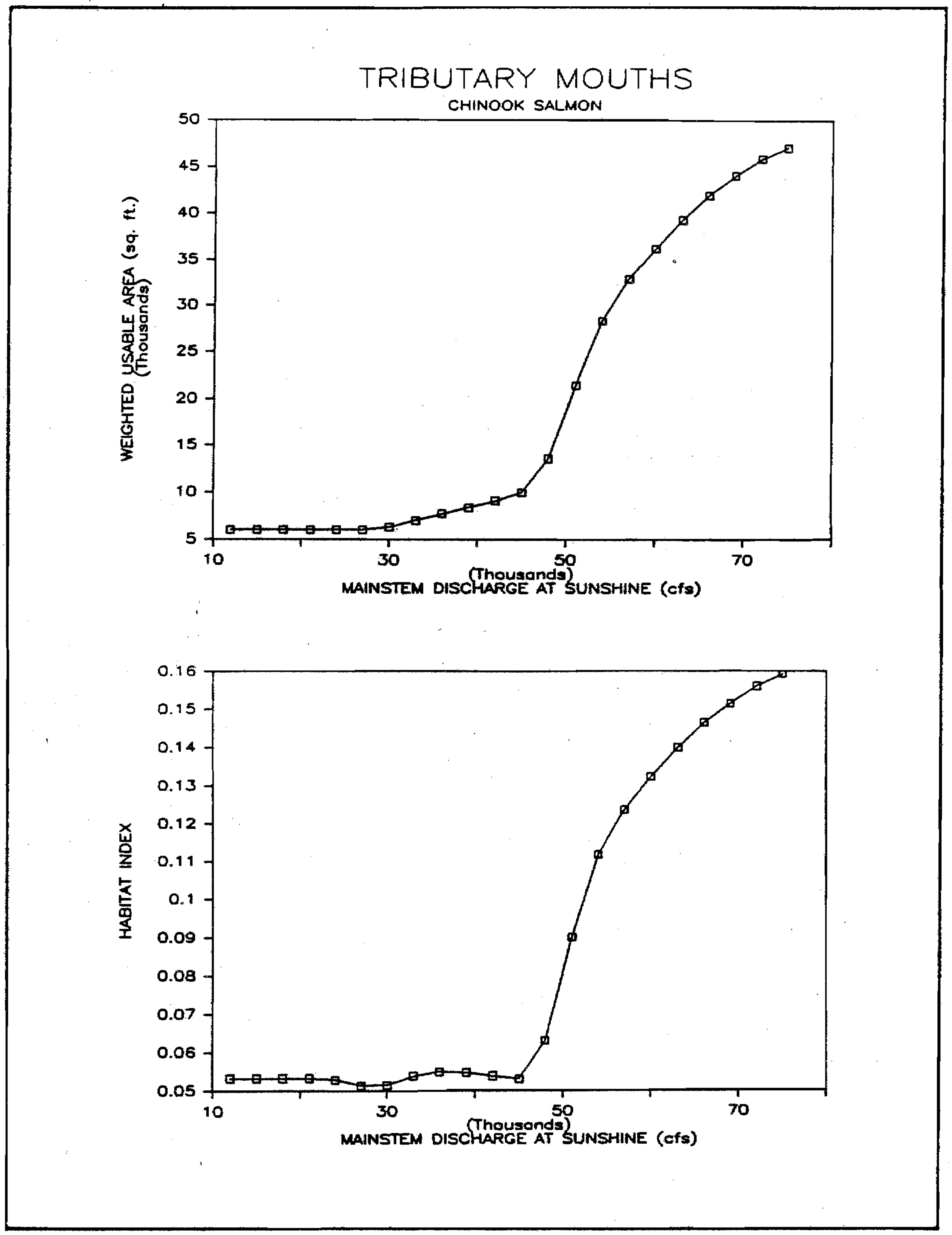


Figure 21. Weighted usable area and habitat indices for juvenile chinook salmon at tributary mouth sites as a function of mainstem discharge, 1984.

When WUA's from the modelled side channels/sloughs are pooled, WUA's increase greatly to approximately 40,000 cfs and then very gradually decline (Figure 22). Habitat indices for the pooled side channels show a similar rise to a peak at 40,000 cfs but then a rapid decrease to approximately 60,000 cfs when the habitat index levels off. The relatively more rapid decrease in the habitat index is due primarily to velocities and depths becoming very unsuitable at the higher discharges.

Turbidity has been shown to be an important determinant of juvenile chinook distribution (Figure 10). Turbidity varies in the Susitna River from the east bank to the west bank downstream from the Chulitna and Talkeetna river confluences (Figure 4). In formulating the pooled side channel/slough response of juvenile salmon habitat, it was desirable to weight turbidity as it varies from site to site.

Although turbidity data for the model sites are limited, an average turbidity for the side channels modelled during the period from June through August was calculated in Appendix Table B-1. A preliminary suitability index for high turbidity was then fit to the data in Figure 10 (Table 7). This index is specific only to the turbidity regimes of lower river side channels and is undefined for application to turbidities of less than approximately 100 NTU. When the turbidity indices and mean turbidities were combined, WUA estimates for the sites were weighted differently (Table 8).

When the WUA estimates for each site are adjusted by these factors and the WUA's are again totalled, the WUA and habitat index response adjusted for turbidity for the side channels combined can again be examined (Figure 23). There is very little change from the previous unadjusted graph in the shape of the WUA response curve, but the magnitude was reduced by almost 40%. Similarly, the shape of the habitat index responses curve has also been changed very little by these adjustments. The lack of change in shape of these curves suggests that the responses of the side channel WUAs and habitat indices are similar for most of the sites.

The mean seasonal chinook salmon habitat index for the 15 side channels and four tributary mouths were calculated and compared with mean chinook catch (Figure 24). The positive relationship was statistically significant ($p \leq 0.001$) but not very strong. Most of the correlation was due to the large catch (5.16 fpc) and habitat index (0.19) at Caswell Creek mouth. Another outlier is Beaver Dam Slough with a habitat index of 0.17 and a mean catch of 0.17 chinook per cell.

3.3.2 Coho Salmon

Since coho salmon were captured in number (more than 20) only at the tributary mouth sites, only results from these sites will be presented here. In Appendix B, values of WUA's and habitat indices at 3,000 cfs increments for these areas are presented.

The response of WUA to mainstem discharge at the three tributary mouths varied (Figure 25). At Caswell Creek mouth, WUA rose with discharge due to increases in area and the amount of preferred cover. At Rolly Creek

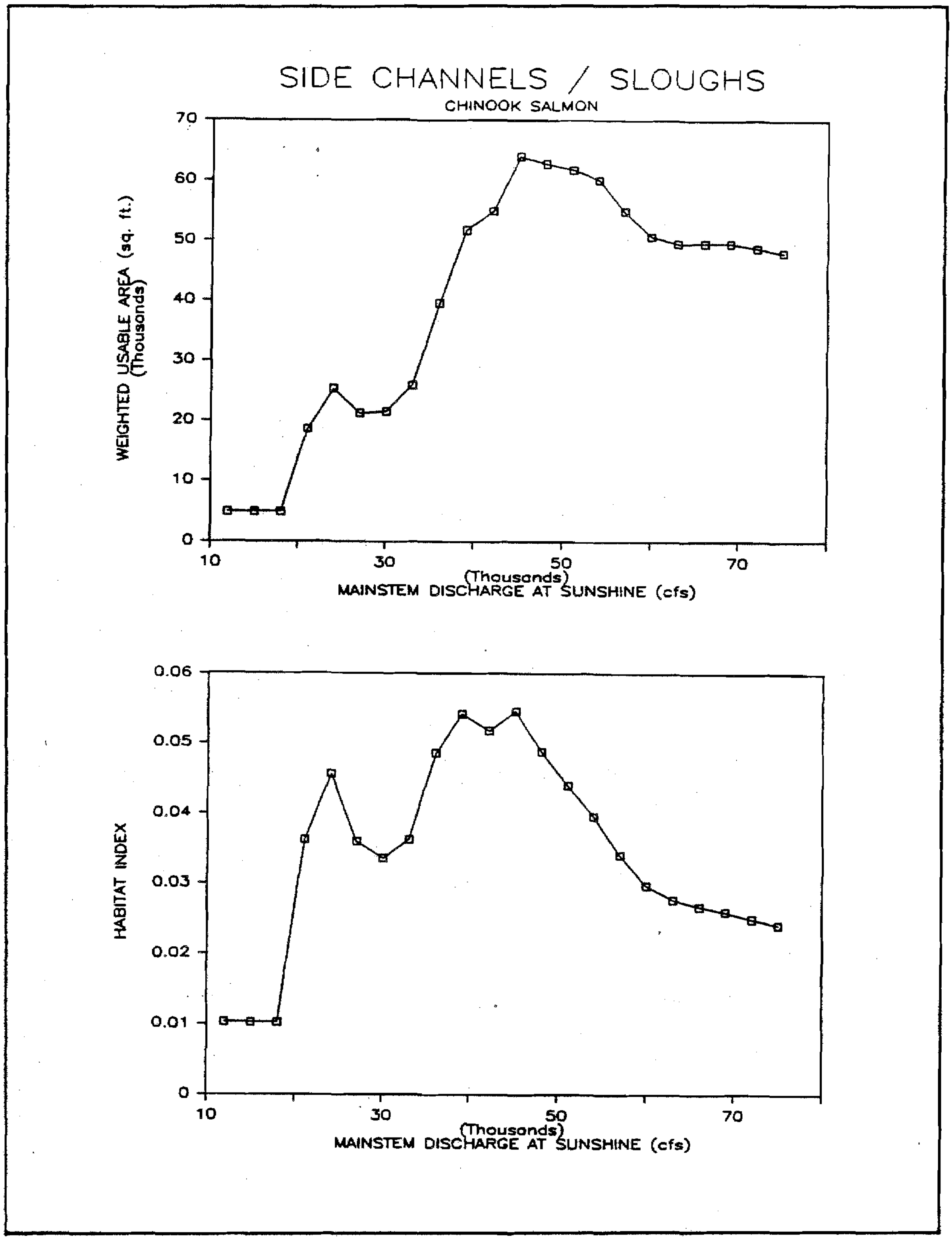


Figure 22. Weighted usable area and habitat indices for juvenile chinook salmon at side channel/slough study sites as a function of mainstem discharge, 1984.

Table 7. Preliminary juvenile chinook salmon turbidity criteria derived from lower Susitna River side channel distribution data for turbidities greater than 100 NTU. These criteria are only applicable to lower Susitna River side channels.

Mean Turbidity (NTU)	Suitability
101 - 200*	1.00
201 - 250	0.65
251 - 300	0.55
301 - 350	0.40
350	0.15

* Suitability index for turbidities of less than 101 NTU is undefined and may be greater than 1.0.

Table 8. Weighting factors for turbidity by side channel site for analysis of juvenile chinook salmon habitat use, 1984.

Site	Mean Turbidity (NTU)	Turbidity Weighting Factor
Hooligan Side Channel	377	0.15
Kroto Slough Head	388	0.15
Bear Bait Side Channel	254	0.55
Last Chance Side Channel	365	0.15
Rustic Wilderness Side Channel	118	1.00
Island Side Channel	215	0.65
Mainstem West Bank	279	0.55
Goose 2 Side Channel	194	1.00
Circular Side Channel	241	0.65
Sauna Side Channel	266	0.55
Sucker Side Channel	140	1.00
Beaver Dam Side Channel	139	1.00
Sunset Side Channel	152	1.00
Sunrise Side Channel	121	1.00
Trapper Creek Side Channel	499	0.15

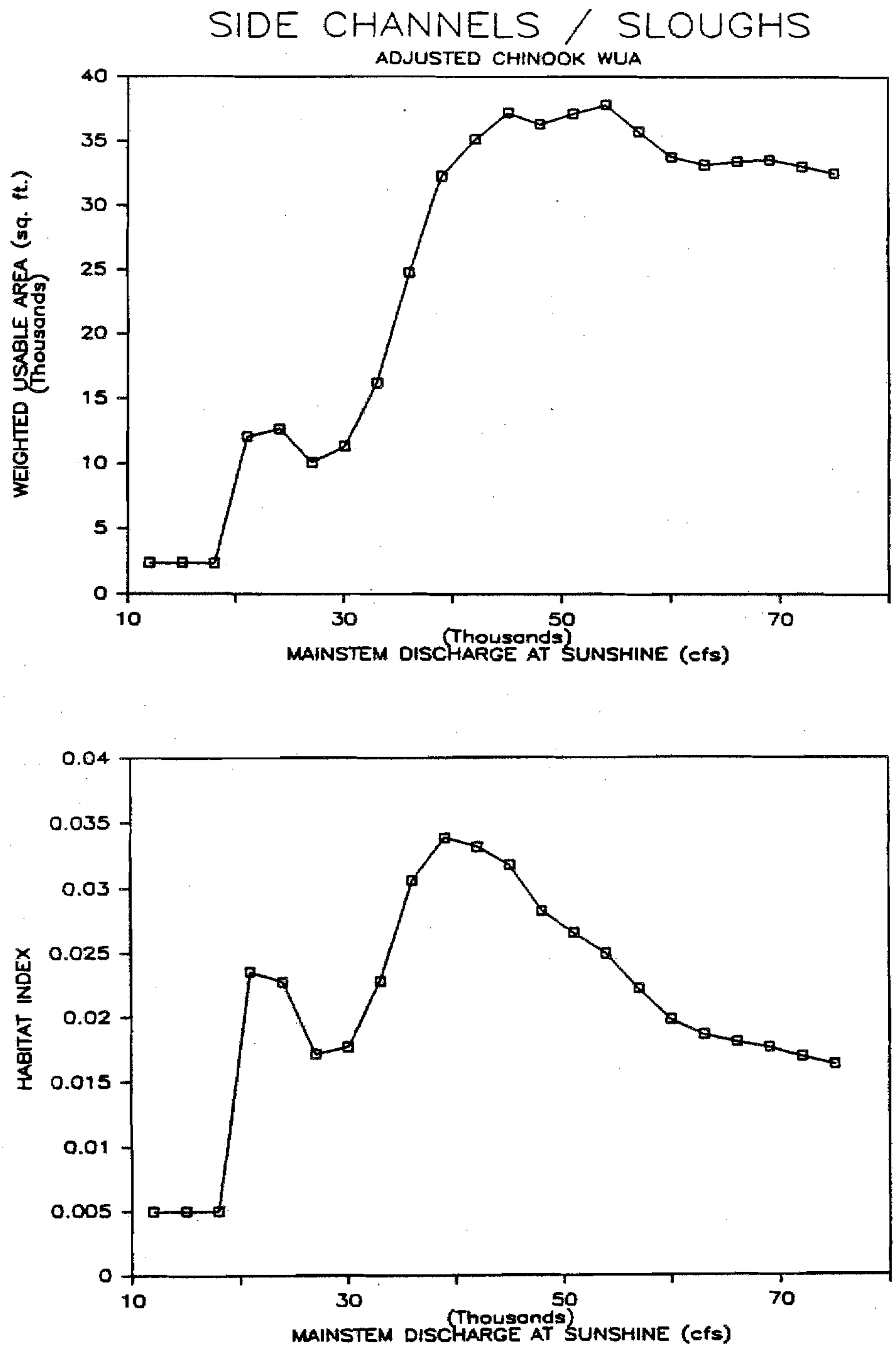


Figure 23. Turbidity adjusted weighted usable area and habitat indices for juvenile chinook salmon at side channel/slough study sites as a function of mainstem discharge, 1984.

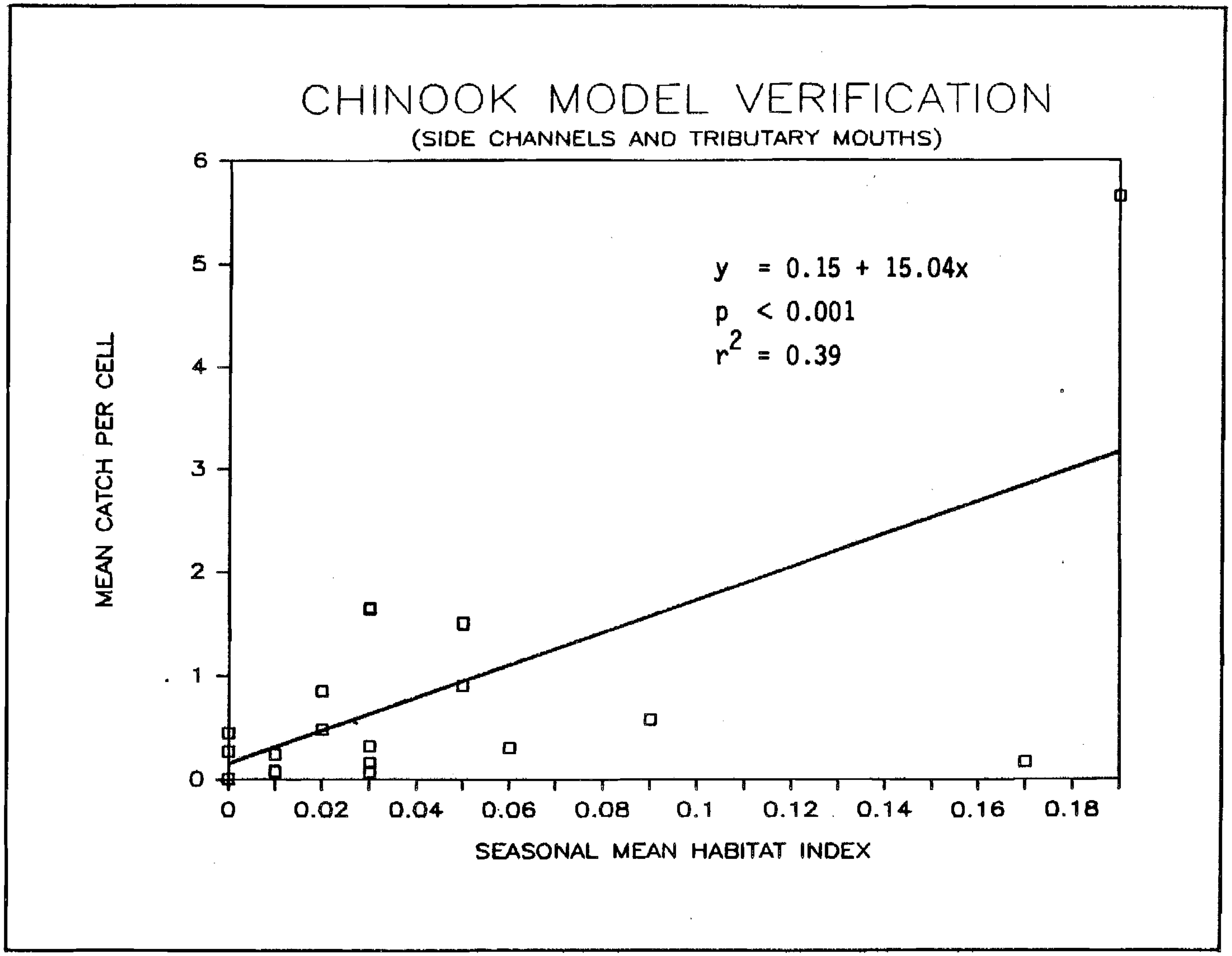


Figure 24. Juvenile chinook salmon mean catch per cell versus seasonal mean habitat indices at side channel and tributary mouth modelling sites on the lower Susitna River, 1984.

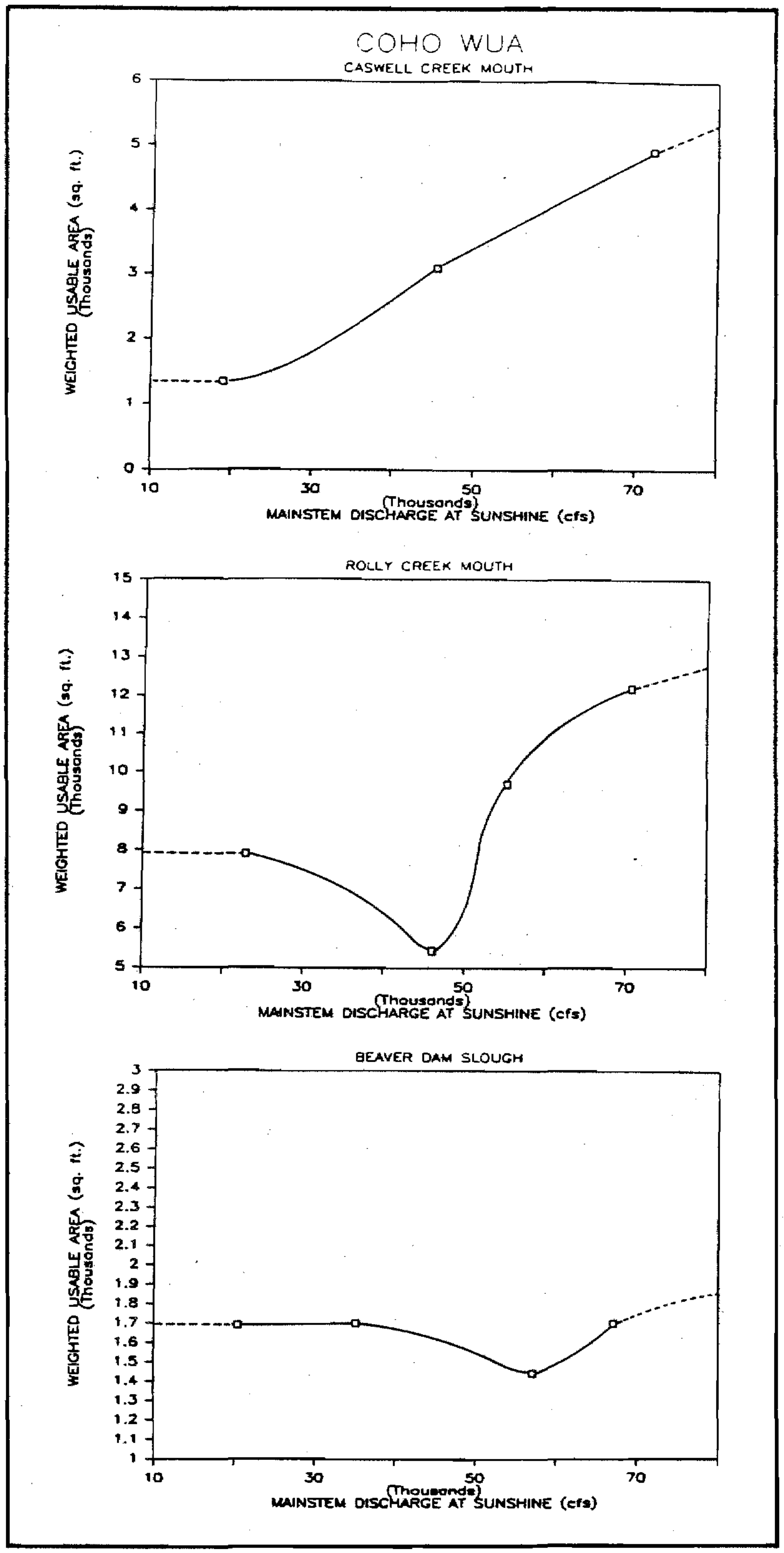


Figure 25. Weighted usable area for juvenile coho salmon at the Caswell Creek, Rolly Creek, and Beaver Dam Slough tributary study sites as a function of mainstem discharge, 1984.

mouth, the WUA first decreased with discharge due to the formation of zero velocity backwater from a free flowing state without major changes in cover or area. At higher discharges, the WUA increases due to a rise in area and usable cover. At Beaver Dam Slough, these effects of backwater formation and increases in cover inundated offset one another so that there was little change in WUA with discharge.

When the WUA's from all three sites are summed (Figure 26), there is little change in WUA until approximately 50,000 cfs when the WUA begins to increase greatly with discharge. When the effect of change in area is taken out by calculating a habitat index, site quality decreases initially as the backwater is formed and then begins to increase as cover is inundated by backwater.

The mean habitat index for the season (May 15 to October 15) was calculated for the four tributary mouths. Since Birch Creek Slough was a natal area, only catches from mid-July through mid-October were used in calculating the mean site catch. The mean catch per cell of coho juveniles increased with the mean habitat index but a linear regression was not statistically significant at the 0.05 level (Figure 27). None of the side channels had mean seasonal habitat indices greater than 0.05 and most were 0.03 or less, primarily due to the lack of suitable cover types.

3.3.3 Chum Salmon

Chum salmon were widely distributed at all of the side channel sites sampled from early June through July 15 (Figure 13). Therefore, graphs of the WUA response as a function of mainstem discharge for all the side channel/slough sites not presented here are included in Appendix B. Also tabulated in Appendix B are values of WUA's and habitat indices at 3,000 cfs increments as digitized from the graphs.

Responses of WUA's at the sites to increases in mainstem discharge were variable. At Rustic Wilderness Side Channel, WUA greatly increased after overtopping and then declined with further increases in discharge as velocities and depths became unsuitable (Figure 28). At other sites, for example Last Chance Side Channel, the increase in WUA after overtopping was considerably less while at Trapper Creek Side Channel (Figure 29), WUA's decreased after overtopping. At Sunset Side Channel, WUA increased after overtopping until about 53,000 cfs when WUA quickly declined. The other sites also showed variations of these response curves (see Appendix B figures).

When WUA's from all modelled side channel/slough sites are pooled, the peak in WUA's for the sites occurs at a discharge of 40,000 to 52,000 cfs (Figure 30). Above this discharge range, WUA's decrease rapidly due to unsuitable velocities and depths. Habitat indices for the same pooled sites are constant through about 24,000 cfs and then decrease steadily.

Chum salmon use of side channels was affected by turbidity (Figure 15), and since turbidity varied from site to site, WUA's for each site were adjusted for turbidity. Since chum salmon outmigration is mostly

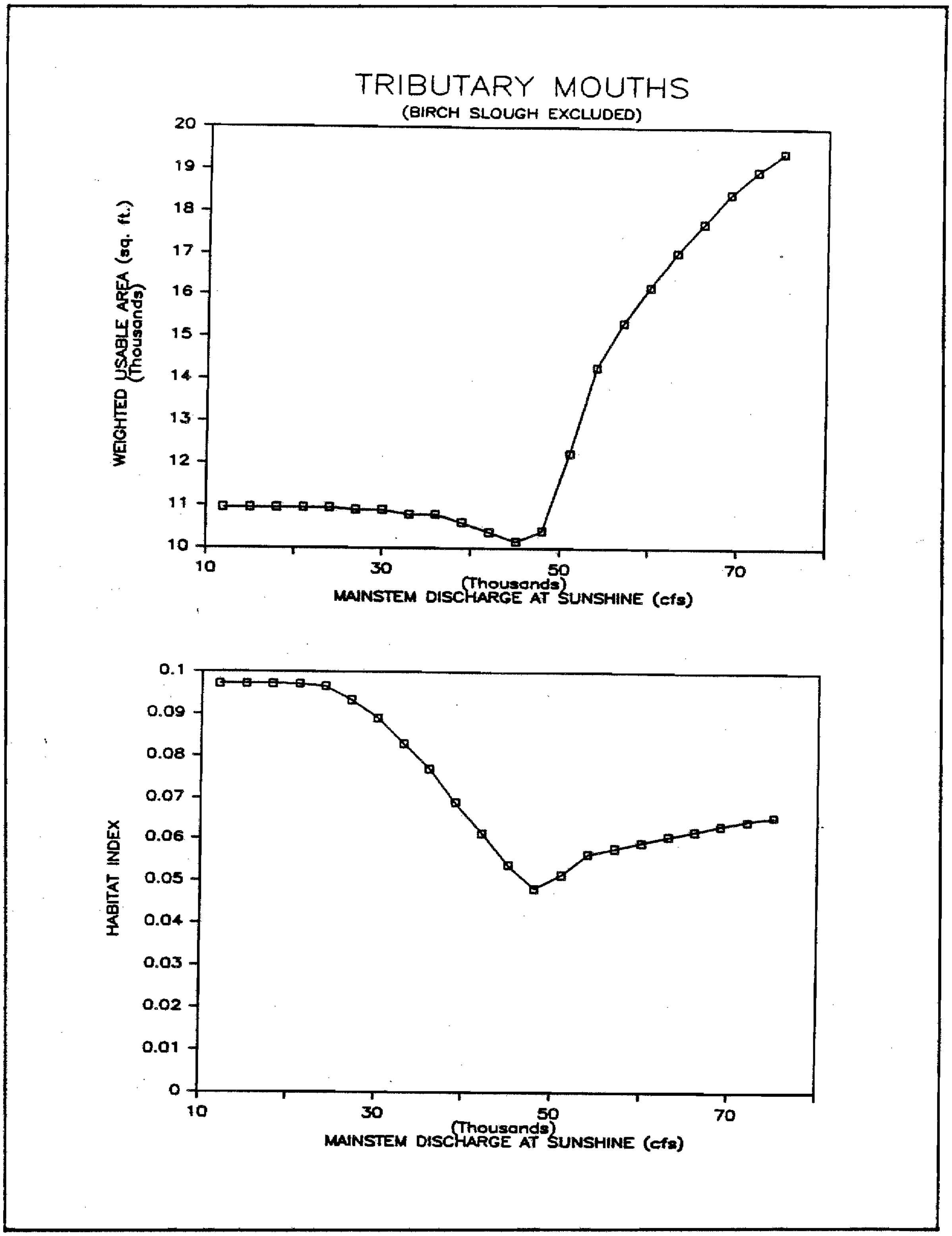


Figure 26. Weighted usable area and habitat indices for juvenile coho salmon at tributary mouth sites (excluding Birch Creek Slough) as a function of mainstem discharge, 1984.

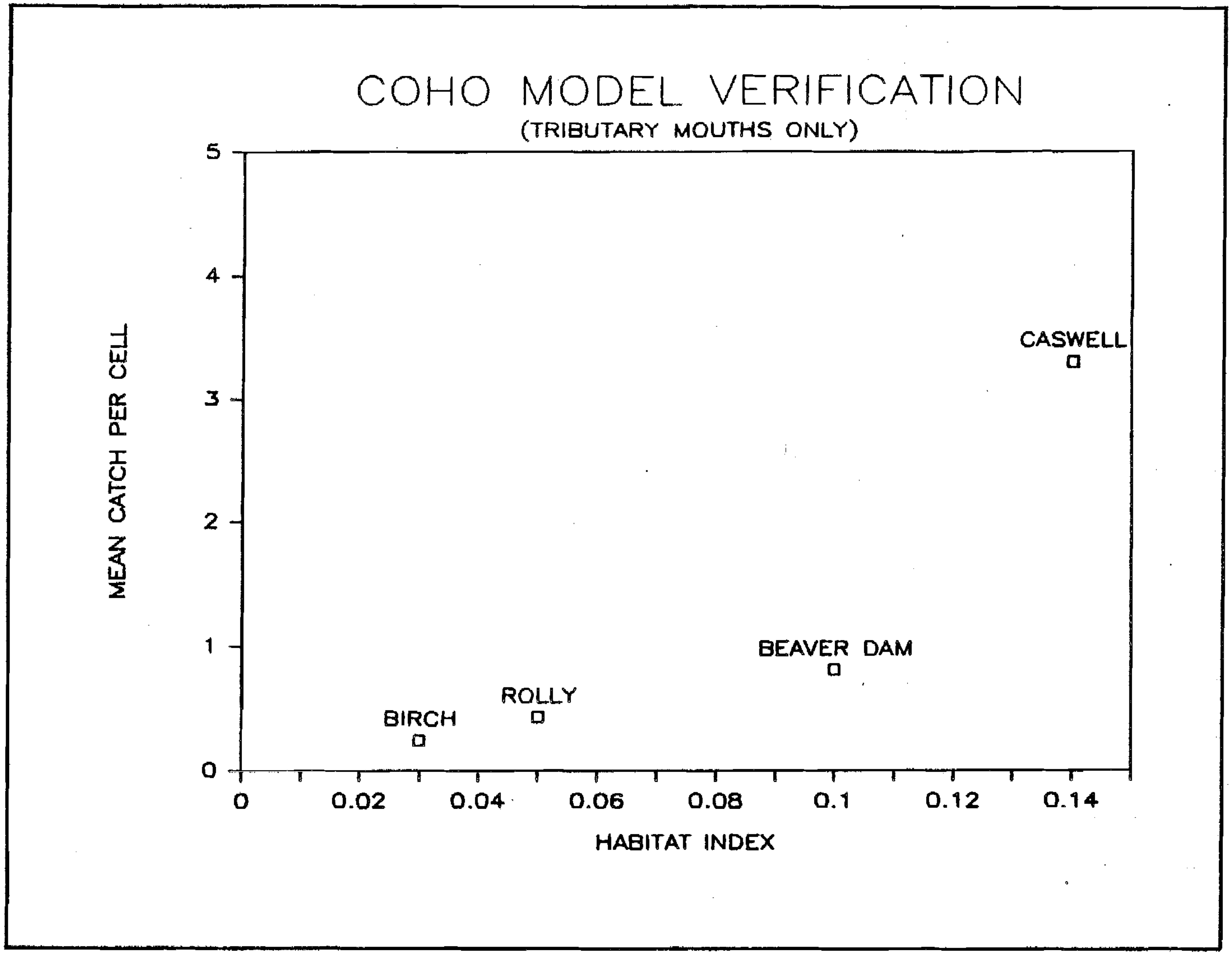


Figure 27. Juvenile coho salmon mean catch per cell versus seasonal mean habitat indices at tributary mouth modelling sites on the lower Susitna River, 1984.

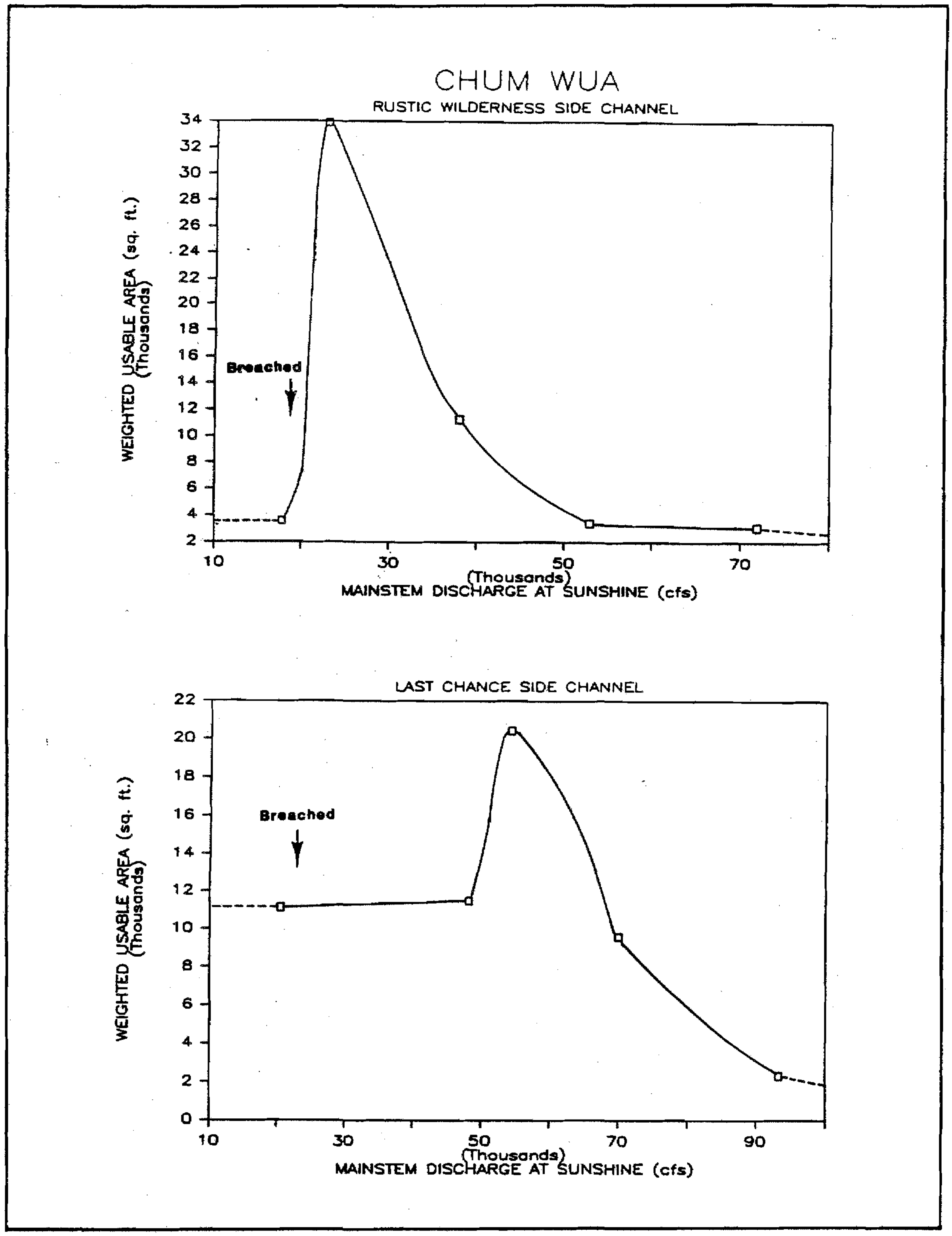


Figure 28. Weighted usable area for juvenile chum salmon at Rustic Wilderness and Last Chance Side Channel study sites as a function of mainstem discharge, 1984.

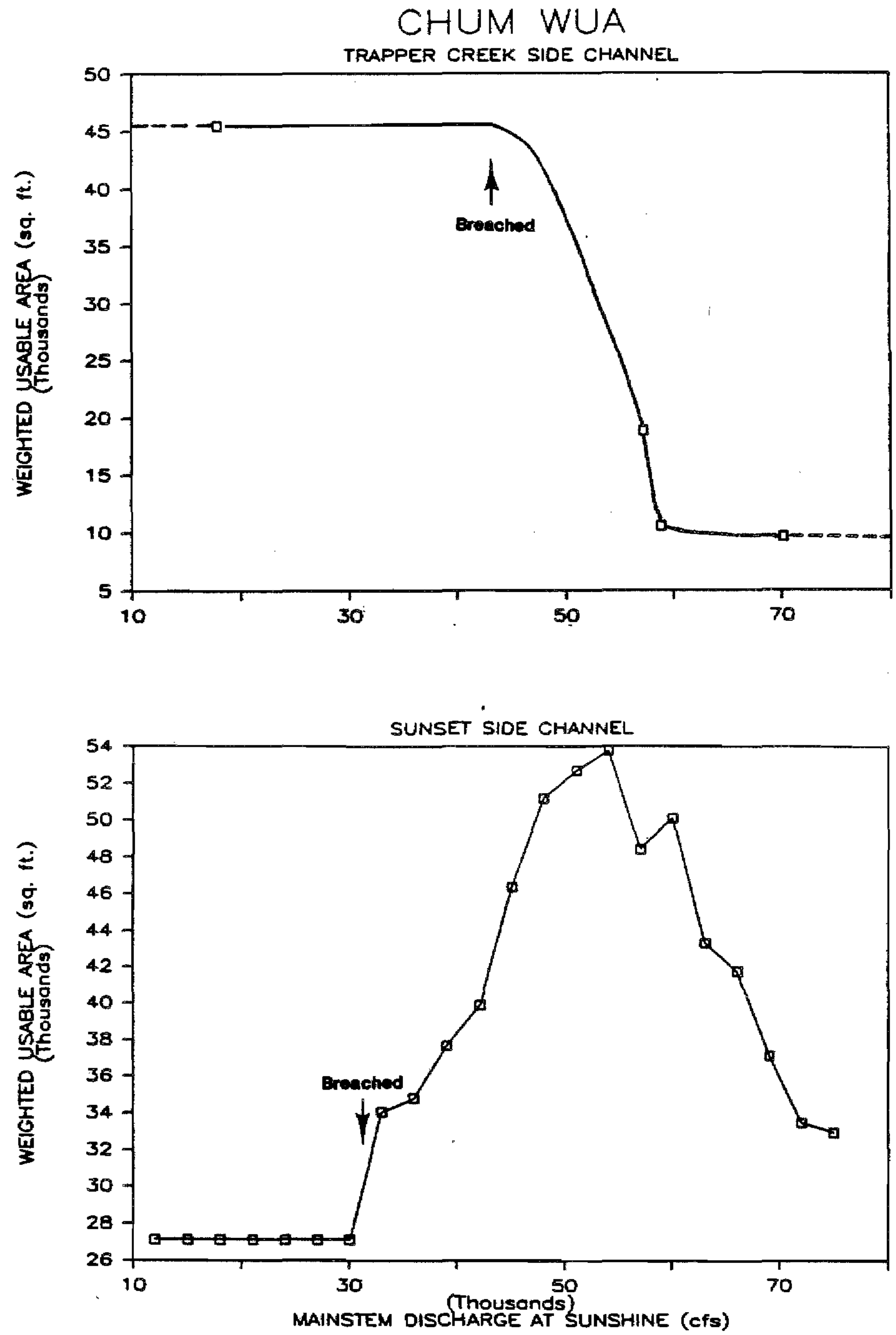


Figure 29. Weighted usable area for juvenile chum salmon at the Trapper Creek and Sunset Side Channel study sites as a function of mainstem discharge, 1984.

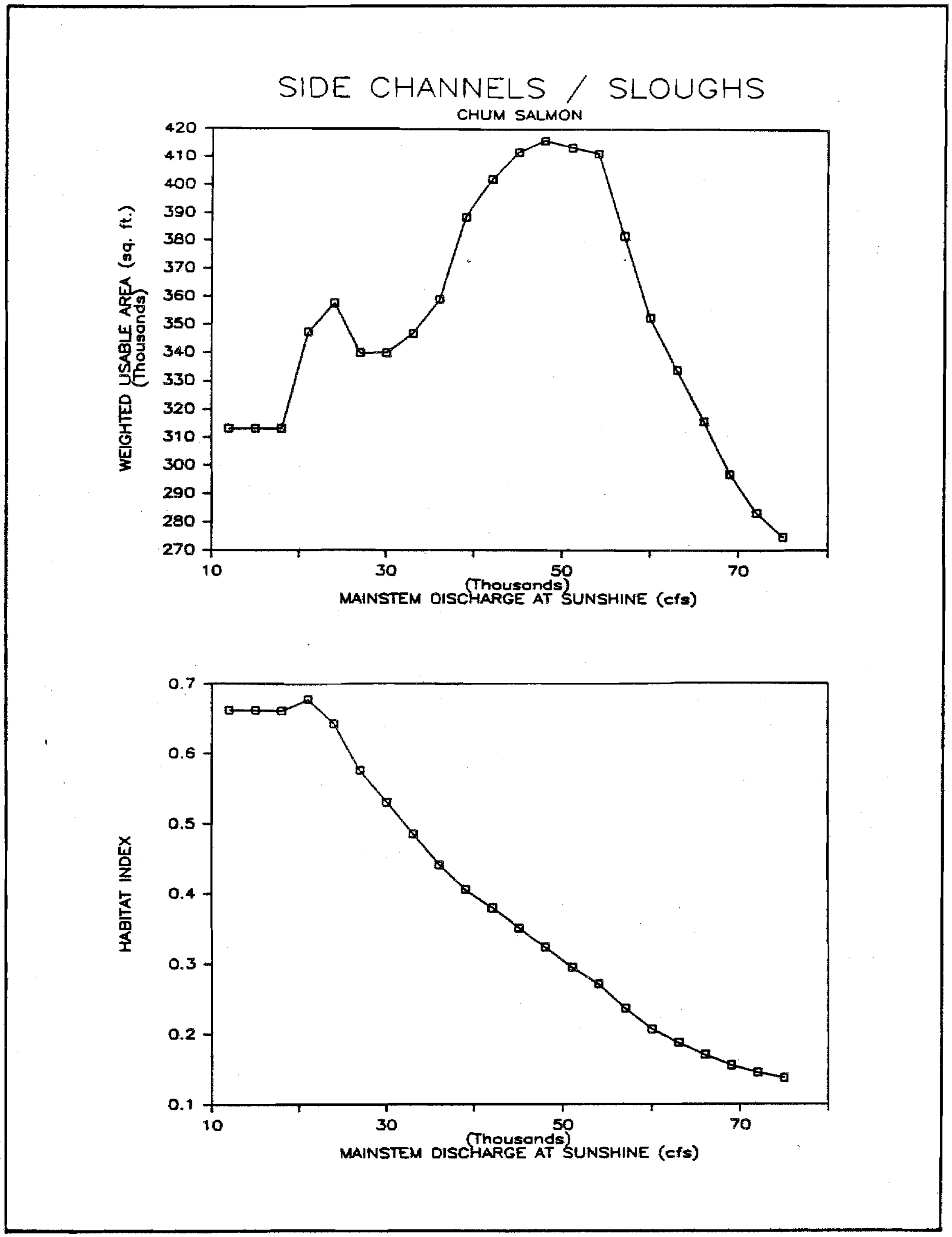


Figure 30. Weighted usable area and habitat indices for juvenile chum salmon at side channel/slough study sites as a function of mainstem discharge, 1984.

completed by July 15, turbidity data contained in Appendix Table B-1 were examined through July 15. Since turbidities greater than 200 NTU appear to affect use greatly (Figure 15), site WUA's were adjusted for periods when the turbidity exceeded 200 NTU. Adjustment factors for the sites ranged from 0.50 to 1.0 (Table 9).

When the chum salmon WUA's were adjusted for turbidity and again totalled, very few changes were noted in the shape of the WUA of habitat index response curves although both WUA's and habitat indices decreased (Figure 31). Since there was little change in these curves, it appears that the shapes of the chum WUA responses at all the side channels are very similar and therefore weighting the sites differently by turbidity only changes the magnitude of the response.

Mean chum salmon adjusted habitat indices were calculated for the period from May 15 through july 15 and compared with mean chum catch during the same time period (Figure 32). There was no sampling effort at two of the side channels, Mainstem West Bank and Sunset Side Channel, during this time so they are not included in this graph. The correlation (0.54) between the seasonal habitat index and chum catch was significant at the 10% probability level but not at the 5% probability level.

3.3.4 Sockeye Salmon

Sockeye salmon were most numerous at the tributary mouth sites with most side channels having some use (Figure 16). Presented here or in Appendix B are graphs of the WUA responses to discharge of the three tributary mouths and the four side channels (Beaver Dam, Sucker, Sunrise and Sunset) which were found to have sockeye salmon present more than half the times sampled.

The typical response of WUA at the tributary mouths to increases in discharge was a steady increase as shown here by the modelling results from Rolly Creek (Figure 33). The WUA increased as the backwater zone increased because sockeye find zero velocity water most suitable and because site area and cover also increased greatly with discharge. The WUA response at Sucker Side Channel was similar to that of the tributary mouths as WUA generally increased with discharge after overtopping. This site is influenced greatly by backwater effects from the side channel at its mouth. At Beaver Dam Side Channel, WUA increased after overtopping and then declined somewhat (Figure 34). At Sunset Side Channel, WUA fluctuated irregularly with discharge as the small amount of usable habitat along the margins of the site moved back and forth with flow changes.

At the combined tributary mouth sites, both WUA and habitat indices increased above discharges of approximately 30,000 cfs (Figure 35). At the pooled side channel/sloughs, on the other hand, WUA's also increased after approximately 30,000 cfs while habitat indices generally declined from the peak at 12,000 to 24,000 cfs (Figure 36). The decrease in the habitat index is due to the steadily increasing velocities in the side channels with increases in flow. No adjustments in turbidity are necessary for the four side channel/slough sites as these have very

Table 9. Weighting factors for turbidity by site for analysis of juvenile chum salmon habitat use, 1984.

Site	Sampling Period When Turbidity Exceeds 200 NTU	Turbidity Weighting Factor
Hooligan Side Channel	June 16-30	0.50
Kroto Slough Head	June 16-30	0.50
Bear Bait Side Channel	June 16-30	0.50
Last Chance Side Channel	June 16-30	0.50
Rustic Wilderness Side Channel	July 16-30	1.00
Island Side Channel	July 1-15	0.75
Mainstem West Bank	June 16-30	0.50
Goose 2 Side Channel	July 1-15	0.75
Circular Side Channel	July 1-15	0.75
Sauna Side Channel	June 16-30	0.50
Sucker Side Channel	July 1-15	0.75
Beaver Dam Side Channel	July 1-15	0.75
Sunset Side Channel	July 1-15	0.75
Sunrise Side Channel	July 1-15	0.75
Trapper Creek Side Channel	June 16-30	0.50

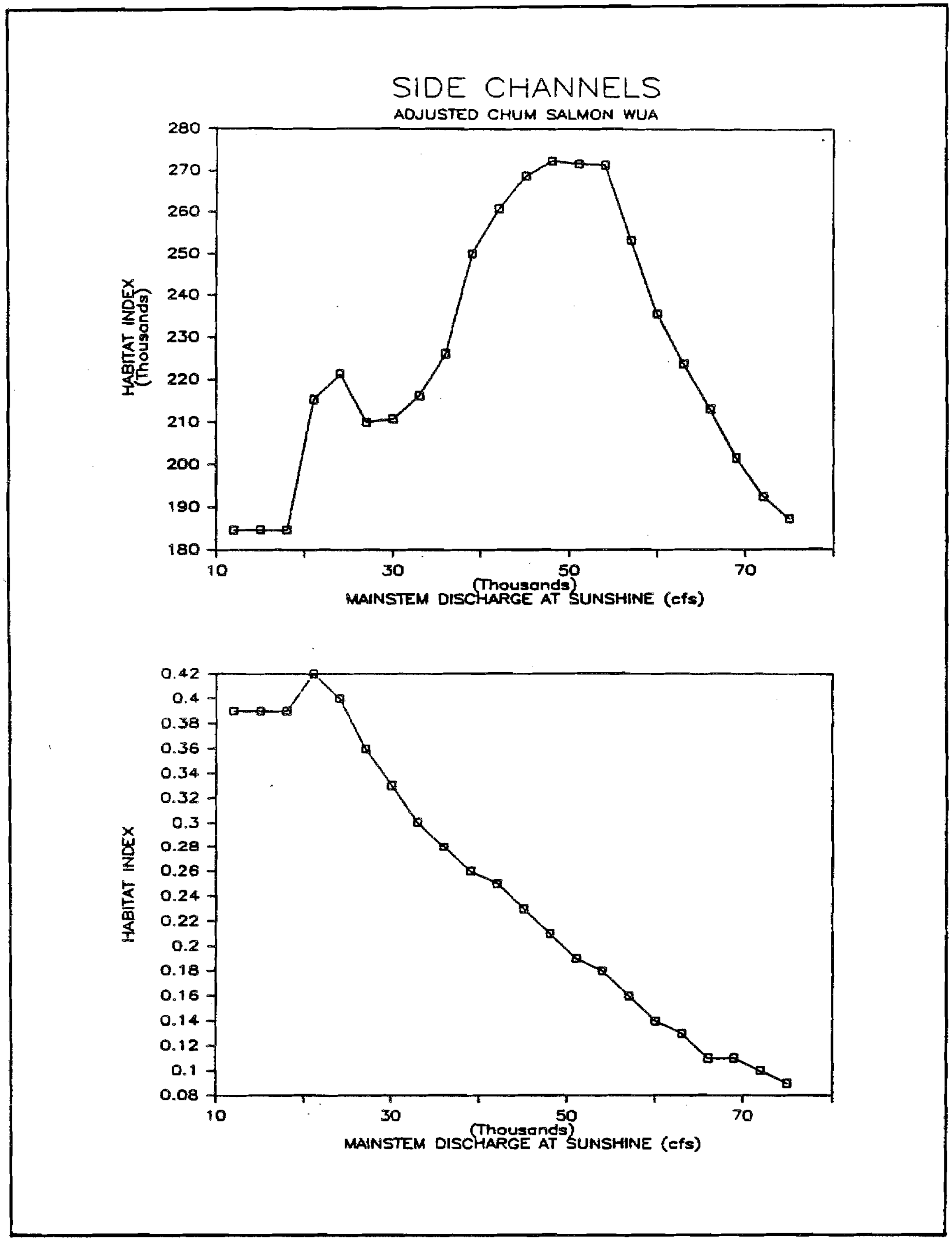


Figure 31. Turbidity adjusted weighted usable area and habitat indices for juvenile chum salmon at side channel/slough study sites as a function of mainstem discharge, 1984.

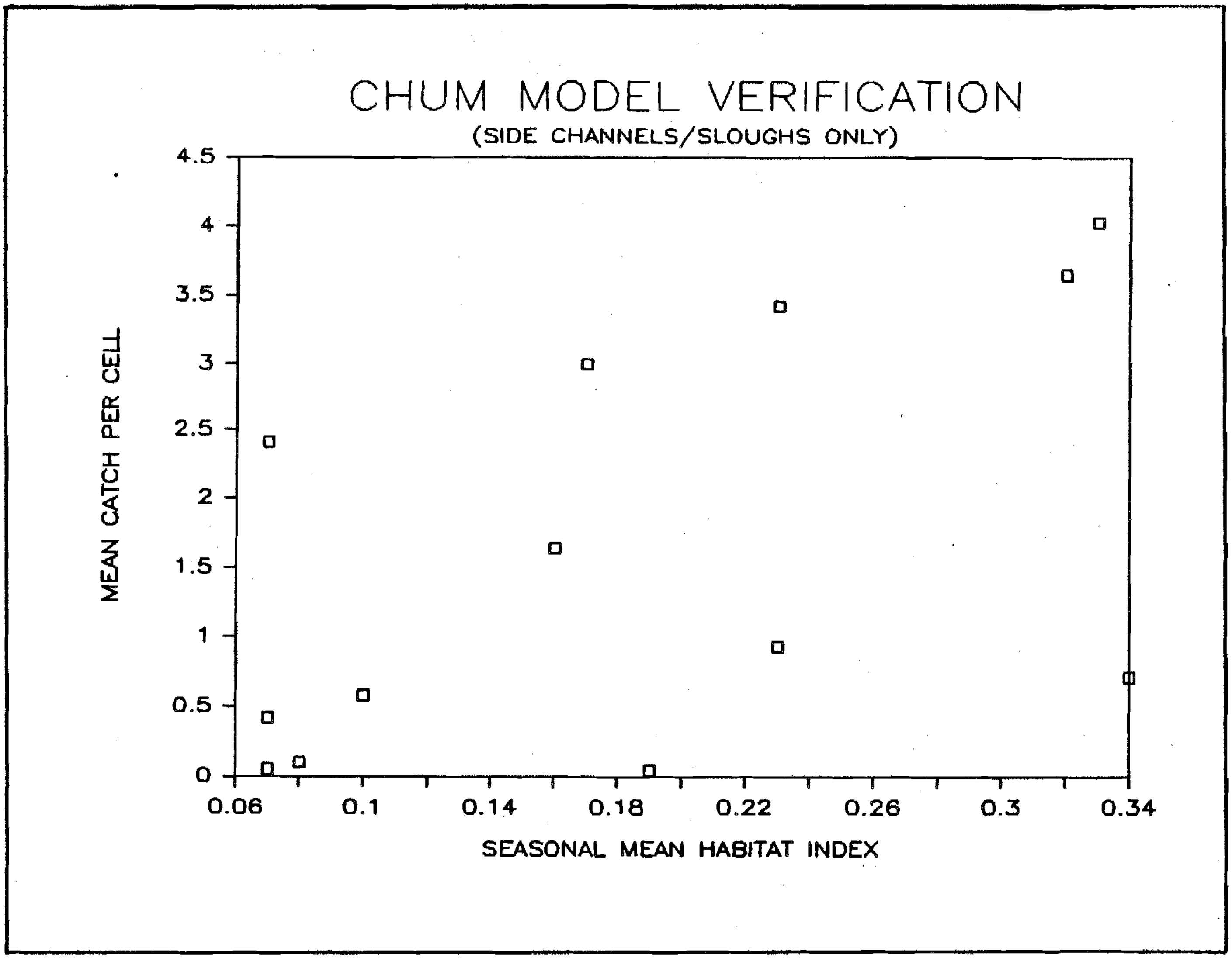


Figure 32. Juvenile chum salmon mean catch per cell versus seasonal mean habitat indices at side channel and slough modelling sites on the lower Susitna River, 1984.

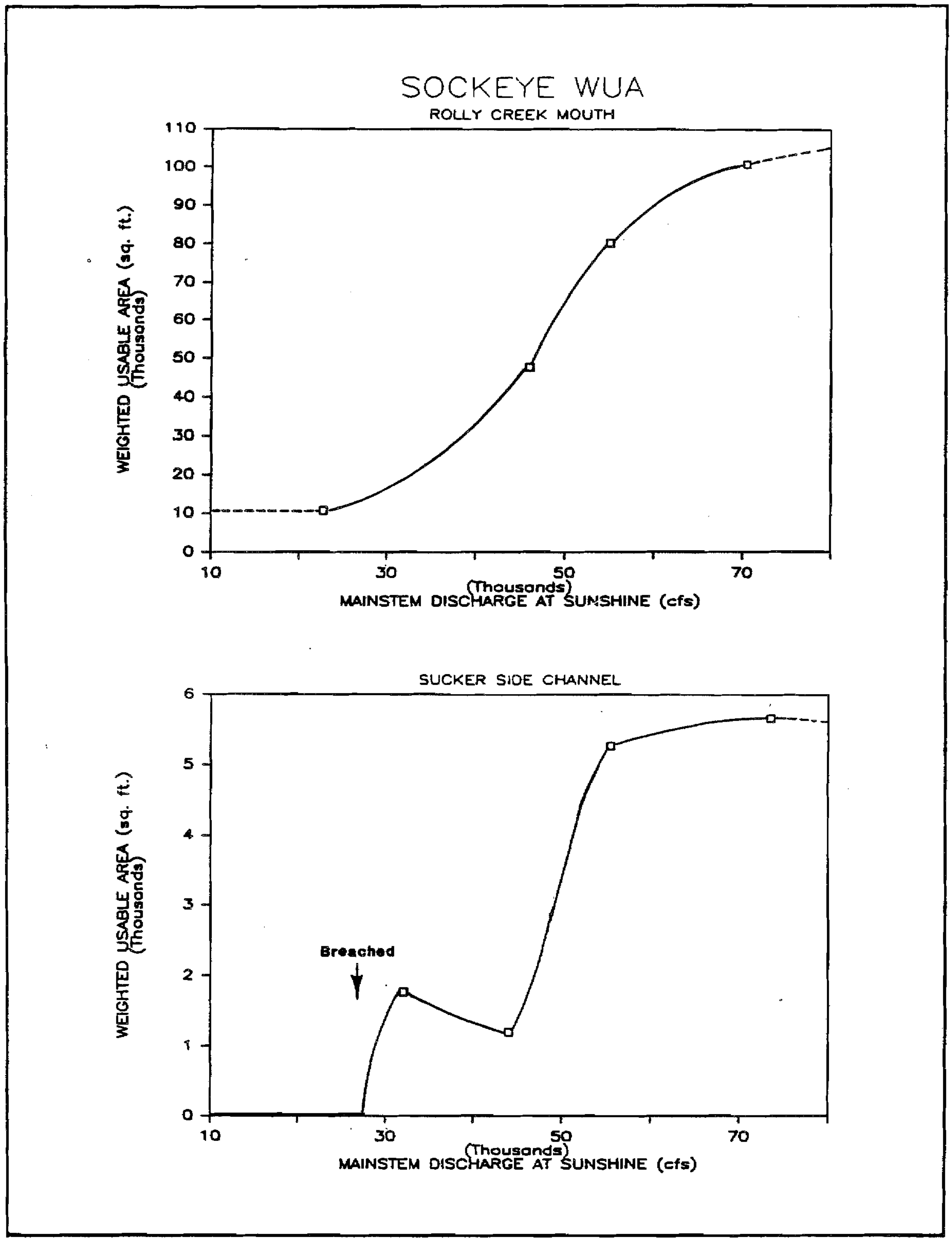


Figure 33. Weighted usable area for juvenile sockeye salmon at Rolly Creek Mouth and Sucker Side Channel study sites as a function of mainstem discharge, 1984.

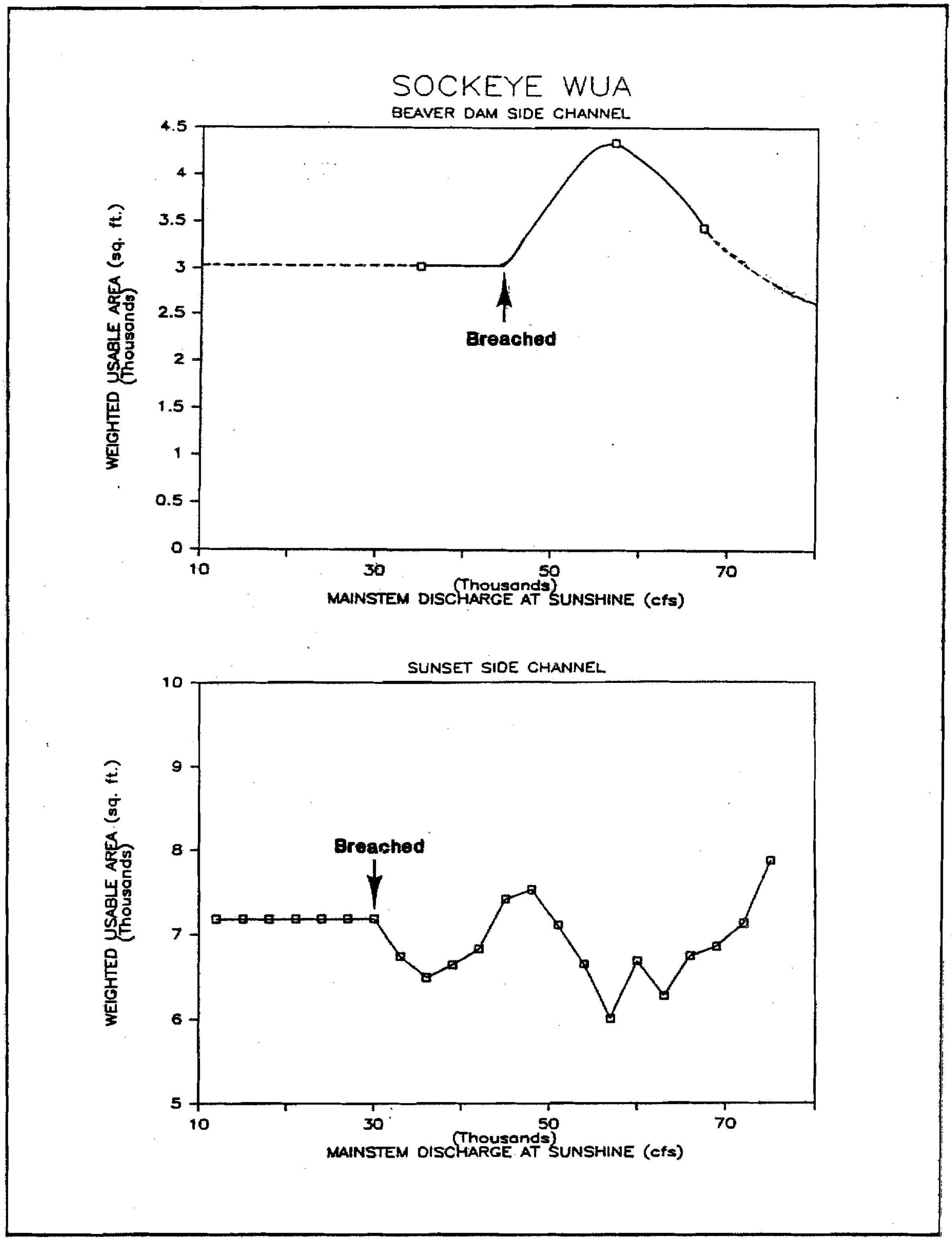


Figure 34. Weighted usable area for juvenile sockeye salmon at the Beaver Dam and Sunset Side Channel study sites as a function of mainstem discharge, 1984.

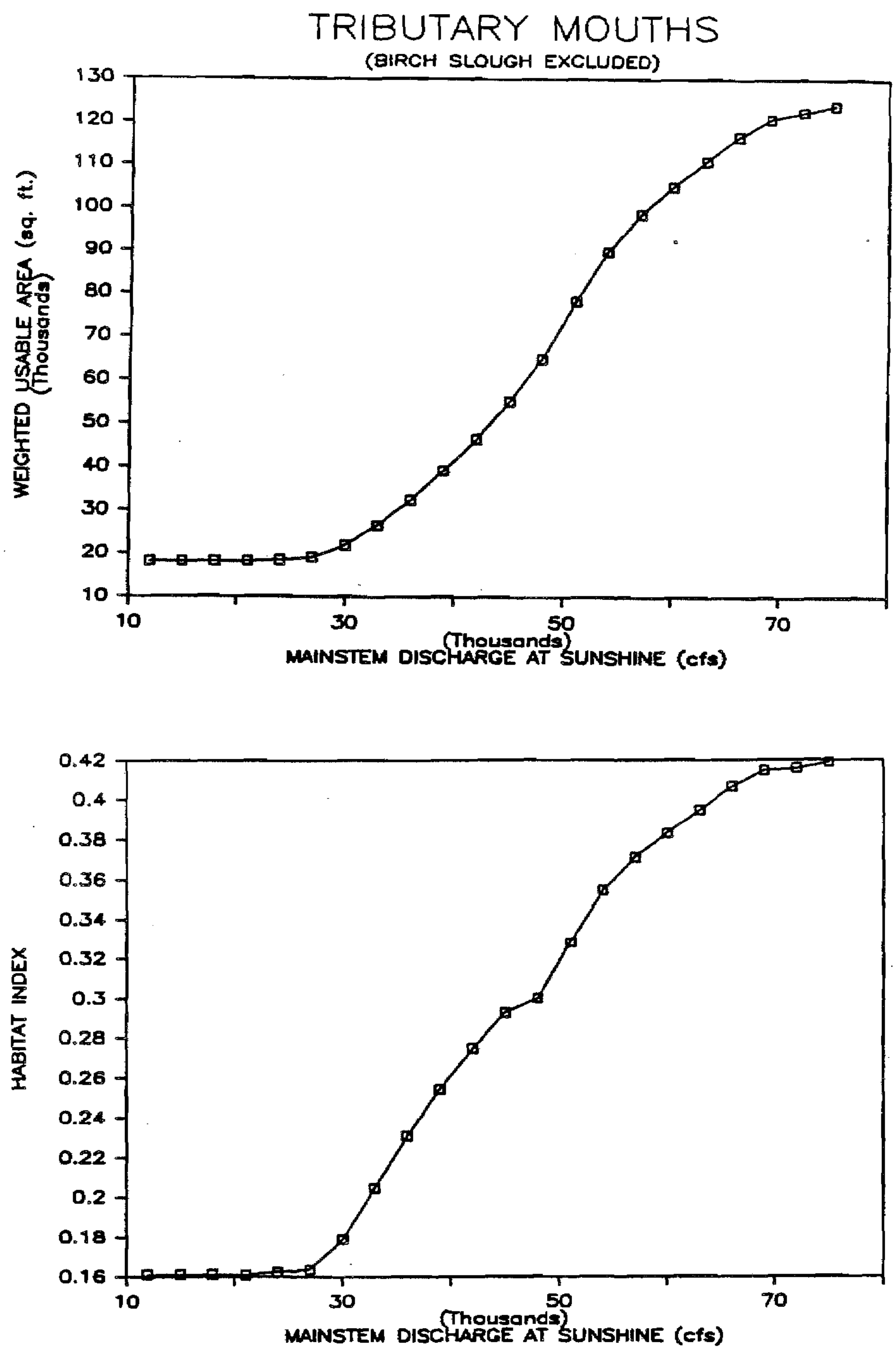


Figure 35. Weighted usable area and habitat indices for juvenile sockeye salmon at tributary mouth study sites on the lower Susitna River as a function of mainstem discharge, 1984.

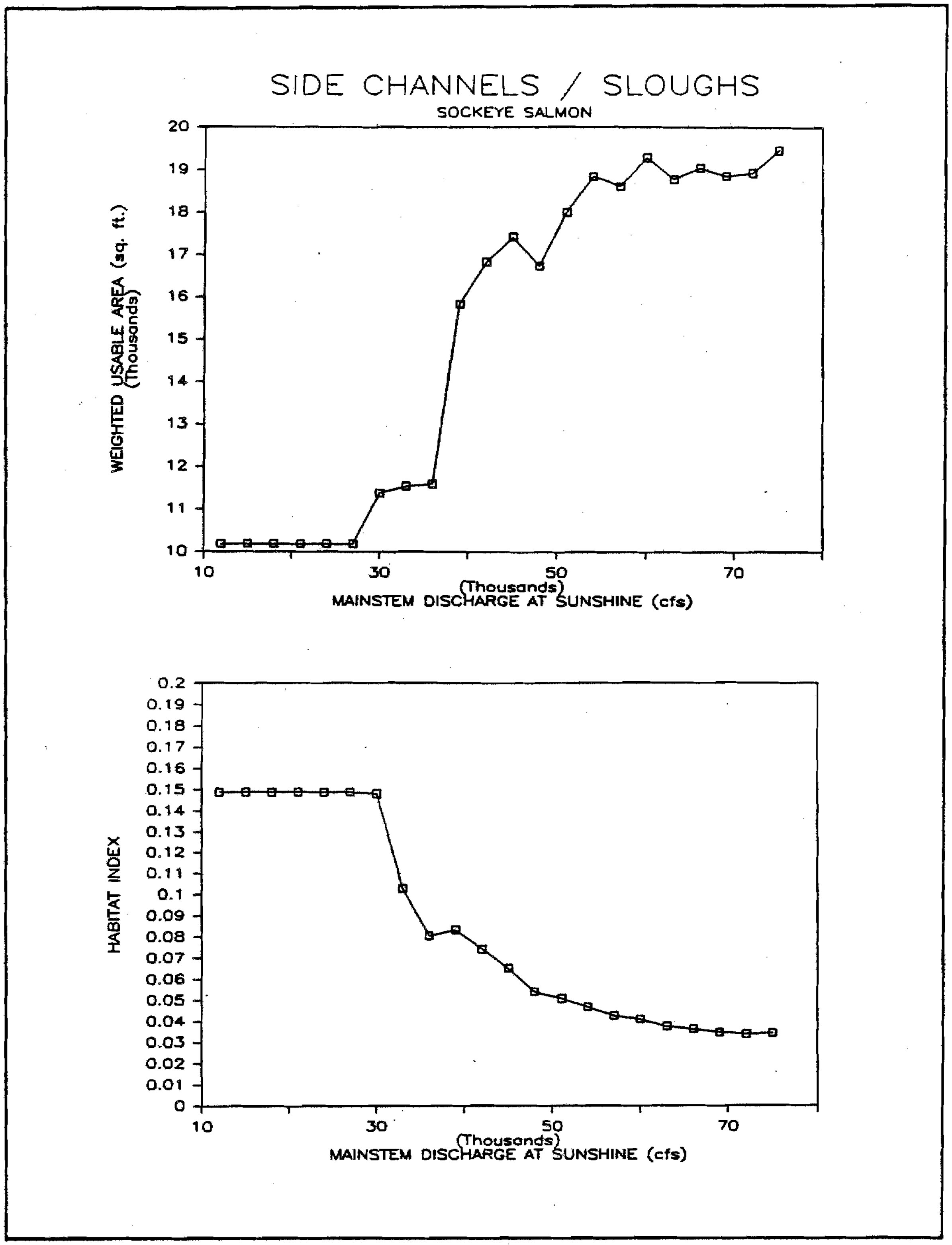


Figure 36. Weighted usable area and habitat indices for juvenile sockeye salmon at side channel and slough study sites on the lower Susitna River as a function of mainstem discharge, 1984.

similar turbidity regimes, being located on the same general location on the river. Use of many of the other side channels is probably limited by turbidity.

The mean seasonal habitat index for sockeye salmon at the four tributary mouths and four side channel sites was calculated for the period from May 15 to October 15, 1984. The mean catch of sockeye salmon juveniles was positively related to the mean habitat index (Figure 37). High turbidities and velocities within the other side channels presumably limited use by sockeye salmon juveniles.

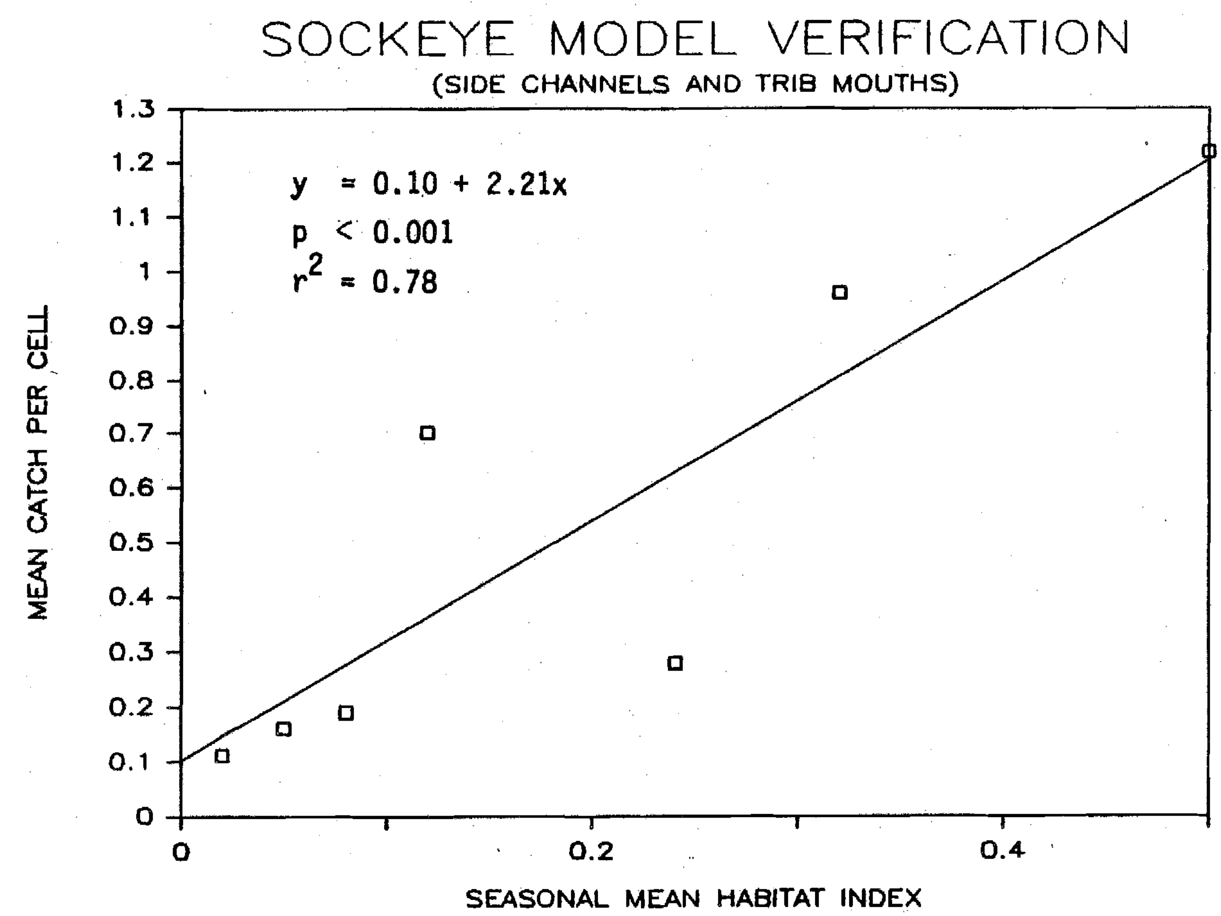


Figure 37. Juvenile sockeye salmon mean catch per cell versus seasonal mean habitat indices at side channel and tributary mouth modelling sites on the lower Susitna River, 1984.

4.0 DISCUSSION

4.1 Chinook Salmon

Chinook salmon were widely distributed throughout tributary mouths and side channels of the lower Susitna River. Densities of juvenile chinook were highest within tributary mouths. This distribution of chinook fry substantiates earlier observations (ADF&G 1981a; Dugan et al. 1983) that densities of chinook are generally highest at tributary mouths. Caswell Creek mouth had the highest CPUE of juvenile chinook salmon in the lower river and appears to be a major rearing or holding area.

Chinook salmon juveniles used side channels for rearing in both the middle and lower Susitna River after moving from tributary natal areas. Redistribution of chinook fry from natal areas to lower density rearing areas has also been observed in the Deshka River (Delaney et al. 1981) and Montana Creek (Riis and Freise 1978). This phenomenon reflects a downstream movement or dispersal of the 0+ age fish (ADF&G 1981c). Most of the 1+ chinook juveniles have outmigrated by August 1.

Use of tributary mouths is limited by the amount of instream cover and suitable velocities. Also, depth may be important to chinook juveniles in tributaries because it probably provides cover in slightly turbid water (10 to 20 NTU) (Appendix A). At Caswell Creek mouth, catches of juvenile chinook were low in September when the mainstem water stage dropped and depths decreased, velocities increased, and amount of cover was reduced.

Use of Susitna River side channels by chinook juveniles for rearing is widespread although it is limited by turbidity in portions of the lower reach. Side channels located in the Talkeetna River plume had much higher use than those located in the more turbid Chulitna River plume or those located further downstream where the water of these two tributaries are mixed. Side channel catch rates of juvenile chinook (in similar habitat) in the middle Susitna River in 1983 were approximately four times higher than those in the lower river in 1984 (Dugan et al. 1984).

Since lower Susitna River side channels are used less by chinook juveniles than middle river side channels, it is not surprising that sloughs are also used less in the lower reach than in the middle reach. As water levels decreased in the fall and side channel heads dewatered, there were very few chinook fry at slough sites in the lower river to take advantage of the lowered turbidity. Also the side sloughs in the lower river contain little cover.

Instream flow effects upon juvenile chinook salmon are related to backwater effects at the tributary mouths and side channel/slough sites and to breaching and side channel flows. When a side slough is not overtopped by the mainstem, access is usually poor and cover is limited.

At tributary mouths, backwater effects increase chinook use significantly because of increases in instream cover and depth and decreases in water velocity. Also, turbid backwater from the mainstem sometimes intrudes into the sites with rapid rises in mainstem stage. Pooled data from three tributary mouths showed major increases in WUA at mainstem discharges greater than 45,000 cfs.

If the study sites had been chosen further upstream in the tributary mouths, WUAs would have begun to increase at a higher discharge, so the 45,000 cfs figure is not absolute. At Birch Creek Slough, for example, there were no measurable effects of backwater to mainstem discharges of 72,000 cfs. In general, increases in mainstem discharge increase the amount of juvenile chinook salmon habitat at tributary mouths. Also, these backwaters may increase access into tributaries where rearing could occur by decreasing water velocities at the mouth.

Within side channel/slough sites, mainstem discharge is very important. When sloughs are breached, the water becomes turbid and cover for the chinook juveniles is improved. High turbidities, however, may also limit use of side channels (Figure 10). High turbidities generally occur from mid-June through September (especially during high discharges), while turbidities are much lower during the rest of the year. Turbidity also varies spatially within the river. Chulitna and Talkeetna river plume effects extend at least 20 miles downriver (Figure 4). Sites located within the Talkeetna River plume have much lower turbidity and higher juvenile chinook salmon use.
Mainstem discharge initially increases chinook WUA within a side channel/slough after it overtops but with further increases in flow, WUA usually remains constant or declines while the proportion of usable chinook habitat declines. The RJHAB model shows a decline in WUA with increasing discharge which is greater than that shown by the IFIM model (Appendix C).

The results obtained by pooling WUA from all modelled sites should not be directly extrapolated to represent the entire lower reach. If the modelling sites would have been chosen randomly, many more large, high velocity side channels with extremely little usable habitat would have been modelled. This study was designed to sample proportionately more side channels with usable habitat which would represent a diversity of channel types in the lower river. The modelled side channels represent a wide range of sizes and shapes of channels with diverse breaching flows, and so these results need to be coupled with a stratification of lower river side channels by breaching discharge and channel size and type. The most important side channel complexes in the lower Susitna River for juvenile chinook salmon rearing are located within the low turbidity plume of the Talkeetna River. Other side channels or side channel complexes should be weighted according to their mean turbidity level.

4.2 Coho Salmon

Juvenile coho salmon in the lower river were found mostly within tributary mouths. Tributaries and tributary mouths were also the most important rearing areas for juvenile coho salmon in the middle Susitna River (Dugan et al. 1984). Upland sloughs were also used by coho salmon for rearing in the middle river, but upland slough habitat is limited in the lower river and was not sampled during this study.

The heavy use of tributary mouths by juvenile coho is due in part to coho in tributary mouths rearing near their natal areas. Their limited use of side channels may be due to their documented tendencies to favor waters with relatively low turbidities. Sigler et al. (1984), for example, found that a larger number of juvenile coho salmon emigrated from experimental laboratory channels with turbidities of 25-50 NTU than from clear water channels. In another laboratory study, Bisson and Bilby (1982) established that coho salmon avoided turbidities exceeding 70 NTU. Turbidities in lower Susitna River side channels during June through August often greatly exceeded 100 NTU.

Use of tributary mouths by juvenile coho varied greatly seasonally and from site to site. Rolly Creek and Beaver Dam Slough CPUE's of coho salmon generally increased from early summer to late fall (Figure 12). This occurrence may be due to both the immigration of coho juveniles and a decrease in site area. The area of Rolly Creek was reduced by approximately 63% from late June and July to September and early October, while the area of Beaver Dam Slough was reduced by approximately 33% between these two time periods. In Birch Creek Slough, on the other hand, a relatively high CPUE occurred in early summer with much smaller values throughout the summer and fall. The relatively high CPUE's in early summer at Birch Creek Slough are probably due to a natal effect. Barrett et al. (1985) reported that Birch Creek has a spawning run of coho salmon.

A comparison of juvenile coho catch rates between tributary mouths and the Talkeetna outmigrant trap (RM 103.0) suggests that a redistribution of juvenile coho into suitable rearing habitat peaks from late July to early August. The catch per hour of age 0+ coho at the Talkeetna outmigrant trap increased during this time period while CPUE's at tributary mouths also changed greatly. Birch Creek Slough, which habitat modelling indicates to be relatively poor coho tributary mouth rearing habitat (Figure 27), shows a reduction in CPUE in late July, following natal emigration, while Caswell Creek, a site evaluated as having relatively good rearing habitat, had increasing CPUE's beginning in late July. A study conducted by Delaney and Wadman (1979) in the Little Susitna River found emigration of emergent fry from natal areas after the end of June.

Instream flow effects of the lower Susitna River upon juvenile coho salmon are limited to the backwater zone effects at tributary mouths because coho juveniles make little use of the side channel/slough sites. Initially, backwater may decrease the amount of habitat slightly as tributary mouths change from free flowing to a backwater zone but then WUA generally increases with mainstem stage as cover is inundated. Also, the backwater can provide access into small tributaries and beaver ponds where rearing and overwintering can occur.

Studies of coho salmon distribution in 1982 by hydraulic zone showed that coho generally preferred free-flowing tributaries over backwater zones (ADF&G 1983). Cover in the free-flowing tributaries is often better than in the backwater areas. For example, Birch Creek Slough generally has poor cover while Birch Creek itself has abundant emergent and aquatic vegetation in which coho were abundant.

4.3 Chum Salmon

The use of minnow trapping during 1981 and 1982 juvenile anadromous studies makes comparisons of lower river catch and CPUE data with 1984 studies difficult because chum salmon are rarely captured in minnow traps. The necessity for very early sampling, almost concurrent with ice-out, becomes important when studying chum salmon juveniles. Their early season movement and short time in the Susitna River system makes detailed conclusions difficult.

The large catches of chum salmon fry in side channels in the lower river contrast with the 1983 distribution data from the middle reach. Dugan et al. (1984) indicated that chum fry CPUE's were greatest at tributaries and side sloughs. The 1983 catch rates, however, reflect the prevalence of natal sloughs in the middle reach, while the lower reach contains few natal side sloughs. Also, side channels in the middle reach were not extensively sampled until July in 1983.

In 1984, chum salmon spawning was observed in several side channel/slough sites where none had been observed previously (Barrett et al. 1985) indicating that under certain conditions, lower river side channels do provide some suitable spawning habitat. Chum salmon fry observed in some of the side channels may be rearing near their natal areas.

The exact stimulus for the outmigration of chum salmon from the Susitna River is not known, but probably reflects a combination of factors (Roth et al. 1984). Mainstem discharge was highly positively correlated with chum salmon CPUE at the Talkeetna outmigrant traps in 1983. The sharp decline in CPUE at the lower river sites from early June (3+ fpc) to late June (1+ fpc) in 1984 followed the peak June discharge on June 17 at Sunshine Station, and the mid-June peak of chum outmigration past the Talkeetna traps.

Since juvenile chum salmon outmigration is mostly completed by mid-July, flow effects are limited to spring and early summer for this species. Juvenile chum salmon used side channels heavily during this time while use of the tributary mouths was limited. Apparently, chum salmon do not move into the tributary mouths as they gradually move downstream and out of the system. Most of the use of side channels for rearing occurs before high turbidities occur.

Use of side channels by juvenile chum salmon is limited by depth and velocity. The presence or lack of instream cover in side channels is not important to juvenile chum (Appendix A). Chum fry were captured primarily in shallow sampling cells ($\leq$ 1.0 ft) which had a relatively low velocity and low to moderate cover. After breaching, side channel WUA's may increase or decrease but the proportion of the area that is suitable generally decreases as velocities and depths become unsuitably large. Turbidities show sharp seasonal increases and some side channels become turbid earlier in the season than others depending upon the turbidity regimes in the Chulitna, Talkeetna, and Susitna rivers.

Since chum salmon side channel WUA's respond very similarly to those of chinook salmon at individual sites, it appears that an analysis of response to changes in mainstem discharge for chinook would also hold for chum salmon. An analysis of flow regimes, would only need to take place through mid-July for chum salmon, however, while chinook salmon fry occur throughout the season in side channels.

4.4 Sockeye Salmon

Tributary mouths were the primary capture sites for sockeye salmon in the lower river. In the middle river, sockeye salmon were captured primarily at side sloughs (Dugan et al. 1984). Side sloughs were the primary spawning areas for sockeye salmon in the middle river, and tributary/lake systems were the major sockeye spawning areas in the lower reach (Barrett et al. 1985). Relatively large catches of juvenile sockeye in the middle river side sloughs were due to fish rearing in their natal areas.

Few sockeye juveniles were captured in early June at modelled JAHS sites. This low incidence was probably due to lack of natal habitat in mainstem influenced areas of the lower river. Outmigrant trap catches at Talkeetna (RM 103.0) and Flathorn (RM 22.4) indicate that sockeye fry were redistributing in the system by the middle of June (Part 1 of this report). The greatest catch per cell of juvenile sockeye occurred at the modelled sites during late June.

The consistently low CPUE's in lower river side channels suggest these areas are of limited value for juvenile sockeye rearing. Possibly these juvenile sockeye catches represent transient populations. Exceptions include Beaver Dam Side Channel and other side channels located in the Talkeetna River plume where lower turbidities allow juveniles to rear. Since turbid glacial lakes are much less productive for sockeye salmon than are clearwater lakes (Lloyd 1985), the productivity of these side channels for sockeye is probably low in comparison to similar clearwater streams.

The larger catches (21 to 101) of sockeye at tributary mouths indicate that these sites are of some value for juvenile sockeye rearing. Beaver Dam Slough had moderate numbers of sockeye present throughout much of the season. Beaver Dam Slough resembled a lake system as it had low velocities, large amounts of cover, and relatively warm temperatures during the open-water season. CPUE's of sockeye fry at Rolly Creek mouth was low until early August. Emergent and aquatic vegetation were profuse at this site during mid-season, making sampling difficult. After late August, CPUE's of sockeye juveniles increased. Although high numbers of these salmon fry were caught late in the season, we do not know if they overwinter.

Instream flow effects upon sockeye salmon rearing occur at both tributary mouths and side channels. Occurrence of sockeye juveniles in side channels appears to be limited by factors such as turbidity and velocity. Juvenile sockeye were captured more than half the times sampled only in four side channel sites in the Talkeetna River plume. Even at these four sites, the number of sockeye fry captured was less than 20 at each, except at Beaver Dam Side Channel where 71 were captured. Typically, WUAs for sockeye increase after overtopping of the side channels but then gradually decrease with further increases in discharge as side channel velocities became unsuitable. Sometimes backwater areas may form at the mouths of side channels (for example, Sucker Side Channel) and modify this relationship somewhat so that WUA may rise with increases in discharge for much longer periods. Generally, the proportion of area that is usable within side channels decreases with flow as velocities become less suitable.

At tributary mouths, the formation of backwater zones has a major effect in increasing WUA for sockeye salmon juveniles. The response of the increase in WUA for sockeye is similar to that of chinook salmon. Access into suitable rearing and overwintering areas may also occur with the increase in backwater or the amount of overtopping. For example, access into potential rearing areas such as Whitsol Lake may be inhibited if Kroto Slough is not overtopped. Also several other small tributaries along the Kroto Slough side channel may be inaccessible if flows are below those required for overtopping.

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6.0 ACKNOWLEDGEMENTS

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

We thank the various consulting agencies working on the Susitna Hydroelectric Project for helpful comments on a draft of this report.

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APPENDIX A

LOWER SUSITNA RIVER
JUVENILE SALMON REARING SUITABILITY
CRITERIA

INTRODUCTION

Habitat suitability criteria are necessary for evaluating fish habitat using the instream flow incremental methodology (Bovee 1982). The criteria express the value of a habitat variable such as velocity on a zero (unusable) to one (optimum) basis for a given fish species and life stage. The suitability criteria are coupled with the habitat present within a study site to produce estimates of equivalent optimal habitat called weighted usable area (WUA).

Juvenile salmon rearing suitability criteria have been used to model the response of juvenile salmon habitat to variations in mainstem discharge of the middle reach (Chulitna River confluence to Devil Canyon) of the Susitna River (Hale et al. 1984, Marshall et al. 1984). The suitability criteria used in these studies were developed specifically for the middle Susitna River by Suchanek et al. (1984). EWT&A (1985) modified a few of the same suitability criteria for use in impact analysis of chinook salmon rearing in the middle Susitna River.

In 1984, some of the juvenile salmon habitat modeling effort was directed toward evaluating responses of juvenile salmon habitat in the lower Susitna River (below the Chulitna River confluence) to discharge variations. Since habitat data collection techniques used in 1984 were similar to those used during the 1983 studies, suitability criteria specific to the lower reach can be developed. The purpose of this appendix is to verify the applicability of the suitability criteria developed in 1983 by Suchanek et al. (1984) for use in the lower river habitat studies. The general philosophy was to use the 1983 middle river criteria curves for the lower river unless the 1984 studies in the lower river provided evidence for modifications.

METHODS

The field sampling methods used are detailed in Section 2.1 of this report. These methods are very similar to those used during the 1983 studies (Suchanek et al. 1984) and will only be summarized briefly here. Sampling sites included: (1) 20 habitat model sites which were normally sampled twice a month and (2) 31 opportunistic sites which were usually sampled only once.

At each site, 6 ft x 50 ft rectangular cells were sampled for fish and then habitat variables were measured in each cell. Cells were selected randomly at model sites, although sometimes additional selected cells with "good" habitat were also sampled. At opportunistic sites, cells were selected to encompass a variety of habitat conditions within potentially usable habitat. Habitat measurements taken at each cell sampled included a representative depth, mean column velocity, and estimates of primary cover type and percent cover (Appendix Table A-1).

The data collected were examined for suitability criteria development by using the procedures described in Suchanek et al. (1984), with a few modifications.

Suitability was represented by mean catch per cell for chinook and coho salmon and proportional presence (proportion of cells sampled in which fish were captured) was used as the suitability measure for chum and sockeye salmon. Data were pooled by species for analysis. Some data were excluded from analysis by using results from the distribution and abundance analysis (Section 3.2) which indicated factors other than the microhabitat variables of velocity, depth, and cover were greatly affecting distribution. Macrohabitat type and turbidity were two factors which greatly affected distribution and were used as a basis for excluding cells fished. Cells which were excluded from the analysis varied by species and are detailed in the results section. The beach seine and electrofishing data were pooled for analysis because these sampling methods were both thought to be equally as effective given the sampling conditions. Although sampling efficiency varies by gear type and conditions fished, we assumed equal efficiency under all conditions as analysis of sampling efficiency was beyond the scope of this study.

Appendix Table A-1. Percent cover and cover type categories.

Group #	% Cover	Group #	Cover Type
1	0-5%	1	No object cover
2	6-25%	2	Emergent vegetation
3	26-50%	3	Aquatic vegetation
4	51-75%	4	Debris or deadfall
5	76-96%	5	Overhanging riparian vegetation
6	96-100%	6	Undercut banks
		7	Gravel (1" to 3" diameter)
		8	Rubble (3" to 5" diameter)
		9	Cobble (larger than 5" diameter)

Groupings of habitat variables were identical to those used in 1983. Percent object cover categories 76-95% and 96-100% were pooled because of small sample sizes. Velocity and depth were pooled in groups identical to those used in 1983 with the exception that cells with depths of 0.1 feet were examined separately. In 1983, only two cells with a depth of 0.1 feet were sampled, and therefore insufficient data were available for examination of suitability of this depth.

Comparisons of the 1983 data with the 1984 data were made by plotting the suitability criteria derived in 1983 on the same graph with comparable 1984 data. On the depth and velocity graphs this was done by normalizing the suitability to 1.0 for the 1984 depth or velocity increment with the highest suitability and then plotting the 1983 suitability criteria normalized to the same scale. The 1984 percent cover data were first regressed against catch per cell or proportional presence, and, if significant, the regression line was plotted and the suitability normalized to 1.0 for the highest cover category. The 1984 percent cover suitability line was then plotted on the same graph, by using the normalized 1.0 as the starting point. The suitability of cover type for each species was calculated with the 1984 data using the methods described in Suchanek et al. (1984). The suitabilities calculated were then graphed against the cover type suitabilities calculated in 1983.

Variations in histogram distributions are to be expected on a univariate basis given that percent cover, cover type, velocity, and depth together affect suitabilities of a cell. Therefore, composite weighting factors were calculated for each cell using the 1983 suitability criteria and revised 1984 criteria and then these weighting factors were compared with catch. Composite weighting factors were calculated by multiplying suitability indices for cover type, percent cover, and velocity together. For chinook and coho salmon, Pearson correlation coefficients were calculated between composite weighting factors and catch per cell [transformed by natural log (X + 1)]. Chi-square association tests were run between chum and sockeye proportional presence and composite weighting factor value intervals calculated using the 1984 criteria data. Intervals of composite weighting factors were specified by dividing the data into four groups of approximately equal sizes by value of the composite weighting factor. Pearson correlation coefficients and results of the chi-square analysis were then compared with the same analyses done in 1983. Most of the statistical tests and data manipulations were done with the Statistical Package for the Social Sciences (SPSS) (Nie et al. 1975).

If the fit of the 1984 data to the 1983 suitability criteria did not seem close upon visual inspection, the 1983 criteria were modified. One of the procedures for modification was as follows. If, for example, the 1984 velocity distribution data appeared to match closely the 1983 velocity criteria, the 1983 velocity criteria were input as suitabilities and averaged over each increment of a variable such as depth for which a modification of suitability was desired. These averages were then multiplied by the mean catch of fish per cell divided by the mean suitability. The actual mean catches per cell by depth increment were then divided by the adjusted mean velocity suitability. If this ratio was less than 1.0, this would indicate less use of a depth increment than expected, given the average suitability for velocity. If the ratio was greater than 1.0, the use would be more than expected by adjusting for the effect of velocity. Sometimes this procedure would be effective in taking out variation caused by the other variable. If necessary, this procedure was used to adjust for effects of two or more variables.

If the above procedure was not effective in discounting the extraneous variation, then the criteria were modified using professional judgement. Correlations or chi-square association tests were then calculated between mean catch and calculated composite weighting factors using the modified criteria.

RESULTS

Abundance and distribution data (Section 3.2) have shown that the number juvenile chinook, coho, chum and sockeye salmon was very small at side sloughs in the lower reach. Even sampling cells at sloughs with good habitat failed to have any significant number of fish present in comparison with similar cells at the other macrohabitat types (tributary mouths and side channels). Fish were therefore responding to factors other than the availability of suitable microhabitat in their use of sloughs. For this reason, data collected at sloughs were eliminated from suitability criteria analyses to avoid comparing similar cells with large differences in mean catch.

Chinook Salmon

Chinook salmon suitability criteria were developed for both clear (< 30 NTU) and turbid (> 30 NTU) water in 1983 because the catch in cells without object cover was much greater in turbid water than in clear water (Suchanek et al. 1984). Data collected in the lower river in 1984 have shown that turbidity may limit the distribution of chinook salmon by being too high (Figure 10). Since cells with good habitat were sampled when high turbidity was limiting use by chinook salmon fry, we decided to eliminate sampled cells with turbidities greater than 350 NTU.

After eliminating cells in side sloughs and cells with turbidities greater than 350 NTU, 1155 cells were available for analysis of chinook distribution. Of the 1155 cells, 400 were sampled in water with a turbidity of 30 NTU or less. Mean adjusted catch (catch adjusted to a standard cell size of 300 ft^2) per cell of chinook fry in the 400 clear water cells was 1.3, while mean adjusted catch per cell in the 755 turbid cells was 1.1.

A scatter plot of chinook salmon catch in cells without object cover versus turbidities ranging to 100 NTU was examined. No notable inflections in catches of chinook salmon fry were noted over this range, although gradual increases in catches occurred across the range. It seemed reasonable, therefore, to keep the same 30 NTU breakpoint between high and low turbidity data for this year's analysis.

Clear Water

Correlations among the values of habitat attributes and clear water (< 30 NTU) chinook catch range to 0.32 in absolute value and a number of the correlations are statistically significant (Appendix Table A-2). In addition to these data, partial habitat data were recorded for four additional clear water cells and these additional data are used in subsequent analyses.

Composite weighting factors for all cells sampled were calculated by using the 1983 suitability criteria and also with modification of the velocity criteria as proposed by EWT&A (1985) and then correlated with chinook catch transformed by natural log (x + 1). In clear water, the correlation in 1983 was 0.43 but the correlation with the 1984 data was only 0.31 for the original criteria data and 0.26 with the change in velocity criteria proposed by EWT&A (1985). It was therefore deemed desirable to modify the criteria where large differences in individual criteria were found.

Appendix Table A-2. Kendall correlation coefficients between habitat variables and chinook catch by cell (N=396) for all gear types, in clear water.

	Percent Cover	Cover Type	Velocity	Depth	Chinook
Percent Cover	1.00				
Cover Type	0.08*	1.00			
Velocity	-0.32**	0.04	1.00		
Depth	0.03	-0.08*	-0.04	1.00	
Chinook	0.07	0.09*	-0.09*	0.21**	1.00

* Significantly different from 0 at $p < 0.05$.
** Significantly different from 0 at $p < 0.01$.

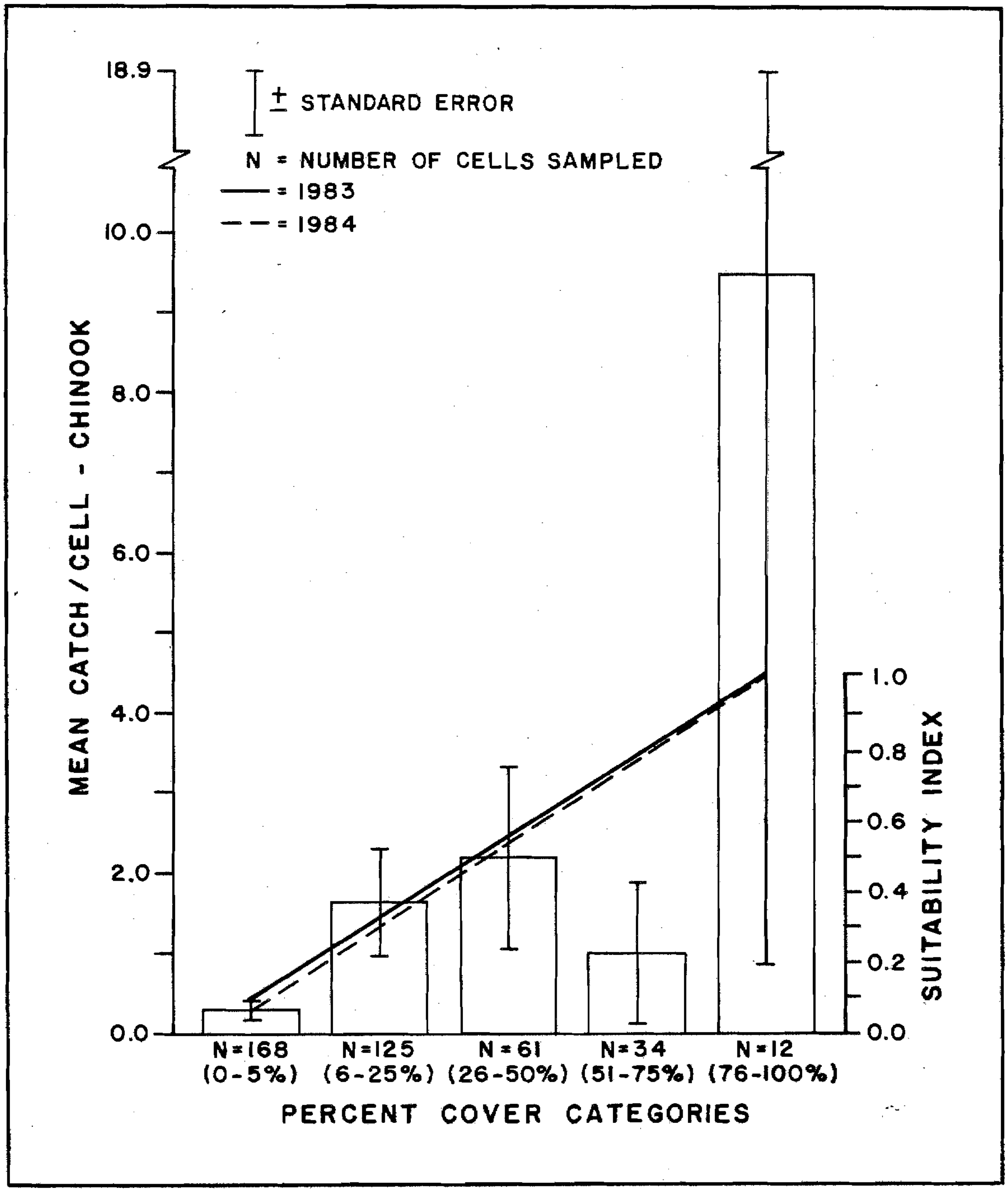
Least squares regressions were run between chinook catch per cell and the percent cover categories in clear water. There was a significant positive regression which is very similar to the suitability line developed in 1983 when the Y axis is normalized to a suitability of one (Appendix Figure A-1). The 1983 suitability criteria was therefore retained as a good estimate of this relationship.

The distribution of mean catch per cell of chinook fry by velocity interval in clear water in 1984 shows that peak catches were made in sampling cells with a velocity ranging from 0.1 to 0.3 fps (Appendix Figure A-2). After normalizing this peak in catch to a suitability of 1.0 and then plotting the 1983 suitability criteria on the same graph, it appears that chinook used lower velocity water in the lower reach than in the middle reach under clear conditions. It was noted that the 1984 clear water distribution of catch by velocity interval was more similar to the 1983 turbid water velocity suitability criteria and therefore the 1983 turbid velocity criteria were plotted against the 1984 data (Appendix Figure A-3). Since the two distributions were similar, the 1983 turbid water velocity criteria were taken as a good estimate of the lower river velocity suitability for chinooks in clear water.

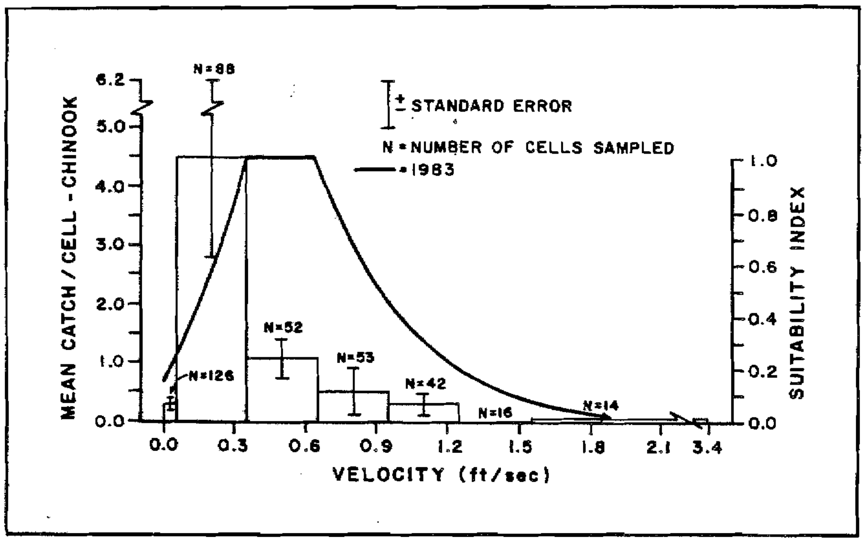
Cover type suitabilities derived in 1984 for juvenile chinook in clear water contrasted sharply with those derived in the middle reach in 1983 (Appendix Figure A-4). Debris was used less by chinook in the lower reach for cover and emergent vegetation was used more. The sample size of the cobble/boulder cover category was only one and therefore this cover type could not be evaluated. Catches in the cells without object cover were also relatively higher in 1984 than in 1983.

Therefore, it appeared that 1983 suitability for cover types would not apply in the lower reach. By adjusting for the effects of velocity and percent cover, better estimates of cover type suitability for the lower river were formulated from the 1984 data (Appendix Figure A-5). Since cobble and boulder sample sizes were low, suitabilities for these cover types were kept proportional in suitability to large gravel as was the case in 1984. Since the "no cover" catches were relatively large because fish were using relatively deep cells without object cover (see next paragraph), we lowered the suitability for no cover cells to 0.10, the suitability found in 1983.
A heavy use of deep, clear water by chinooks was found in 1984 while in 1983 the data suggested a peak in use of cells 1.0 to 1.5 feet deep (Appendix Figure A-6). In 1983, an evaluation of depth found it had little effect on increasing the correlation of fish catch with composite weighting factors using it. Depth was used in the 1983 modelling efforts as having no value if less than 0.14 ft and having a suitability of 1.0 if greater than 0.15 ft. In order to evaluate depth, suitability criteria were fit to the data using professional judgement after first adjusting for mean velocity and percent cover suitability (Appendix Figure A-7).

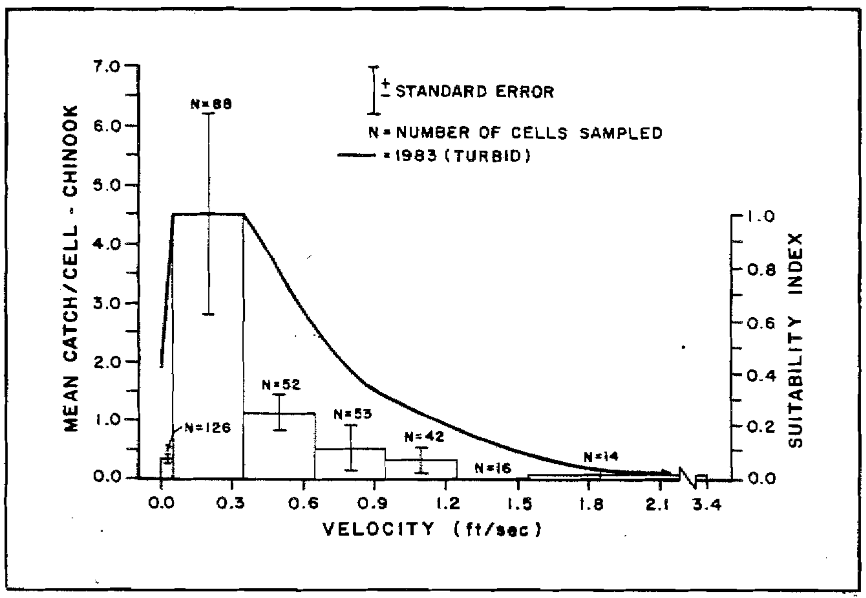
After the modifications to the cover suitability and depth criteria were made, we then correlated transformed chinook catch with the composite



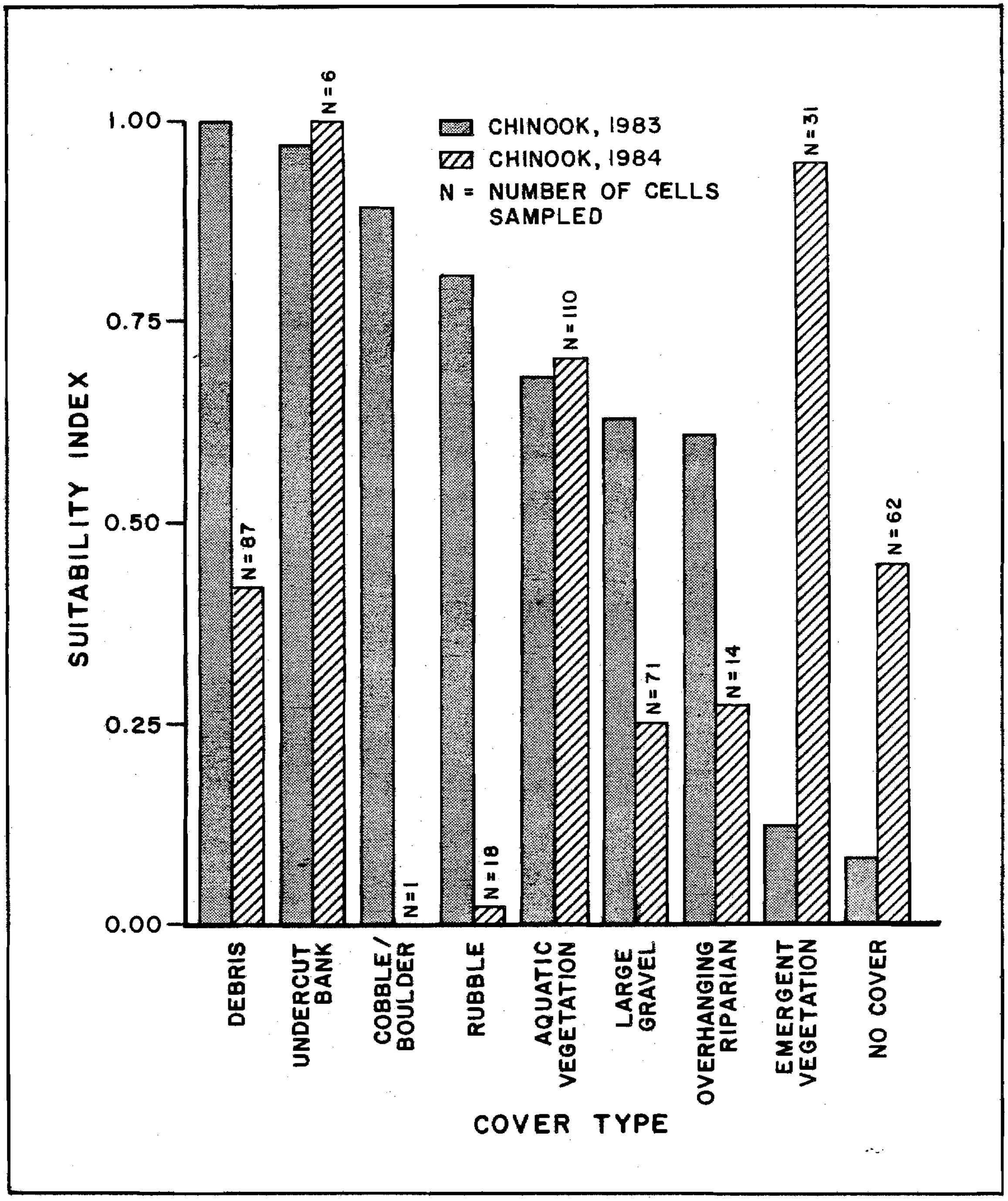
Appendix Figure A-1. Mean catch of juvenile chinook salmon per cell by percent cover category (bars) in clear water of the lower Susitna River, 1984 and comparison of fitted suitability indices (lines) calculated in 1984 and for the middle Susitna River, 1983.



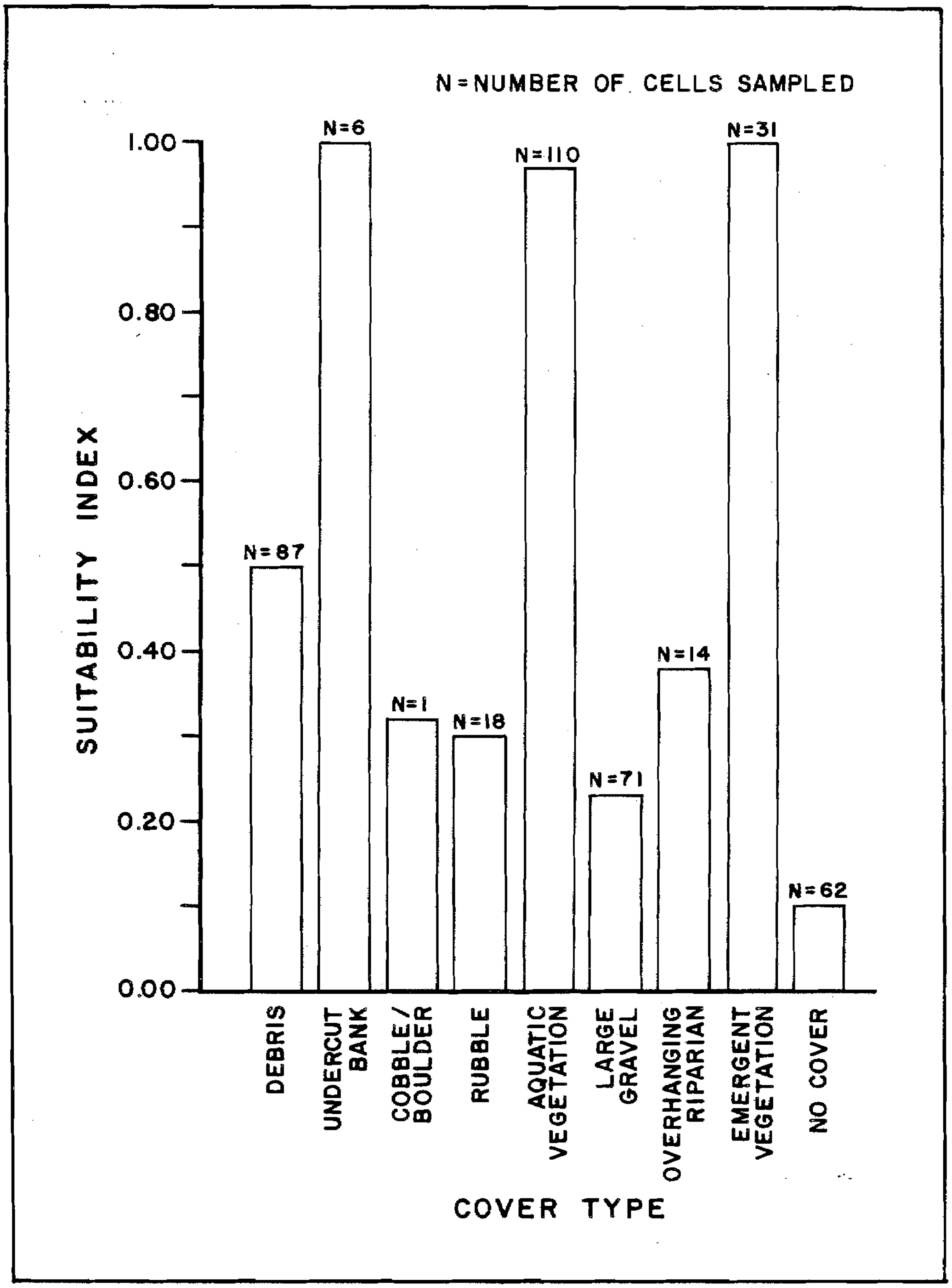
Appendix Figure A-2. Mean catch of juvenile chinook salmon per cell by velocity intervals (bars) in clear water of the lower Susitna River, 1984 and fitted suitability index (line) developed for the middle Susitna River, 1983.



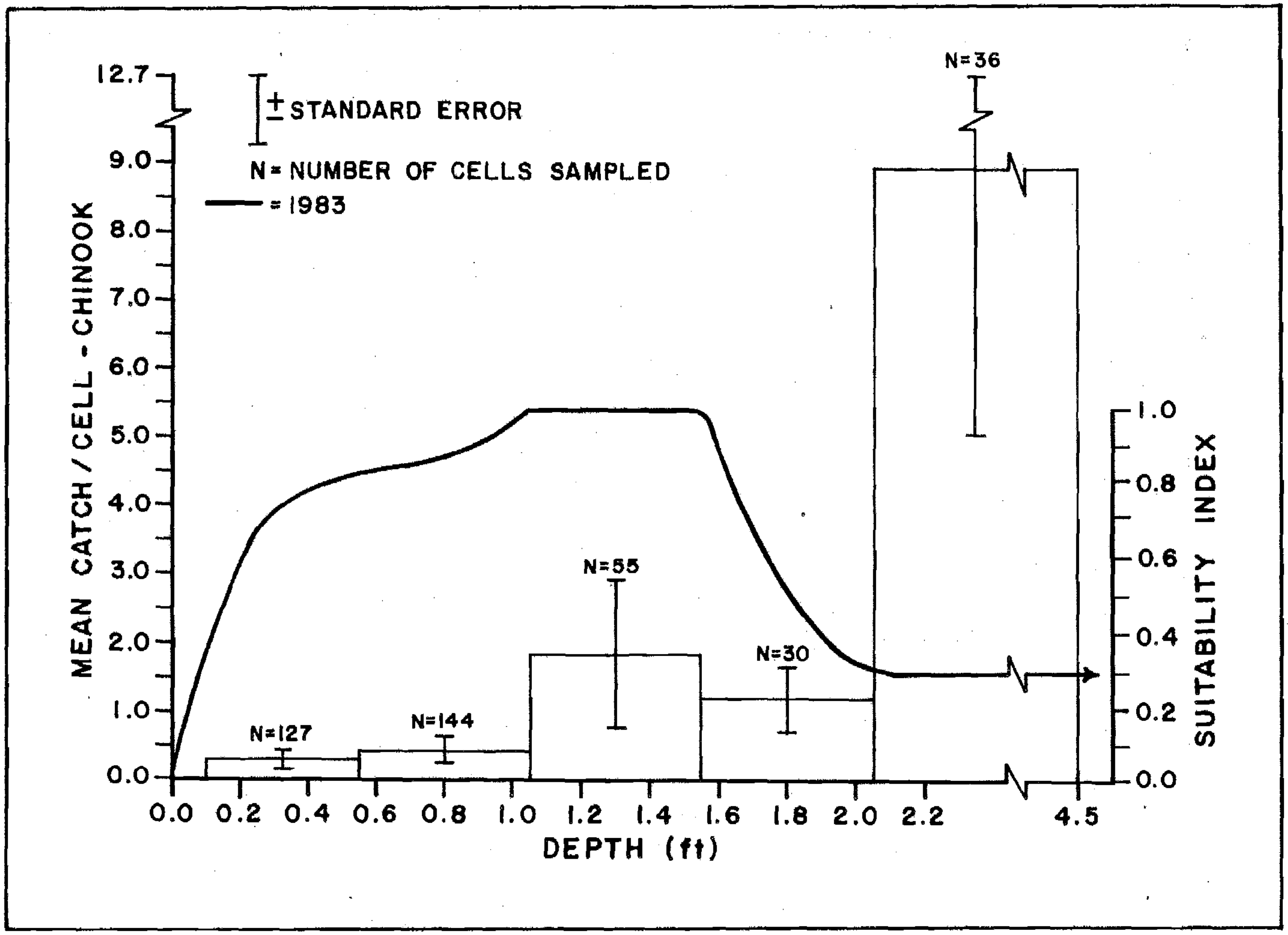
Appendix Figure A-3. Mean catch of juvenile chinook salmon per cell by velocity intervals (bars) in clear water of the lower Susitna River, 1984 and fitted suitability index (line) developed for turbid water in the middle Susitna River, 1983.



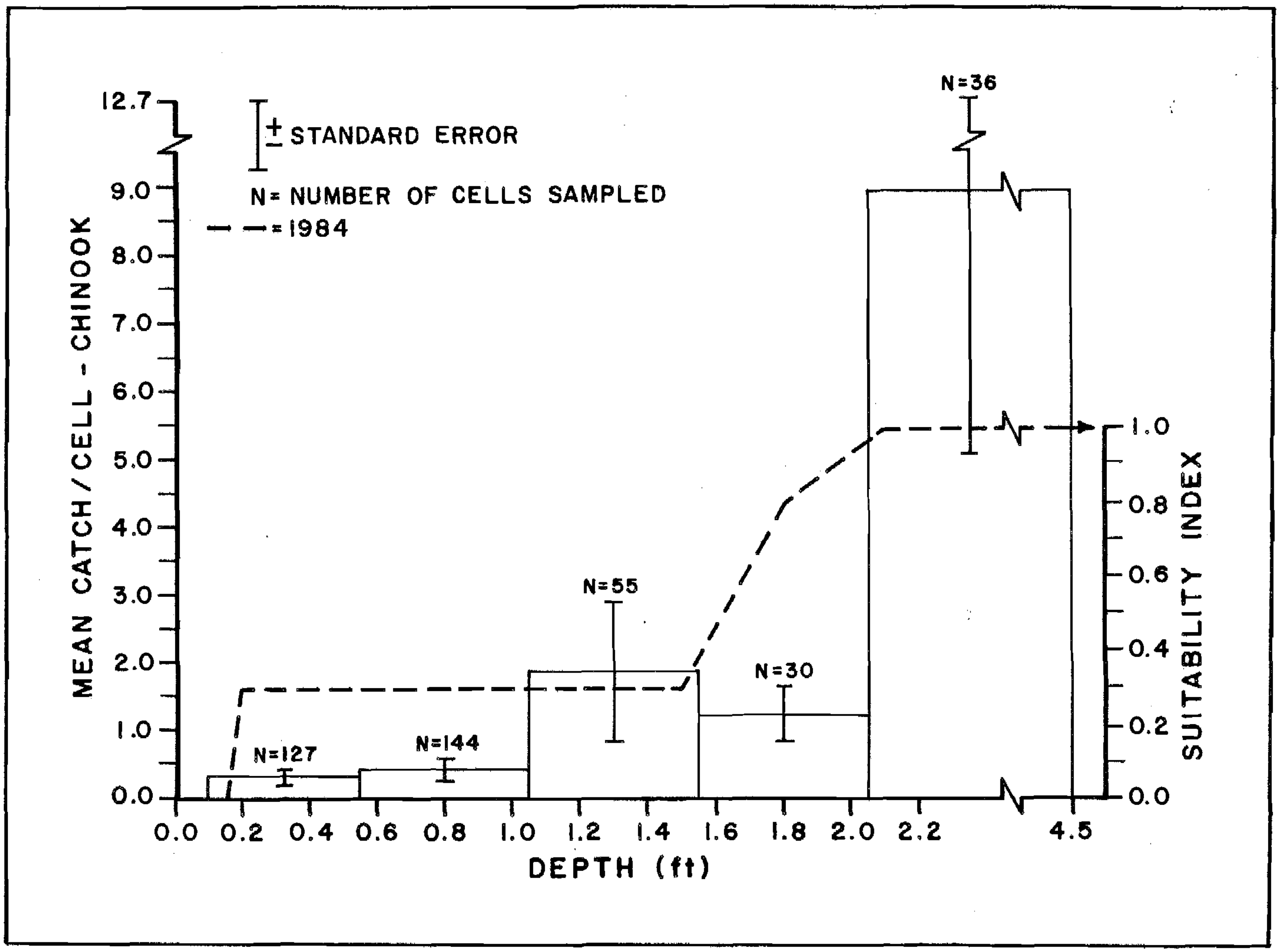
Appendix Figure A-4. Comparison of cover type suitability indices for juvenile chinook salmon in clear water calculated from 1984 lower Susitna River distribution data and 1983 distribution data.



Appendix Figure A-5. Cover type suitability indices for juvenile chinook salmon in clear water calculated from 1984 lower Susitna River distribution data after adjusting for velocity and percent cover.



Appendix Figure A-6. Mean catch of juvenile chinook salmon per cell by depth intervals (bars) in clear water of the lower Susitna River, 1984 and fitted suitability index (line) developed for the middle Susitna River, 1983.



Appendix Figure A-7. Mean catch of juvenile chinook salmon per cell by depth intervals (bars) in clear water of the lower Susitna River, 1984. Suitability index (line) fitted by hand using professional judgement.

weighting factors calculated with the 1983 percent cover criteria and turbid water velocity criteria along with the 1984 lower river cover type and depth suitability criteria. The correlation was 0.61, substantially higher than the original 1983 criteria. If depth was eliminated from the calculations, the correlation dropped to 0.26 and if primary cover type was dropped the correlation dropped to 0.52. Therefore, it seemed reasonable to keep the newly modified cover type and depth criteria as inputs.

Turbid Water

Correlations between the values of habitat attributes and chinook catch in turbid water range to 0.39 in absolute value and a number are statistically significant (Appendix Table A-3). Partial habitat data were recorded for 11 additional turbid cells and these additional data were used in subsequent univariate histograms.

Correlations between composite weighting factors calculated with the 1983 turbid water criteria and 1984 chinook catch was 0.31, while composite weighting factors calculated by incorporating the cover modifications proposed by EWT&A (1985) were correlated with an r-value of 0.26. Comparable correlation with the 1983 data was 0.38. These data again suggested that some modifications could be made, especially given the changes already made in the clear-water cover type suitabilities.

A comparison of 1984 velocity distribution data and the 1983 velocity suitability criteria for chinook salmon showed few differences (Appendix Figure A-8), and therefore the 1983 velocity criteria were accepted as the 1984 criteria curve.

Least squares regressions were run between chinook catch per cell and the percent cover categories in turbid water. There was no significant relationship between catch per cell and percent cover category and mean catch per cell decreased with increases in cover (Appendix Figure A-9). By adjusting for velocity, a slight trend upward was noted over the first three categories. The percent cover criteria developed in 1983 was therefore accepted as reasonable, as increases in the amount of object cover would seem more desirable for fish and sample sizes were very small in the 51-75% and 76-100% cover categories.

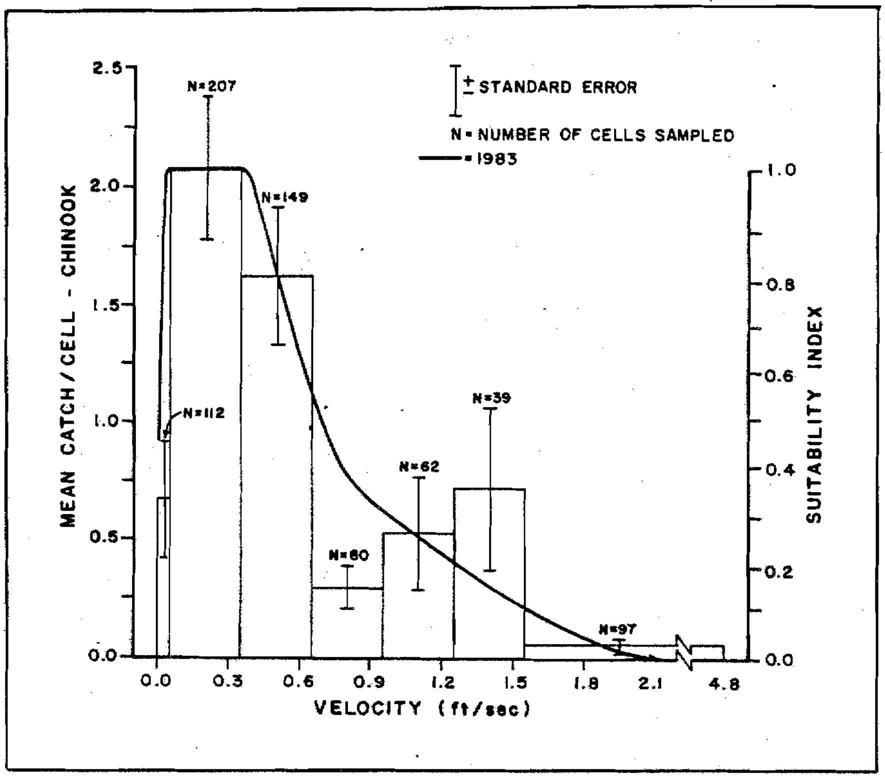
In 1983, cover type for chinook in turbid water was not evaluated. EWT&A (1985) modified the turbid water criteria, however, so that they more closely reflected the clear water criteria developed in 1983. In 1984, mean catches of chinooks in turbid water were highest in the emergent vegetation, rubble, and debris-deadfall categories, but catches were only slightly higher than in the cover category "no cover".

Cover type was evaluated in 1984 by using the method of EWT&A (1985) for calculating turbidity factors from the fitted regressions of percent cover in clear and turbid water and their associated chinook mean catches. Turbidity factors were calculated (Appendix Table A-4) and then applied to the revised lower river cover suitability data. These

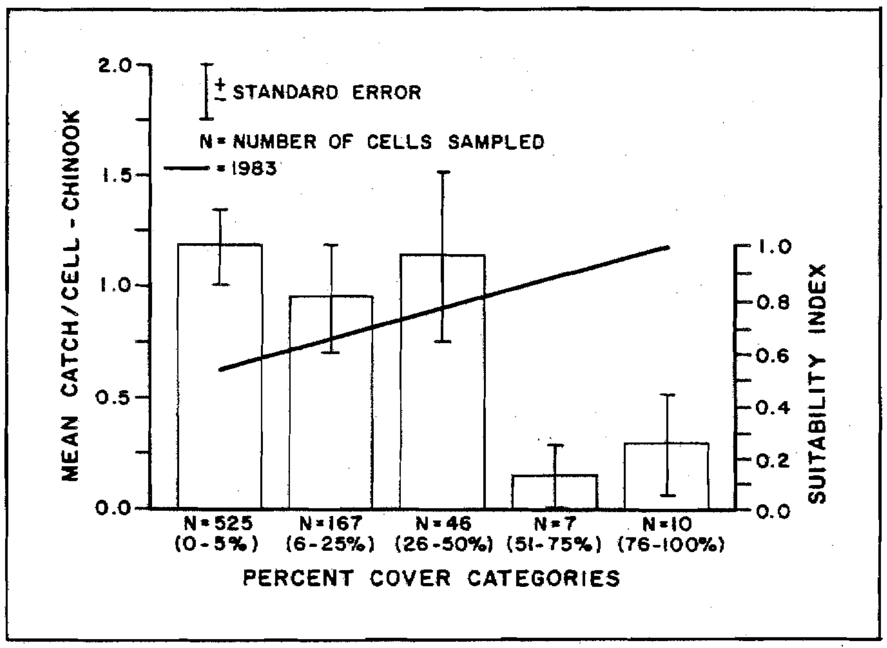
Appendix Table A-3. Kendall correlation coefficients between habitat variables and chinook catch by cell (N=744) for all gear types, in turbid water.

	Percent Cover	Cover Type	Velocity	Depth	Chinook
Percent Cover	1.00				
Cover Type	0.39**	1.00			
Velocity	0.05*	0.16**	1.00		
Depth	0.06*	0.26**	0.21**	1.00	
Chinook	-0.02	0.00	-0.17**	-0.15**	1.00

* Significantly different from 0 at $p < 0.05$.
** Significantly different from 0 at $p < 0.01$.



Appendix Figure A-8. Mean catch of juvenile chinook salmon per cell by velocity intervals (bars) in turbid waters of the lower Susitna River, 1984 and fitted suitability index (line) developed for the middle Susitna River, 1983.



Appendix Figure A-9. Mean catch of juvenile chinook salmon per cell by percent cover category (bars) in turbid water of the lower Susitna River, 1984 and fitted suitability index (line) calculated for the middle Susitna River, 1983.

revised suitabilities were much too low for many categories given observed catches and therefore a suitability of 0.15 was assigned as a minimum for cover type suitability in turbid water based on observed mean catches. Using this method, none of the suitabilities for cover type in conjunction with percent cover in turbid water are greater than 0.40 (Appendix Figure A-10).

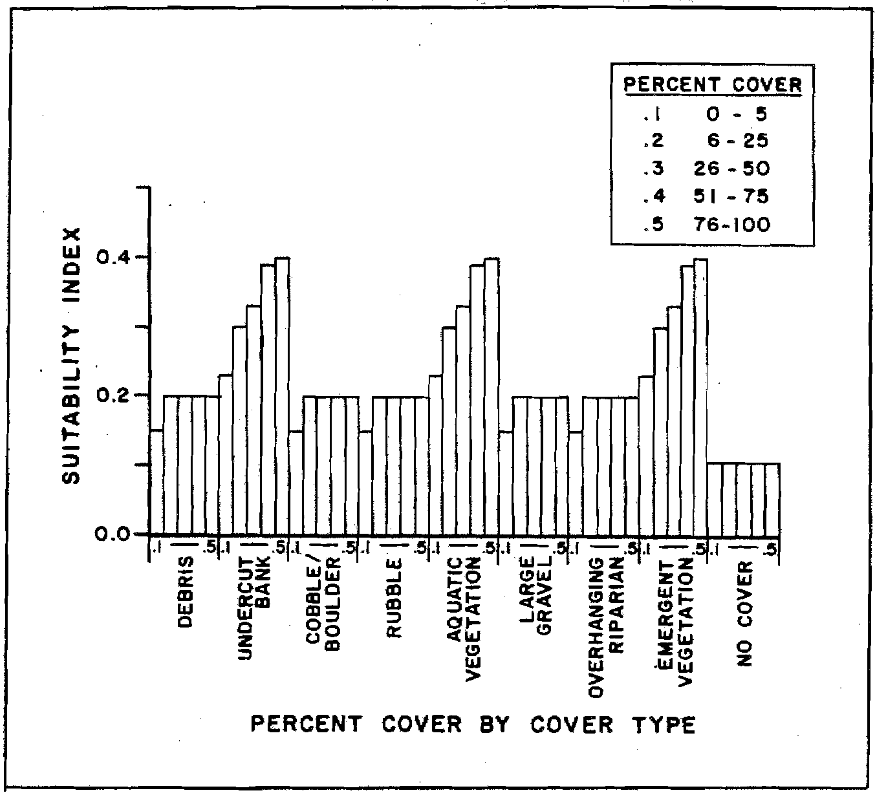
Appendix Table A-4. Calculations of turbidity factors for 1984 lower river data.

Percent Cover	Number of Fish Per Cell (Fitted to a Line) Clear	Turbid	Turbidity Factor
0-5%	0.5	1.1	2.2
6-25%	1.5	1.3	0.9
25-50%	2.5	1.5	0.6
51-75%	3.5	1.7	0.5
76-100%	4.5	1.9	0.4

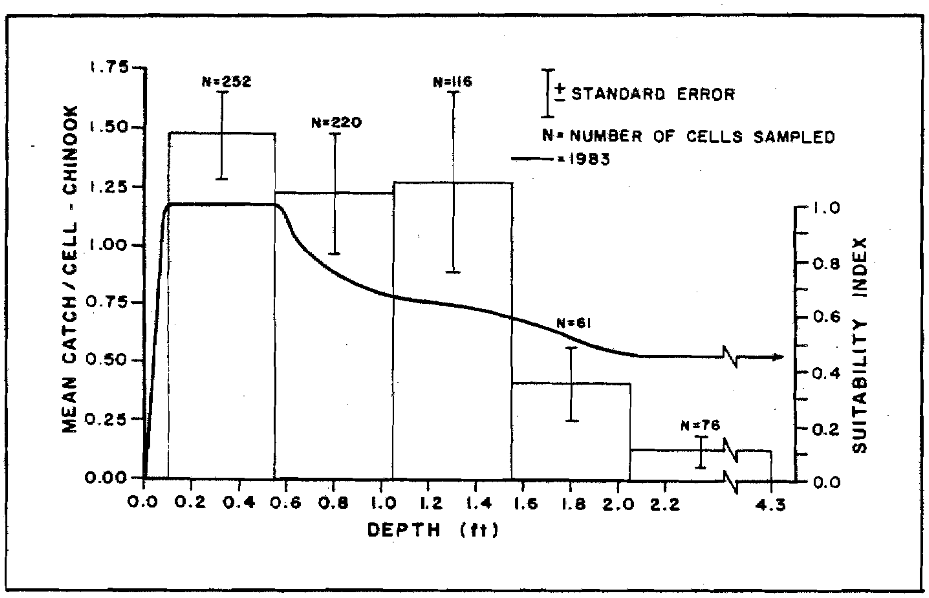
In turbid water, peaks in chinook use were found in water less than 0.5 ft deep in both 1983 and 1984 (Appendix Figure A-11). In 1983, since fitting the depth suitability line to the data did not increase the composite weighting factor much, the depth criteria used for clear water (0 if less than 0.14 ft, 1.0 if greater than 0.15 ft) was used for modelling.

In 1983 there was only one turbid cell sampled with a depth of 0.1 feet and therefore the value of cells with this depth could not be evaluated. For purposes of IFIM modelling, this depth was assigned a suitability of 0, while in the RJHAB model data this depth did not occur. In turbid water, 21 cells of 0.1 feet depth were fished in 1984 and the mean catch was 0.5 chinook juveniles per cell. These data suggest that under turbid conditions the value of 0.1 feet cells is greater than 0. A suitability criteria line was fit to the 1984 turbid water depth data by first adjusting for the effects of velocity (Appendix Figure A-12). The optimum depth ranged from 0.3 to 1.5 feet.

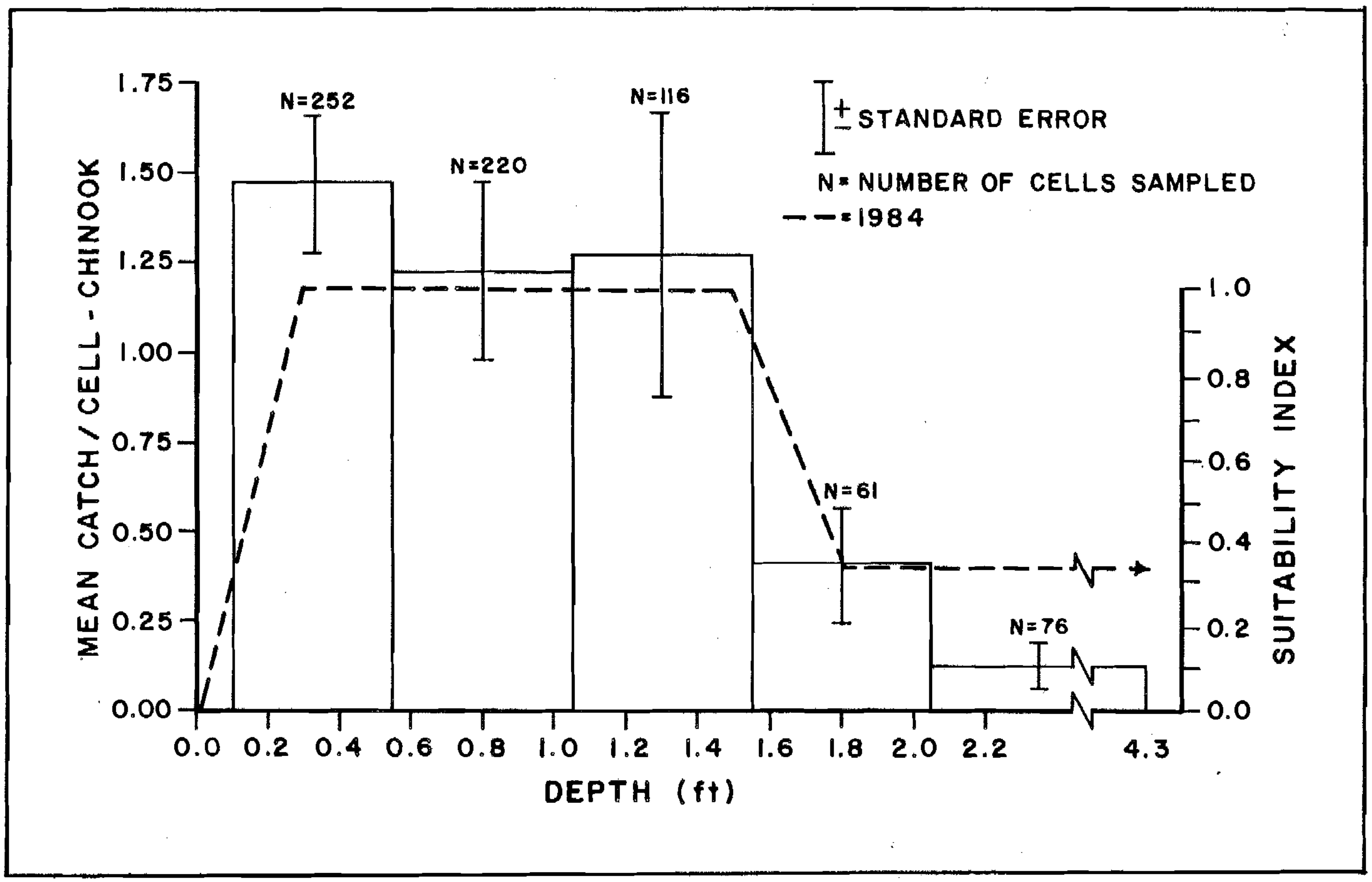
Once all the criteria were modified, correlations were calculated between catch transformed by natural log (x + 1) and the composite weighting factor calculated by multiplying the suitabilities for velocity, cover, and depth together. The correlation was 0.33, and if depth were removed the correlation dropped to 0.28. If cover was removed from calculations of the composite weighting factor, the correlation increased to 0.36. Since instream cover has value as a velocity break in turbid water, it seemed reasonable to keep velocity, cover, and depth in the modelling.



Appendix Figure A-10. Cover type suitability indices for juvenile chinook salmon in turbid water developed from 1984 lower Susitna River chinook turbid water distribution data.



Appendix Figure A-11. Mean catch of juvenile chinook salmon per cell by depth intervals (bars) in turbid water of the lower Susitna River, 1984 and fitted suitability index (line) developed for the middle Susitna River, 1983.



Appendix Figure A-12. Mean catch of juvenile chinook salmon per cell by depth intervals (bars) in turbid water of the lower Susitna River, 1984. Suitability index (line) fitted by hand using professional judgement.

Coho Salmon

Juvenile coho salmon suitability criteria were developed only for clear water in 1983. Very few coho were captured in macrohabitat types other than tributary mouths in the lower reach and therefore only tributary mouth data were used in suitability criteria comparisons. Most of the turbidities in the tributary mouths were less than 30 NTU although on two occasions, turbidities were over 100 NTU.

A total of 345 cells with complete habitat data were sampled in tributary mouths and another 2 cells with partial habitat data were sampled. Mean adjusted catch in the cells sampled was 1.2 fpc. Kendall correlations among the values of habitat attributes and coho catch ranged to 0.43 in absolute value (Appendix Table A-5). Cover type was most highly correlated with coho catch.

The distribution of mean coho catch per cell by velocity interval in 1984 matched quite closely with the suitability criteria derived in 1983 for the middle river (Appendix Figure A-13). The 1983 velocity criteria were therefore chosen as representative for the lower river.

A regression of coho catch to percent cover category was significant (Appendix Figure A-14). When the 1983 and 1984 data were normalized to 1.0 on the Y-axis for the 76-100% category, the 1983 suitability line had a much greater slope, and suitability for 0-5 percent cover in 1983 was 0.12, while in 1984 it was 0.33. After adjusting for the effect of velocity, the distribution of catches by percent cover interval appeared to be more similar to the 1983 distribution and since the sample size in 1983 was larger, the 1983 percent cover suitability relationship was chosen for use in the lower river.

Initial calculations of the suitability of cover type for coho salmon indicated that suitabilities in the lower river were similar to those found in 1983 (Appendix Figure A-15). After adjusting for the effects of velocity and percent cover, these estimates of cover suitability for the cover types were revised for use in the lower river in 1984 (Appendix Figure A-16). Since sample sizes for the three substrate cover types were small, the suitability of 0.10 calculated in 1983 for rubble and boulders was used for these three categories.

The distribution of CPUE's for depth was very different from that found in 1983 (Appendix Figure A-17). By adjusting for the effects of velocity, percent cover, and cover type there still was no trend in depth suitabilities and therefore depth suitability was not changed from that used in 1983.

The correlation between transformed coho catch and the composite weighting factor calculated by multiplying the velocity, cover, and depth suitabilities together was 0.32.

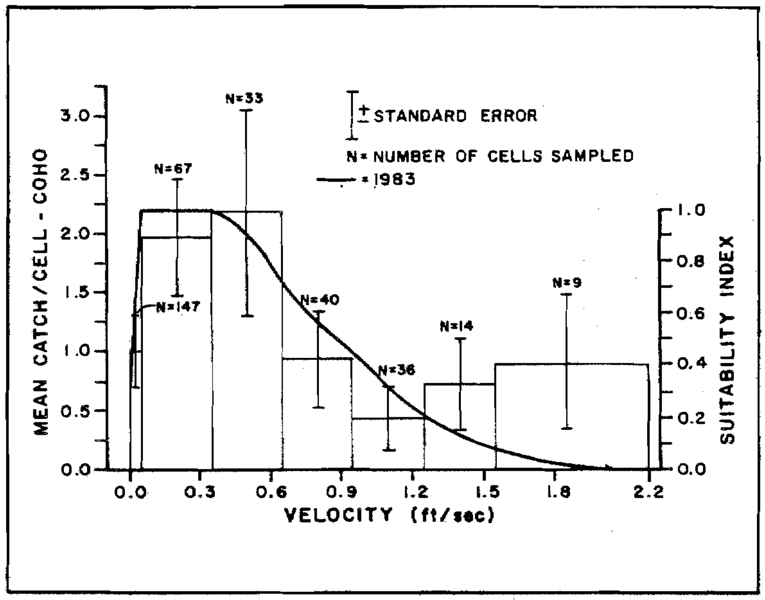
Sockeye Salmon

Juvenile sockeye salmon suitability criteria were developed by pooling data over gear type and turbidity level in 1983. Since abundance and distribution data have indicated that sockeye salmon use of lower river

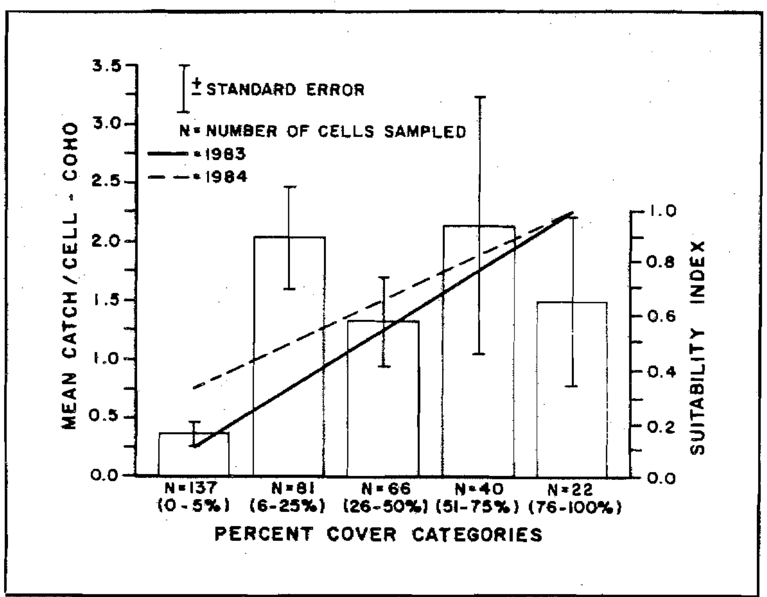
Appendix Table A-5. Kendall correlation coefficients between habitat variables and coho catch by cell (N=345) in clear water.

	Percent Cover	Cover Type	Velocity	Depth
Percent Cover	1.00			
Cover Type	0.05	1.00		
Velocity	-0.43**	0.02	1.00	
Depth	0.05	-0.09*	-0.14**	1.00
Coho	0.09*	0.23**	-0.01	0.05

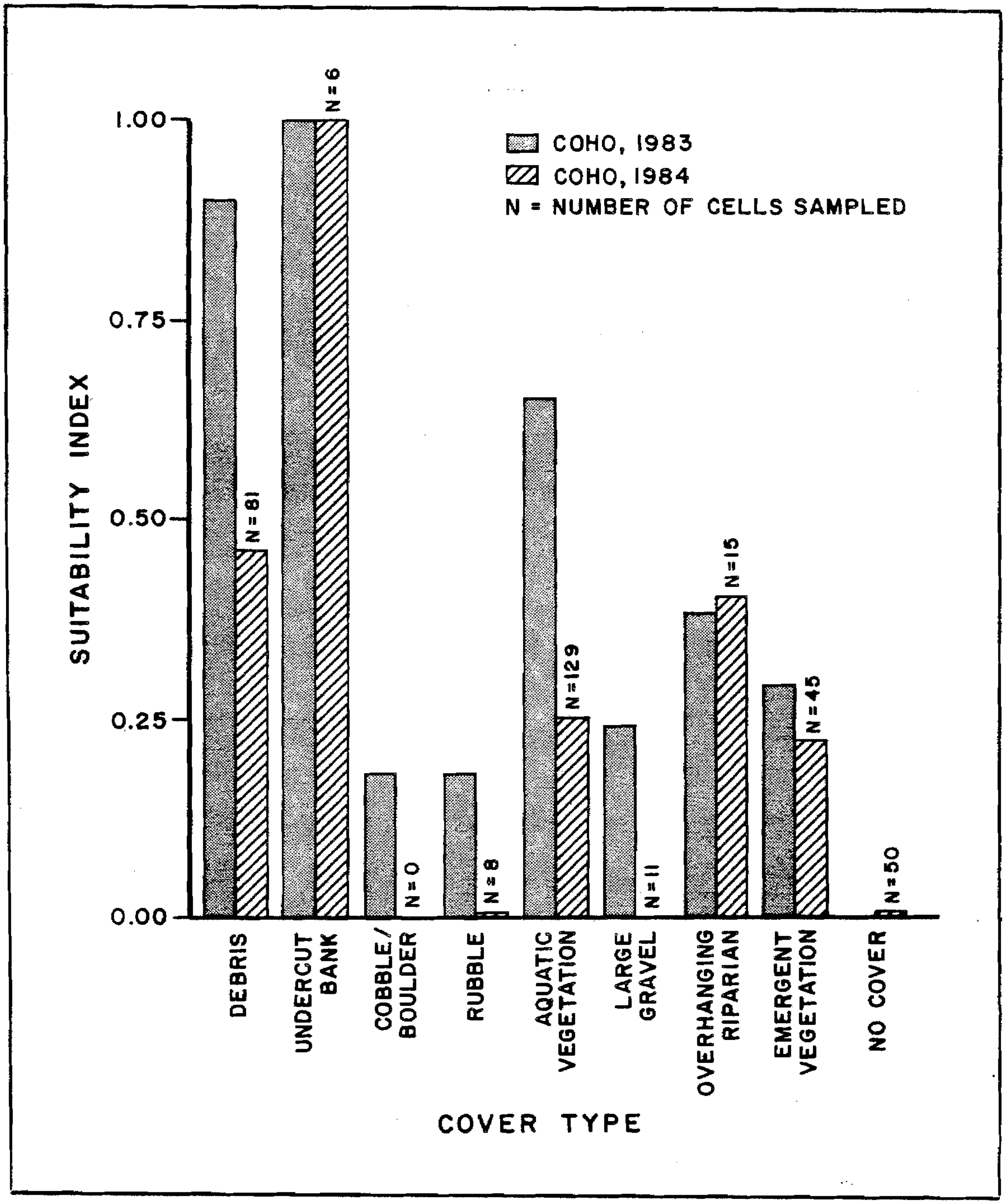
* Significantly different from 0 at $p < 0.05$.
** Significantly different from 0 at $p < 0.01$.



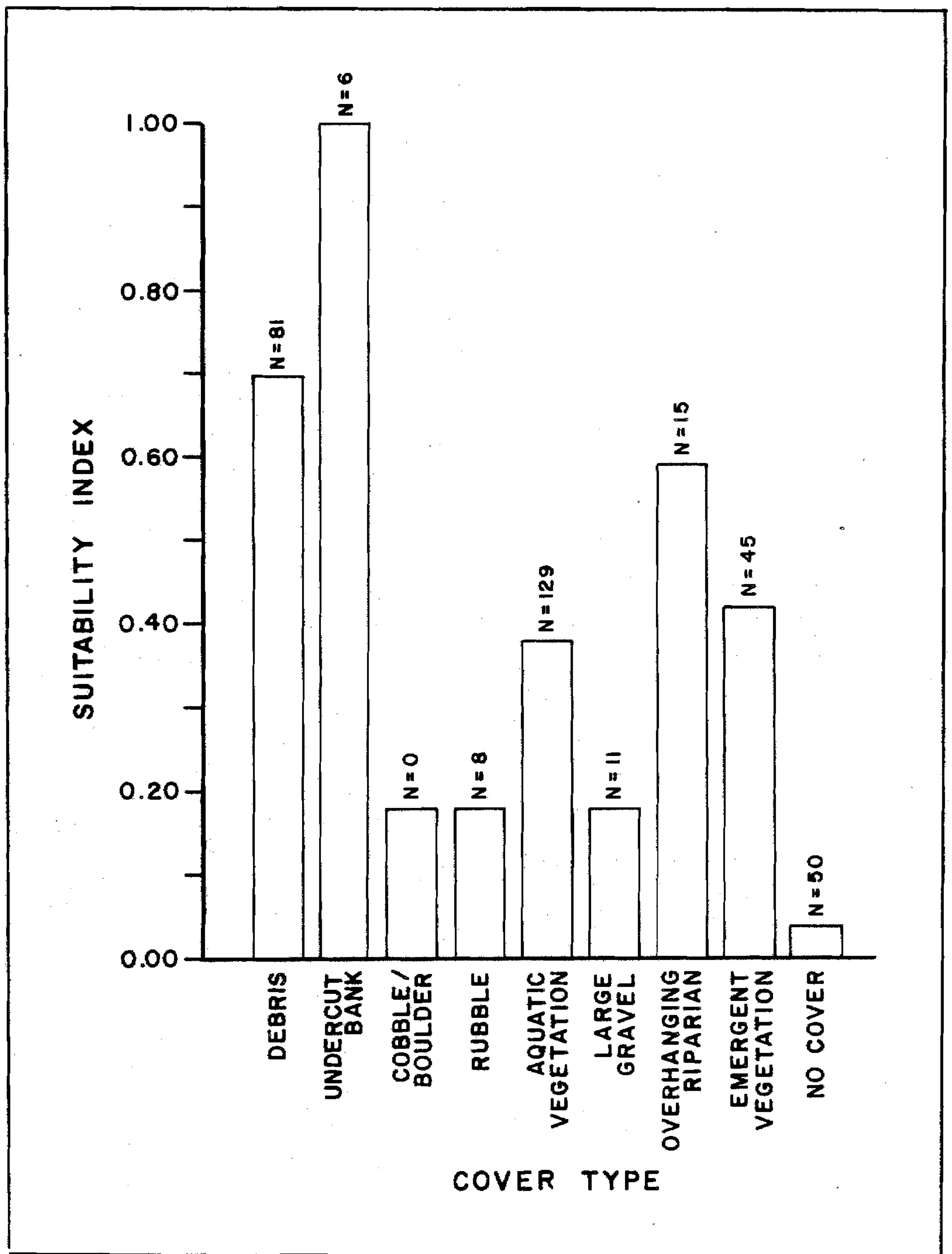
Appendix Figure A-13. Mean catch of juvenile coho salmon per cell by velocity intervals (bars) in the lower Susitna River, 1984 and fitted suitability index (line) developed for the middle Susitna River, 1983.



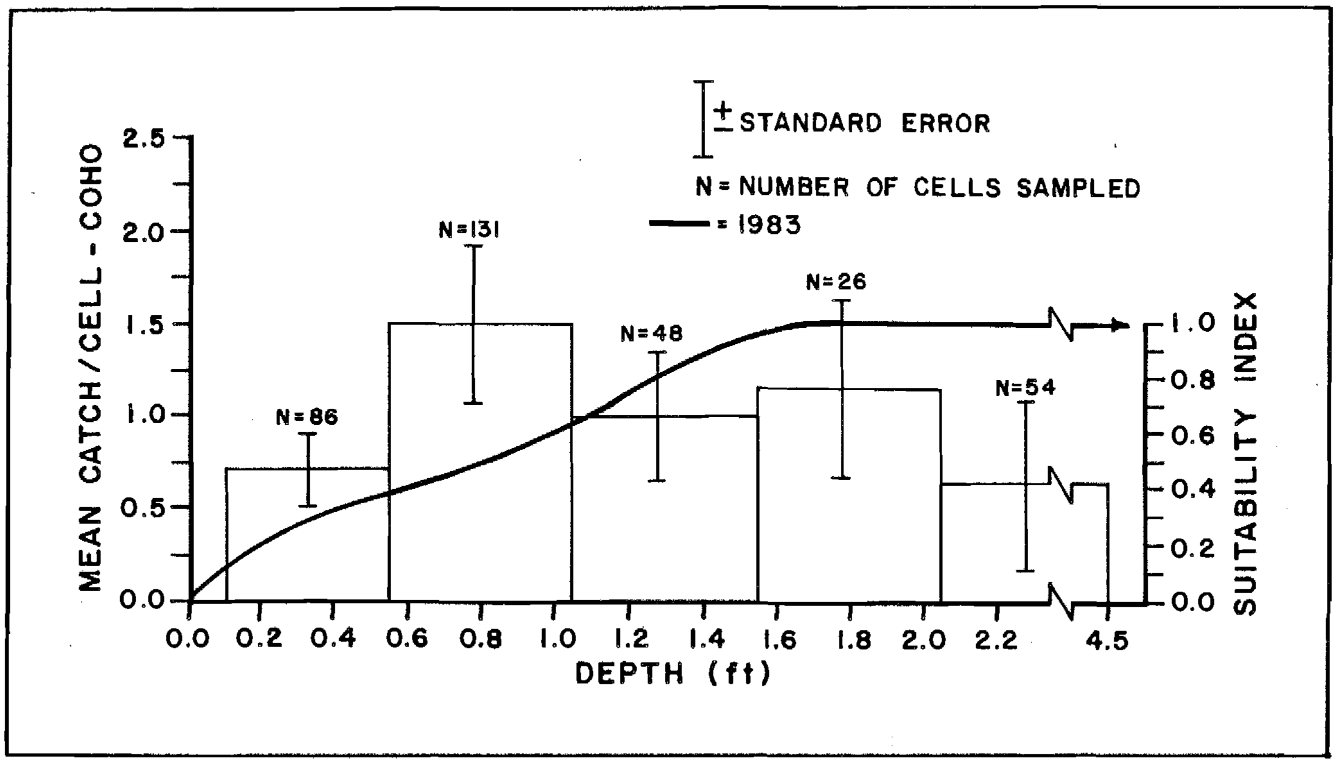
Appendix Figure A-14. Mean catch of juvenile coho salmon per cell by percent cover category (bars) in the lower Susitna River, 1984 and comparison of fitted suitability indices (lines) calculated in 1984 and for the middle Susitna River, 1983.



Appendix Figure A-15. Comparison of cover type suitability indices for juvenile coho salmon calculated from 1984 lower Susitna River distribution data.



Appendix Figure A-16. Cover type suitability indices for juvenile coho salmon developed for the lower Susitna River in 1984.



Appendix Figure A-17. Mean catch of juvenile coho salmon per cell by depth intervals (bars) in clear water of the lower Susitna River, 1984 and fitted suitability index (line) developed for the middle Susitna River, 1983.

side channels is limited by high turbidities (Figure 18), cells with turbidities greater than 250 NTU were eliminated from suitability criteria development.

After cells with turbidities greater than 250 NTU were eliminated, 922 cells with complete habitat data were available for analysis. Sockeye were captured in 117 (12.7%) of these cells. Correlations among the habitat variables ranged to 0.65 in absolute value and velocity was most highly correlated with sockeye catch (Appendix Table A-6). In addition to these cells, partial habitat data were collected at six additional cells and these data are used in subsequent univariate histograms.

The distribution of proportional presence by velocity interval was very similar to that found in 1983 (Appendix Figure A-18). There was no use of velocities greater than 1.2 fps, however, and in 1983 there also was no use of velocities greater than 1.2 fps although sample sizes were smaller. Since these high velocities are not used, the lower river velocity suitability criteria were modified so that velocities greater than 1.2 fps have 0 suitability (Appendix Figure A-18).

Distribution of proportional presence by percent cover categories was similar to that found in 1983 (Appendix Figure A-19). The 1983 suitability relationship was therefore selected for use in 1984.

The distribution of proportional presence by cover type categories was somewhat different than that found in 1983 (Appendix Figure A-20). Suitabilities for the cover types used in the lower river in 1984 will be those developed in 1984 with the following two exceptions. Since sample sizes were small (less than 25) for the cover type categories, undercut banks and overhanging riparian vegetation, the suitabilities calculated in 1983 were averaged with the 1984 suitabilities to give a value intermediate between the two.

No trend was noted in the 1984 depth distribution data and therefore no suitability criteria were fit to these data (Appendix Figure A-21). Of the 20 cells sampled with 0.1 ft depth, fish were sampled in 2 suggesting that this depth does have value. Therefore any depth will be assumed to have a suitability of 1.

Composite weighting factor intervals calculated by multiplying cover and velocity suitabilities together were associated with proportional presence of sockeye salmon (Appendix Table A-7).

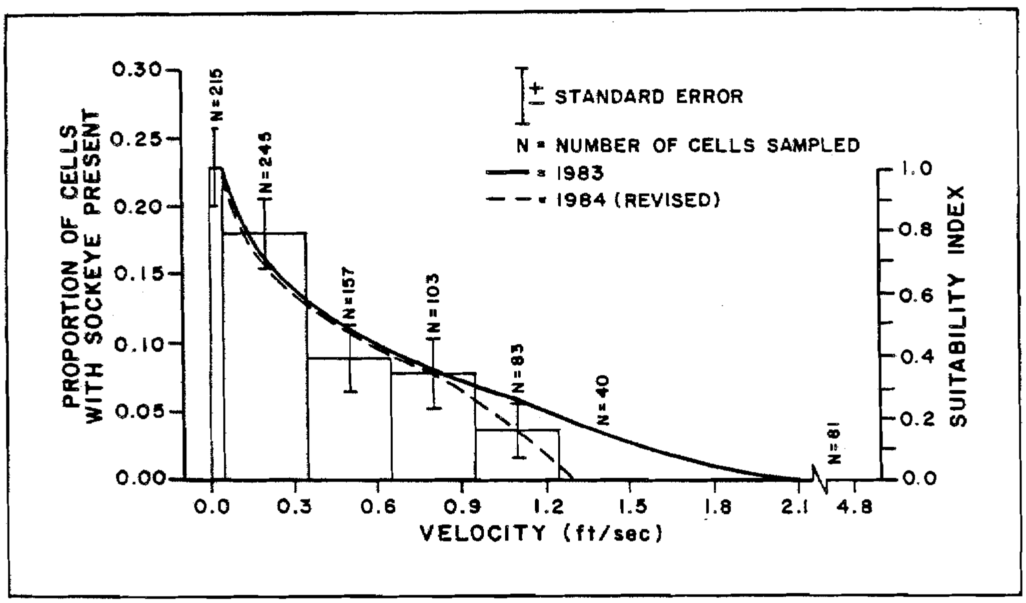
Chum Salmon

Juvenile chum salmon suitability criteria were developed by pooling data over gear type and turbidity in 1983. Abundance and distribution data indicate that chum salmon use of lower river side channels is limited by high turbidities (Figure 15). Cells with turbidities greater than 200 NTU were eliminated from suitability criteria development. Also, since most chum salmon outmigrate before July 16, only data collected before this date were retained for suitability criteria analysis.

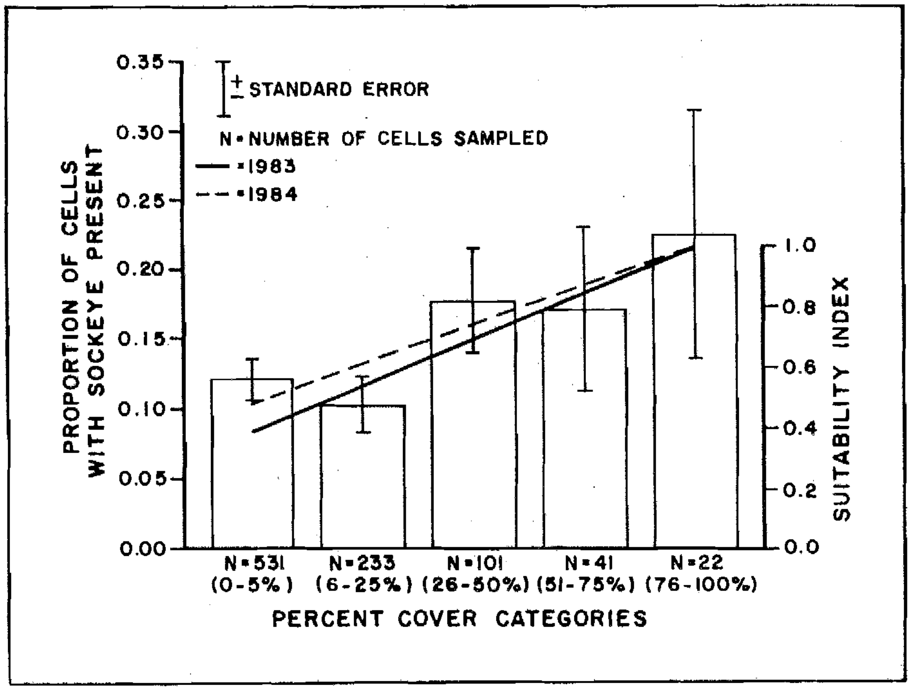
Appendix Table A-6. Kendall correlation coefficients between habitat variables and sockeye catch by cell (N=922).

	Percent Cover	Cover Type	Velocity	Depth
Percent Cover	1.00			
Cover Type	0.30**	1.00		
Velocity	-0.18**	0.65**	1.00	
Depth	0.05*	-0.01	0.07**	1.00
Sockeye	0.04	-0.06*	-0.21**	0.02

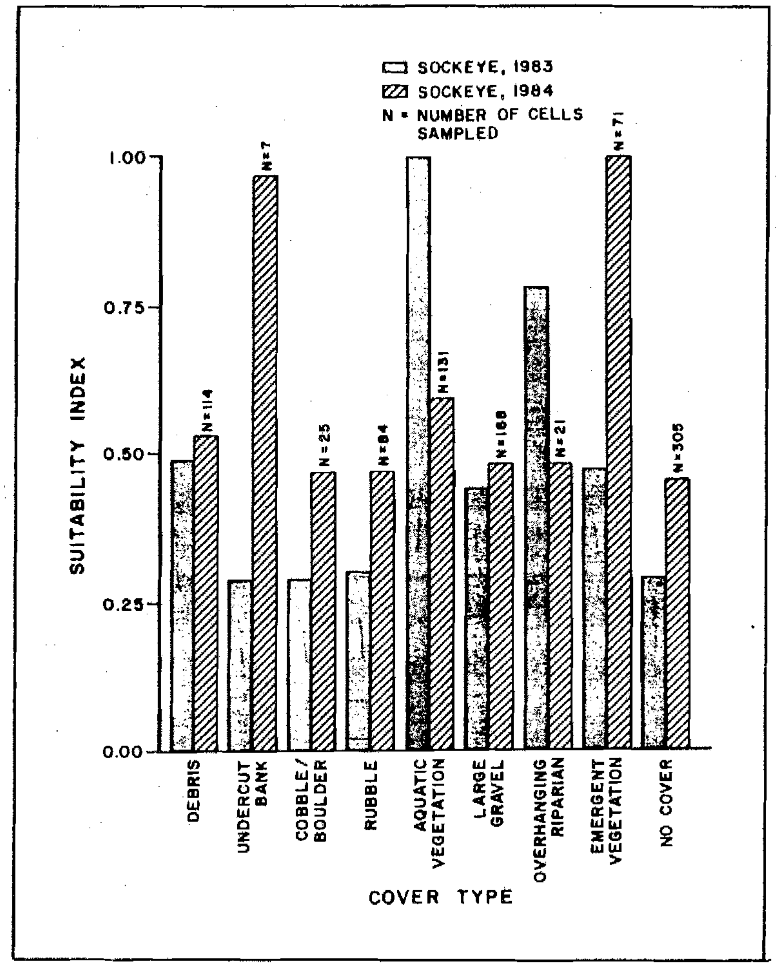
* Significantly different from 0 at $p<0.05$.
** Significantly different from 0 at $p<0.01$.



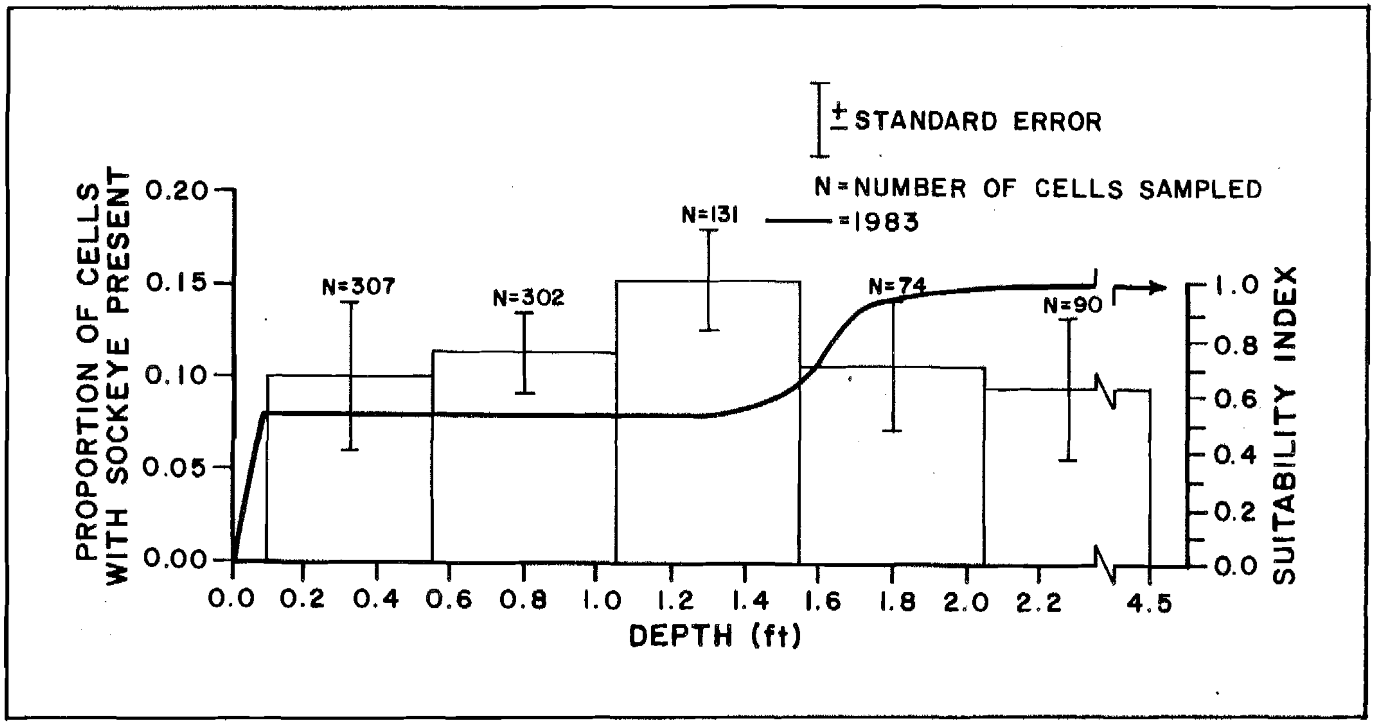
Appendix Figure A-18. Proportion of cells with juvenile sockeye salmon present by velocity intervals (bars) in the lower Susitna River, 1984 and fitted suitability index (line) developed for the middle Susitna River, 1983 and revised in 1984 for the lower Susitna River using professional judgement.



Appendix Figure A-19. Proportion of cells with juvenile sockeye salmon present by percent cover category (bars) in the lower Susitna River, 1984 and comparison of fitted suitability indices (lines) calculated in 1984 and for the middle Susitna River, 1983.



Appendix Figure A-20. Comparison of cover type suitability indices for juvenile sockeye salmon calculated from 1984 lower Susitna River distribution data and 1983 middle Susitna River distribution data.



Appendix Figure A-21. Proportion of cells with juvenile sockeye salmon présent by depth intervals (bars) in the lower Susitna River, 1984 and suitability index (line) developed for the middle Susitna River, 1983.

Appendix Table A-7. Proportional presence of sockeye salmon associated with the composite weighting factor calculated by multiplying velocity and cover suitabilities together.

Composite Weighting Factor Interval	Total Number of Cells	Proportion With Fish Present	Chi-Square
0 - 0.06	244	0.02	$X^2 = 55.3$
0.07 - 0.11	213	0.08	
0.12 - 0.19	228	0.17	$p < 0.001$
0.20 - 1.00	241	0.23	

The number of cells available for analysis of juvenile chum distribution totaled 249 after elimination of the cells outlined above. Chum salmon were captured in 98 (39.4%) of these cells. Correlations among the habitat variables and chum fry catch ranged to 0.32 in absolute value (Appendix Table A-8). Partial habitat data were collected at two additional cells.

The chum salmon distribution by velocity interval in 1984 was similar to 1983 (Appendix Figure A-22). Therefore, the suitability criteria for chum salmon developed in 1983 was selected for use in 1984.

In 1983, the relationship of chum salmon use to percent cover and cover type was the weakest of any of the four species. In 1984, the 0-5% cover category and the "no cover" type had the highest proportional presence within their respective distributions (Appendix Figures A-23 and A-24). These data indicate that chum salmon fry do not orient to cover during rearing. Even when velocity suitability was adjusted for, no real trends in percent cover and cover type utilization were noted, although large gravel and rubble were used slightly more than was the "no cover" type. Since there were no trends, cover type and percent cover will not be used in the 1984 analysis of chum habitat use.

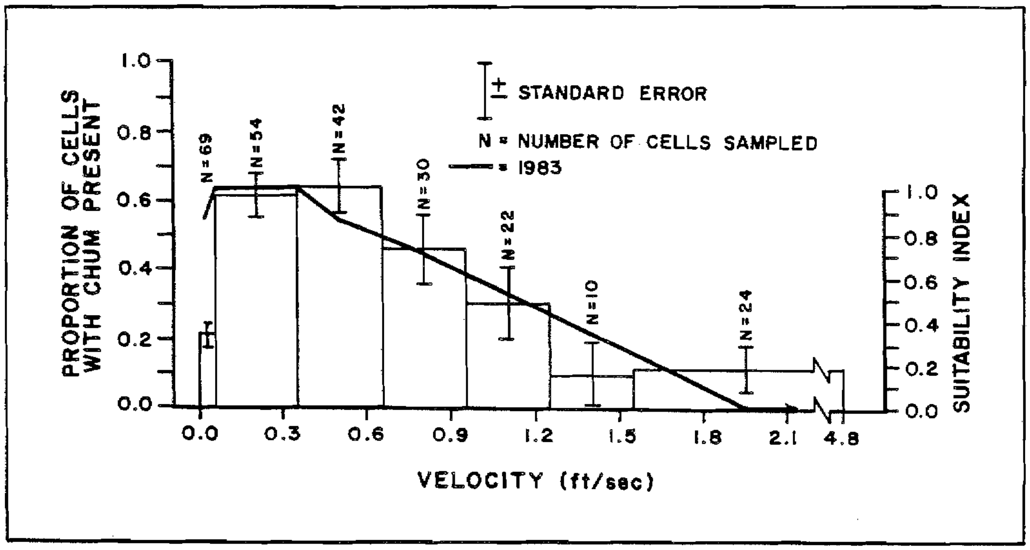
The distribution of chum proportional presence by depth intervals in 1984 was similar to that found in the 1983 studies (Appendix Figure A-25). Since the distributions were similar, the criteria fit in 1983 was used to test for the value of depth in increasing the associations with chum catch. Therefore velocity was first used alone and then with depth to form categories which were associated with chum proportional presence.

Although composite weighting factors calculated by velocity alone and velocity and depth together were both significantly associated with chum proportional presence, the composite weighting factor calculated by depth and velocity together seemed to fit the observed distribution data better (Appendix Table A-9). Therefore both velocity and depth suitability criteria will be used to model chum salmon habitat.

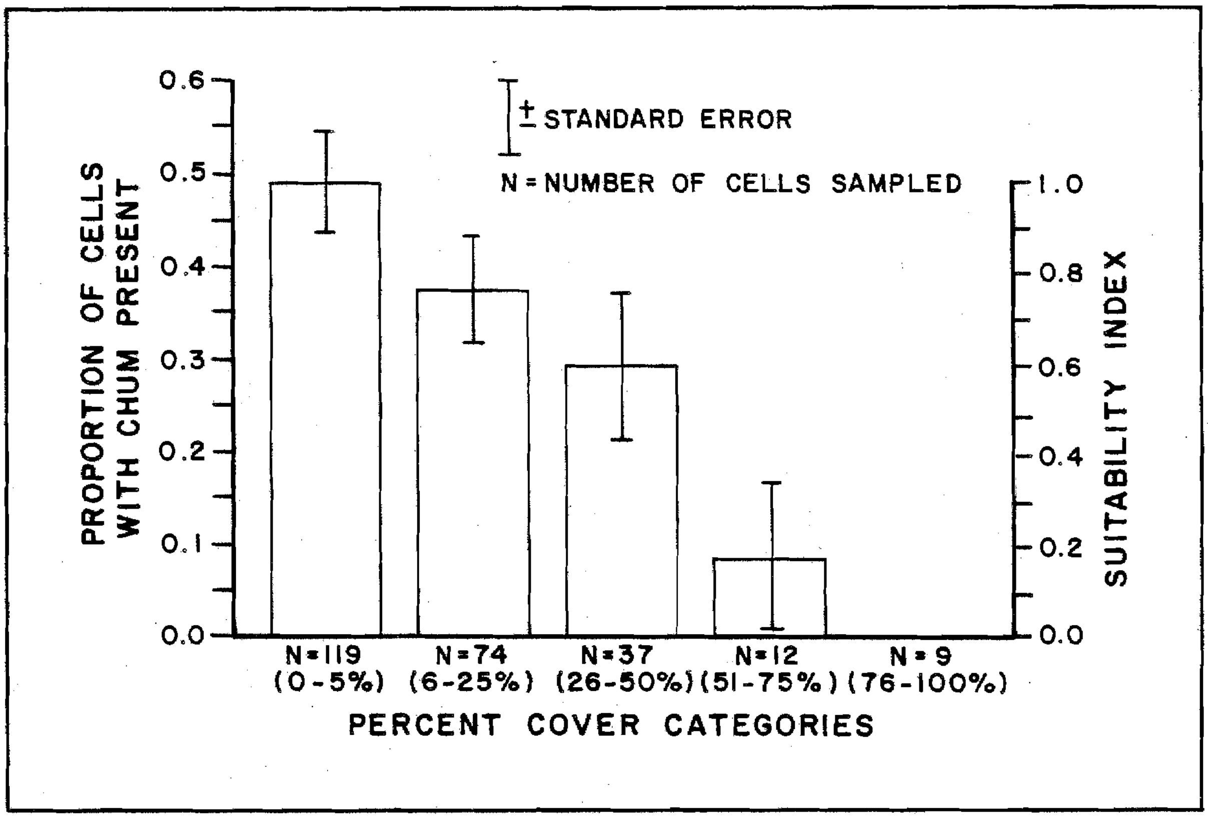
Appendix Table A-8. Kendall correlation coefficients between habitat variables and chum catch by cell (N=249) for all gear types, turbidity below 200 NTU.

	Percent Cover	Cover Type	Velocity	Depth	Chum
Percent Cover	1.00				
Cover Type	0.13**	1.00			
Velocity	-0.25**	0.15**	1.00		
Depth	-0.05	-0.03	0.07	1.00	
Chum	-0.20**	-0.07	-0.04	-0.32**	1.00

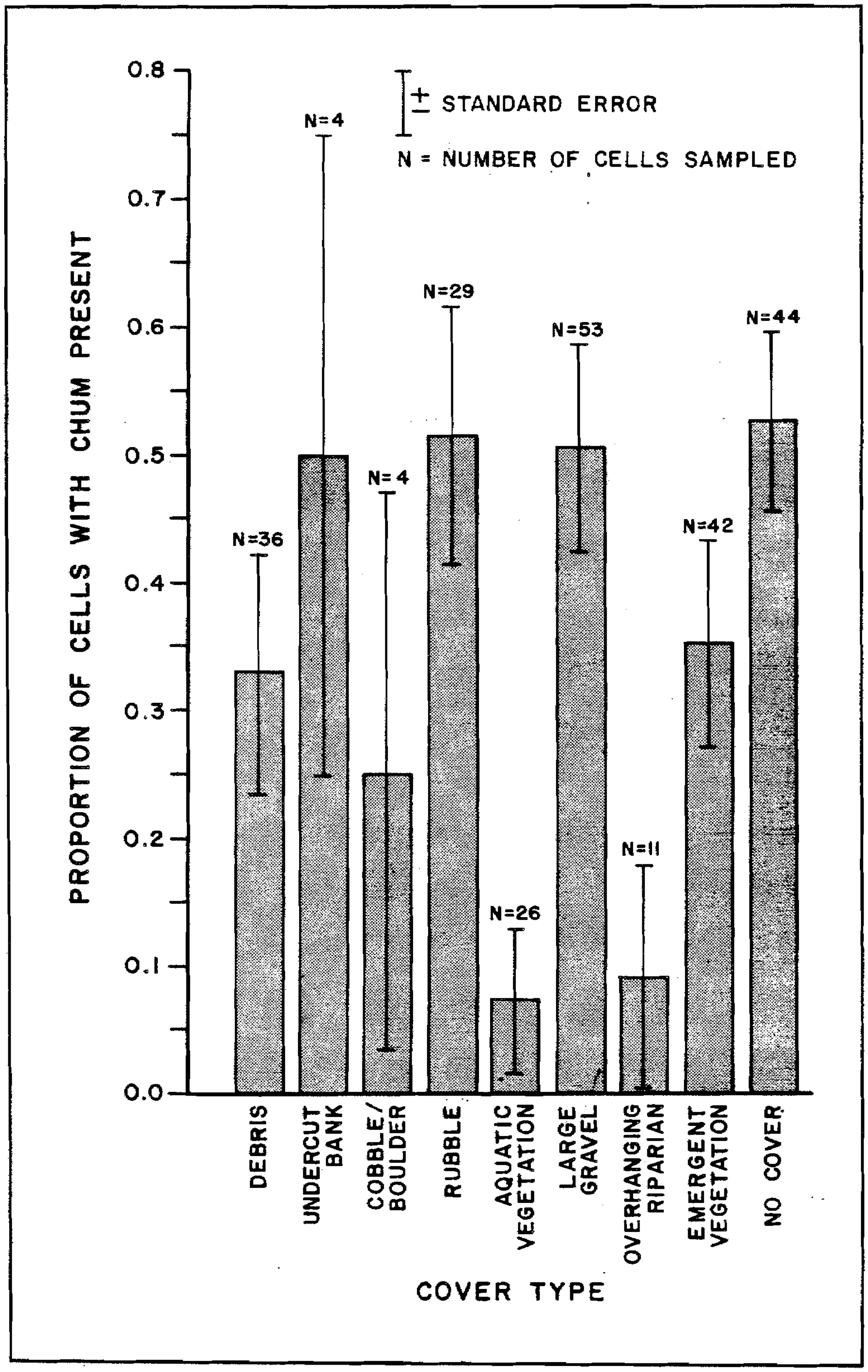
* Significantly different from 0 at $p<0.05$.
** Significantly different from 0 at $p<0.01$.



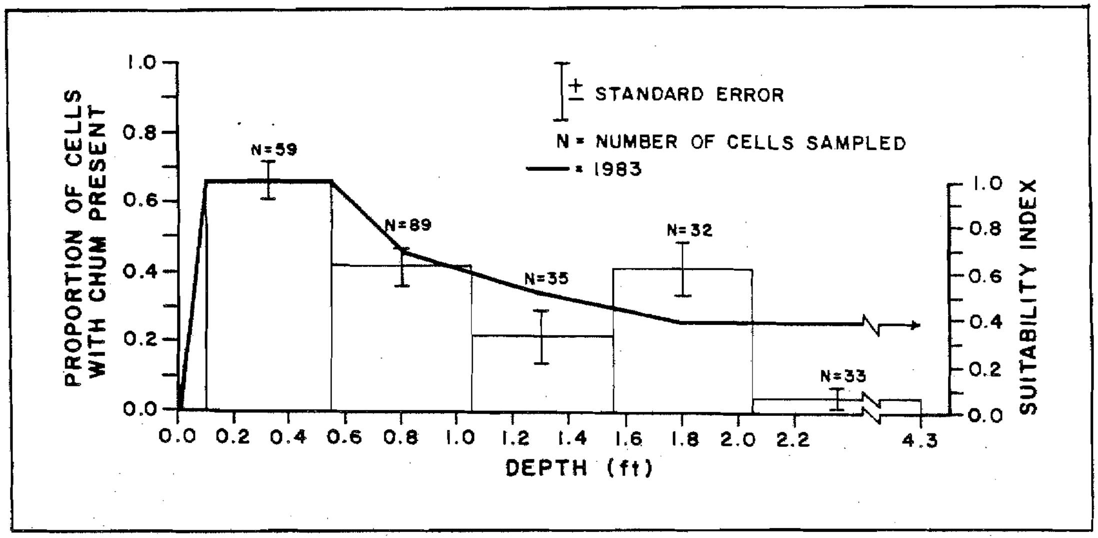
Appendix Figure A-22. Proportion of cells with juvenile chum salmon present by velocity intervals (bars) in the lower Susitna River, 1984 and fitted suitability index (line) developed for the middle Susitna River, 1983.



Appendix Figure A-23. Proportion of cells with juvenile chum salmon present by percent cover category (bars) in the lower Susitna River, 1984 and fitted suitability index (line) calculated for the middle Susitna River, 1983.



Appendix Figure A-24. Proportion of cells with juvenile chum salmon present by cover type (bars) in the lower Susitna River, 1984.



Appendix Figure A-25. Proportion of cells with juvenile chum salmon present by depth intervals (bars) in the lower Susitna River, 1984 and fitted suitability index (line) developed for the middle Susitna River, 1983.

Appendix Table A-9. Proportional presence of chum salmon fry associated with several composite weighting factors.

Composite Weighting Factor Calculation	Composite Weighting Factor Interval	Total Number of Cells	Proportion With Fish Present	Chi-Square
Velocity	0 - 0.55	49	0.20	$\chi^2 = 34.3$
	0.60 - 0.81	51	0.49	$p<0.001$
	0.86	82	0.24	
	0.93 - 1.00	69	0.64	
Velocity*Depth	0 - 0.32	71	0.10	
	0.34 - 0.49	54	0.43	$\chi^2 = 46.8$
	0.50 - 0.73	60	0.42	$p < 0.001$
	0.76 - 1.00	66	0.67	

Summary

A summary table of revisions of the middle river suitability criteria for use in the lower river reveals that about half the criteria were not changed or changed only slightly (Appendix Table A-10). The velocity and percent cover relationships were often not changed while the depth and cover type criteria have often been modified. Point specific values for all the suitability criteria developed for use in the lower river are presented in Appendix Table A-11.

DISCUSSION

Chinook Salmon

The turbid water velocity criteria developed in 1983 were used for both clear and turbid chinook distributions in the lower river in 1984. The reason that there was no shift in velocity optima from clear to turbid water may be due to several factors. In the middle river, substrate is much larger and therefore, juvenile chinooks may find higher velocities because suitable as there is always some substrate cover to hide under or behind. In the lower river, however, very little substrate cover is present and therefore chinook use lower velocity water much more.

In the lower river, cover suitabilities were often somewhat different than in the middle river. Part of this difference may be due to the actual cover in cover type categories being of a different type. For instance, the aquatic vegetation in Caswell Creek, which harbored large numbers of chinook fry, was not present in any of the sampled streams in the middle river. Also the debris cover type in the lower river was often much more silted in than in the middle river and therefore less suitable. The primary cover type is associated with a variety of secondary cover types and it is likely that, on the average, secondary cover types associated with a primary cover type in the lower river are different than the secondary cover types most common in the middle river. If these secondary cover types are more suitable for fish, then they might raise the suitability of the primary cover type.

Most notable in the analysis of chinook suitability criteria was the effect of depth upon the distribution of chinook salmon. In the lower river, chinook salmon found deep, water much more suitable than in the middle river (Appendix Figure A-7). This is probably due to the tributaries in the lower river having a turbidity of approximately 10 to 20 NTU and therefore depth might have a cover value in deeper waters. In the middle river, much of the data were collected in Portage Creek, Indian River, and other areas where the turbidity was usually less than 5 NTU and depth would not provide cover at depths which can be sampled. Sometimes juvenile salmon thought to be chinook fry could be seen feeding on the surface in tributary mouths such as Rolly Creek where depths were greater than 5.0 ft.

In turbid water, on the other hand, depths greater than 1.5 ft were less suitable than shallower cells (Appendix Figure A-11). This trend was

Appendix Table A-10. Summary of revisions of 1983 middle river juvenile salmon criteria for use in the lower Susitna River, 1984.

Species	Velocity	Percent Cover	Cover Type	Depth
Chinook (clear)	Turbid chinook criteria developed in 1983 used	Same as 1983	Modified	Modified
Chinook (turbid)	Same as 1983	Same as 1983	Modified	Modified
Coho	Same as 1983	Same as 1983	Modified	Same as 1983
Sockeye	Modified Slightly	Same as 1983	Modified Slightly	Modified Slightly
Chum	Same as 1983	Modified (Set to 1.0)	Modified (Set to 1.0)	Modified

Appendix Table A-11. Suitability indices for juvenile salmon for velocity, depth, and cover in the lower Susitna River, 1984.

VELOCITY

Chinook		Coho		Sockeye		Chum	
Velocity (ft/sec)	Suita-bility	Velocity (ft/sec)	Suita-bility	Velocity (ft/sec)	Suita-bility	Velocity (ft/sec)	Suita-bility
0.00	0.42	0.00	0.29	0.00	1.00	0.00	0.86
0.05	1.00	0.05	1.00	0.05	1.00	0.05	1.00
0.35	1.00	0.35	1.00	0.20	0.71	0.35	1.00
0.50	0.80	0.50	0.88	0.50	0.48	0.50	0.87
0.80	0.38	0.80	0.55	0.80	0.35	0.80	0.70
1.10	0.25	1.10	0.32	1.10	0.14	1.10	0.56
1.40	0.15	1.40	0.12	1.30	0.00	1.40	0.37
1.70	0.07	1.70	0.04			1.70	0.15
2.00	0.02	2.00	0.01			2.00	0.03
2.30	0.01	2.10	0.00			2.10	0.00
2.60	0.00						

DEPTH

Chinook (turbid)		Chinook (clear)		Coho		Sockeye		Chum	
Depth (ft)	Suita-bility	Depth (ft)	Suita-bility	Depth (ft)	Suita-bility	Depth (ft)	Suita-bility	Depth (ft)	Suita-bility
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.10	0.29	0.15	0.00	0.14	0.00	0.10	1.00	0.10	1.00
0.30	1.00	0.20	0.25	0.15	1.00	10.00	1.00	0.50	1.00
1.50	1.00	1.50	0.25	10.00	1.00			0.80	0.68
1.80	0.33	1.80	0.80					1.30	0.50
10.00	0.33	2.10	1.00					1.80	0.38
		10.00	1.00					10.00	0.38

Appendix Table A-11 (Continued)

Cover Type	Percent Cover	Chinook (turbid)	Chinook (clear)	Coho	Sockeye	Chum
No cover	0-5%	0.15	0.01	0.00	0.18	1.00
Emergent Vegetation	0-5%	0.23	0.11	0.05	0.39	1.00
	6-25%	0.30	0.33	0.14	0.54	1.00
	26-50%	0.33	0.55	0.24	0.70	1.00
	51-75%	0.39	0.78	0.33	0.85	1.00
	76-100%	0.40	1.00	0.42	1.00	1.00
Aquatic Vegetation	0-5%	0.23	0.10	0.04	0.23	1.00
	6-25%	0.30	0.32	0.13	0.32	1.00
	26-50%	0.33	0.53	0.21	0.41	1.00
	51-75%	0.39	0.76	0.30	0.50	1.00
	76-100%	0.40	0.97	0.38	0.59	1.00
Debris or Deadfall	0-5%	0.15	0.05	0.08	0.21	1.00
	6-25%	0.20	0.17	0.24	0.29	1.00
	26-50%	0.20	0.28	0.39	0.37	1.00
	51-75%	0.20	0.39	0.55	0.45	1.00
	76-100%	0.20	0.50	0.70	0.53	1.00
Overhanging Riparian Vegetation	0-5%	0.15	0.04	0.07	0.25	1.00
	6-25%	0.20	0.13	0.20	0.34	1.00
	26-50%	0.20	0.21	0.33	0.44	1.00
	51-75%	0.20	0.30	0.46	0.54	1.00
	76-100%	0.20	0.38	0.59	0.63	1.00
Undercut Banks	0-5%	0.23	0.11	0.12	0.25	1.00
	6-25%	0.30	0.33	0.34	0.34	1.00
	26-50%	0.33	0.55	0.56	0.44	1.00
	51-75%	0.39	0.78	0.78	0.54	1.00
	76-100%	0.40	1.00	1.00	0.63	1.00

Appendix Table A-11 (Continued)

Cover Type	Percent Cover	Chinook (turbid)	Chinook (clear)	Coho	Sockeye	Chum
Large Gravel (1-3")	0-5%	0.15	0.02	0.02	0.18	1.00
	6-25%	0.20	0.08	0.06	0.24	1.00
	26-50%	0.20	0.13	0.10	0.32	1.00
	51-75%	0.20	0.18	0.14	0.38	1.00
	76-100%	0.20	0.23	0.18	0.45	1.00
Rubble (3-5")	0-5%	0.15	0.03	0.02	0.18	1.00
	6-25%	0.20	0.10	0.06	0.24	1.00
	26-50%	0.20	0.17	0.10	0.32	1.00
	51-75%	0.20	0.23	0.14	0.38	1.00
	76-100%	0.20	0.30	0.18	0.45	1.00
Cobble or Boulder (> 5")	0-5%	0.15	0.03	0.02	0.18	1.00
	6-25%	0.20	0.11	0.06	0.24	1.00
	26-50%	0.20	0.18	0.10	0.32	1.00
	51-75%	0.20	0.25	0.14	0.38	1.00
	76-100%	0.20	0.32	0.18	0.45	1.00

also found in 1983 although discounted at the time. This difference may be due to fish reacting to high suspended solid concentrations by staying near the surface (Wallen 1951 as cited in Beauchamp et al. 1983). It also could be due to fish not being able to feed at depths where there is very little light, whereas in shallower water a greater amount of light may enable fish to feed.

Coho Salmon

The suitability criteria developed for coho salmon juveniles in the middle river were modified only slightly in cover suitability for use in the lower reach. The fit of the data to the composite weighting factor was not very high (r=0.32) however, which suggests that coho respond to other factors than those studied. These factors include food supply or seasonal movements.

Sockeye Salmon

Since sockeye normally rear in lakes (Morrow 1980), it is not surprising that velocity is one of the most important variables affecting their distribution. In both the lower and middle Susitna river, no sockeye were captured in cells with velocities greater than 1.2 ft/sec. The highest catches of sockeye in the lower river were made at Beaver Dam Slough, which is a backwater site with minimal velocity.

Instream cover also has an effect on juvenile sockeye salmon distribution and it appears they use turbidity as cover (Section 3.2.4). In lakes which are turbid due to glacial input, however, production of sockeye smolts on an area basis is much smaller than that of clear lakes (Lloyd 1985). Deep water in the clear lakes would provide cover while in the Susitna, depths of 10 feet or more are infrequently found, and therefore turbidity would be used as cover. Cover type suitabilities were somewhat different in the lower reach than in the middle reach, perhaps due to differences in the primary or secondary cover type within the categories between the two reaches.

Chum Salmon

Chum salmon, in contrast to the other species, did not show any positive response to the presence of cover. The response shown, which is a negative one, is probably partly a function of gear efficiency. They did respond to velocity and depth, however. The lack of relationship with cover may partly be a function of schooling behavior which reduces the need for cover. It is also possible that since chum fry rear in fresh water for only a short period, they usually are searching for food instead of hiding in cover.

The reason for the heavier use of shallower depths by chum juveniles found in both years not known. It could be due to a use of shallow depths and low velocities in side channels where some of the suspended solids may settle out. Perhaps these areas also are somewhat warmer than adjacent areas because the sunlight strikes the substrate and is absorbed heating the water above.

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APPENDIX B

MODELLED SITE TURBIDITIES, JUVENILE SALMON CATCHES, AREAS, SIDE CHANNEL FLOWS, WEIGHTED USABLE AREAS, AND HABITAT INDICES

This appendix is a compilation of data arranged into a number of graphs and tables. The first three tables (Appendix Tables B-1, B-2, and B-3) present: modelled side channel turbidities; modelled site catches and CPUE's of juvenile salmon; and lengths of RJHAB model sites; respectively. Appendix Table B-4 presents modelled side channel flows as a function of mainstem discharge at 3,000 cfs increments.

Next weighted usable areas and habitat indices are presented by species in the following order:

Chinook Salmon

Tabulation of weighted usable areas and habitat indices for 18 sites (Appendix Table B-5).

Graphs of weighted usable area versus mainstem discharge for sites not presented in Section 3.3:

Caswell Creek Mouth	(Appendix Figure B-1)
Beaver Dam Slough	(Appendix Figure B-1)
Hooligan Side Channel	(Appendix Figure B-2)
Bearbait Side Channel	(Appendix Figure B-2)
Last Chance Side Channel	(Appendix Figure B-3)
Rustic Wilderness Side Channel	(Appendix Figure B-3)
Island Side Channel	(Appendix Figure B-4)
Mainstem West Bank	(Appendix Figure B-4)
Goose 2 Side Channel	(Appendix Figure B-5)
Circular Side Channel	(Appendix Figure B-5)
Sauna Side Channel	(Appendix Figure B-6)
Bearbait Side Channel	(Appendix Figure B-6)
Sunset Side Channel	(Appendix Figure B-7)
Sunrise Side Channel	(Appendix Figure B-7)
Trapper Creek Side Channel	(Appendix Figure B-8)

Coho Salmon

Tabulation of weighted usable areas and habitat indices for three sites (Appendix Table B-6).

Chum Salmon

Tabulation of weighted usable areas and habitat indices for 15 sites (Appendix Table B-7).

Graphs of weighted usable area versus mainstem discharge for sites not presented in Section 3.3:

Hooligan Side Channel	(Appendix Figure B-9)
Kroto Slough Head	(Appendix Figure B-9)
Bearbait Side Channel	(Appendix Figure B-10)
Island Side Channel	(Appendix Figure B-10)
Mainstem West Bank	(Appendix Figure B-11)
Goose 2 Side Channel	(Appendix Figure B-11)
Circular Side Channel	(Appendix Figure B-12)
Sauna Side Channel	(Appendix Figure B-12)
Sucker Side Channel	(Appendix Figure B-13)
Beaver Dam Side Channel	(Appendix Figure B-13)
Sunrise Side Channel	(Appendix Figure B-14)

Sockeye Salmon

Tabulation of weighted usable areas and habitat indices for seven sites (Appendix Table B-8).

Graphs of weighted usable area versus mainstem discharge for sites not presented in Section 3.3:

Caswell Creek Mouth	(Appendix Figure B-15)
Beaver Dam Slough	(Appendix Figure B-15)
Sunrise Side Channel	(Appendix Figure B-16)

Appendix Table B-1. Turbidities within modelled side channels of the lower Susitna River, June through August, 1984. Values within parentheses were calculated by inputting the overall mean for all the side channels during a given two week period.

Site	June 1-15	June 16-30	July 1-15	July 16-30	Aug 1-15	Aug 16-30[1]	Mean
West Bank Lateral Side Channels							
Kroto Side Channel	(64)	394	(369)	272,704	784	126	388
Bear Bait Side Channel	(64)	392	284	312	328	142	254
Mainstem West Bank	(64)	(227)	(369)	368	324	324	279
Sauna Side Channel	120	(227)	496	364	244	156,256	266
Trapper Side Channel	96	576	940	470	306	608	499
Middle Side Channels							
Hooligan Side Channel	(64)	365	288	296	704	544	377
Last Chance Side Channel	(64)	(227)	296	672	352	576	365
Island Side Channel	55	126	334	336	228	(209)	215
Circular Side Channel	89	122	592	288	216	78,304	241
Sucker Side Channel	26	64	276	118	292	44,163	140
Sunrise Side Channel	18	112	180	88	280	44,124	121
East Bank Lateral Side Channels							
Rustic Wilderness Side Channel	(64)	120	130	160	196	38	118
Goose Side Channel	41	140	384	300	188	64,244	194
Sunset Side Channel	(64)	(227)	(369)	114	100	41,146	152
Beaver Dam Side Channel	(64)	90	224	134	170	150	139
OVERALL MEAN	64	227	369	312	314	209	

[1] Two turbidities are given in this column for six sites because there were two sampling trips during this two week period in the Sunshine area. Turbidities were dropping rapidly in late August and so turbidities taken on the first late August trip were much higher than those taken during the second trip in late August.

Appendix Table B-2. Catch and catch per cell (CPUE) of juvenile salmon within lower Susitna River sampling sites, 1984. Cells have been standardized to an area of 300 ft^2.

Site	No. of cells sampled	Chinook catch	Coho catch	Chum catch	Sockeye catch	Chinook CPUE	Coho CPUE	Chum CPUE	Sockeye CPUE
Hooligan Side Channel	77	21	0	78	3	0.27	0.00	1.01	0.04
Eagles Nest Side Channel	30	5	0	0	0	0.17	0.00	0.00	0.00
Kroto Slough Head	56.5	4	0	1	2	0.07	0.00	0.02	0.04
Rolly Creek Mouth	91	53	39	2	87	0.58	0.43	0.02	0.96
Bearbait Side Channel	49.4	4	0	3	0	0.08	0.00	0.06	0.00
Last Chance Side Channel	50	0	0	1	0	0.00	0.00	0.02	0.00
Rustic Wilderness Side Channel	65	55	1	11	0	0.85	0.02	0.17	0.00
Caswell Creek Mouth	74	419	245	0	21	5.66	3.31	0.00	0.28
Island Side Channel	82	39	1	74	2	0.48	0.01	0.90	0.02
Mainstem West Bank	45	7	0	0	1	0.16	0.00	0.00	0.02
Goose 2 Side Channel	82	74	1	30	2	0.90	0.01	0.37	0.02
Circular Side Channel	88	28	0	114	6	0.32	0.00	1.30	0.07
Sauna Side Channel	44	3	0	41	5	0.07	0.00	0.93	0.11
Sucker Side Channel	77.1	23	0	112	15	0.30	0.00	1.45	0.19
Beaver Dam Slough	83	14	67	0	101	0.17	0.81	0.00	1.22
Beaver Dam Side Channel	102	153	9	23	71	1.50	0.09	0.23	0.70
Sunset Side Channel	73.5	121	0	0	12	1.65	0.00	0.00	0.16
Sunrise Side Channel	73	120	1	43	8	1.64	0.01	0.59	0.11
Birch Creek Slough	96	23	71	45	29	0.24	0.74	0.47	0.30
Trapper Creek Side Channel	96	43	2	20	4	0.45	0.02	0.21	0.04
SUBTOTAL	1434.5	1209	437	598	369	0.84	0.30	0.42	0.26
Opportunistic sites	163.7	249	5	10	43	1.52	0.03	0.06	0.26
TOTAL	1598.2	1458	442	608	412	0.91	0.28	0.38	0.26

Appendix Table B-3. Lengths of RJHAB model sites in the lower Susitna River, 1984.

Site	Length (feet)
Hooligan Side Channel	1377
Eagle's Nest Side Channel	490
Kroto Slough Head	748
Rolly Creek Mouth	1437
Bearbait Side Channel	496
Last Chance Side Channel	961
Rustic Wilderness Side Channel	1169
Caswell Creek Mouth	712
Island Side Channel	769
Goose 2 Side Channel	1030
Sucker Side Channel	658
Beaver Dam Slough	436
Beaver Dam Side Channel	608
Sunrise Side Channel	1003
Birch Creek Slough	841
Trapper Creek Side Channel	968

Appendix Table B-4. Side channel flows at the 15 modelled side channels in the lower Susitna River as a function of mainstem discharge, 1984. Flows calculated from rating curves presented in Quane et al. (1985).

	HOOLIGAN S. C.		KROTO SLOUGH HEAD		BEARBAIT SIDE CHANNEL		LAST CHANCE S. C.		RUSTIC WILDERNESS S. C.	
MAINSTEM DISCHARGE	SITE AREA	FLOW	SITE AREA	FLOW	SITE AREA	FLOW	SITE AREA	FLOW	SITE AREA	FLOW
12000	63400	0	48200	0	3100	0	17500	0	4800	0
15000	63400	0	48200	0	3100	0	17500	0	4800	0
18000	63400	0	48200	0	3100	0	17500	0	4800	0
21000	63400	0	48200	0	3100	0	17500	0	31900	54
24000	79800	50	48200	0	3100	0	20000	1	49500	76
27000	86900	72	48200	0	3100	0	22000	3	60700	103
30000	90800	100	48200	0	3100	0	27000	5	69700	134
33000	96500	135	48200	0	3100	0	34000	8	76800	171
36000	104800	178	50000	<5 a	5700	33	46500	13	83300	213
39000	113700	229	67900	74	10800	48	70000	21	89900	261
42000	122900	288	77500	98	14600	67	81000	31	97000	315
45000	131300	358	86800	128	17900	93	91000	46	104000	375
48000	141200	439	95100	163	21100	125	94000	67	109000	442
51000	152000	531	102200	206	23800	166	96300	95	114000	516
54000	163000	636	106700	255	26400	217	98500	131	117400	596
57000	174100	753	110200	314	29000	279	100200	178	119200	684
60000	186800	885	113500	381	31500	354	101800	238	120700	779
63000	200800	1032	116600	459	33900	445	103200	314	121700	b
66000	213300	1194	119000	547	36300	552	104400	408	122200	b
69000	226000	1373	120100	648	38300	b	105500	526	122700	b
72000	239000	1570	121000	761	40000	b	106300	669	123000	b
75000	250900	1785	121400	889	41500	b	107000	844	123500	b

a = Flow estimated
b = Rating curve not available
c = IFIM model rated unacceptable at this site flow
d = Modelled at flow of 6 cfs for IFIM
e = Modelled at flow of 5 cfs for IFIM
f = These flows are approximate because they are heavily influenced by Cache Creek flow

Appendix Table B-4. Continued.

MAINSTEM DISCHARGE	ISLAND SIDE CHANNEL SITE AREA	ISLAND SIDE CHANNEL FLOW	MAINSTEM WEST BANK SITE AREA	MAINSTEM WEST BANK FLOW	GOOSE 2 SIDE CHANNEL SITE AREA	GOOSE 2 SIDE CHANNEL FLOW	CIRCULAR SIDE CHANNEL SITE AREA	CIRCULAR SIDE CHANNEL FLOW	SAUNA SIDE CHANNEL SITE AREA	SAUNA SIDE CHANNEL FLOW
12000	31500	<1 d	61603	<1 d	0	0	59464	<1 d	42093	<1 e
15000	31500	<1 d	61603	<1 d	0	0	59464	<1 d	42093	<1 e
18000	31500	<1 d	61603	<1 d	0	0	59464	<1 d	42093	<1 e
21000	31500	<1 d	73426	19	0	0	59464	<1 d	42093	<1 e
24000	31500	<1 d	80904	53	0	0	59464	<1 d	42093	<1 e
27000	31500	<1 d	93353	134	0	0	59464	<1 d	42093	<1 e
30000	31500	<1 d	108613	307	9600	<5 a	59464	<1 d	42093	<1 e
33000	31500	<1 d	114738	470	21500	24	59464	<1 d	42093	<1 e
36000	39200	69	117696	559	34300	32	71590	27	42093	<1 e
39000	45300	94	120505	657	47800	41	76534	38	49127	21 c
42000	51000	126	123397	762	61400	52	80557	54	49758	25 c
45000	58500	166	129211	874	72000	65	85140	73	50289	29
48000	65500	215	133649	995	81400	81	92944	98	50889	34
51000	72000	273	136885	1123 c	87800	98	102530	129	51451	39
54000	79400	342	140761	1260 c	93200	118	113323	167	52011	44
57000	86700	424	144269	1404 c	97100	141	125753	213	52676	50
60000	93100	520	147899	1555 c	99900	166	134218	268	53294	56
63000	99800	631	151842	1715 c	102000	195	143575	334	54275	63
66000	106200	758	154205	1882 c	103200	226	150869	412 c	55184	70 c
69000	111900	904	156425	2057 c	104200	261	154657	503 c	56053	77 c
72000	118200	1070 c	158522	2241 c	104800	300	157074	610 c	57142	85 c
75000	123300	1256 c	160818	2431 c	105100	342	159211	733 c	61018	93 c

a = Flow estimated
b = Rating curve not available
c = IFIM model rated unacceptable at this site flow
d = Modelled at flow of 6 cfs for IFIM
e = Modelled at flow of 5 cfs for IFIM
f = These flows are approximate because they are heavily influenced by Cache Creek flow

Appendix Table B-4. Continued.

MAINSTEM DISCHARGE	SUCKER SIDE CHANNEL SITE AREA	SUCKER SIDE CHANNEL FLOW	BEAVER DAM SIDE CHANNEL SITE AREA	BEAVER DAM SIDE CHANNEL FLOW	SUNSET SIDE CHANNEL SITE AREA	SUNSET SIDE CHANNEL FLOW	SUNRISE SIDE CHANNEL SITE AREA	SUNRISE SIDE CHANNEL FLOW	TRAPPER CREEK S. C. SITE AREA	TRAPPER CREEK S. C. FLOW
12000	0	0	18900	<1	49562	1 e	0	0	73300	9 f
15000	0	0	18900	<1	49562	1 e	0	0	73300	12 f
18000	0	0	18900	<1	49562	1 e	0	0	73300	14 f
21000	0	0	18900	<1	49562	1 e	0	0	73300	16 f
24000	0	0	18900	<1	49562	1 e	0	0	73300	18 f
27000	0	0	18900	<1	49562	1 e	0	0	73300	20 f
30000	8500	13	18900	<1	49562	1 e	0	0	73300	22 f
33000	14900	18	18900	<1	78488	47	0	0	73300	24 f
36000	16900	24	18900	<1	89472	68	19000	19	73300	26 f
39000	19400	31	18900	<1	97943	96	53900	29	73300	28 f
42000	23600	39	18900	<1	106320	132	78500	41	73300	30 f
45000	29600	48	18900	<1	122338	178	97100	58	77600	39
48000	37100	59	22400	7	135476	235	115400	79	91200	72
51000	46600	71	28000	11	149248	305	131100	106	108100	129
54000	57900	86	32600	18	165990	390	146900	139	123300	221
57000	66900	101	35700	29	173483	492	160600	181	137700	370
60000	71300	119	38000	45	188419	614	175600	233	151200	564
63000	73900	139	39600	68	194419	757	192000	295	158000	683
66000	75900	161	40800	101	203000	925	207300	370	163100	819
69000	77300	185	41500	148	206972	1119 c	221400	459	166900	975 c
72000	76100	211	41900	213	210728	1345 c	229000	564	170700	1151 c
75000	78300	240	42100	302	215861	1603 c	233300	688	173500	1351 c

a = Flow estimated
b = Rating curve not available
c = IFIM model rated unacceptable at this site flow
d = Modelled at flow of 6 cfs for IFIM
e = Modelled at flow of 5 cfs for IFIM
f = These flows are approximate because they are heavily influenced by Cache Creek flow

Appendix Table B-5. Weighted usable areas and habitat indices for juvenile chinook salmon in lower Susitna River model sites, 1984.

ROLLY CREEK MOUTH

MAINSTEM DISCHARGE	SITE AREA	CHINOOK WUA	CHINOOK H. I.
12000	84900	3900	0.05
15000	84900	3900	0.05
18000	84900	3900	0.05
21000	84900	3900	0.05
24000	85300	3900	0.05
27000	88300	3900	0.04
30000	93200	3900	0.04
33000	99800	4100	0.04
36000	108900	4200	0.04
39000	121000	4300	0.04
42000	135000	4400	0.03
45000	152600	4500	0.03
48000	178500	7300	0.04
51000	198800	14100	0.07
54000	213000	20100	0.09
57000	223200	23400	0.10
60000	229800	25800	0.11
63000	235000	28000	0.12
66000	238700	30000	0.13
69000	241600	31500	0.13
72000	243200	32800	0.13
75000	243600	33500	0.14

CASWELL CREEK MOUTH

MAINSTEM DISCHARGE	SITE AREA	CHINOOK WUA	CHINOOK H. I.
12000	16200	800	0.05
15000	16200	800	0.05
18000	16200	800	0.05
21000	16200	800	0.05
24000	16200	800	0.05
27000	16300	800	0.05
30000	16700	1100	0.07
33000	17300	1600	0.09
36000	18000	2200	0.12
39000	18900	2700	0.14
42000	19800	3200	0.16
45000	21000	3700	0.18
48000	21800	4200	0.19
51000	22700	4700	0.21
54000	23700	5200	0.22
57000	24600	5700	0.23
60000	25500	6200	0.24
63000	26300	6700	0.25
66000	27200	7200	0.26
69000	27900	7600	0.27
72000	28900	8000	0.28
75000	29700	8400	0.28

BEAVER DAM SLOUGH

MAINSTEM DISCHARGE	SITE AREA	CHINOOK WUA	CHINOOK H. I.
12000	11600	1300	0.11
15000	11600	1300	0.11
18000	11600	1300	0.11
21000	11700	1300	0.11
24000	11900	1300	0.11
27000	12200	1300	0.11
30000	12500	1300	0.10
33000	13000	1300	0.10
36000	13400	1300	0.10
39000	13900	1400	0.10
42000	14400	1500	0.10
45000	15000	1800	0.12
48000	15700	2100	0.13
51000	16300	2600	0.16
54000	16800	3000	0.18
57000	17600	3700	0.21
60000	18500	4200	0.23
63000	19700	4600	0.23
66000	20800	4800	0.23
69000	21600	5000	0.23
72000	22100	5100	0.23
75000	22600	5200	0.23

HOOLIGAN SIDE CHANNEL

MAINSTEM DISCHARGE	SITE AREA	CHINOOK WUA	CHINOOK H. I.
12000	63400	500	0.01
15000	63400	500	0.01
18000	63400	500	0.01
21000	63400	500	0.01
24000	79800	7600	0.10
27000	86900	7200	0.08
30000	90800	6700	0.07
33000	96500	6100	0.06
36000	104800	5500	0.05
39000	113700	4900	0.04
42000	122900	4200	0.03
45000	131300	3600	0.03
48000	141200	2900	0.02
51000	152000	2200	0.01
54000	163000	2000	0.01
57000	174100	2000	0.01
60000	186800	1900	0.01
63000	200800	1800	0.01
66000	213300	1800	0.01
69000	226000	1800	0.01
72000	239000	1800	0.01
75000	250900	1800	0.01

KROTO SLOUGH HEAD

MAINSTEM DISCHARGE	SITE AREA	CHINOOK WUA	CHINOOK H. I.
12000	48200	100	.00
15000	48200	100	.00
18000	48200	100	.00
21000	48200	100	.00
24000	48200	100	.00
27000	48200	100	.00
30000	48200	100	.00
33000	48200	100	.00
36000	50000	2000	0.04
39000	67900	4800	0.07
42000	77500	6200	0.08
45000	86800	7300	0.08
48000	95100	8100	0.09
51000	102200	7900	0.08
54000	106700	6900	0.06
57000	110200	6000	0.05
60000	113500	5100	0.04
63000	116600	4300	0.04
66000	119000	3400	0.03
69000	120100	2900	0.02
72000	121000	2500	0.02
75000	121400	2200	0.02

BEARBAIT SIDE CHANNEL

MAINSTEM DISCHARGE	SITE AREA	CHINOOK WUA	CHINOOK H. I.
12000	3100	20	0.01
15000	3100	20	0.01
18000	3100	20	0.01
21000	3100	20	0.01
24000	3100	20	0.01
27000	3100	20	0.01
30000	3100	20	0.01
33000	3100	20	0.01
36000	5700	200	0.04
39000	10800	350	0.03
42000	14600	530	0.04
45000	17900	650	0.04
48000	21100	720	0.03
51000	23800	790	0.03
54000	26400	800	0.03
57000	29000	750	0.03
60000	31500	700	0.02
63000	33900	650	0.02
66000	36300	610	0.02
69000	38300	590	0.02
72000	40000	570	0.01
75000	41500	560	0.01

Appendix Table B-5. Continued.

LAST CHANCE S. C.

MAINSTEM DISCHARGE	SITE AREA	CHINOOK WUA	CHINOOK H. I.
12000	17500	110	0.01
15000	17500	110	0.01
18000	17500	110	0.01
21000	17500	110	0.01
24000	20000	1200	0.06
27000	22000	1320	0.06
30000	27000	1370	0.05
33000	34000	1400	0.04
36000	46500	1420	0.03
39000	70000	1440	0.02
42000	81000	1470	0.02
45000	91000	1500	0.02
48000	94000	1610	0.02
51000	96300	2050	0.02
54000	98500	2560	0.03
57000	100200	2620	0.03
60000	101800	2540	0.02
63000	103200	2460	0.02
66000	104400	2350	0.02
69000	105500	2240	0.02
72000	106300	2100	0.02
75000	107000	1900	0.02

RUSTIC WILDERNESS S. C.

MAINSTEM DISCHARGE	SITE AREA	CHINOOK WUA	CHINOOK H. I.
12000	4800	30	0.01
15000	4800	30	0.01
18000	4800	30	0.01
21000	31900	4800	0.15
24000	49500	5100	0.10
27000	60700	4300	0.07
30000	69700	3700	0.05
33000	76800	3000	0.04
36000	83300	2400	0.03
39000	89900	1900	0.02
42000	97000	1500	0.02
45000	104000	1200	0.01
48000	109000	900	0.01
51000	114000	700	0.01
54000	117400	500	.00
57000	119200	500	.00
60000	120700	600	.00
63000	121700	600	.00
66000	122200	600	.00
69000	122700	700	0.01
72000	123000	700	0.01
75000	123500	800	0.01

ISLAND SIDE CHANNEL

MAINSTEM DISCHARGE	SITE AREA	CHINOOK WUA	CHINOOK H. I.
12000	31500	400	0.01
15000	31500	400	0.01
18000	31500	400	0.01
21000	31500	400	0.01
24000	31500	400	0.01
27000	31500	400	0.01
30000	31500	400	0.01
33000	31500	400	0.01
36000	39200	3500	0.09
39000	45300	4800	0.11
42000	51000	4100	0.08
45000	58500	3400	0.06
48000	65500	2900	0.04
51000	72000	2400	0.03
54000	79400	2100	0.03
57000	86700	1800	0.02
60000	93100	1700	0.02
63000	99800	1800	0.02
66000	106200	2100	0.02
69000	111900	2400	0.02
72000	118200	2600	0.02
75000	123300	2700	0.02

MAINSTEM WEST BANK

MAINSTEM DISCHARGE	SITE AREA	CHINOOK WUA	CHINOOK H. I.
12000	61603	1082	0.02
15000	61603	1082	0.02
18000	61603	1082	0.02
21000	73426	10041	0.14
24000	80904	8325	0.10
27000	93353	5224	0.06
30000	108613	4045	0.04
33000	114738	3959	0.03
36000	117696	3861	0.03
39000	120505	3775	0.03
42000	123397	3855	0.03
45000	129211	4113	0.03
48000	133649	4630	0.03
51000	136885	5080	0.04
54000	140761	5554	0.04
57000	144269	6217	0.04
60000	147899	6728	0.05
63000	151842	7092	0.05
66000	154205	7598	0.05
69000	156425	7913	0.05
72000	158522	8078	0.05
75000	160818	8438	0.05

GOOSE 2 SIDE CHANNEL

MAINSTEM DISCHARGE	SITE AREA	CHINOOK WUA	CHINOOK H. I.
12000	0	0	0.00
15000	0	0	0.00
18000	0	0	0.00
21000	0	0	0.00
24000	0	0	0.00
27000	0	0	0.00
30000	9600	1500	0.16
33000	21500	2900	0.13
36000	34300	4000	0.12
39000	47800	5100	0.11
42000	61400	6100	0.10
45000	72000	6900	0.10
48000	81400	7000	0.09
51000	87800	6700	0.08
54000	93200	6000	0.06
57000	97100	4600	0.05
60000	99900	3100	0.03
63000	102000	2700	0.03
66000	103200	2400	0.02
69000	104200	2100	0.02
72000	104800	1800	0.02
75000	105100	1600	0.02

CIRCULAR SIDE CHANNEL

MAINSTEM DISCHARGE	SITE AREA	CHINOOK WUA	CHINOOK H. I.
12000	59464	747	0.01
15000	59464	747	0.01
18000	59464	747	0.01
21000	59464	747	0.01
24000	59464	747	0.01
27000	59464	747	0.01
30000	59464	747	0.01
33000	59464	747	0.01
36000	71590	8717	0.12
39000	76534	8404	0.11
42000	80557	8013	0.10
45000	85140	7472	0.09
48000	92944	7077	0.08
51000	102530	6998	0.07
54000	113323	6999	0.06
57000	125753	6634	0.05
60000	134218	6516	0.05
63000	143575	6906	0.05
66000	150869	7926	0.05
69000	154657	8561	0.06
72000	157074	8840	0.06
75000	159211	8854	0.06

Appendix Table B-5. Continued.

SAUNA SIDE CHANNEL

MAINSTEM DISCHARGE	SITE AREA	CHINOOK WUA	CHINOOK H. I.
12000	42093	165	.00
15000	42093	165	.00
18000	42093	165	.00
21000	42093	165	.00
24000	42093	165	.00
27000	42093	165	.00
30000	42093	165	.00
33000	42093	165	.00
36000	42093	165	.00
39000	49127	5759	0.12
42000	49758	5740	0.12
45000	50289	5503	0.11
48000	50889	4980	0.10
51000	51451	4470	0.09
54000	52011	4046	0.08
57000	52678	3645	0.07
60000	53294	3365	0.06
63000	54275	3116	0.06
66000	55184	2947	0.05
69000	56053	2757	0.05
72000	57142	2678	0.05
75000	61018	2714	0.04

SUCKER SIDE CHANNEL

MAINSTEM DISCHARGE	SITE AREA	CHINOOK WUA	CHINOOK H. I.
12000	0	0	0.00
15000	0	0	0.00
18000	0	0	0.00
21000	0	0	0.00
24000	0	0	0.00
27000	0	0	ERR
30000	8500	1060	0.12
33000	14900	1600	0.11
36000	16900	1570	0.09
39000	19400	1510	0.08
42000	23600	1450	0.06
45000	29600	1550	0.05
48000	37100	2070	0.06
51000	46600	2940	0.06
54000	57900	4230	0.07
57000	66900	4680	0.07
60000	71300	4490	0.06
63000	73900	4230	0.06
66000	75900	3940	0.05
69000	77300	3610	0.05
72000	78100	3270	0.04
75000	78300	3010	0.04

BEAVER DAM SIDE CHANNEL

MAINSTEM DISCHARGE	SITE AREA	CHINOOK WUA	CHINOOK H. I.
12000	18900	50	.00
15000	18900	50	.00
18000	18900	50	.00
21000	18900	50	.00
24000	18900	50	.00
27000	18900	50	.00
30000	18900	50	.00
33000	18900	50	.00
36000	18900	50	.00
39000	18900	50	.00
42000	18900	50	.00
45000	18900	50	.00
48000	22400	820	0.04
51000	28000	2370	0.08
54000	32600	3560	0.11
57000	35700	3840	0.11
60000	38000	3570	0.09
63000	39600	3060	0.08
66000	40800	2510	0.06
69000	41500	2260	0.05
72000	41900	2100	0.05
75000	42100	2000	0.05

SUNSET SIDE CHANNEL

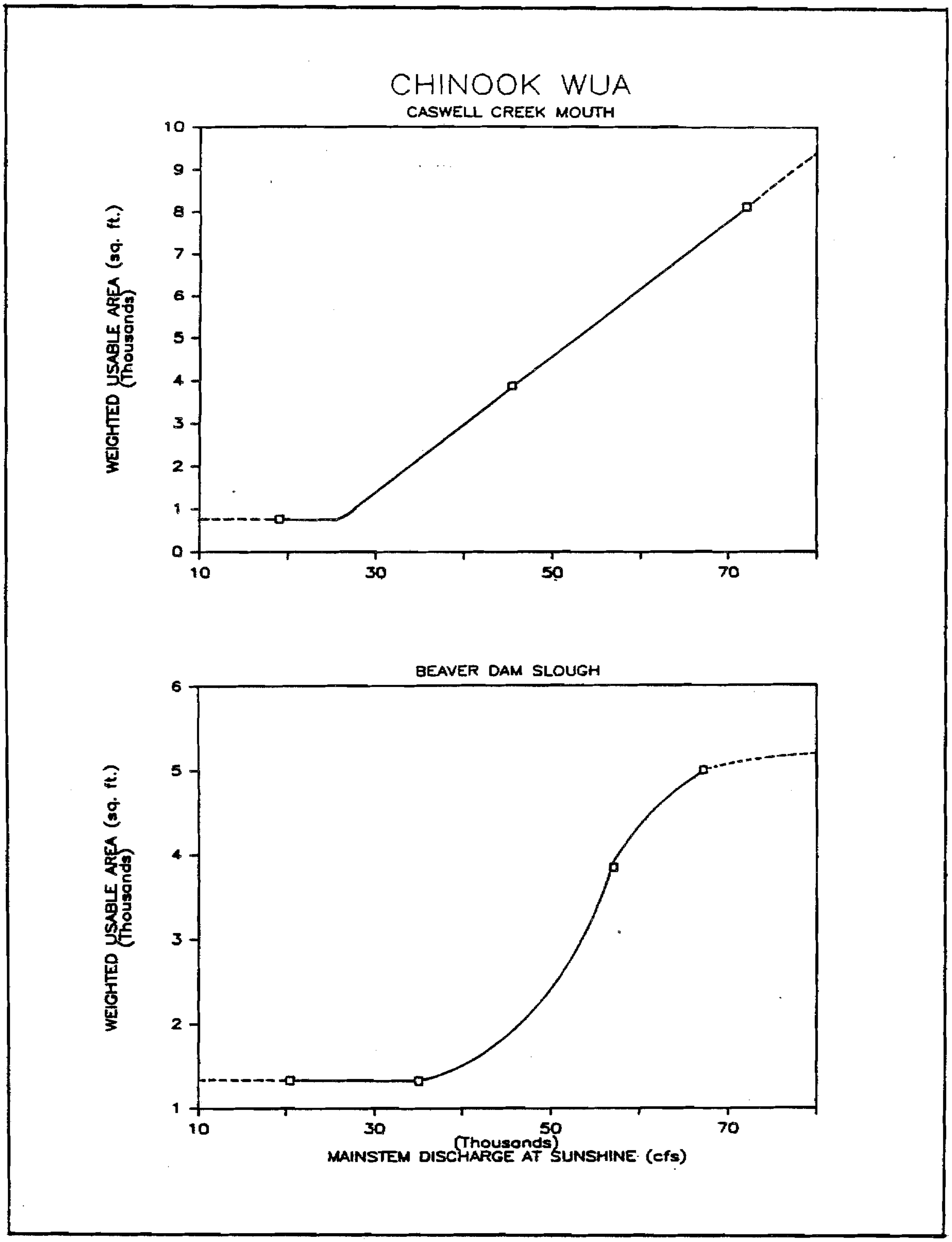
MAINSTEM DISCHARGE	SITE AREA	CHINOOK WUA	CHINOOK H. I.
12000	49562	568	0.01
15000	49562	568	0.01
18000	49562	568	0.01
21000	49562	568	0.01
24000	49562	568	0.01
27000	49562	568	0.01
30000	49562	568	0.01
33000	78488	4378	0.06
36000	89472	4420	0.05
39000	97943	4630	0.05
42000	106320	4984	0.05
45000	122338	5436	0.04
48000	135476	5846	0.04
51000	149248	5868	0.04
54000	165990	5768	0.03
57000	173483	5487	0.03
60000	188419	5931	0.03
63000	194419	6000	0.03
66000	203000	6231	0.03
69000	206972	6263	0.03
72000	210728	6157	0.03
75000	215861	5848	0.03

SUNRISE SIDE CHANNEL

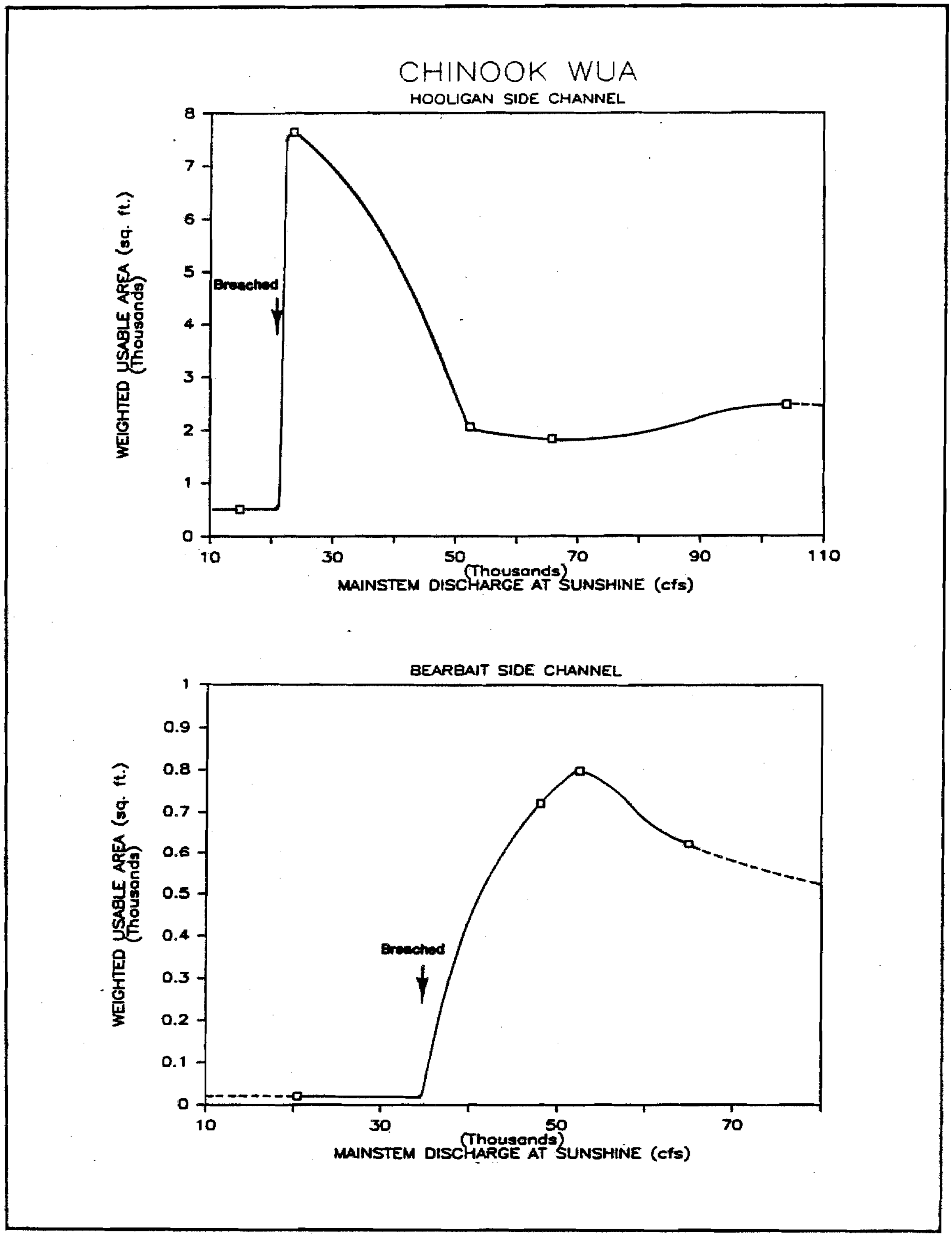
MAINSTEM DISCHARGE	SITE AREA	CHINOOK WUA	CHINOOK H. I.
12000	0	0	0.00
15000	0	0	0.00
18000	0	0	0.00
21000	0	0	0.00
24000	0	0	0.00
27000	0	0	0.00
30000	0	0	0.00
33000	0	0	0.00
36000	19000	610	0.03
39000	53900	3250	0.06
42000	78500	5660	0.07
45000	97100	6090	0.06
48000	115400	4270	0.04
51000	131100	3820	0.03
54000	146900	3540	0.02
57000	160600	3250	0.02
60000	175600	3180	0.02
63000	192000	3460	0.02
66000	207300	3760	0.02
69000	221400	4080	0.02
72000	229000	4190	0.02
75000	233300	4210	0.02

TRAPPER CREEK S. C.

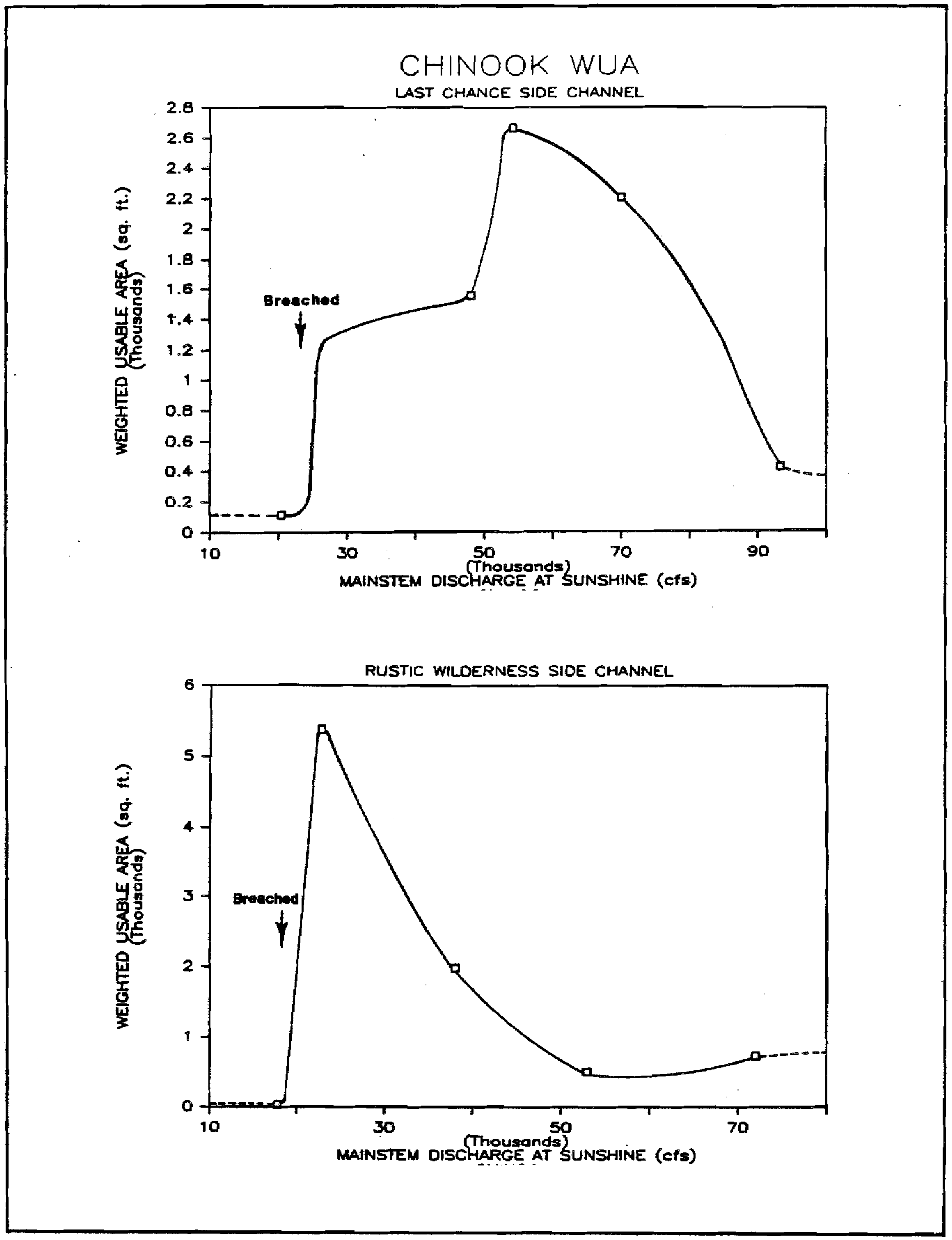
MAINSTEM DISCHARGE	SITE AREA	CHINOOK WUA	CHINOOK H. I.
12000	73300	1100	0.02
15000	73300	1100	0.02
18000	73300	1100	0.02
21000	73300	1100	0.02
24000	73300	1100	0.02
27000	73300	1100	0.02
30000	73300	1100	0.02
33000	73300	1100	0.02
36000	73300	1100	0.02
39000	73300	1100	0.02
42000	73300	1100	0.02
45000	77600	9300	0.12
48000	91200	9000	0.10
51000	108100	7500	0.07
54000	123300	5600	0.05
57000	137700	2900	0.02
60000	151200	1300	0.01
63000	158000	1330	0.01
66000	163100	1360	0.01
69000	166900	1390	0.01
72000	170700	1400	0.01
75000	173500	1400	0.01



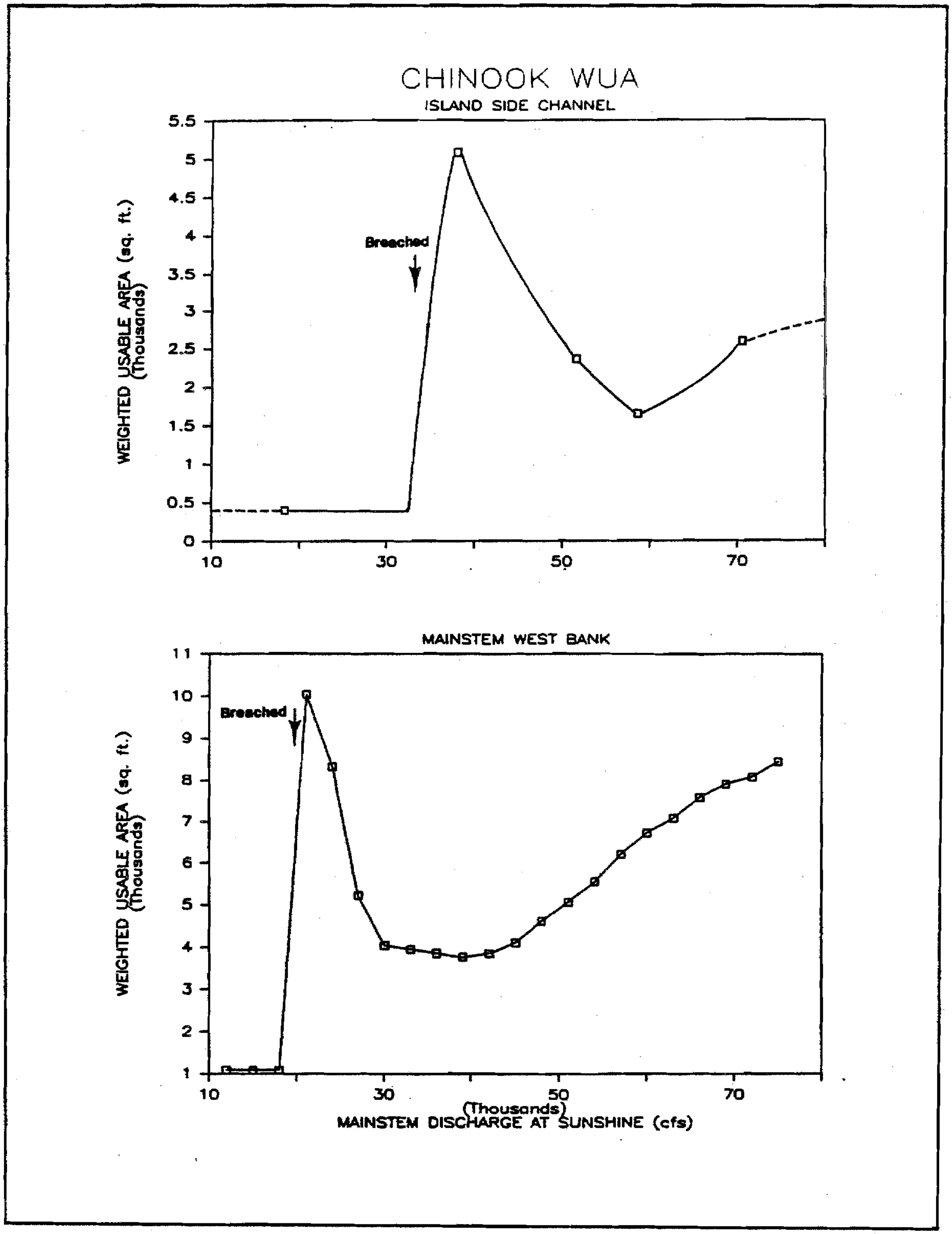
Appendix Figure B-1. Weighted usable area for juvenile chinook salmon at Caswell Creek and Beaver Dam tributary study sites as a function of mainstem discharge.



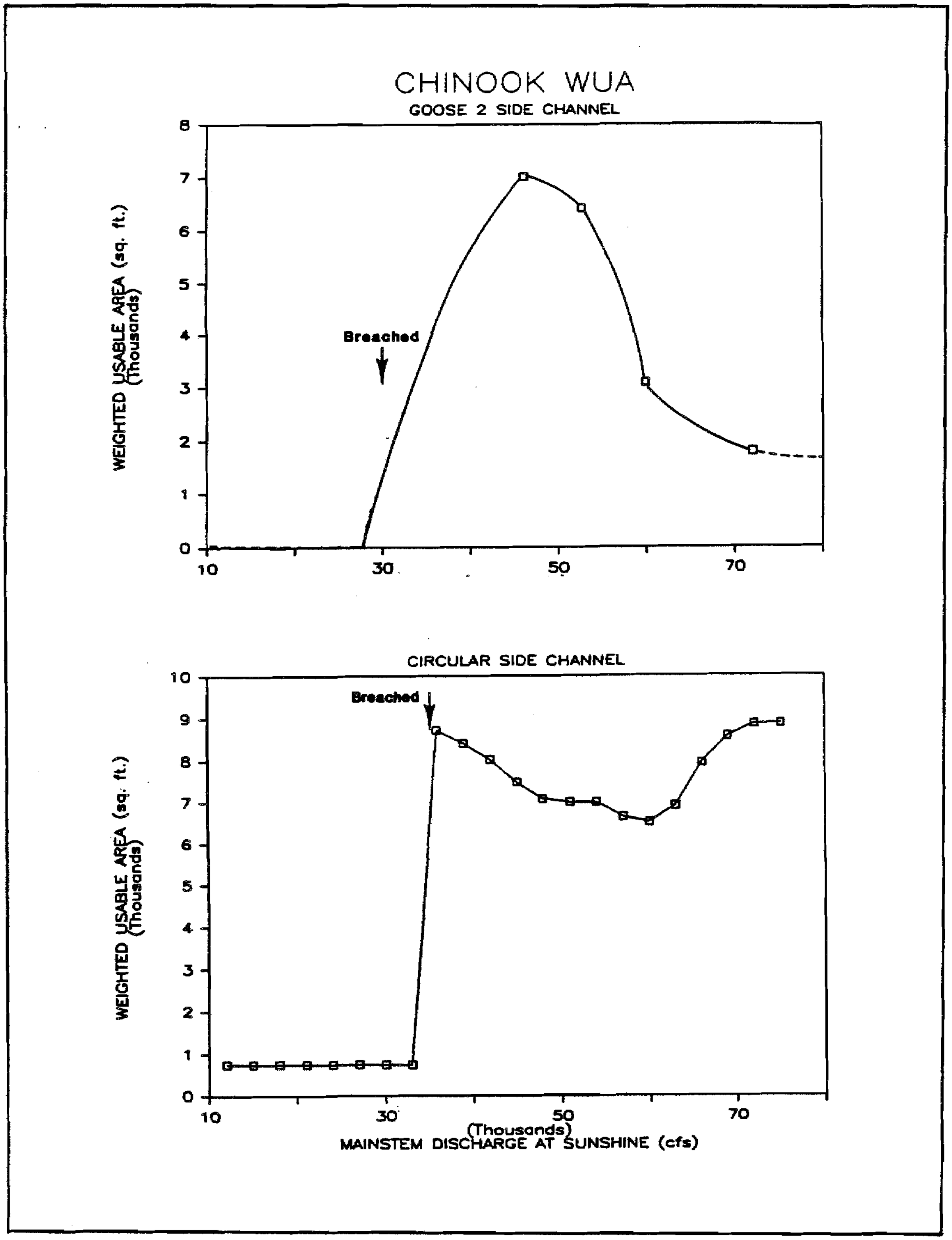
Appendix Figure B-2. Weighted usable area for juvenile chinook salmon at the Hooligan and Bearbait Side Channel study sites as a function of mainstem discharge.



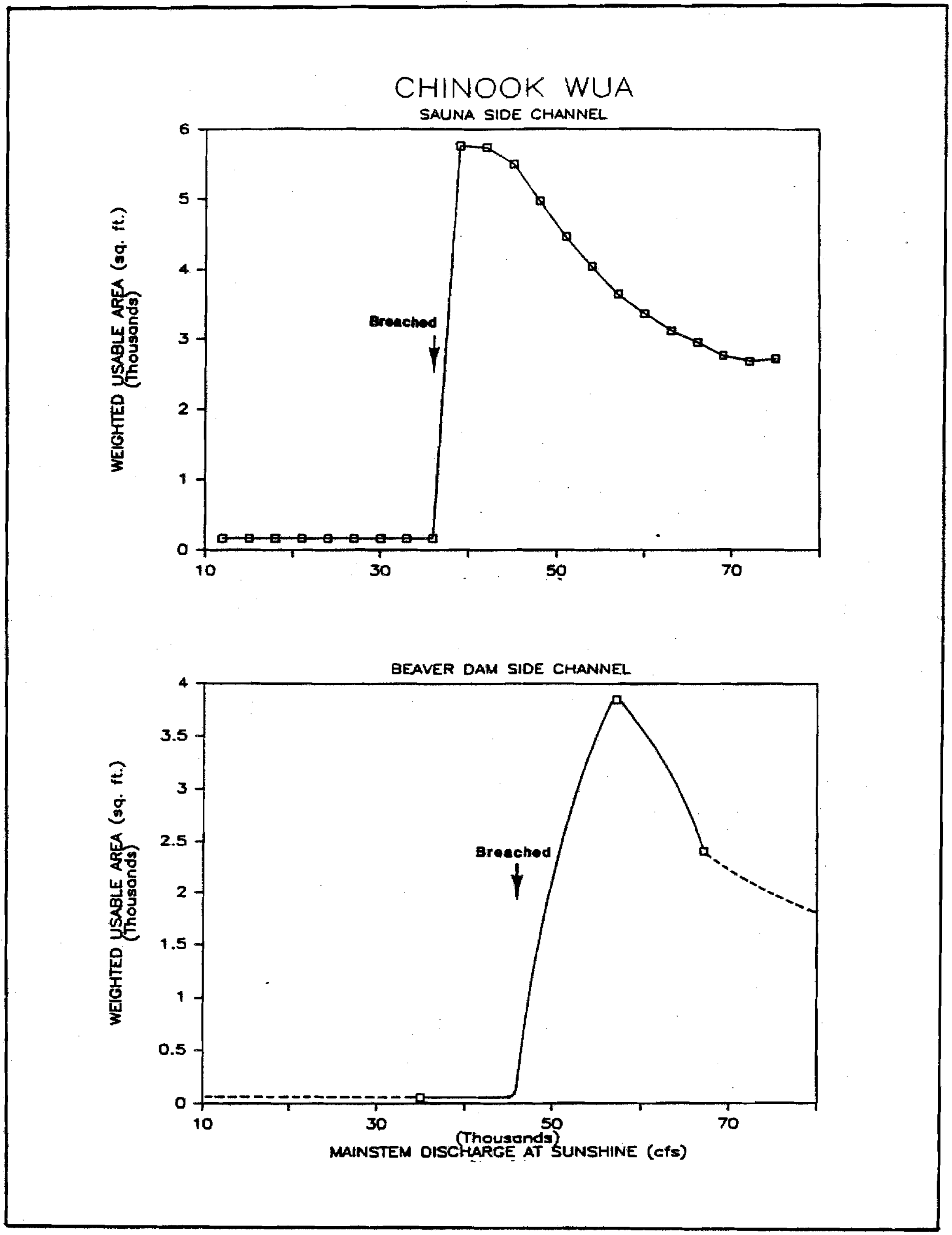
Appendix Figure B-3. Weighted usable area for juvenile chinook salmon at Last Chance and Rustic Wilderness Side Channel study sites as a function of mainstem discharge.



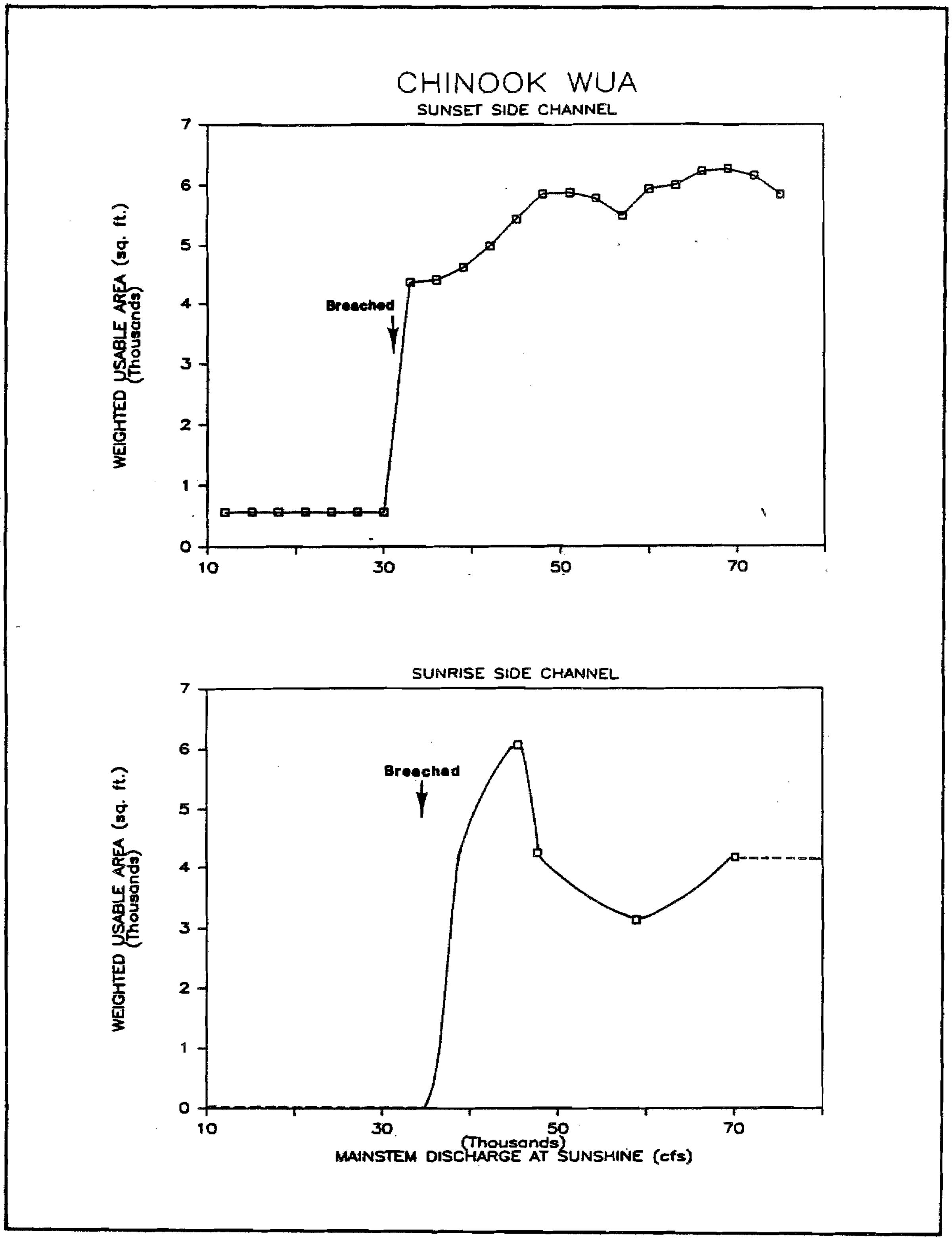
Appendix Figure B-4. Weighted usable area for juvenile chinook salmon at the Island Channel and Mainstem West Bank study sites as a function of mainstem discharge.



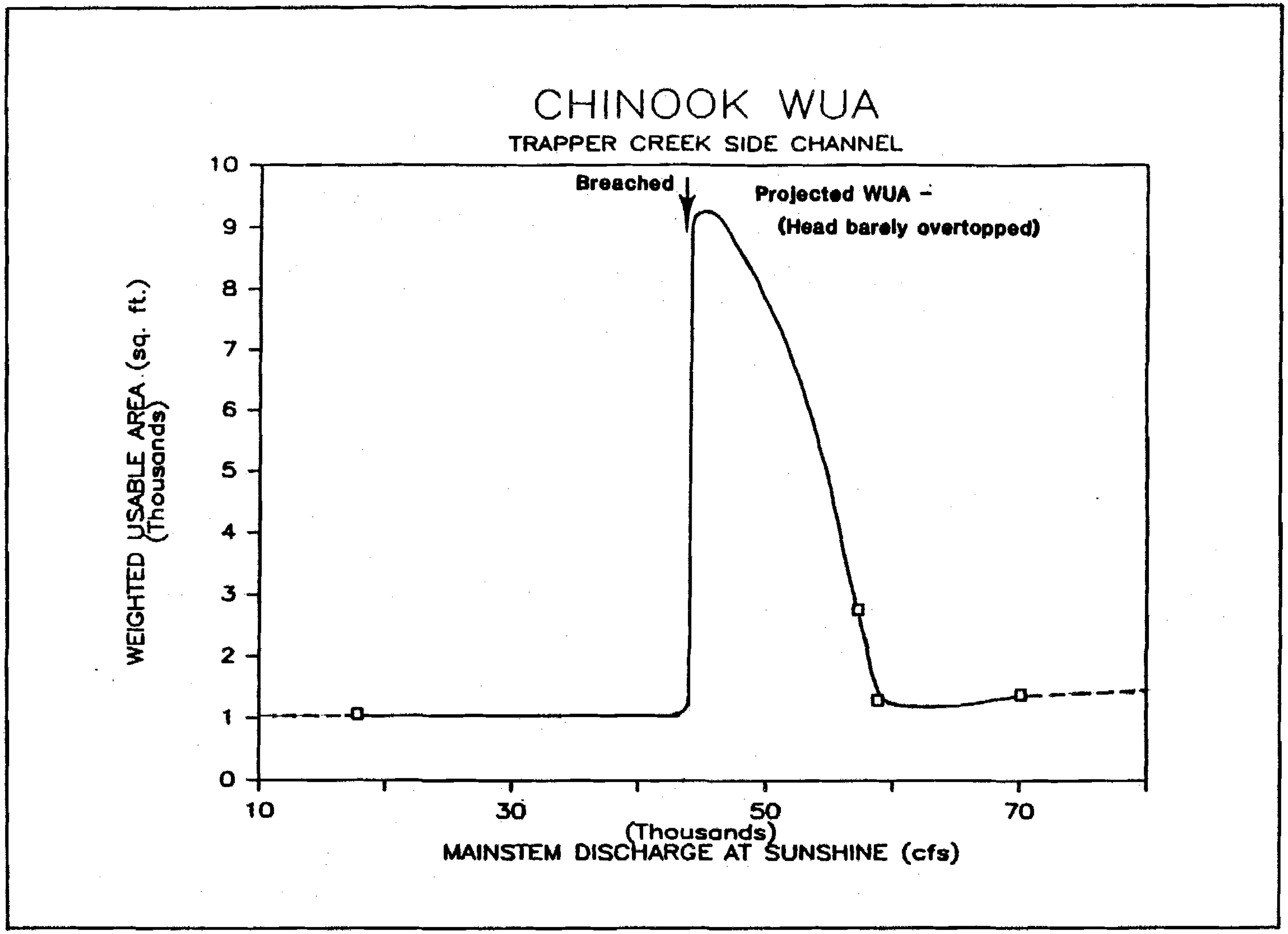
Appendix Figure B-5. Weighted usable area for juvenile chinook salmon at the Goose 2 and Circular Side Channel study sites as a function of mainstem discharge.



Appendix Figure B-6. Weighted usable area for juvenile chinook salmon at the Sauna and Beaver Dam Side Channel study sites as a function of mainstem discharge.



Appendix Figure B-7. Weighted usable area for juvenile chinook salmon at the Sunset and Sunrise Side Channel study sites as a function of mainstem discharge.



Appendix Figure B-8. Weighted usable area for juvenile chinook salmon at the Trapper Creek Side Channel study site as a function of mainstem discharge.

Appendix Table B-6. Weighted usable areas and habitat indices for juvenile coho salmon in lower Susitna River model sites, 1984.

ROLLY CREEK MOUTH				CASWELL CREEK MOUTH				BEAVER DAM SLOUGH			
MAINSTEM DISCHARGE	SITE AREA	COHO WUA	COHO H. I.	MAINSTEM DISCHARGE	SITE AREA	COHO WUA	COHO H. I.	MAINSTEM DISCHARGE	SITE AREA	COHO WUA	COHO H. I.
12000	84900	7900	0.09	12000	16200	1350	0.08	12000	11600	1700	0.15
15000	84900	7900	0.09	15000	16200	1350	0.08	15000	11600	1700	0.15
18000	84900	7900	0.09	18000	16200	1350	0.08	18000	11600	1700	0.15
21000	84900	7900	0.09	21000	16200	1350	0.08	21000	11700	1700	0.15
24000	85300	7900	0.09	24000	16200	1350	0.08	24000	11900	1700	0.14
27000	88300	7700	0.09	27000	16300	1500	0.09	27000	12200	1700	0.14
30000	93200	7500	0.08	30000	16700	1700	0.10	30000	12500	1700	0.14
33000	99800	7100	0.07	33000	17300	2000	0.12	33000	13000	1700	0.13
36000	108900	6800	0.06	36000	18000	2300	0.13	36000	13400	1700	0.13
39000	121000	6400	0.05	39000	18900	2500	0.13	39000	13900	1700	0.12
42000	135000	5900	0.04	42000	19800	2800	0.14	42000	14400	1670	0.12
45000	152600	5500	0.04	45000	21000	3000	0.14	45000	15000	1650	0.11
48000	178500	5600	0.03	48000	21800	3200	0.15	48000	15700	1610	0.10
51000	198800	7300	0.04	51000	22700	3400	0.15	51000	16300	1540	0.09
54000	213000	9200	0.04	54000	23700	3600	0.15	54000	16800	1480	0.09
57000	223200	10100	0.05	57000	24600	3800	0.15	57000	17600	1430	0.08
60000	229800	10700	0.05	60000	25500	4000	0.16	60000	18500	1480	0.08
63000	235000	11200	0.05	63000	26300	4300	0.16	63000	19700	1540	0.08
66000	238700	11700	0.05	66000	27200	4400	0.16	66000	20800	1630	0.08
69000	241600	12000	0.05	69000	27900	4700	0.17	69000	21600	1740	0.08
72000	243200	12300	0.05	72000	28900	4900	0.17	72000	22100	1780	0.08
75000	243600	12500	0.05	75000	29700	5100	0.17	75000	22600	1810	0.08

Appendix Table B-7. Weighted usable areas and habitat indices for juvenile chum salmon in lower Susitna River model sites, 1984.

HOOLIGAN SIDE CHANNEL				KROTO SLOUGH HEAD				BEARBAIT SIDE CHANNEL			
MAINSTEM DISCHARGE	SITE AREA	CHUM WUA	CHUM H. I.	MAINSTEM DISCHARGE	SITE AREA	CHUM WUA	CHUM H. I.	MAINSTEM DISCHARGE	SITE AREA	CHUM WUA	CHUM H. I.
12000	63400	28500	0.45	12000	48200	39600	0.82	12000	3100	1300	0.42
15000	63400	28500	0.45	15000	48200	39600	0.82	15000	3100	1300	0.42
18000	63400	28500	0.45	18000	48200	39600	0.82	18000	3100	1300	0.42
21000	63400	28500	0.45	21000	48200	39600	0.82	21000	3100	1300	0.42
24000	79800	47900	0.60	24000	48200	39600	0.82	24000	3100	1300	0.42
27000	86900	46700	0.54	27000	48200	39600	0.82	27000	3100	1300	0.42
30000	90800	44000	0.48	30000	48200	39600	0.82	30000	3100	1300	0.42
33000	96500	41700	0.43	33000	48200	39600	0.82	33000	3100	1300	0.42
36000	104800	38400	0.37	36000	50000	39600	0.79	36000	5700	1400	0.25
39000	113700	34700	0.31	39000	67900	42000	0.62	39000	10800	1900	0.18
42000	122900	30300	0.25	42000	77500	44500	0.57	42000	14600	2600	0.18
45000	131300	26100	0.20	45000	86800	46100	0.53	45000	17900	3300	0.18
48000	141200	21900	0.16	48000	95100	47600	0.50	48000	21100	4100	0.19
51000	152000	18900	0.12	51000	102200	46500	0.45	51000	23800	5300	0.22
54000	163000	18100	0.11	54000	106700	42300	0.40	54000	26400	5700	0.22
57000	174100	17600	0.10	57000	110200	38300	0.35	57000	29000	5500	0.19
60000	186800	17200	0.09	60000	113500	34400	0.30	60000	31500	5100	0.16
63000	200800	16900	0.08	63000	116600	29700	0.25	63000	33900	4700	0.14
66000	213300	16700	0.08	66000	119000	24100	0.20	66000	36300	4400	0.12
69000	226000	16400	0.07	69000	120100	19800	0.16	69000	38300	4200	0.11
72000	239000	16100	0.07	72000	121000	17800	0.15	72000	40000	4100	0.10
75000	250900	15800	0.06	75000	121400	15200	0.13	75000	41500	4000	0.10

Appendix Table B-7. Continued.

LAST CHANCE S. C.

MAINSTEM DISCHARGE	SITE AREA	CHUM WUA	CHUM H. I.
12000	17500	11500	0.66
15000	17500	11500	0.66
18000	17500	11500	0.66
21000	17500	11500	0.66
24000	20000	11500	0.58
27000	22000	11500	0.52
30000	27000	11500	0.43
33000	34000	11500	0.34
36000	46500	11500	0.25
39000	70000	11500	0.16
42000	81000	11500	0.14
45000	91000	11500	0.13
48000	94000	11700	0.12
51000	96300	15100	0.16
54000	98500	20200	0.21
57000	100200	19500	0.19
60000	101800	18000	0.18
63000	103200	16200	0.16
66000	104400	13600	0.13
69000	105500	10500	0.10
72000	106300	8800	0.08
75000	107000	7600	0.07

RUSTIC WILDERNESS S. C.

MAINSTEM DISCHARGE	SITE AREA	CHUM WUA	CHUM H. I.
12000	4800	3600	0.75
15000	4800	3600	0.75
18000	4800	3600	0.75
21000	31900	30800	0.97
24000	49500	32500	0.66
27000	60700	27600	0.45
30000	69700	22700	0.33
33000	76800	18100	0.24
36000	83300	13700	0.16
39000	89900	10600	0.12
42000	97000	8800	0.09
45000	104000	7400	0.07
48000	109000	5800	0.05
51000	114000	4200	0.04
54000	117400	3300	0.03
57000	119200	3000	0.03
60000	120700	3000	0.02
63000	121700	3000	0.02
66000	122200	3000	0.02
69000	122700	3000	0.02
72000	123000	3000	0.02
75000	123500	3000	0.02

ISLAND SIDE CHANNEL

MAINSTEM DISCHARGE	SITE AREA	CHUM WUA	CHUM H. I.
12000	31500	19300	0.61
15000	31500	19300	0.61
18000	31500	19300	0.61
21000	31500	19300	0.61
24000	31500	19300	0.61
27000	31500	19300	0.61
30000	31500	19300	0.61
33000	31500	19300	0.61
36000	39200	28100	0.72
39000	45300	28800	0.64
42000	51000	25800	0.51
45000	58500	22700	0.39
48000	65500	19700	0.30
51000	72000	17400	0.24
54000	79400	15100	0.19
57000	86700	13200	0.15
60000	93100	12400	0.13
63000	99800	12700	0.13
66000	106200	13000	0.12
69000	111900	13300	0.12
72000	118200	13600	0.12
75000	123300	13600	0.11

MAINSTEM WEST BANK

MAINSTEM DISCHARGE	SITE AREA	CHUM WUA	CHUM H. I.
12000	61603	47090	0.76
15000	61603	47090	0.76
18000	61603	47090	0.76
21000	73426	53955	0.73
24000	80904	43289	0.54
27000	93353	31606	0.34
30000	108613	27151	0.25
33000	114738	23420	0.20
36000	117696	21782	0.19
39000	120505	21096	0.18
42000	123397	21218	0.17
45000	129211	22389	0.17
48000	133649	26770	0.20
51000	136885	27661	0.20
54000	140761	30382	0.22
57000	144269	31815	0.22
60000	147899	33950	0.23
63000	151842	35953	0.24
66000	154205	36489	0.24
69000	156425	36211	0.23
72000	158522	37029	0.23
75000	160818	36809	0.23

GOOSE 2 SIDE CHANNEL

MAINSTEM DISCHARGE	SITE AREA	CHUM WUA	CHUM H. I.
12000	0	0	0.00
15000	0	0	0.00
18000	0	0	0.00
21000	0	0	0.00
24000	0	0	0.00
27000	0	0	0.00
30000	9600	4900	0.51
33000	21500	11000	0.51
36000	34300	17400	0.51
39000	47800	25500	0.53
42000	61400	31800	0.52
45000	72000	37900	0.53
48000	81400	41600	0.51
51000	87800	42600	0.49
54000	93200	40700	0.44
57000	97100	33400	0.34
60000	99900	24000	0.24
63000	102000	18600	0.18
66000	103200	13800	0.13
69000	104200	10400	0.10
72000	104800	8300	0.08
75000	105100	7400	0.07

CIRCULAR SIDE CHANNEL

MAINSTEM DISCHARGE	SITE AREA	CHUM WUA	CHUM H. I.
12000	59464	46109	0.78
15000	59464	46109	0.78
18000	59464	46109	0.78
21000	59464	46109	0.78
24000	59464	46109	0.78
27000	59464	46109	0.78
30000	59464	46109	0.78
33000	59464	46109	0.78
36000	71590	44495	0.62
39000	76534	44606	0.58
42000	80557	42269	0.52
45000	85140	42176	0.50
48000	92944	43074	0.46
51000	102530	45026	0.44
54000	113323	50073	0.44
57000	125753	50248	0.40
60000	134218	46305	0.34
63000	143575	49339	0.34
66000	150869	49565	0.33
69000	154657	50346	0.33
72000	157074	48491	0.31
75000	159211	46797	0.29

Appendix Table B-7. Continued.

SAUNA SIDE CHANNEL

MAINSTEM DISCHARGE	SITE AREA	CHUM WUA	CHUM H. I.
12000	42093	31754	0.75
15000	42093	31754	0.75
18000	42093	31754	0.75
21000	42093	31754	0.75
24000	42093	31754	0.75
27000	42093	31754	0.75
30000	42093	31754	0.75
33000	42093	31754	0.75
36000	42093	31754	0.75
39000	49127	27307	0.56
42000	49758	26413	0.53
45000	50289	25204	0.50
48000	50889	23670	0.47
51000	51451	22565	0.44
54000	52011	21836	0.42
57000	52678	21381	0.41
60000	53294	20990	0.39
63000	54275	20669	0.38
66000	55184	20938	0.38
69000	56053	21017	0.37
72000	57142	21153	0.37
75000	61018	23075	0.38

SUCKER SIDE CHANNEL

MAINSTEM DISCHARGE	SITE AREA	CHUM WUA	CHUM H. I.
12000	0	0	0.00
15000	0	0	0.00
18000	0	0	0.00
21000	0	0	0.00
24000	0	0	0.00
27000	0	0	ERR
30000	8500	7300	0.86
33000	14900	11800	0.79
36000	16900	12700	0.75
39000	19400	13200	0.68
42000	23600	13400	0.57
45000	29600	14300	0.48
48000	37100	19900	0.54
51000	46600	27700	0.59
54000	57900	33700	0.58
57000	66900	34400	0.51
60000	71300	32900	0.46
63000	73900	30800	0.42
66000	75900	28200	0.37
69000	77300	25000	0.32
72000	78100	21800	0.28
75000	78300	19200	0.25

BEAVER DAM SIDE CHANNEL

MAINSTEM DISCHARGE	SITE AREA	CHUM WUA	CHUM H. I.
12000	18900	11900	0.63
15000	18900	11900	0.63
18000	18900	11900	0.63
21000	18900	11900	0.63
24000	18900	11900	0.63
27000	18900	11900	0.63
30000	18900	11900	0.63
33000	18900	11900	0.63
36000	18900	11900	0.63
39000	18900	11900	0.63
42000	18900	11900	0.63
45000	18900	11900	0.63
48000	22400	13200	0.59
51000	28000	15700	0.56
54000	32600	17500	0.54
57000	35700	18800	0.53
60000	38000	18200	0.48
63000	39600	16400	0.41
66000	40800	14000	0.34
69000	41500	12100	0.29
72000	41900	11300	0.27
75000	42100	10700	0.25

SUNSET SIDE CHANNEL

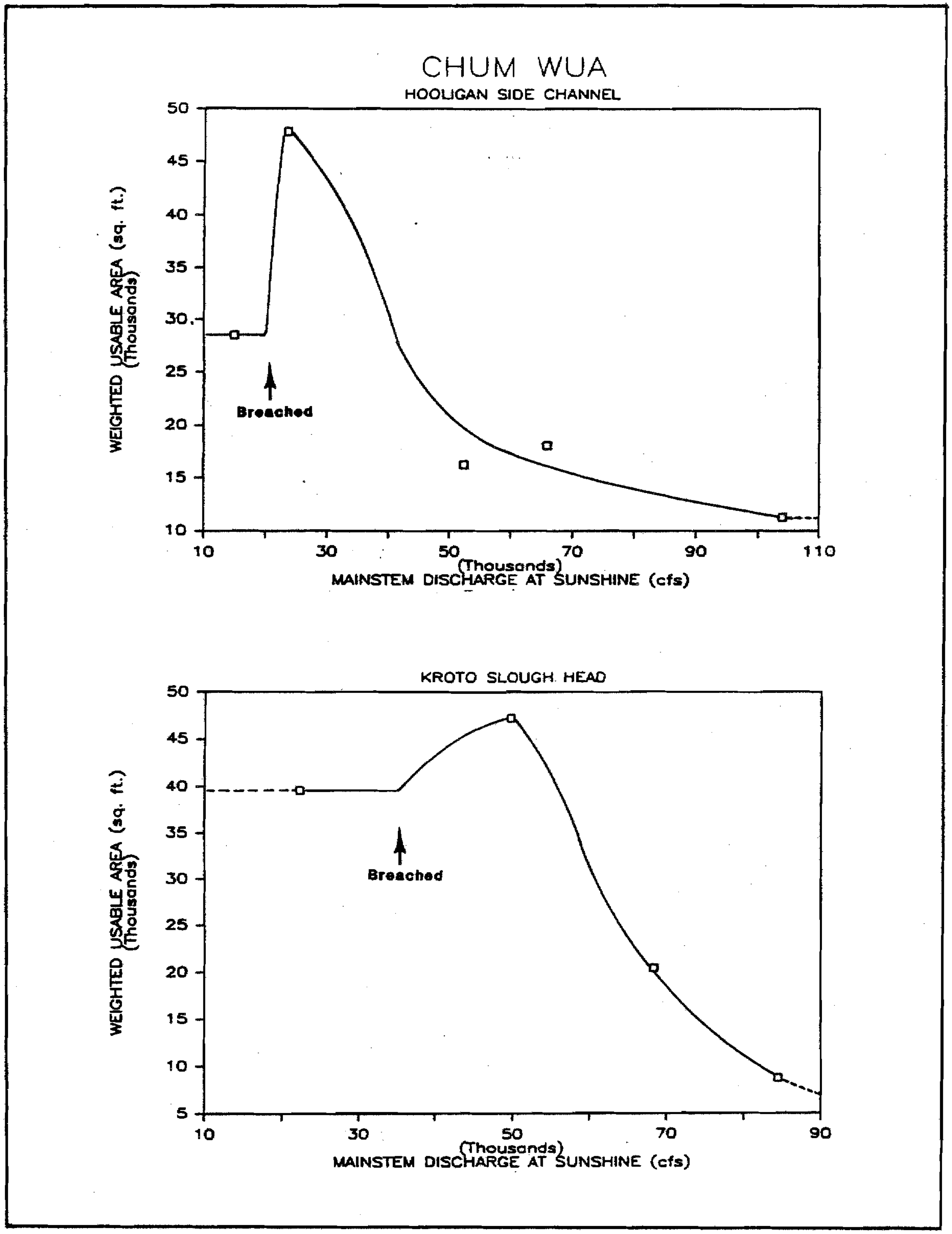
MAINSTEM DISCHARGE	SITE AREA	CHUM WUA	CHUM H. I.
12000	49562	27135	0.55
15000	49562	27135	0.55
18000	49562	27135	0.55
21000	49562	27135	0.55
24000	49562	27135	0.55
27000	49562	27135	0.55
30000	49562	27135	0.55
33000	78488	34059	0.43
36000	89472	34808	0.39
39000	97943	37649	0.38
42000	106320	39888	0.38
45000	122338	46376	0.38
48000	135476	51185	0.38
51000	149248	52671	0.35
54000	165990	53786	0.32
57000	173483	48410	0.28
60000	188419	50093	0.27
63000	194419	43299	0.22
66000	203000	41715	0.21
69000	206972	37100	0.18
72000	210728	33481	0.16
75000	215861	32949	0.15

SUNRISE SIDE CHANNEL

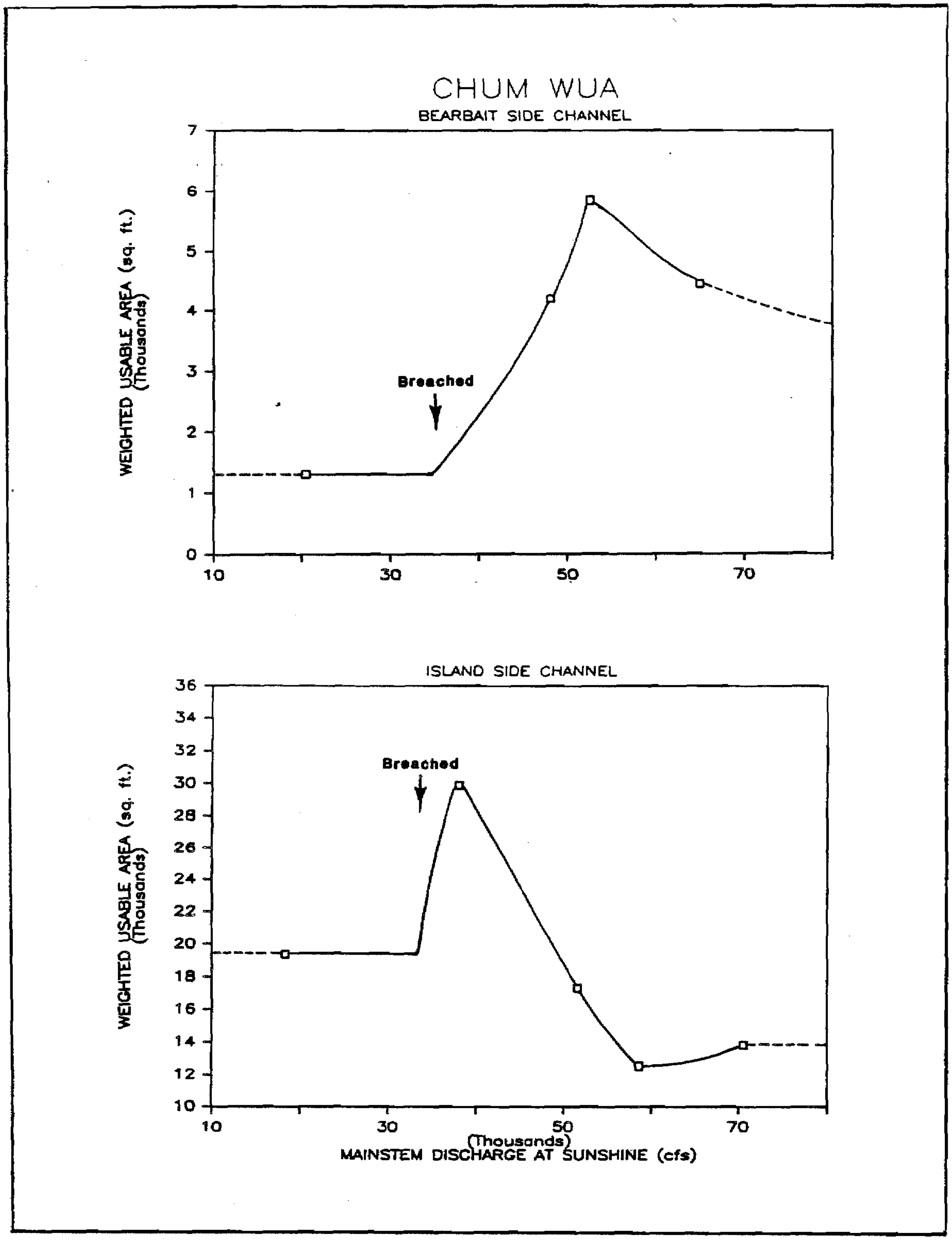
MAINSTEM DISCHARGE	SITE AREA	CHUM WUA	CHUM H. I.
12000	0	0	0.00
15000	0	0	0.00
18000	0	0	0.00
21000	0	0	0.00
24000	0	0	0.00
27000	0	0	0.00
30000	0	0	0.00
33000	0	0	0.00
36000	19000	6200	0.33
39000	53900	32400	0.60
42000	78500	46400	0.59
45000	97100	49700	0.51
48000	115400	44500	0.39
51000	131100	37500	0.29
54000	146900	31100	0.21
57000	160600	26600	0.17
60000	175600	25200	0.14
63000	192000	25300	0.13
66000	207300	26200	0.13
69000	221400	27700	0.13
72000	229000	28500	0.12
75000	233300	29000	0.12

TRAPPER CREEK S. C.

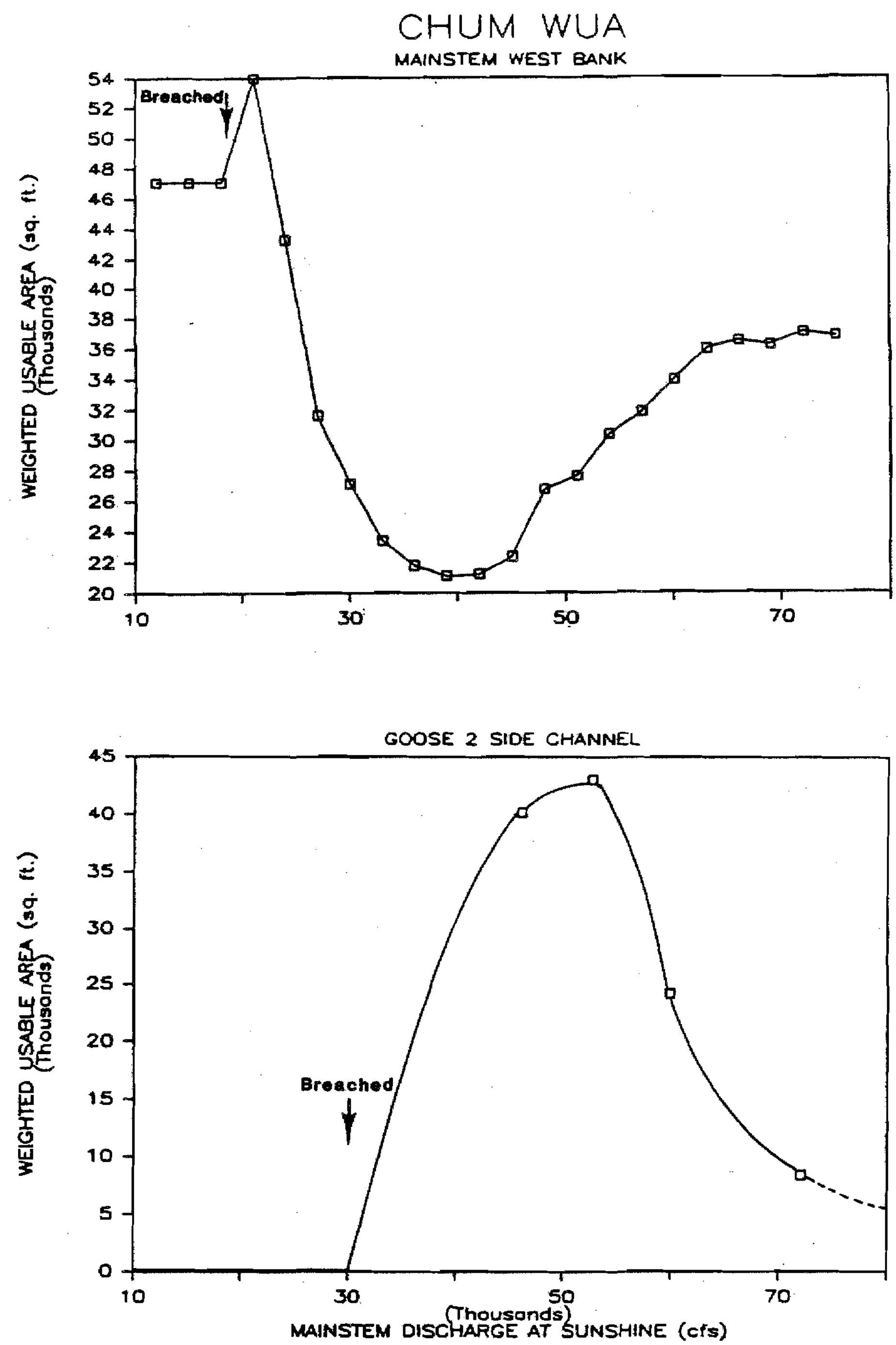
MAINSTEM DISCHARGE	SITE AREA	CHUM WUA	CHUM H. I.
12000	73300	45400	0.62
15000	73300	45400	0.62
18000	73300	45400	0.62
21000	73300	45400	0.62
24000	73300	45400	0.62
27000	73300	45400	0.62
30000	73300	45400	0.62
33000	73300	45400	0.62
36000	73300	45400	0.62
39000	73300	45400	0.62
42000	73300	45400	0.62
45000	77600	44800	0.58
48000	91200	41200	0.45
51000	108100	34600	0.32
54000	123300	27500	0.22
57000	137700	19500	0.14
60000	151200	10700	0.07
63000	158000	10200	0.06
66000	163100	10000	0.06
69000	166900	9800	0.06
72000	170700	9600	0.06
75000	173500	9500	0.05



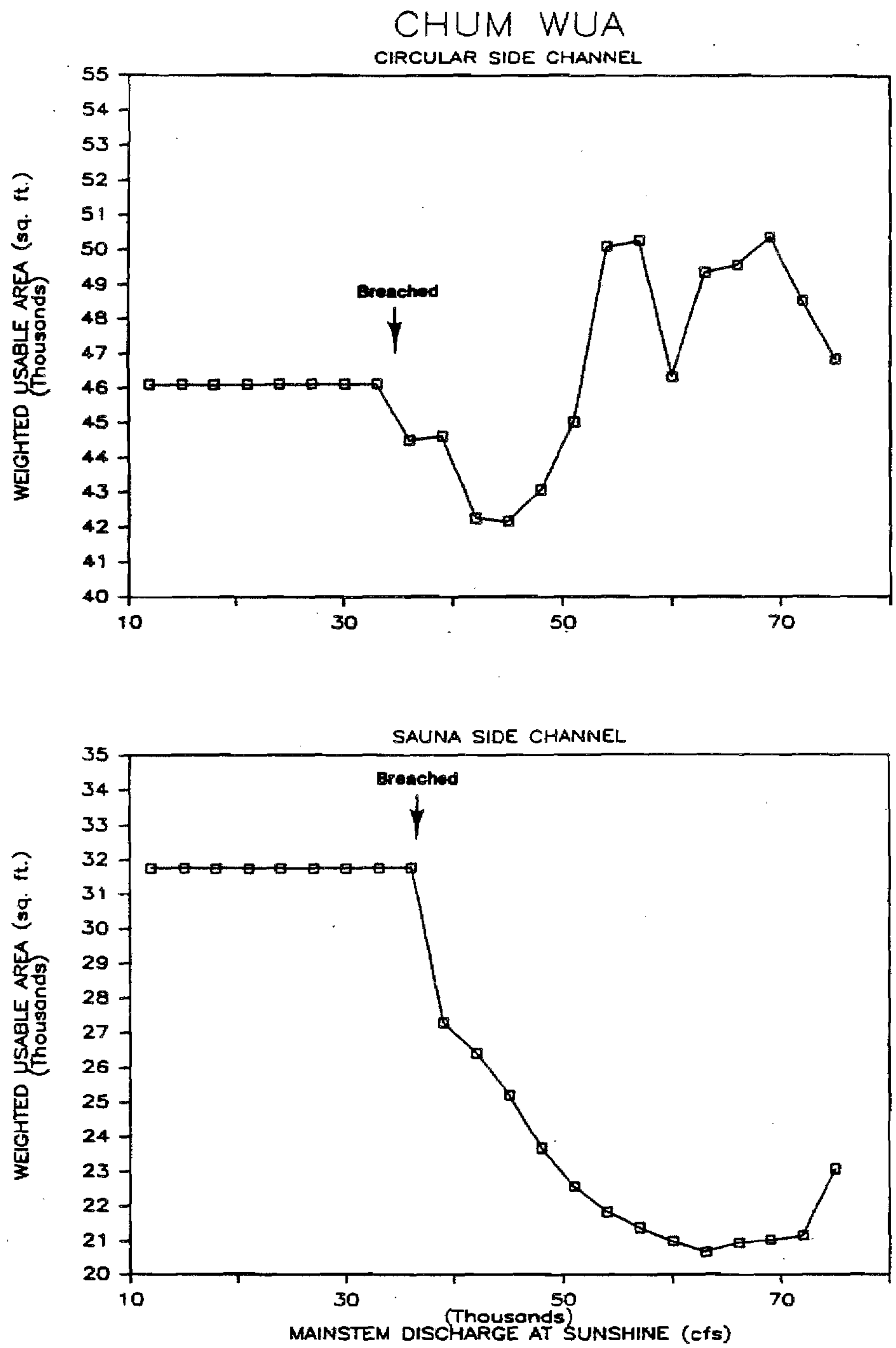
Appendix Figure B-9. Weighted usable area for juvenile chum salmon at the Hooligan Side Channel and Kroto Slough Head study sites as a function of mainstem discharge.



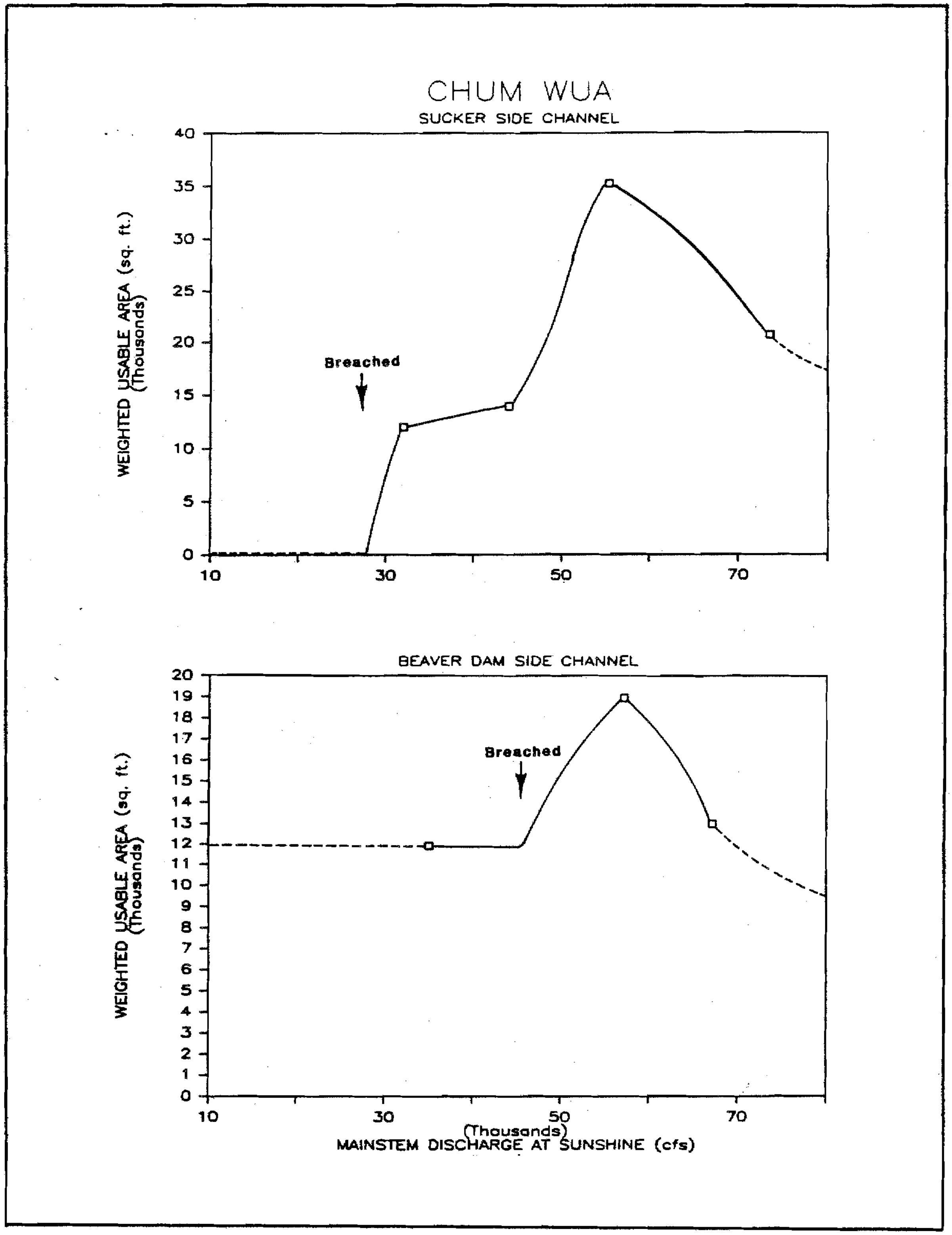
Appendix Figure B-10. Weighted usable area for juvenile chum salmon at Bearbait and Island Side Channel study sites as a function of mainstem discharge.



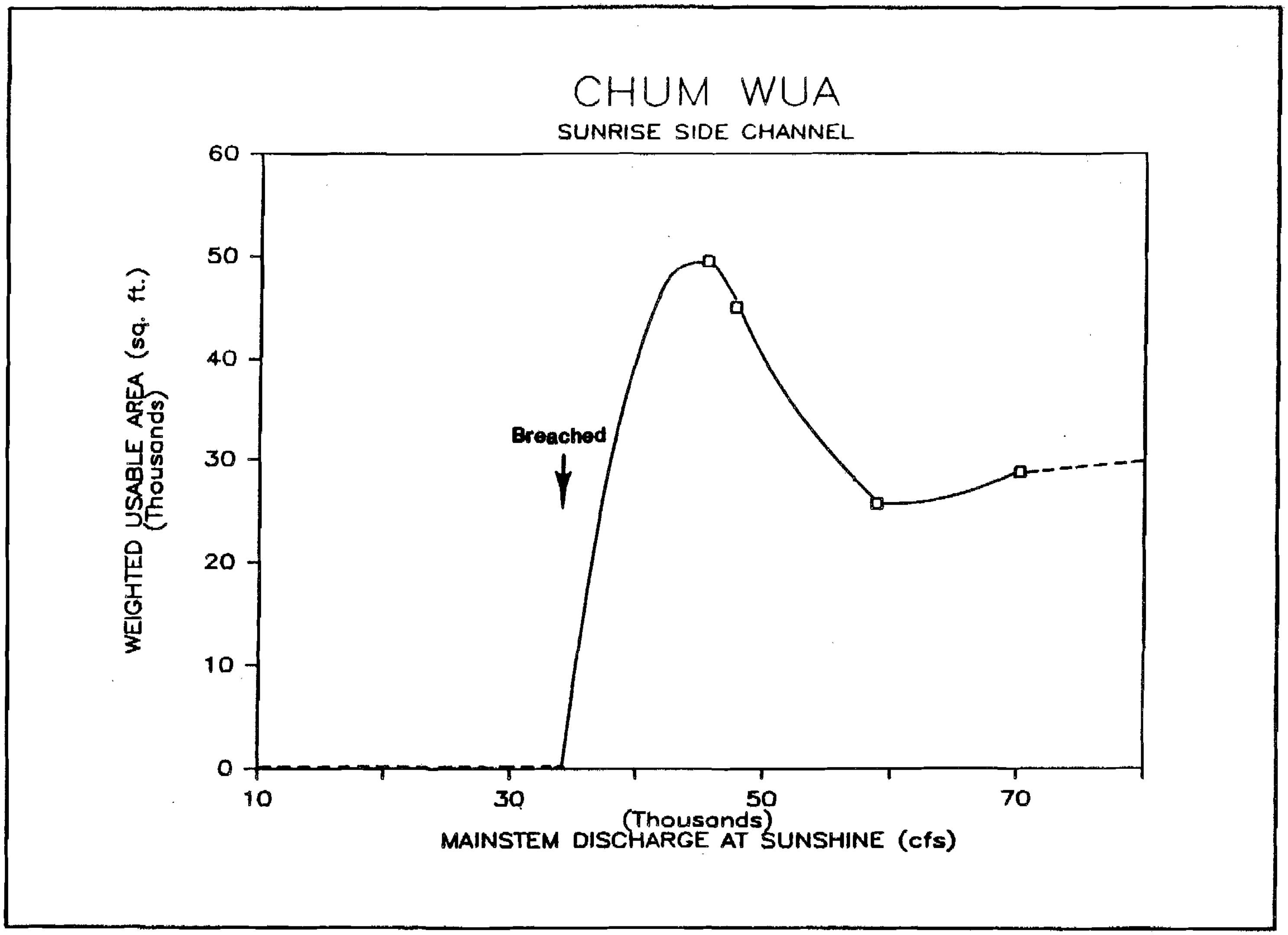
Appendix Figure B-11. Weighted usable area for juvenile chum salmon at the Mainstem West Bank and Goose 2 Side Channel study sites as a function of mainstem discharge.



Appendix Figure B-12. Weighted usable area for juvenile chum salmon at the Circular and Sauna Side Channel study sites as a function of mainstem discharge.



Appendix Figure B-13. Weighted usable area for juvenile chum salmon at the Sucker and Beaver Dam Side Channel study sites as a function of mainstem discharge.



Appendix Figure B-14. Weighted usable area for juvenile chum salmon at the Sunrise Side Channel study site as a function of mainstem discharge.

Appendix Table B-8. Weighted usable areas and habitat indices for juvenile sockeye salmon in lower Susitna River model sites, 1984.

ROLLY CREEK MOUTH

MAINSTEM DISCHARGE	SITE AREA	SOCKEYE WUA	SOCKEYE H. I.
12000	84900	10600	0.12
15000	84900	10600	0.12
18000	84900	10600	0.12
21000	84900	10600	0.12
24000	85300	10600	0.12
27000	88300	11000	0.12
30000	93200	13400	0.14
33000	99800	17600	0.18
36000	108900	22800	0.21
39000	121000	28900	0.24
42000	135000	35500	0.26
45000	152600	43400	0.28
48000	178500	52100	0.29
51000	198800	64400	0.32
54000	213000	75300	0.35
57000	223200	82800	0.37
60000	229800	88200	0.38
63000	235000	93000	0.40
66000	238700	97200	0.41
69000	241600	99900	0.41
72000	243200	100700	0.41
75000	243600	101500	0.42

CASWELL CREEK MOUTH

MAINSTEM DISCHARGE	SITE AREA	SOCKEYE WUA	SOCKEYE H. I.
12000	16200	1350	0.08
15000	16200	1350	0.08
18000	16200	1350	0.08
21000	16200	1350	0.08
24000	16200	1600	0.10
27000	16300	1700	0.10
30000	16700	1900	0.11
33000	17300	2300	0.13
36000	18000	2600	0.14
39000	18900	3100	0.16
42000	19800	3700	0.19
45000	21000	4300	0.20
48000	21800	5000	0.23
51000	22700	5700	0.25
54000	23700	6400	0.27
57000	24600	7200	0.29
60000	25500	7900	0.31
63000	26300	8600	0.33
66000	27200	9200	0.34
69000	27900	10000	0.36
72000	28900	10600	0.37
75000	29700	11400	0.38

BEAVER DAM SLOUGH

MAINSTEM DISCHARGE	SITE AREA	SOCKEYE WUA	SOCKEYE H. I.
12000	11600	6200	0.53
15000	11600	6200	0.53
18000	11600	6200	0.53
21000	11700	6200	0.53
24000	11900	6200	0.52
27000	12200	6400	0.52
30000	12500	6600	0.53
33000	13000	6700	0.52
36000	13400	7000	0.52
39000	13900	7100	0.51
42000	14400	7300	0.51
45000	15000	7500	0.50
48000	15700	7700	0.49
51000	16300	8000	0.49
54000	16800	8200	0.49
57000	17600	8600	0.49
60000	18500	8900	0.48
63000	19700	9400	0.48
66000	20800	10200	0.49
69000	21600	10800	0.50
72000	22100	11000	0.50
75000	22600	11000	0.49

SUCKER SIDE CHANNEL

MAINSTEM DISCHARGE	SITE AREA	SOCKEYE WUA	SOCKEYE H. I.
12000	0	0	0.00
15000	0	0	0.00
18000	0	0	0.00
21000	0	0	0.00
24000	0	0	0.00
27000	0	0	ERR
30000	8500	1200	0.14
33000	14900	1800	0.12
36000	16900	1700	0.10
39000	19400	1500	0.08
42000	23600	1200	0.05
45000	29600	1200	0.04
48000	37100	2600	0.07
51000	46600	4000	0.09
54000	57900	5000	0.09
57000	66900	5300	0.08
60000	71300	5400	0.08
63000	73900	5500	0.07
66000	75900	5600	0.07
69000	77300	5600	0.07
72000	78100	5600	0.07
75000	78300	5600	0.07

BEAVER DAM SIDE CHANNEL

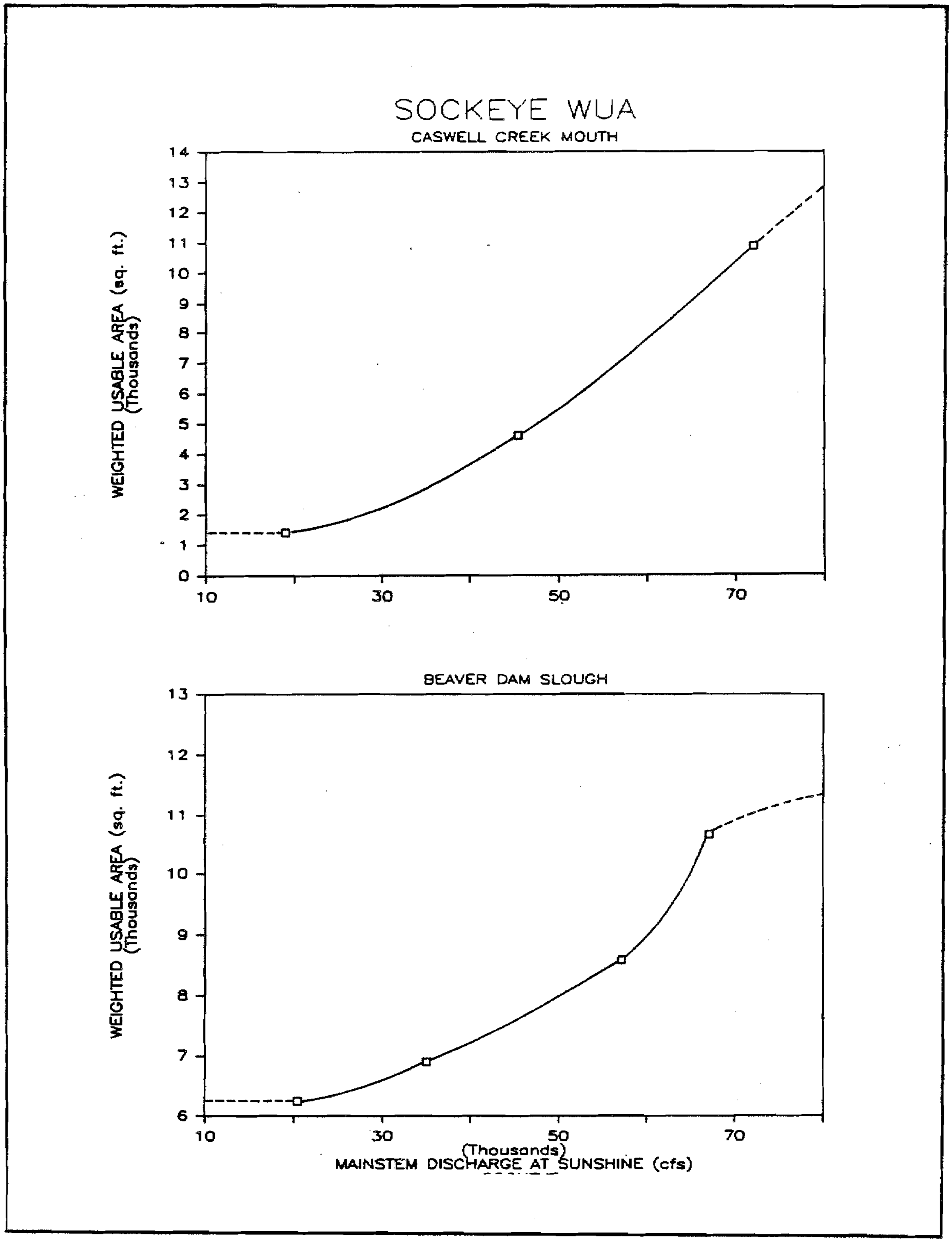
MAINSTEM DISCHARGE	SITE AREA	SOCKEYE WUA	SOCKEYE H. I.
12000	18900	3000	0.16
15000	18900	3000	0.16
18000	18900	3000	0.16
21000	18900	3000	0.16
24000	18900	3000	0.16
27000	18900	3000	0.16
30000	18900	3000	0.16
33000	18900	3000	0.16
36000	18900	3000	0.16
39000	18900	3000	0.16
42000	18900	3000	0.16
45000	18900	3000	0.16
48000	22400	3200	0.14
51000	28000	3700	0.13
54000	32600	4100	0.13
57000	35700	4300	0.12
60000	38000	4200	0.11
63000	39600	3900	0.10
66000	40800	3600	0.09
69000	41500	3200	0.08
72000	41900	3000	0.07
75000	42100	2800	0.07

SUNSET SIDE CHANNEL

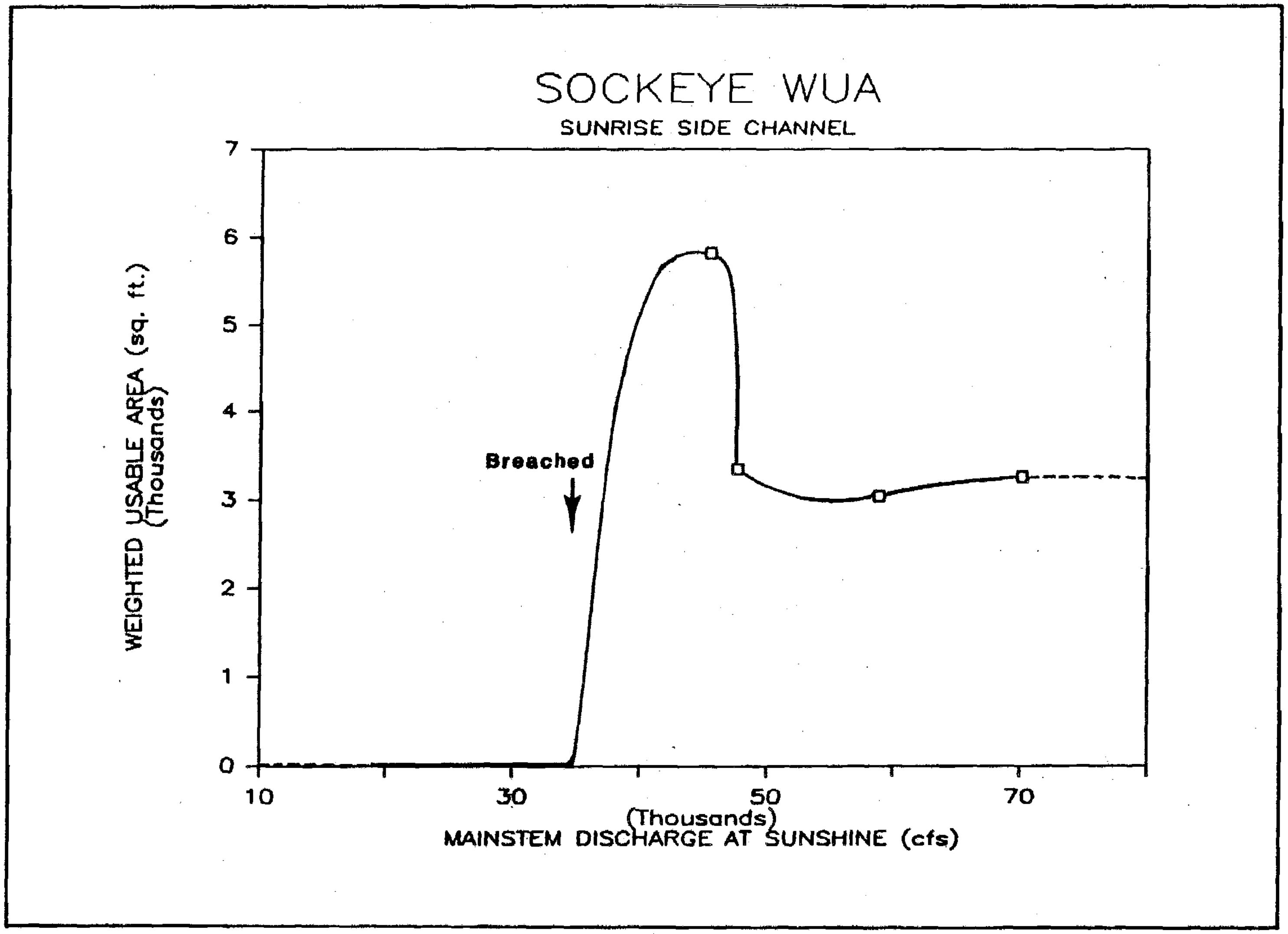
MAINSTEM DISCHARGE	SITE AREA	SOCKEYE WUA	SOCKEYE H. I.
12000	49562	7182	0.14
15000	49562	7182	0.14
18000	49562	7182	0.14
21000	49562	7182	0.14
24000	49562	7182	0.14
27000	49562	7182	0.14
30000	49562	7182	0.14
33000	78488	6738	0.09
36000	89472	6493	0.07
39000	97943	6639	0.07
42000	106320	6828	0.06
45000	122338	7412	0.06
48000	135476	7529	0.06
51000	149248	7108	0.05
54000	165990	6643	0.04
57000	173483	6006	0.03
60000	188419	6682	0.04
63000	194419	6275	0.03
66000	203000	6740	0.03
69000	206972	6850	0.03
72000	210728	7124	0.03
75000	215861	7861	0.04

SUNRISE SIDE CHANNEL

MAINSTEM DISCHARGE	SITE AREA	SOCKEYE WUA	SOCKEYE H. I.
12000	0	0	0.00
15000	0	0	0.00
18000	0	0	0.00
21000	0	0	0.00
24000	0	0	0.00
27000	0	0	0.00
30000	0	0	0.00
33000	0	0	0.00
36000	19000	400	0.02
39000	53900	4700	0.09
42000	78500	5800	0.07
45000	97100	5800	0.06
48000	115400	3400	0.03
51000	131100	3200	0.02
54000	146900	3100	0.02
57000	160600	3000	0.02
60000	175600	3000	0.02
63000	192000	3100	0.02
66000	207300	3100	0.01
69000	221400	3200	0.01
72000	229000	3200	0.01
75000	233300	3200	0.01



Appendix Figure B-15. Weighted usable area for juvenile sockeye salmon at Caswell Creek and Beaver Dam tributary study sites as a function of mainstem discharge.



Appendix Figure B-16. Weighted usable area for juvenile sockeye salmon at Sunrise Side Channel study site as a function of mainstem discharge.

APPENDIX C

COMPARISON OF THE IFIM AND RJHAB MODELLING TECHNIQUES AT TWO SELECTED SITES

INTRODUCTION

In 1983, two techniques were used to model the effects of mainstem discharge on juvenile salmon habitat within the middle Susitna River. The Instream Flow Incremental Methodology (IFIM) (Bovee 1982) was used at seven sites (Hale et al. 1984) and the RJHAB habitat model developed in Marshall et al. (1984) was used to model six other sites. Since studies of the effects of mainstem discharge on juvenile salmon habitat within the lower Susitna River were begun in 1984, it was desirable to compare these two modelling methods. Both methods were used, therefore, at the same transects within two sites to compare results from the two techniques.

METHODS

Trapper Creek Side Channel (RM 91.6) and Island Side Channel (RM 63.2) were selected as sampling sites for this comparative study because they represent two different channel types of the lower Susitna River. Trapper Creek Side Channel is a simple straight channel. Island Side Channel is a more complex, winding channel. Further descriptions and photos of these two sites are contained in Quane et al. (1985).

Descriptions of the two modelling techniques will not be presented here. Detailed descriptions of the IFIM are presented in Appendix D of this report and Bovee (1982), and summarized in Section 2.0 of this report. The original RJHAB model was first developed and described in Marshall et al. (1984) and modifications were described in Section 2.0 of this report.

Both techniques entail taking depth, velocity, and cover or substrate measurements spaced at intervals across transects running at right angles to the channel. Hydraulic models which have been developed for use in the IFIM include the IFG-2 model which is based on open channel flow theory and one set of field data and the IFG-4 model which is based more strongly on field data as three sets of field measurements are recommended (Milhous et al. 1981). Fewer measurements are taken for each RJHAB field data set than for the IFIM models but up to seven data sets are taken. No hydraulic model is developed by the RJHAB and the model runs on a spreadsheet with a microcomputer. The IFIM models can generate estimates of equivalent optimum habitat called weighted usable areas (WUA's) with any flow within their calibration range, while the RJHAB model only calculates WUA's at discharges for which measurements are taken. Therefore, it is necessary to interpolate between point measurements generated by the RJHAB model. The RJHAB model does have the advantage of being able to run in areas heavily influenced by mainstem backwater or sloughs with flows less than 5 cfs. The measurements and data analysis for the RJHAB model were taken by different investigators than those who took the IFIM measurements and analyzed them.

The RJHAB model uses measurements at an additional upper transect within each of the sites. This upper area was very similar to lower sections of the site, and therefore would not change comparability of the two methods. The IFIM presents results of the analysis on the basis of a 1000 foot reach, while the RJHAB model presents WUA's for the site. Therefore, the length of each site as used in the RJHAB model was calculated and WUA's were adjusted to the basis of a 1000 foot reach.

At Island Side Channel, two additional partial transects were put in for IFIM analysis of the site (see Appendix D), and no RJHAB measurements were taken at these transects. A trial run which minimized the effect of these two additional transects showed only very minor changes in WUA.

RESULTS

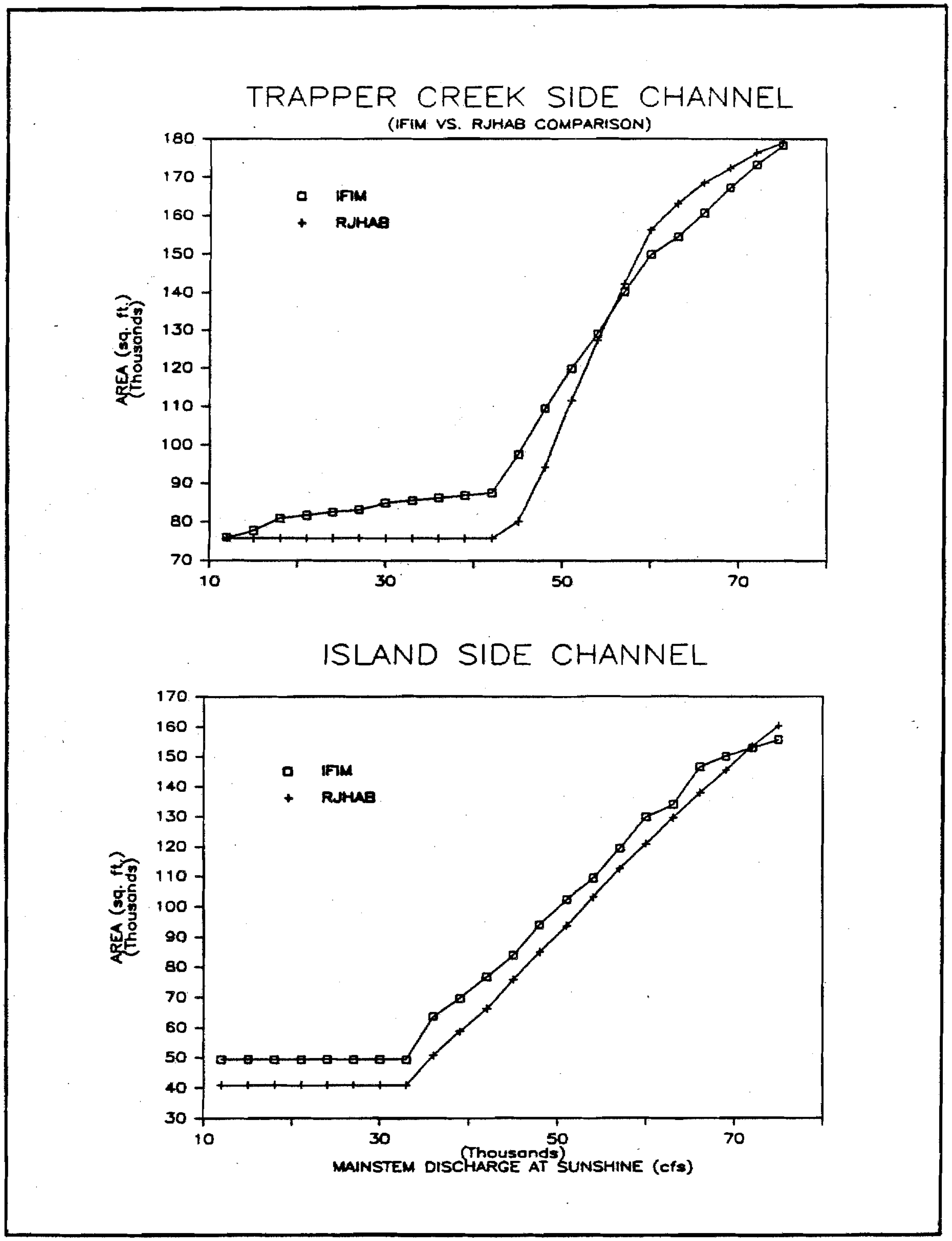
An IFG-2 IFIM model was run at Island Side Channel and hydraulic data were collected at a side channel flow of 338 cfs (Appendix D). At Trapper Creek Side Channel, hydraulic data for an IFG-4 IFIM model were collected at flows of 16, 32, and 389 cfs. Habitat data for the RJHAB model were collected four times at Trapper Creek Side Channel and five times at Island Side Channel and the RJHAB models at both sites were evaluated as "good" (Table 6).

The modelled response of area at the Trapper Creek and Island side channel sites to changes in discharge was almost identical for both the IFIM and RJHAB modelling techniques (Appendix Figure C-1). Differences in areas below the overtopping flow at Island Side Channel are probably due to the IFIM not being able to model flows below 5 cfs while the RJHAB WUA was measured at a flow of less than one cfs. Other differences are readily attributable to sampling error. Since juvenile chinook and chum salmon are the two salmon species which make the heaviest use of side channels for rearing, only WUA results from these two species will be presented here.

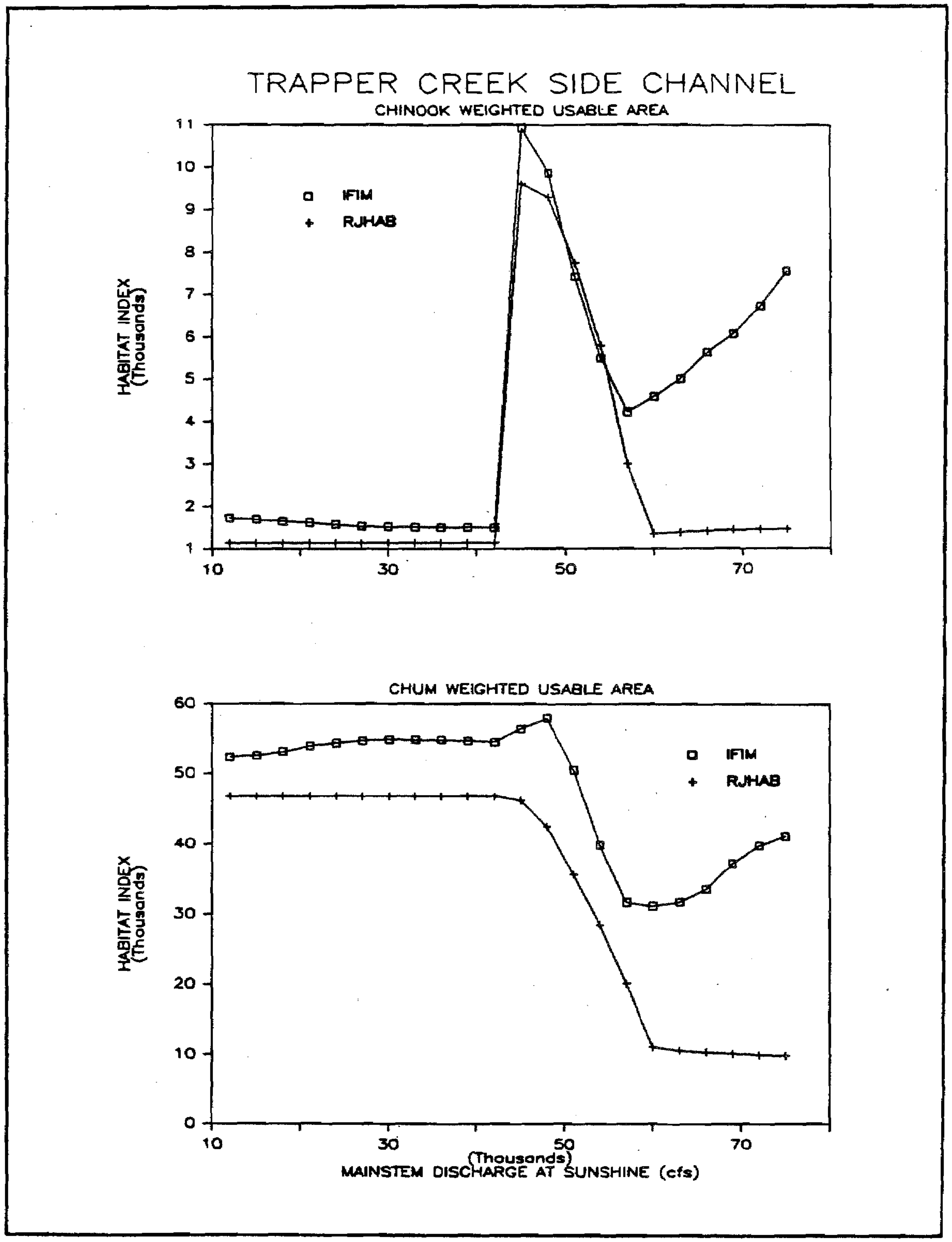
At Trapper Creek Side Channel, the shape of the WUA curves for both species were basically the same for both modelling methods (Appendix Figure C-2). The RJHAB model appears to consistently underestimate the amount of WUA in comparison to the IFIM model. The underestimation of WUA by the RJHAB model leads to smaller habitat indices although the shapes of the habitat index curves are similar for both techniques (Appendix Figure C-3).

At Island Side Channel, on the other hand, WUAs from the two modelling methods do not compare closely (Appendix Figure C-4). The chinook and chum WUA response curves look more similar to each other than do the modelling techniques. Peaks in WUA for the RJHAB model occur at approximately 40,000 cfs while the IFIM model predicts a peak WUA at approximately 60,000 cfs. The IFIM model does predict a chinook salmon WUA of 6,230 ft^2 to 6,600 ft^2 at side channel flows of 6 to 11 cfs which corresponds to the peak in the RJHAB model where a measurement was taken at a side channel flow of approximately 10 cfs.

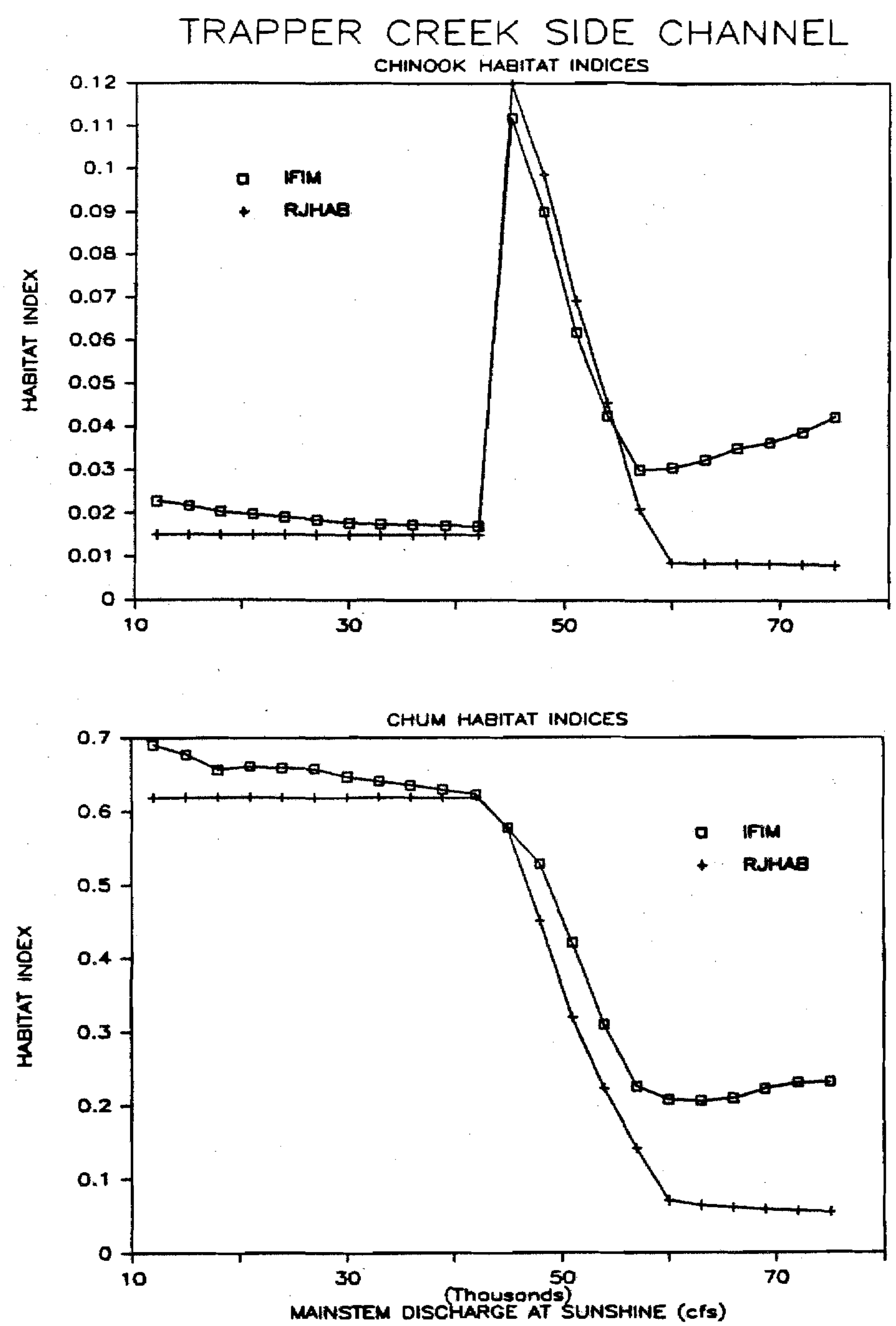
When habitat indices are calculated for both methods at Island Side Channel, differences between the two techniques appear smaller (Appendix Figure C-5). The RJHAB model shows a peak habitat index for chinook salmon at approximately 39,000 cfs which the IFIM model would also show at side channel flows of 6 to 11 cfs. Chum habitat indices for both



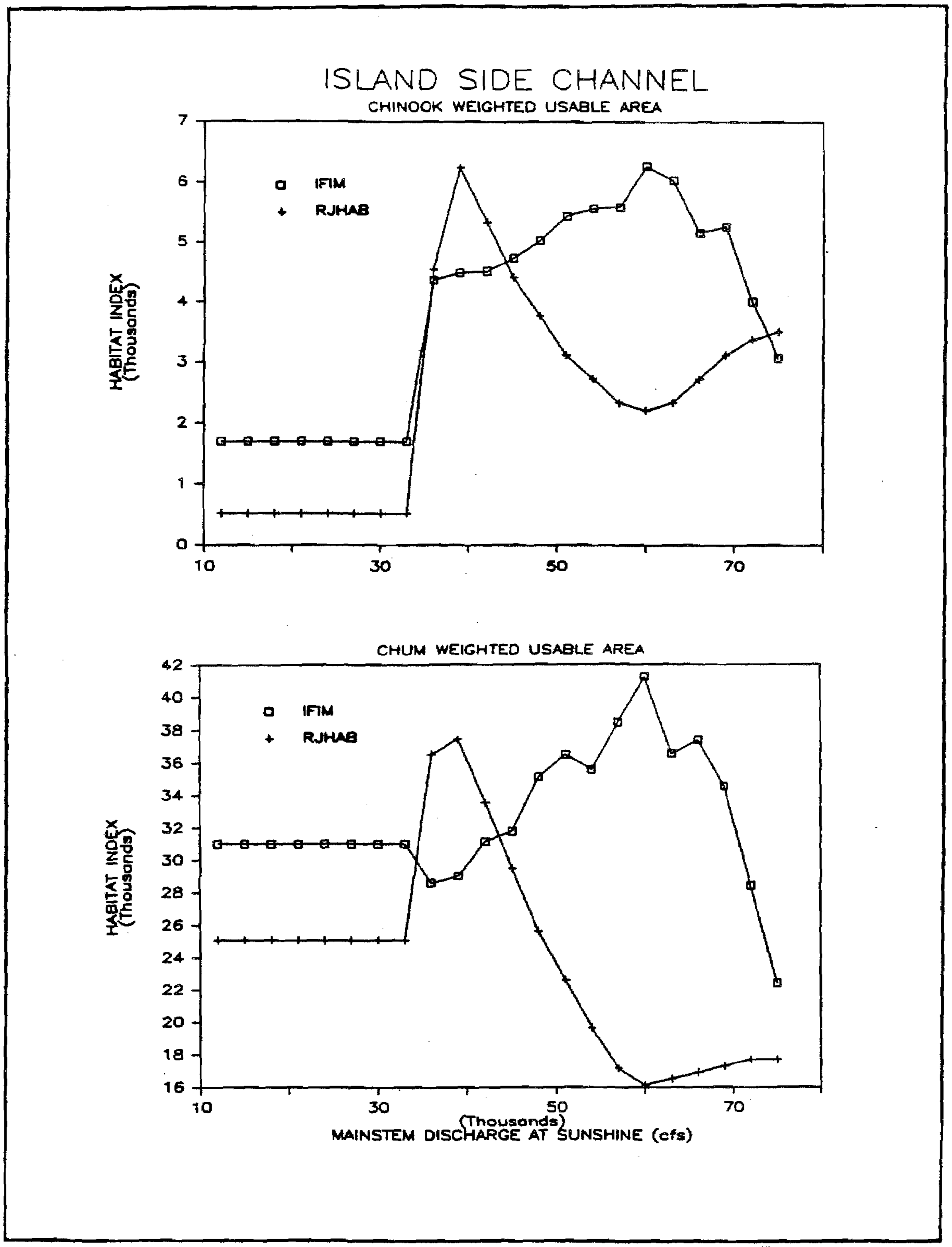
Appendix Figure C-1. Comparison of site areas calculated with the RJHAB and IFIM modelling techniques for the Trapper Creek and Island Side Channel study sites.



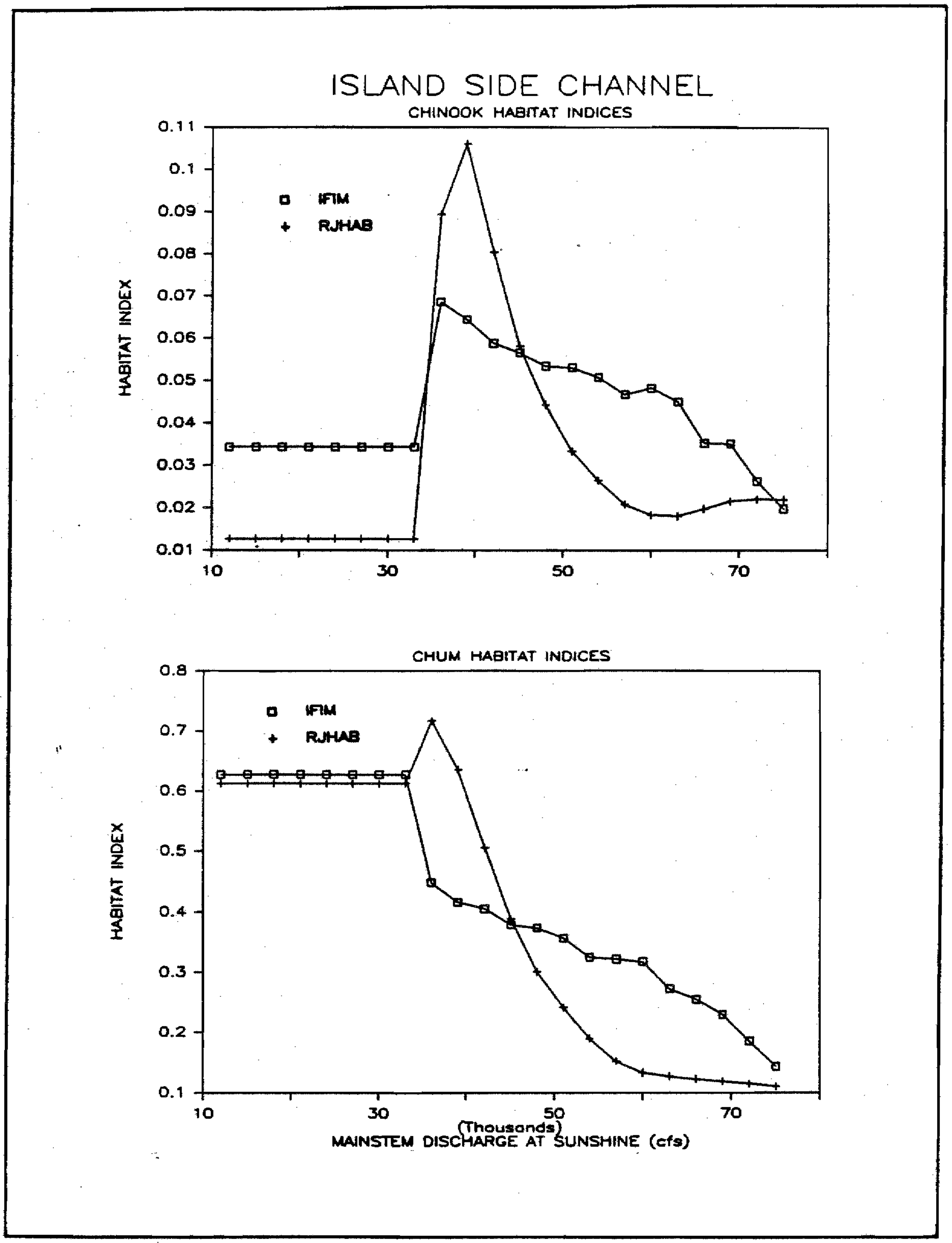
Appendix Figure C-2. Comparison of weighted usable areas calculated with the RJHAB and IFIM modelling techniques for juvenile chinook and chum salmon at Trapper Creek Side Channel, 1984.



Appendix Figure C-3. Comparison of habitat indices calculated with the RJHAB and IFIM modelling techniques for juvenile chinook salmon at Trapper Creek Side Channel, 1984.



Appendix Figure C-4. Comparison of weighted usable areas calculated with the RJHAB and IFIM modelling techniques for juvenile chinook and chum salmon at Island Side Channel, 1984.



Appendix Figure C-5. Comparison of habitat indices calculated with the RJHAB and IFIM modelling techniques for juvenile chinook and chum salmon at Island Side Channel, 1984.

techniques decrease after overtopping although the RJHAB habitat indices drop off more steeply.

DISCUSSION

The two modelling methods compared very favorably at calculating areas within the two sites. The shape of the chum and chinook WUA and habitat index responses at Trapper Creek Side Channel were very similar. The RJHAB model consistently underestimated WUA in comparison to the IFIM model. This is probably due to the RJHAB model not taking into account the area between the shoreline cell and the cell located one-third of the way across the channel. This area was often marginal habitat with barely suitable velocities.

At Island Side Channel, large differences in WUA can also be attributed, in part, to the RJHAB model not taking into account peripheral marginal habitat more than six feet from shore. This difference is also reflected in the habitat indices where the proportion of usable area drops off more quickly for the RJHAB model. The differences in WUA below the overtopping flow can be attributed to the fact that the IFIM model does not run at flows less than five cfs while actual flows at discharges below the overtopping one are less than one cfs (Quane et al. 1985).

The effects of sampling errors in data collection on WUA estimates from both the RJHAB and IFIM techniques are unknown. Since many more measurements are taken for the IFIM, it should be less susceptible to sampling errors. Because only one IFIM measurement was taken at Island Side Channel at a flow of 338 cfs, however, the reliability of modelling flows as small as 5 cfs is unknown. It seems reasonable to assume that an IFG-4 model at Island Side Channel would have given somewhat different results than did the IFG-2 model. The RJHAB model works well in situations where the primary effect of discharge is due to backwater and the IFIM model cannot be used or works poorly.

In summary, the RJHAB model generally gives lower WUA estimates than does the IFIM methodology. Also peaks in WUA are often narrower for the RJHAB model. Both models show the same general trends in the habitat indices for chum and chinook salmon although the RJHAB model is more sensitive to increases in velocity and depth which decrease the habitat indices more quickly. Since the habitat indices for both sites calculated using both techniques are not appreciably different, analysis of trends and optimal flows by use of habitat indices would lead to similar conclusions using both methods. Comparisons of the IFIM with other instream flow methodologies have also shown differences in output, and no one method has yet been proven best (Annear and Conder 1984).

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APPENDIX D

HYDRAULIC MODELS FOR USE IN ASSESSING THE REARING HABITAT OF JUVENILE SALMON IN SIX SIDE CHANNELS OF THE LOWER SUSITNA RIVER

APPENDIX D

HYDRAULIC MODELS FOR USE IN ASSESSING THE REARING HABITAT OF JUVENILE SALMON IN SIX SIDE CHANNELS OF THE LOWER SUSITNA RIVER

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ABSTRACT

Six side channels (Island, Mainstem West Bank, Circular, Sauna, Sunset, and Trapper Creek) in the lower reach of the Susitna River were evaluated using an Instream Flow Incremental Methodology (IFIM) physical habitat simulation (PHABSIM) modelling approach to describe the effects that site flow and mainstem discharge have on rearing juvenile salmon habitat. These sites were thought to contain potential habitat for rearing juvenile salmon and were chosen to range greatly in size, shape, and overtopping discharge.

Six hydraulic simulation models (either IFG-2 or IFG-4) were calibrated to simulate depths and velocities associated with a range of site-specific flows at the six modelling study sites. Comparisons between corresponding sites of simulated and measured depths and velocities indicated that the models provide reliable estimates of depths and velocities within their recommended calibration ranges.

The recommended of ranges of mainstem Susitna River discharge over which these models can hydraulically simulate the habitat of rearing juvenile salmon are: Island Side Channel from 35,000 to 70,000 cfs mainstem discharge; Mainstem West Bank Side Channel from 18,000 to 48,000 cfs; Circular Side Channel from 36,000 to 63,000 cfs; Sauna Side Channel from 44,000 to 63,000 cfs; Sunset Side Channel from 32,000 to 67,000 cfs; and Trapper Creek Side Channel from 20,000 to 66,000 cfs.

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INTRODUCTION

About 40% of the annual discharge of the lower Susitna River at the Parks Highway bridge originates from the mainstem Susitna River above the confluence of the Talkeetna and Chulitna Rivers (Acres 1982). Thus, operation of the proposed hydroelectric project will alter the natural flow regime of this lower river reach beyond the normal variations in flow which occur naturally during the open-water season.

One of the predominant aquatic habitat types in this lower river reach which may be affected by such flow alterations are side channels. Side channel areas in this river reach currently provide habitat for rearing juvenile salmon. The quantity and quality of juvenile salmonid rearing habitat in side channels in this river reach is dependent on a multitude of interrelated habitat variables, including water depth and velocity, which are intimately related to mainstem discharge.

This appendix presents results of the physical habitat modelling simulation efforts that Alaska Department of Fish and Game (ADF&G) Su Hydro personnel conducted during the open-water season of 1984. The objective of the study was to provide calibrated hydraulic simulation models for selected lower river juvenile salmon habitat modelling study sites. The approach of the study was to apply a methodology which used water depth and velocity as the dominant hydraulic variables to quantify the responses of rearing habitat to changes in site flow and mainstem discharge. The methodology used was the system developed by the U.S. Fish and Wildlife Service (USF&WS) Instream Flow Group (IFG) called the Instream Flow Incremental Methodology (IFIM) Physical Habitat Simulation (PHABSIM) modelling system (IFG 1980, Bovee 1982). The calibrated hydraulic simulation models will be utilized to assess how site flows and mainstem discharge affect juvenile salmon rearing habitat in side channels of the lower Susitna River.

METHODS

Analytical Approach

A common methodology used for assessing habitat responses to flow variations is the IFIM, PHABSIM modelling system. The IFIM, PHABSIM modelling 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. It is based on the theory that changes in riverine habitat conditions can be estimated from a sufficient hydraulic and biological field data base. It is intended for use in those situations where flow regime and channel structure are the major factors influencing river habitat conditions.

The modelling 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 habitat variables important for the species/life phase under study as a function of flow. The second step involves the collection and analysis of biological data to determine the behavioral responses of a particular species/life phase to important physical habitat variables. This information is used to develop weighted behavioral response criteria curves (e.g., utilization curves, preference curves, or suitability curves). The third step combines information gained in the first two steps to calculate weighted usable area (WUA) indices of habitat usability as a function of flow for the species/life phase under study.

Hydraulic modelling is of central importance to the PHABSIM system. The primary purpose of incorporating hydraulic modelling into the 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 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 open channel flow 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. Either model can be used to forecast depths and velocities occurring in a stream channel over a broad range of streamflow conditions.

The IFG-4 model, which is based upon a greater number of observed sets of field data (i.e. flow levels), generally can be used to model a greater range of flow conditions than the IFG-2 model. Additionally, since the IFG-4 model is more dependent upon observed depths and velocities than the IFG-2 model, predicted depths and velocities can be directly compared with the observed values. This comparison is a useful tool for verifying the models.

Both models are most applicable to streams of moderate size and are based on the assumption that steady flow conditions exist within a rigid stream channel. 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. 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 (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 Sunshine, Alaska (station number 15292780). This location was selected as the index station primarily because it is the gage located near the center of the river segment that is of greatest interest in this particular analysis. The target mainstem discharge range for data collection was from 12,000 to 75,000 cfs.

Site specific streamflow data collected during 1984 provided the basis for correlating flow through the various study sites to the average daily streamflow of the Susitna River at the Sunshine gage. Detailed site specific channel geometry and hydraulic measurements provided the necessary data base to calibrate hydraulic models for each study site.

Information for two other physical habitat variables, substrate and cover, were also collected. Substrate was not incorporated into the models at this time, but cover, an important variable in assessing the habitat quality for most rearing salmon juveniles, was.

These data and hydraulic models make up the physical habitat component of the PHABSIM analysis. For a given discharge of the Susitna River at Sunshine, the flow through each study site can be determined and site specific hydraulic conditions (velocity and depth) can be predicted. The results based on velocity, depth, and cover may be used to forecast the effects of mainstem discharge on the weighted usable area for juvenile rearing salmonids of these modelled side channel habitats.

Study Site Selection

Two basic approaches are commonly used for selecting study sites to be evaluated using the IFIM PHABSIM modelling system: the critical and representative concepts (Bovee and Milhous 1978; Trihey 1979; Bovee 1982). Application of the critical 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 concept are less restrictive, enabling this concept to be used when only limited biological information is available or when critical habitat conditions cannot be identified with any degree of certainty.

In the critical concept, a study area is selected because one or more of the physical or chemical attributes of the habitat are known to be of critical importance to the fish resource. That is, recognizable physical or chemical characteristics of the watershed hydrology, instream hydraulics, or water quality are known to control species distribution or relative abundance within the study area. Because of this, an evaluation of critical areas will provide a meaningful index of species response in the overall critical study area.

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

For this study, an adaptation of the representative concept was the approach used to assess how mainstem discharges affect the rearing habitat of juvenile salmon in side channel complexes. The six lower river IFG study sites are most representative, morphologically, of intermediate side channels and of the habitat type designation, secondary side channel as described by Ashton and Klinger-Kingsley (1985). The results from these six IFIM-PHABSIM models are probably most applicable to these types of areas in segments I and II of the lower Susitna River. This segmentation of the lower river is also described in Ashton and Klinger-Kingsley (1985). The six study sites were chosen by ADF&G Su Hydro Resident and Juvenile Anadromous (RJ) project personnel in conjunction with ADF&G Su Hydro Aquatic Habitat and Instream Flow Study (AH) project and E. Woody Trihey and Associates (EWT&A) personnel from lower river side channels which met the following basic criteria:

1. The sites were chosen to range greatly in size, shape, and overtopping discharge;
2. The sites were thought to contain potential habitat conditions for rearing juvenile salmon;
3. The sites were judged by AH project and EWT&A personnel to be readily modelled using the IFIM methodology;
4. The sites were accessible by boat at normal mainstem discharges during the open-water season; and,
5. The sites were above Kashwitna landing and therefore much easier to sample for logistical purposes.

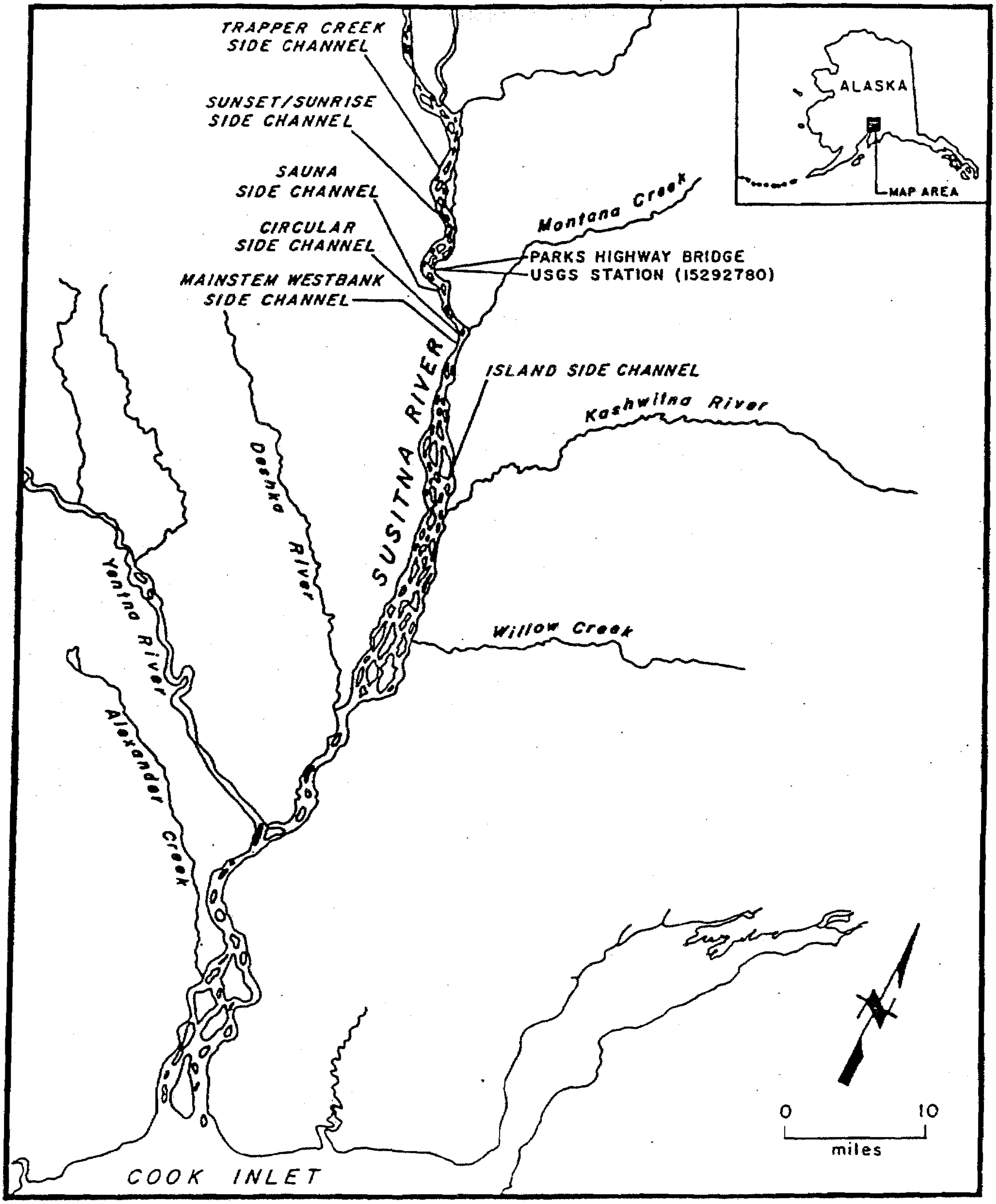
The six sites chosen for modelling complemented other sites modelled using another habitat model (see main text). All of the six sites were side channels, the majority of potential habitat in the lower river is composed of this habitat. Much of the other habitat is difficult to model with the IFIM methodology because it is affected primarily by mainstem backwater. Appendix Figure D-1 shows the location of each of the six sites selected for study, the corresponding river mile location is presented in Appendix Table D-1.

General Techniques for Data Collection

A study reach was selected for detailed evaluation in each of the six side channel sites. The length of the reach was determined by placing enough transects within the area to adequately represent the major macrohabitat types of the particular side channel area.

Transects were located within each study reach following field methods described in Bovee and Milhous (1978) and Trihey and Wegner (1981), and were located to facilitate collection of hydraulic and channel geometry measurements of importance in evaluating flow effects on salmon rearing habitat. Field data were obtained to describe a representative spectrum of water depth and velocity patterns, cover, and substrate composition at each side channel reach.

The number of transects established at the study reaches varied from four to eight. The end points of each transect were marked with 30-inch steel rods (headpins) driven approximately 28 inches into the ground. The elevation of each headpin was determined by differential



Appendix Figure D-1. Location of the six IFG hydraulic modelling sites in the lower Susitna River.

Appendix Table D-1. The six lower river IFG modelling sites with corresponding river mile location.

Side Channel Site	River Mile
Island Side Channel	63.2
Mainstem West Bank Side Channel	74.4
Circular Side Channel	75.3
Sauna Side Channel	79.8
Sunset Side Channel	86.9
Trapper Creek Side Channel	91.6

leveling using temporary benchmarks set at assumed elevations of 100.00 feet.

Cross section profiles at each transect were measured with a level, survey rod, and fiberglass tape. Horizontal distances were recorded to the nearest 1.0 foot and streambed elevations to the nearest 0.1 foot. Water surface elevations at each cross section in the study site were determined to the nearest 0.01 foot by differential leveling or by 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 (Trihey 1980).

A longitudinal streambed profile (thalweg profile) was surveyed and plotted to scale for each modelling site (Quane et al. 1985).

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 1969; 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 to the left bank headpin.

Cover and substrate values were also determined for each cell along modelling transects. Methods described in Suchanek et al. (1985) were used to code cover (Appendix Table D-2). Substrate categories were classified by visual observation employing the substrate classifications presented in Appendix Table D-3. The distribution of various substrate types was indicated on field maps. Substrates were classified using a single or dual code. In those instances that a dual code was used, the first code references the most predominant (i.e., 70% rubble/30% cobble = 9/11).

General Techniques for Calibration

The calibration procedure for each of the hydraulic models was preceded by 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 obtained at each of the different calibration flows. The data reduction entailed determining the streambed and water surface elevations, velocity distribution, the stage of zero flow for each cross section, and determining a mean discharge for all the cross sections in the study site. A model was considered calibrated when: 1) the

Appendix Table D-2. Percent cover and cover type categories.

Cover Type	Code	% Cover	Code
silt, sand (no cover)	1	0-5	.1
emergent vegetation	2	6-25	.2
aquatic vegetation	3	26-50	.3
1-3" gravel	4	51-75	.4
3-5" rubble	5	76-100	.5
5" cobble, boulder	6		
debris	7		
overhanging riparian vegetation	8		
undercut bank	9		

Appendix Table D-3. Substrate classifications.

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

majority of predicted water surface profiles were within ±0.05 ft of the observed elevations and 2) the majority of predicted velocities were within ±0.10 ft/sec of the measured velocities. 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 is reviewed with the observed data before it is considered calibrated.

For a more detailed explanation of the general techniques used for calibrating the IFG-2 and IFG-4 models in the lower river see Hilliard et al. (1985).

General Techniques for Verification

The verification of how well each of these six hydraulic models simulated their respective site flows was performed by the hydraulic engineers at EWT&A. The approach used to assess the quality of each model was based on two levels of criteria. The first was a qualitative evaluation of four separate sub-criteria. These sub-criteria were:

1. How well does the model conform to the IFG (Main 1978 and Milhous et al. 1984) and EWT&A (Hilliard 1985) guidelines?

2. How well does the extrapolation range of the model conform to the desired range?

3. Are the models appropriate for the species and life stage being considered?

4. How well do the ranges of depth and velocities of the forecasted data conform to the ranges of depth and velocity of the suitability criteria curves being considered based on a "visual" evaluation?

After the first level of qualitative evaluation was performed, an overall rating was given to the various segments of each model. The ratings given were excellent, good, acceptable, and unacceptable. Figures depicting these rating are presented for each site in the results section. The second level of the verification process required a statistical analysis to evaluate the models calibration. It was only performed when the forecast capabilities of either the IFG-2 and IFG-4 model were not given an excellent rating in the level one evaluation. For a detailed explanation of the verification analysis see Hilliard (1985).

RESULTS

The results of the physical habitat simulation modelling studies are presented below by study site. The six lower river side channel IFG modelling sites with type of hydraulic model used, dates calibration flows were measured, and corresponding site specific flows and mainstem discharges for the open-water period in 1984 are presented in Appendix Table D-4. The following items are presented for each study site: (1) a general site description, (2) a summary of data collected, (3) a description of procedures used to calibrate the model, (4) the verification of the model, and (5) the recommended application of the model for each study site.

Appendix Table D-4. The six lower river side channel IFG modelling sites with type of hydraulic model used, dates calibration flows measured, and corresponding site specific flows and mainstem discharges for the open water period in 1984.

Side Channel Site (RM)	Type of Hydraulic Model	Date Calibration Flow Measured	Site Specific Flow (cfs)	Mainstem Discharge at Sunshine[a] (cfs)
Island Side Channel (63.2)	IFG-2	July 25	338	56,100
Mainstem West Bank (74.4)	IFG-4	September 2	450	32,000
		September 20	310	30,500
		September 25	6	19,600
Circular Side Channel (75.3)	IFG-4	July 24	204	55,200
		August 17	50	42,500
Sauna Side Channel (79.8)	IFG-2	July 23	52	52,000
Sunset Side Channel (86.9)	IFG-4	July 22	496	57,800
		August 17	127	42,500
Trapper Creek Side Channel (91.6)	IFG-4	September 18	16	20,900
		August 16	32	44,000
		July 21	389	57,700

[a] Mainstem discharge determined from provisional USGS streamflow data from the stream gage at Sunshine, Alaska (station number 15292780).

Island Side Channel (RM 63.2)

Site Description

Island Side Channel is located on the east bank of the main channel of the Susitna River at river mile (RM) 63.2 (Appendix Figure D-2). This side channel is located downstream of a braided, vegetated floodplain and is not directly connected to the main channel Susitna River. It is approximately 0.7 miles in length with both the mouth and head portions adjoining side channel networks. Breaching flows in this side channel result from overtopping of the head by an adjoining larger side channel. Prior to breaching, flow in the side channel is small with a series of pools remaining (Quane et al. 1985).

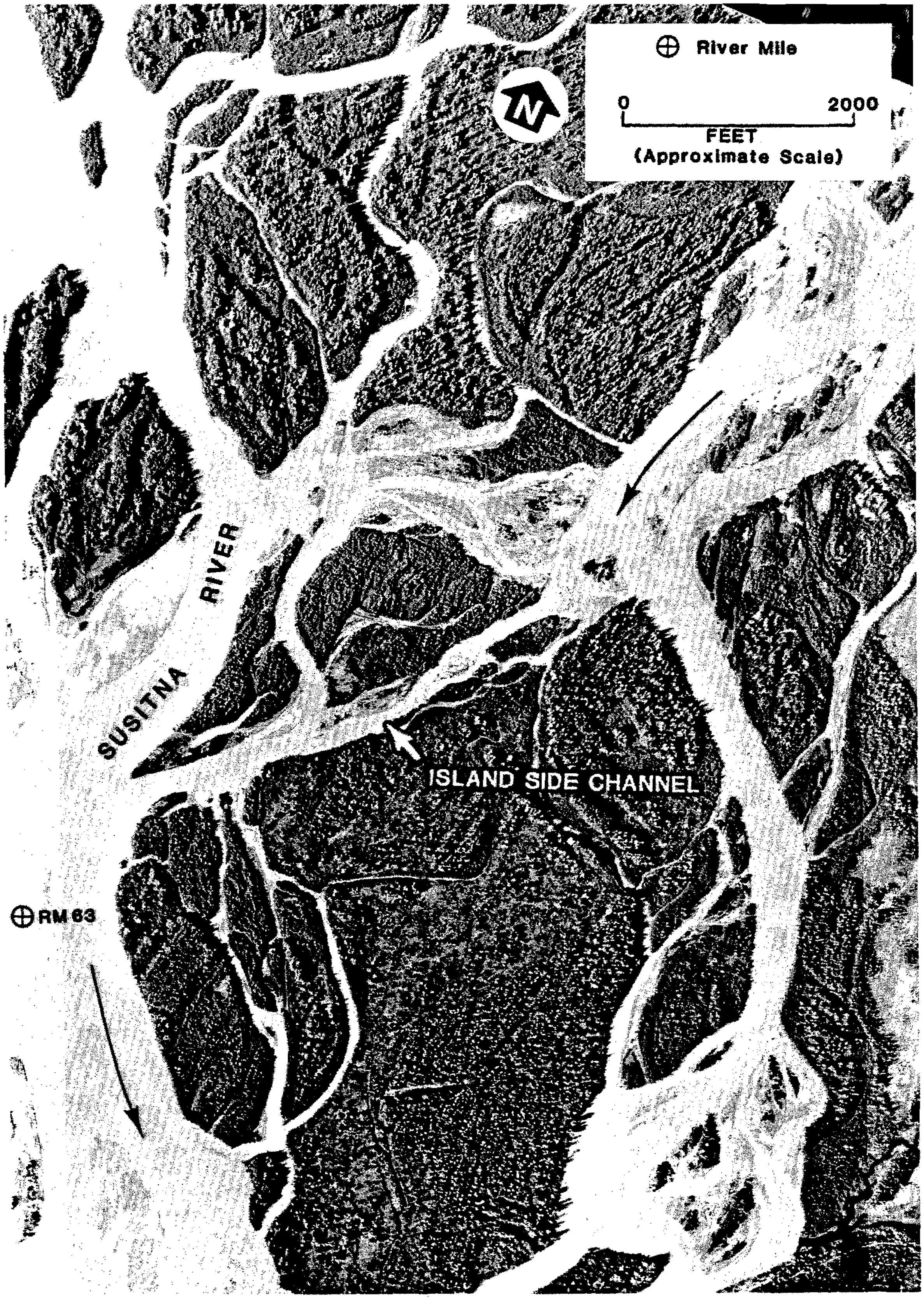
The IFG modelling site at Island Side Channel was 735 feet long and located in the lower portion of the side channel (Appendix Figure D-3). The site generally consists of a pool-riffle-pool sequence. Based on assessments by Quane et al. (1985), an area of backwater extends through the study site to a point at least 1,100 feet upstream from the mouth of the side channel at a non-breaching mainstem discharge of 35,000 cfs. During mainstem discharges of 38,000 to 66,700 cfs, the area of backwater extends throughout the study site.

The right bank of the study site is about five feet high, and the bank is steep due to the effects of erosion. The primary riparian vegetation along this bank is alder. There are two side pocket areas along this bank, which become slack water areas during higher site flows (400 cfs). In contrast, the left bank of the study site is a gently sloping depositional bank. The riparian vegetation on this bank is sparse consisting primarily of shrub willow.

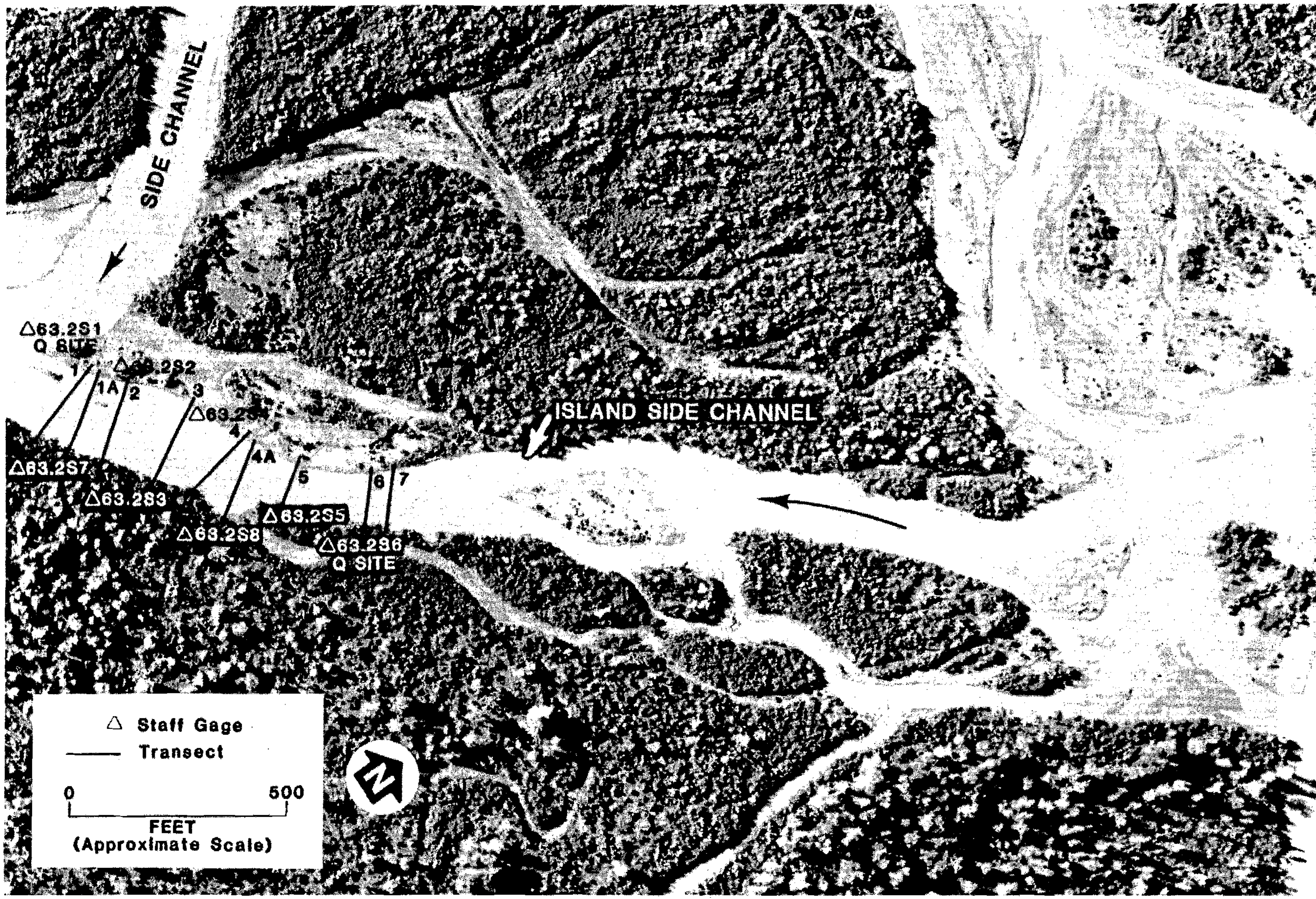
Substrate at the study site consists primarily of gravels and rubbles, with substrate changing to sand and silt in slackwater areas. The thalweg gradient of the side channel is 15.6 ft/mile (Quane et al. 1985). From an evaluation of field observations, aerial photography, and the stage/discharge relationship developed for this side channel, an initial breaching has been estimated to occur at a discharge of 34,000 cfs (Quane et al. 1985).

Based on a review of available rating curves (Appendix Figure D-4) it was determined that the hydraulics within this side channel are directly controlled by mainstem discharges exceeding 35,000 cfs (Quane et al. 1985). A side channel streamflow of 43.5 cfs has been estimated to occur at a mainstem discharge of 35,000 cfs (Quane et al. 1985).

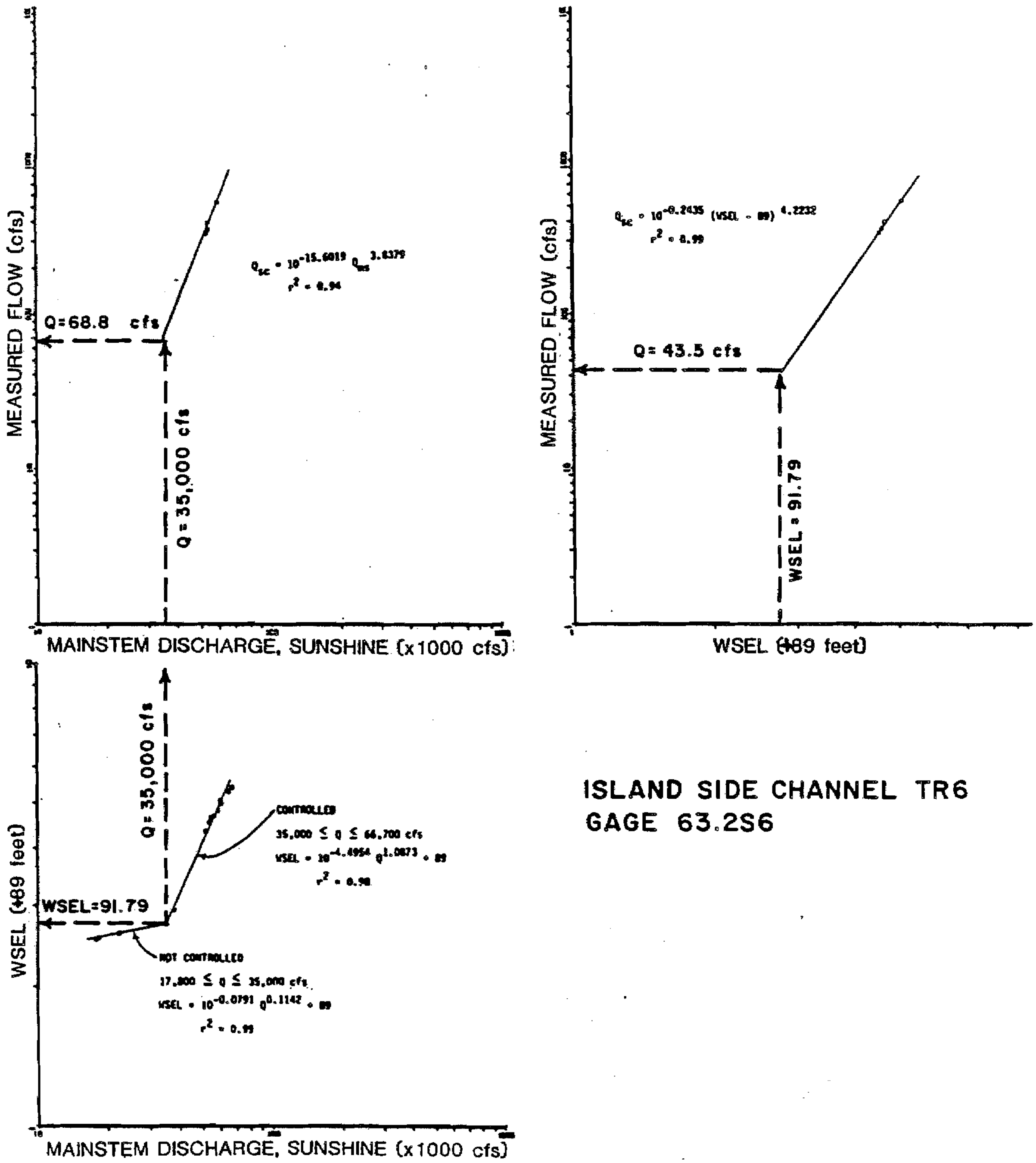
Eight cross sections were surveyed within this site during 1984 to define channel geometry (Appendix Figures D-5 & D-6). The upper two transects (5 and 6) were primarily located in pool habitat. Transects 4A and 4 primarily represent riffle habitat in the main portion of the channel. Transect 4A was placed as a partial transect originating from the right bank. It represents the larger of the two slack water areas in this reach. The four downstream most transects are primarily in pool type habitat. Transect 1A was also a partial transect, representing the smaller slack water area along the right bank.



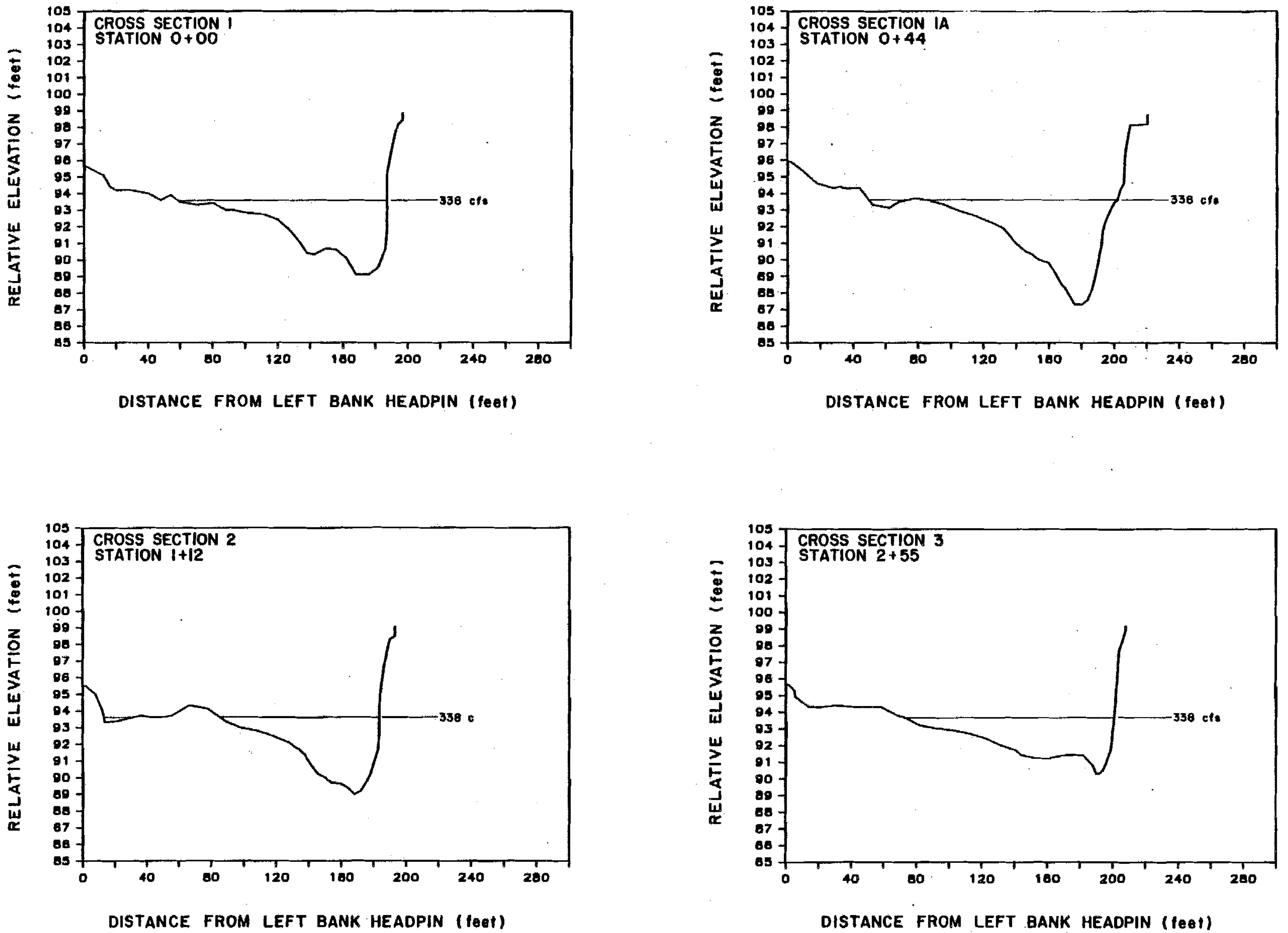
Appendix Figure D-2. Overview of Island Side Channel (RM 63.2).



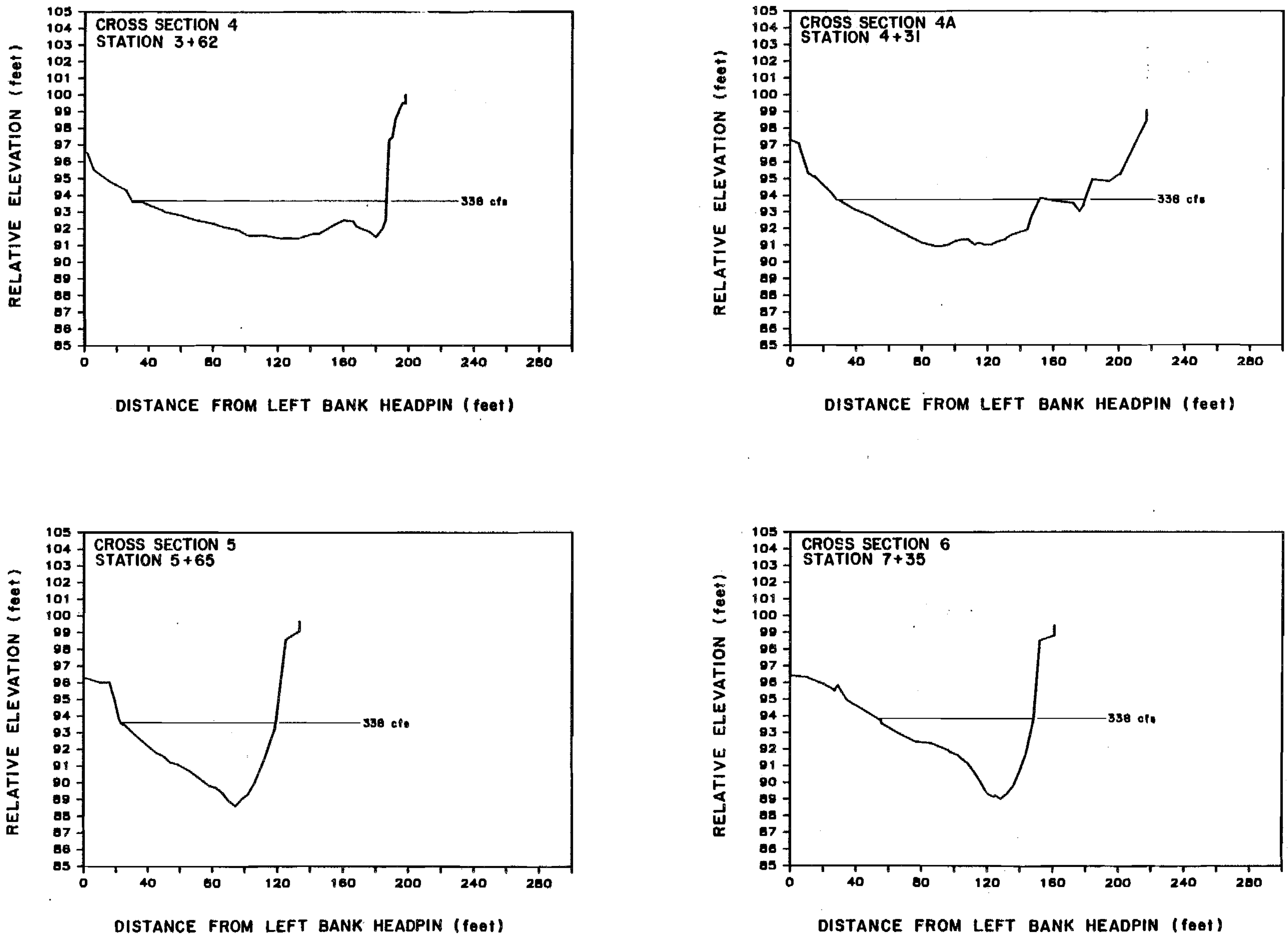
Appendix Figure D-3. Location of Island Side Channel study site (RM 63.2).



Appendix Figure D-4. Comparison of rating curves for Island Side Channel transect 6(Q site) (from Quane et. al. 1985).



Appendix Figure D-5. Cross section of transects 1, 1A, 2, and 3 at Island Side Channel (adapted from Quane et al. 1985).



Appendix Figure D-6. Cross section of transects 4, 4A, 5, and 6 at Island Side Channel (adapted from Quane et al. 1985).

Calibration

Calibration data available at the close of 1984 field season were limited to that obtained for a side channel flow of 338 cfs (56,100 cfs mainstem discharge) (Appendix Table D-4). As a result, an IFG-2 model was used to forecast instream hydraulics based on this single calibration flow. The streambed profile, stages of zero flow, and observed and predicted water surface elevations for this study reach are plotted to scale in Appendix Figure D-7.

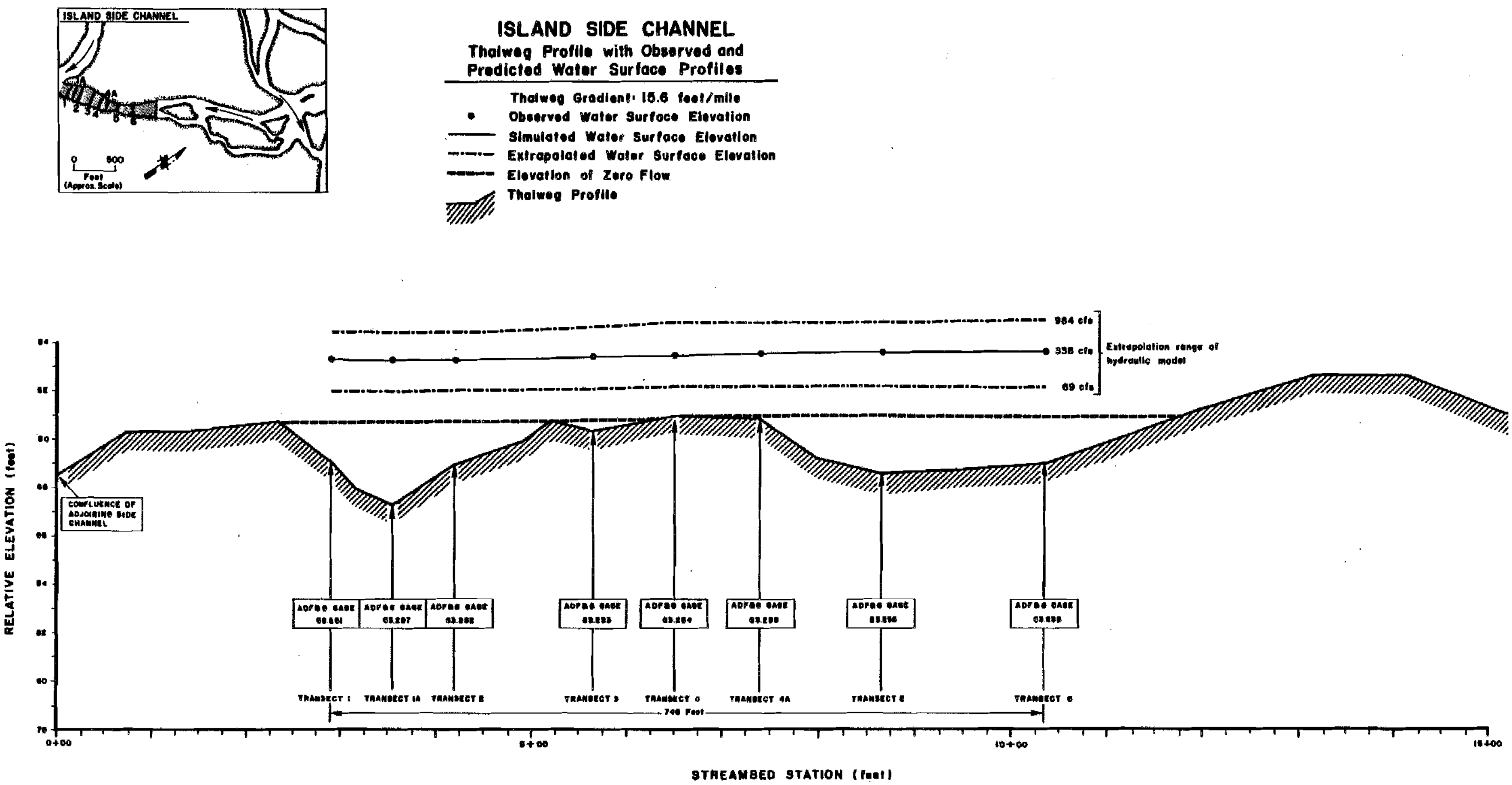
The original field water surface elevations (WSEL's) were compared to the model predicted WSEL's for the calibration flow of 338 cfs (Appendix Table D-5). At transect 1A, the original field WSEL was surveyed at 93.46 feet. In examining the WSEL's of transects 1 and 2 (93.33 and 93.41 feet in elevation respectively), it was felt that an error in surveying occurred at transect 1A. As a result, the WSEL for this transect was lowered by 0.1 feet to 93.36 feet. For all other transects, the difference between the field WSEL's and the model predicted WSEL's for the calibration flow were 0.05 ft. or less.

The two partial transects (1A and 4A) which represent slackwater habitat were extended out to the principal velocity corridor. This corridor is where most of the flow in the channel occurs. In order to complete the data sets for these two partial transects for use in the model, the associated data from transects 1 and 4 were used. At partial transect 1A, the velocities were all negative. In order to use this information in the model, these velocities were treated as positive, as it was felt that the direction of the current would not influence the utilization of this area by juvenile salmon. Only 6.5 cfs or about 2% of the water flowed through this section.

Verification

Based on the first level of verification conducted by EWT&A, the model does an excellent job of simulating hydraulics between 35,000 and 56,000 cfs mainstem discharge (69 and 416 cfs site flow) (Appendix Figure D-8). Above 56,000 cfs, however, the simulated depth and velocity distributions begin to deteriorate in quality. As a result, the model simulations were rated good between 56,000 and 64,000 cfs (416 and 692 cfs site flow), acceptable between 64,000 and 70,000 cfs (692 and 984 cfs site flow), and unacceptable above 70,000 cfs mainstem. Below 35,000 cfs mainstem, the site flow was less than 5 cfs, and the model does not simulate accurately below 5 cfs.

The velocity profiles produced by the IFG-2 hydraulic model for the two flows, 338 and 520 cfs, are compared to their associated observed velocities at two transects (Appendix Figures D-9 & D-10). The observed and predicted velocities are in good agreement for both flows at transect 1. At transect 6 there is also good agreement between the observed and predicted velocities at the 338 cfs flow. But at the 520 cfs flow, from 85 to 140 feet, there is notable differences between the observed and predicted values.



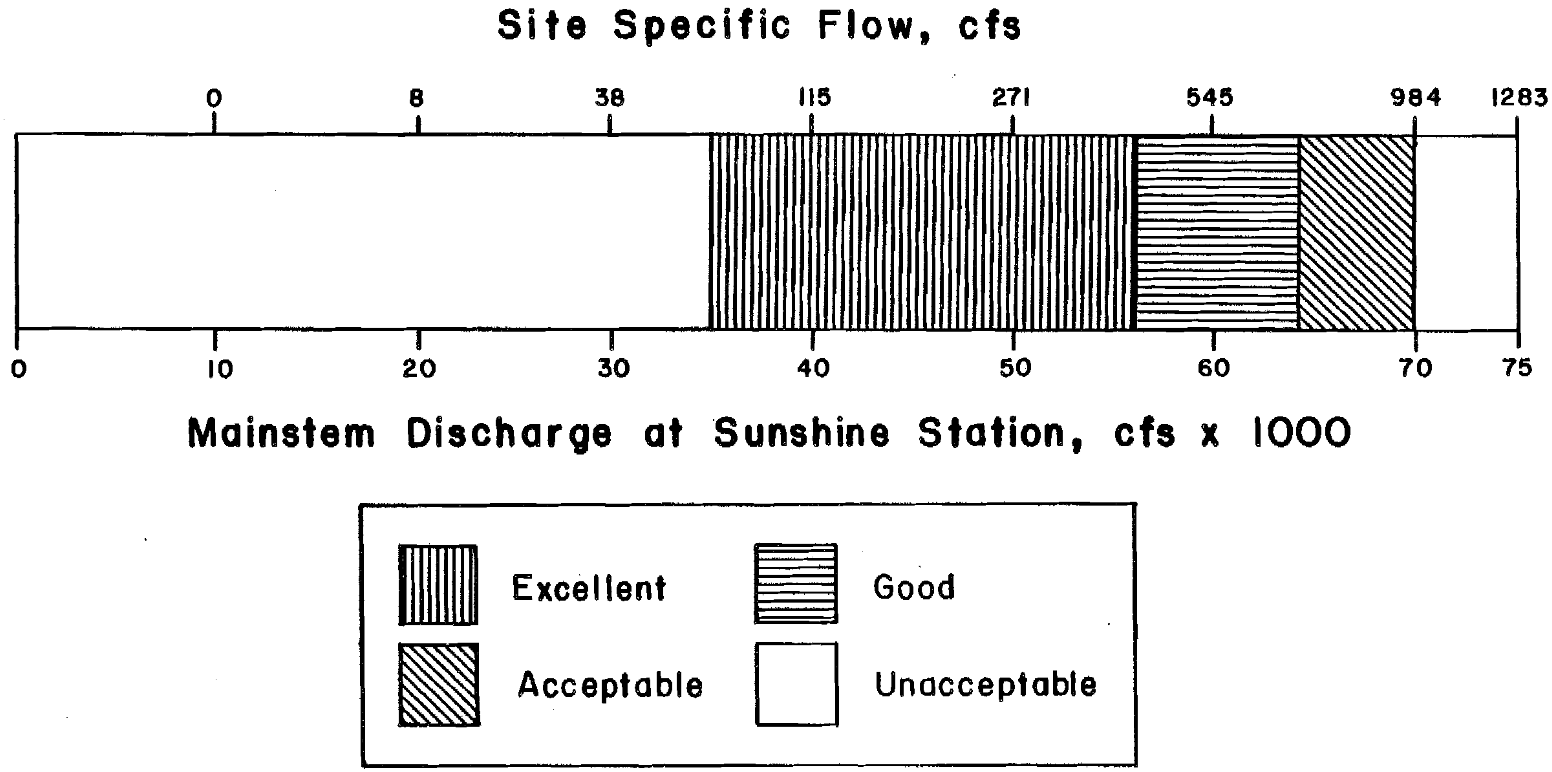
Appendix Figure D-7. Comparison of observed and predicted water surface profiles from calibrated model and surveyed thalweg profile at Island Side Channel (adapted from Quane et al. 1985).

Appendix Table D-5. Comparison of field measured and model predicted water surface elevations at the calibration flow of 338 cfs for Island Side Channel.

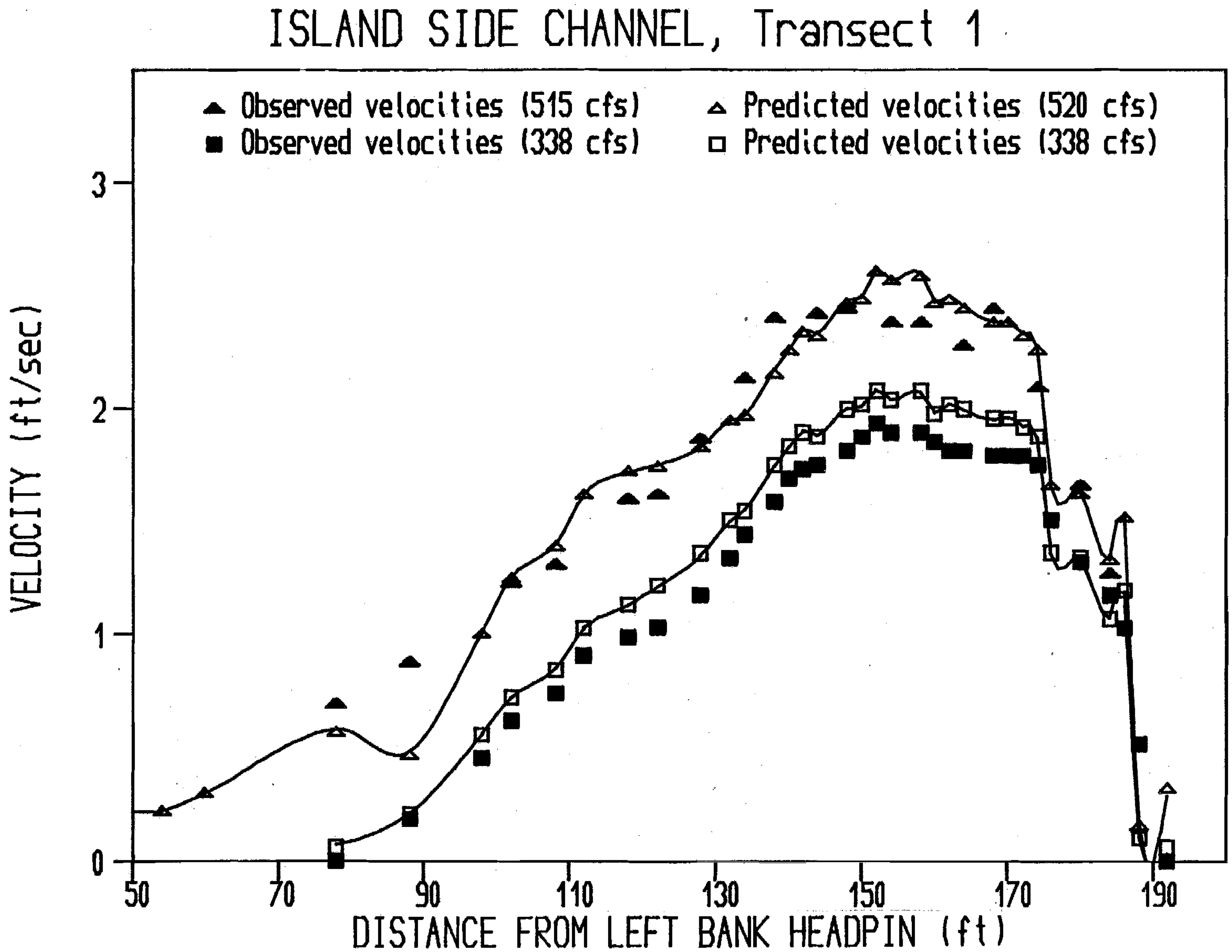
Transect	Water Surface Elevation (ft) Field	Model Predicted	Difference
1	93.33	93.33	--
1A	93.46[a]	93.36	0.00
2	93.41	93.36	0.05
3	93.44	93.40	0.04
4	93.48	93.46	0.02
4A	93.52	93.50	0.02
5	93.56	93.53	0.03
6	93.55	93.56	0.01

[a] Water surface elevation reduced by 0.1 feet to 93.36 feet.

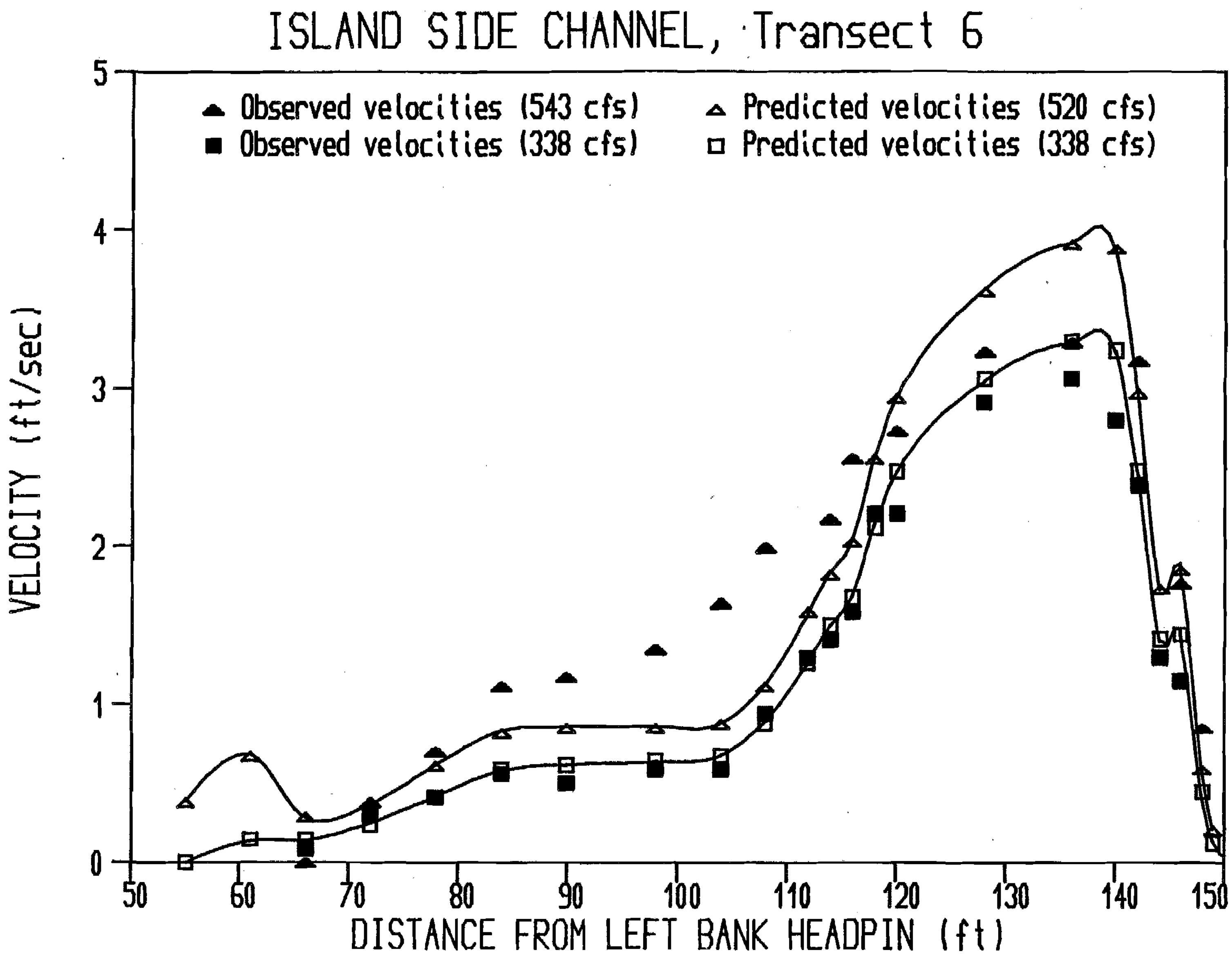
Application Range of the Calibrated Hydraulic Model
at Island Side Channel
RM (63.2)



Appendix Figure D-8. Application range of the calibrated hydraulic model at Island Side Channel.



Appendix Figure D-9. Comparison of observed and predicted velocities from the IFG-2 hydraulic model at Island Side Channel, using two flows at the transect 1 discharge site.



Appendix Figure D-10. Comparison of observed and predicted velocities from the IFG-2 hydraulic model at Island Side Channel, using two flows at the transect 6 discharge site.

Application

For habitat simulation modelling purposes, the hydraulic simulation model developed for Island Side Channel can simulate channel flows in the mainstem discharge range of 35,000 to 70,000 cfs.

Mainstem West Bank Side Channel (RM 74.4)

Site Description

Mainstem West Bank Side Channel is located on the west bank of the main channel Susitna River at river mile 74.4 (Appendix Figure D-12). It is approximately 2.2 miles in length. The mouth and two heads of this side channel connect directly with the Susitna River.

The IFG modelling site in the lower portion of this side channel was 930 feet long (Appendix Figure D-11). The study site is confined on the west by a steep bank and on the east by a well vegetated island. The portion of the side channel upstream of the study site is separated from the mainstem by a network of side channels and well vegetated islands. A minor channel is located within the study site on the east bank of the side channel. During nonbreached conditions, the side channel primarily consists of a series of pools and small riffles. Groundwater provides the major contribution of flow prior to breaching of the head (Quane et al. 1985).

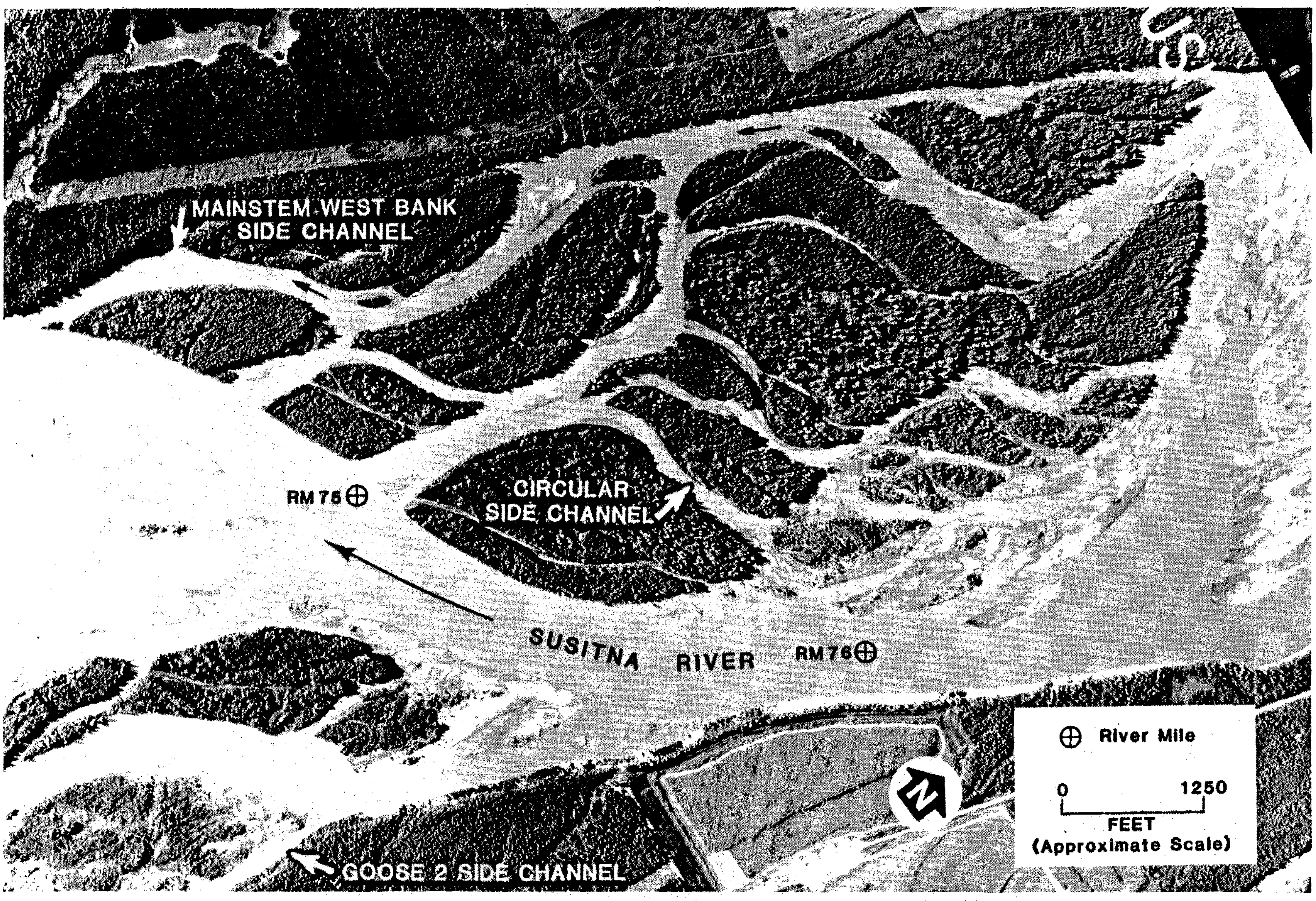
The two heads are both located approximately 1.5 miles upstream of the study site (Quane et al. 1985). Breaching of Mainstem West Bank Side Channel occurs when the mainstem overtops either of the two side channel heads. The side channel has been estimated to be initially breached at a mainstem discharge of 19,000 cfs (Quane et al. 1985).

Based on a review by Quane et al. (1985) of the stage versus mainstem discharge rating curve (Appendix Figure D-13), it has been determined that at mainstem discharges greater than 19,600 cfs, the hydraulics within this side channel are directly controlled by mainstem discharge. The site flow that occurs at 19,600 cfs was measured to be 5.7 cfs.

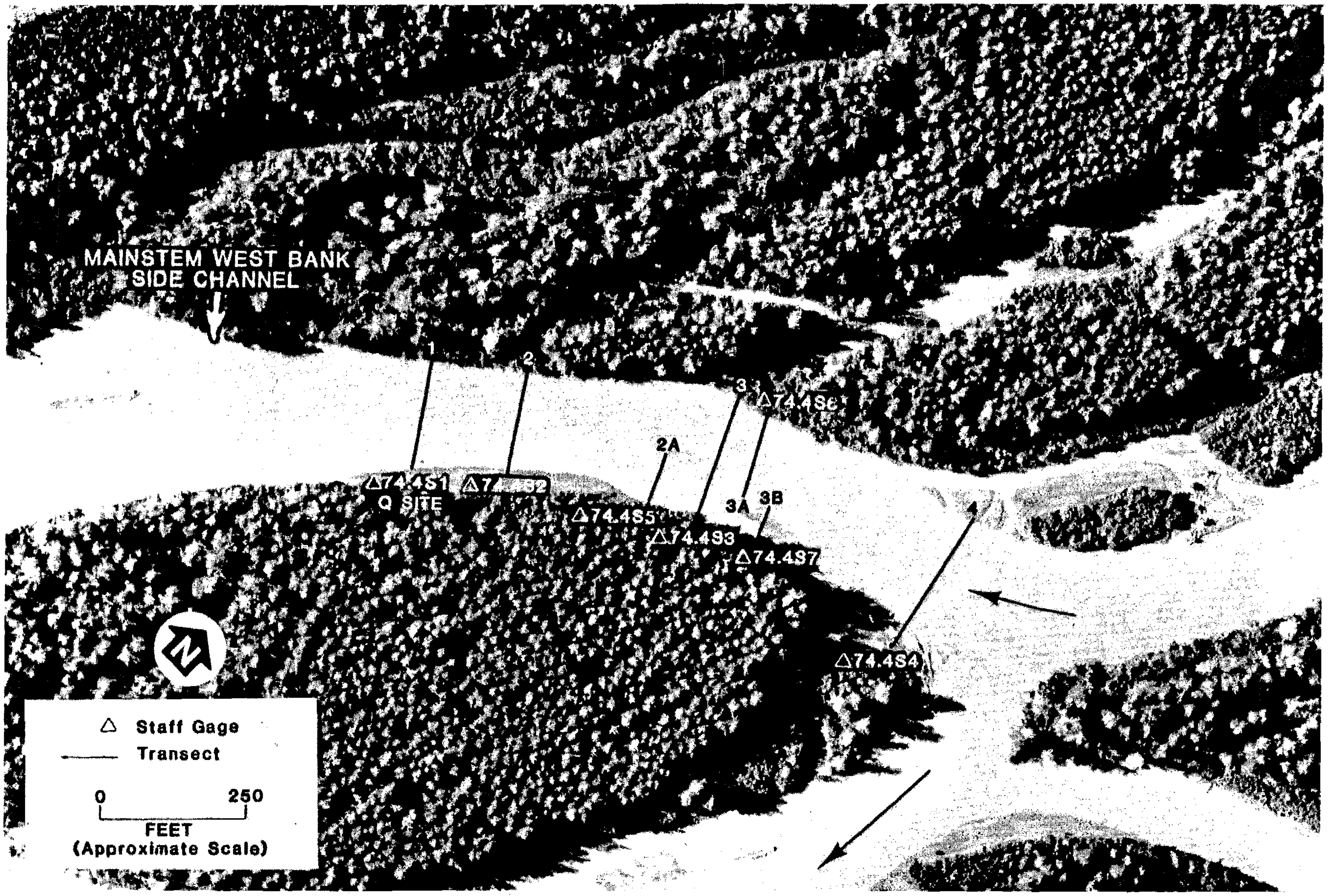
Hydraulic information was gathered from five transects (1, 2, 3, 3A, 4) in the main channel and three transects (2A, 3 in part, 3B) in a minor side channel of this study site (Appendix Figure D-12). The corresponding cross sections are presented in Appendix Figure D-14 & D-15.

The two lower transects (1 & 2) bisect primarily pool and run habitat, the banks are gently sloping on both sides. On the upper three transects (3, 3A, & 4) the left bank consisted of an erosional bank and was primarily bordered by alder. For modelling purposes, transects 3 and 3A were ended on a finger-like gravel bar on the right bank which longitudinally bisected the site with the main channel on the left and a minor channel on the right which was free flowing at high flows, backwater at median flows, and dry at low flows. This bar began downstream from transect 4 and ended between transects 2 and 3. Transect 3A was placed in order to obtain a better representation of the slow water debris-strewn habitat along the left bank. The main channel habitat of these three transects (3, 3A, & 4) consisted of run and riffle habitat.

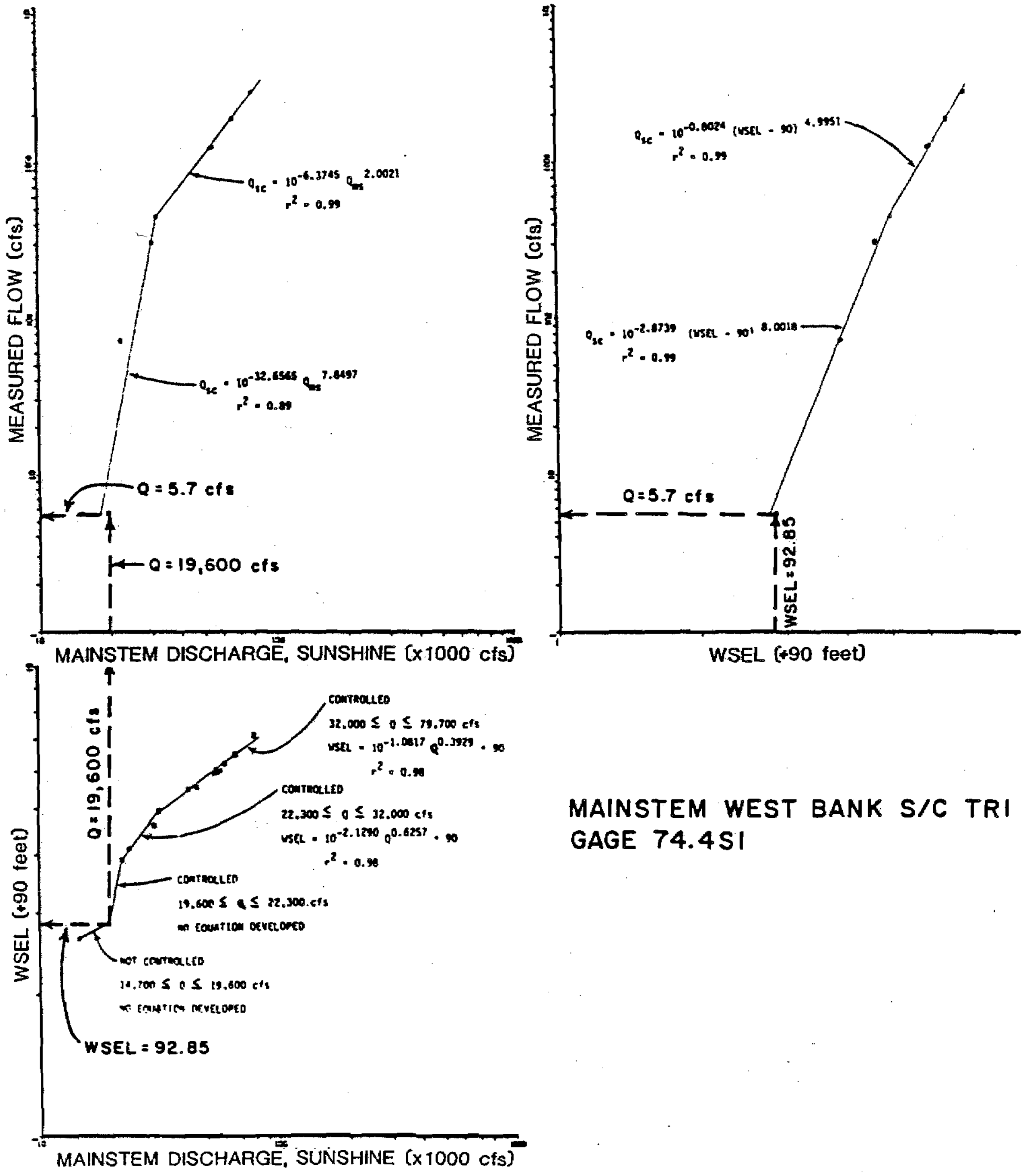
Substrate at this site primarily consisted of rubble and cobble. The thalweg gradient of the side channel is approximately 12.3 ft/mile (Quane et al. 1985).



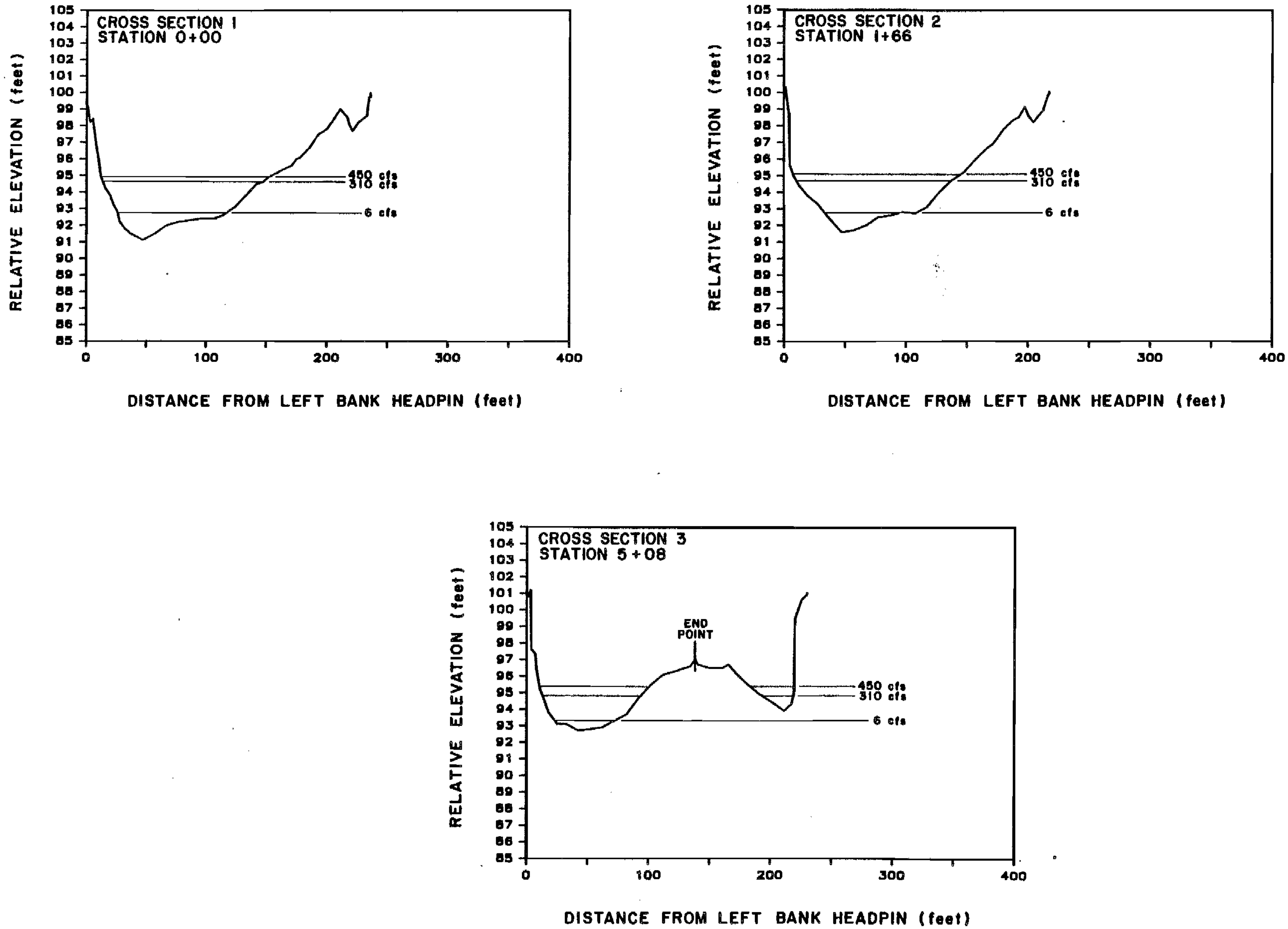
Appendix Figure D-11. Overview of Mainstem West Bank Side Channel (RM 74.4).



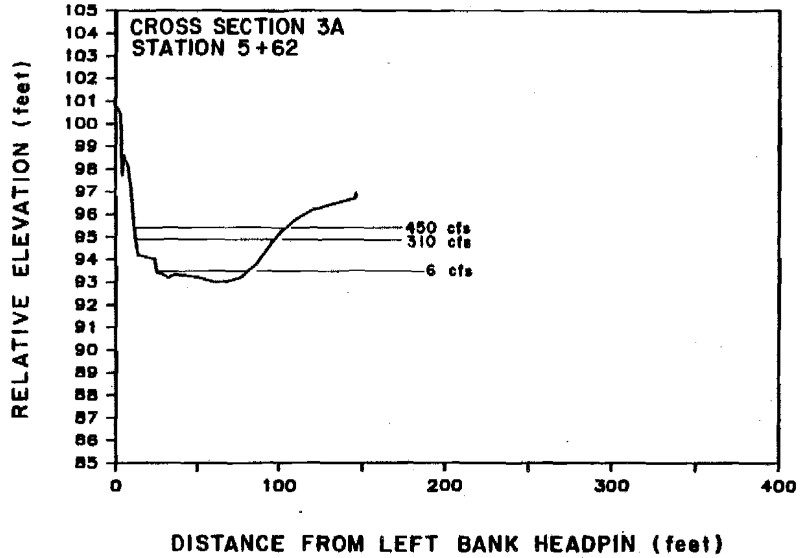
Appendix Figure D-12. Location of Mainstem West Bank Side Channel study site (RM 74.4).

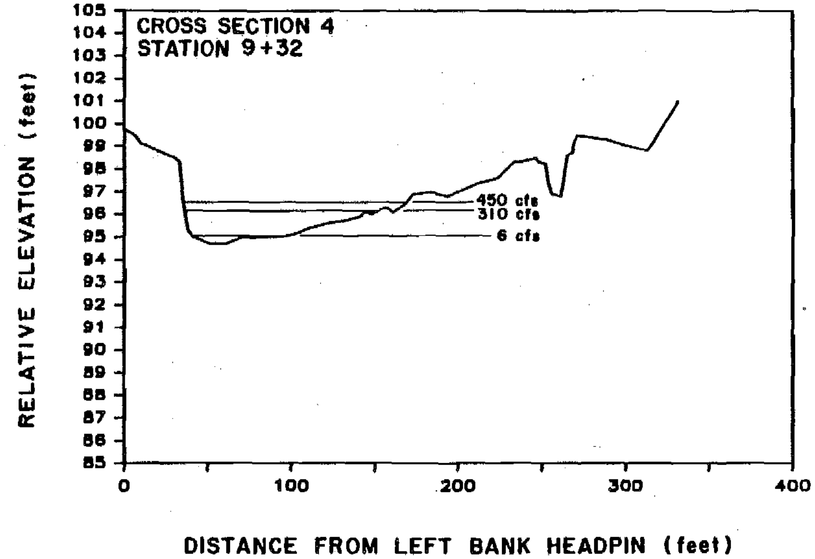


Appendix Figure D-13. Comparison of rating curves for Mainstem West Bank Side Channel transect 1(Q site) (from Quane et. al. 1985).



Appendix Figure D-14. Cross section of transects 1, 2, and 3 at Mainstem West Bank Side Channel (adapted from Quane et al. 1985).





Appendix Figure D-15. Cross section of transects 3A and 4 at Mainstem West Bank Side Channel (adapted from Quane et al. 1985).

Calibration

Hydraulic data were collected for model calibration at three site flows: 6, 310, and 450 cfs, the corresponding mean daily discharges for the Susitna River were 19,600 cfs, 30,500 cfs, and 32,000 cfs, respectively (Appendix Table D-4). Based on these data, an IFG-4 model was used to forecast instream hydraulics. The streambed profile, stage of zero flow, and observed and predicted water surface elevations for the study reach are plotted to scale in Appendix Figure D-16. All three data sets were used to predict hydraulic information for side channel flows of 6 to 2,431 cfs (mainstem discharges of 18,000 to 75,000 cfs).

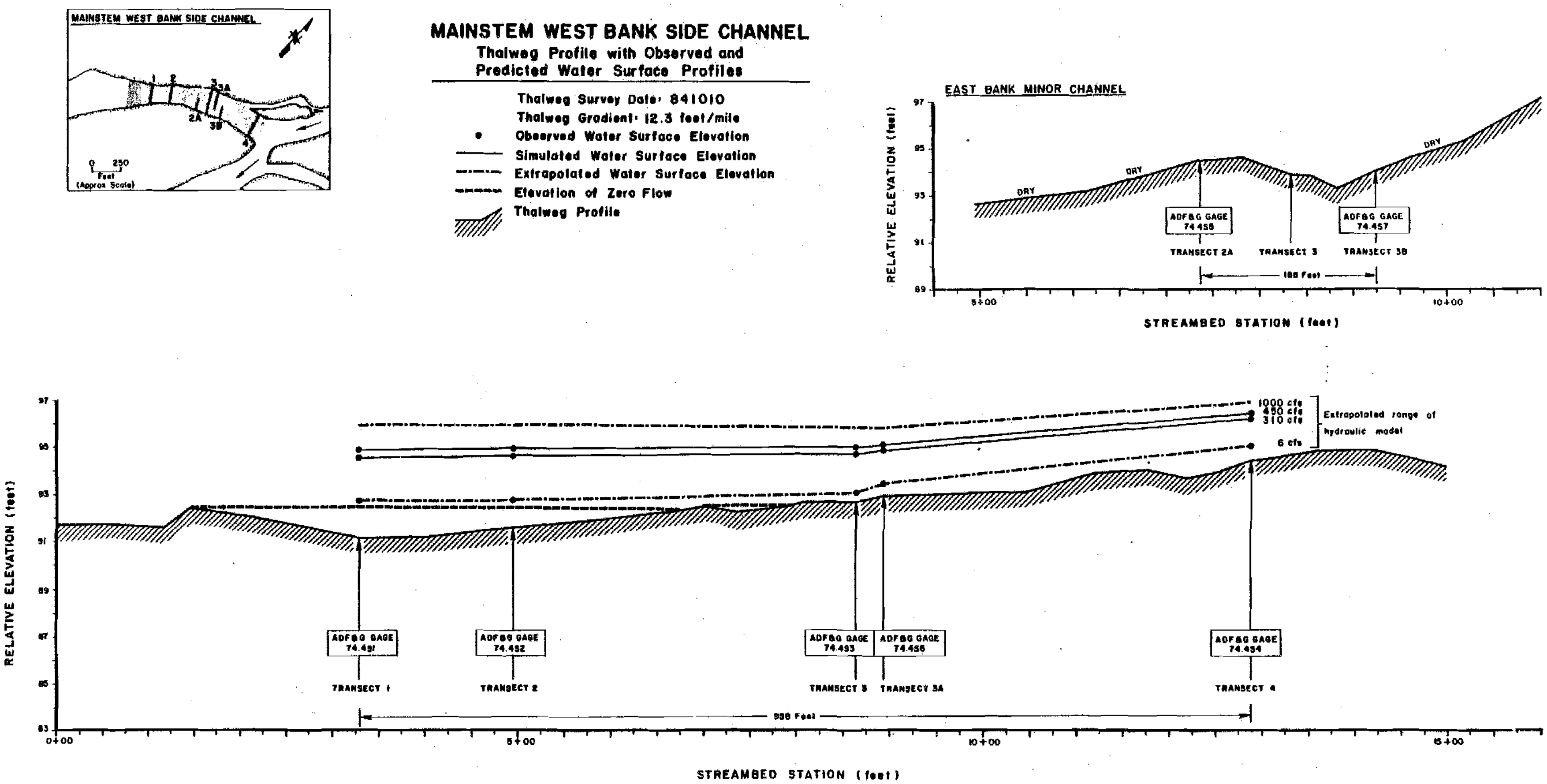
To evaluate the performance of the hydraulic model, observed and predicted water surface elevations, discharges, and velocity adjustment factors were compared (Appendix Table D-6). The 15 sets of observed and predicted WSEL's for the five transects of the 3 calibration flows were all within ± 0.02 ft. of each other except for 2 sets which were within ± 0.10 feet of each other. All the observed and predicted discharges were within 10% of each other and all velocity adjustment factors were within the good range of 0.9 to 1.1. Additionally, the stage information of the model was compared to available rating curves (Appendix Figure D-13).

Transect (3A) was placed about 60 feet upstream from transect 3 to represent the slackwater debris area along the left bank of the upper portion of this study site. In order to complete this data set for transect 3A for use in the model, the velocity information from transect 3 for the two site flows of 310 and 450 cfs were incorporated into transect 3A cross sectional area and water surface elevations. After incorporating this information into transect 3A, the discharge for the 310 cfs site flow, however, did not fall within 10% of the respective discharge that was calculated at the discharge transect. As a result, velocities for the 310 cfs site flow were adjusted upward by 17%.

At the low flow measurement of 6 cfs, the velocity measurements were made completely across transect 3A. The discharge calculated at this site was 18% higher than calculated at the discharge transect. The velocities at this transect were therefore reduced by 15%.

At transect 4 the water surface elevations were not similar across the transect at the 6 cfs flow measurement. Therefore, a weighted average water surface elevation was calculated for this transect.

At higher site flows several small side channel/backwater areas existed which were not represented in the IFG-4 analysis. In order to evaluate this potential habitat several transects were placed across one of these areas, weighted usable area was to be determined by hand calculations. However, this was not done because it was determined that this side channel habitat was so small compared to the total area being hydraulically modelled that it would not affect the total weighted usable area response.



Appendix Figure D-16. Comparison of observed and predicted water surface profiles from calibrated model and surveyed thalweg at Mainstem West Bank Side Channel (adapted from Quane et al. 1985).

Appendix Table D-6. Comparison between observed and predicted water surface elevations, discharges, and velocities for 1984 Mainstem West Bank side channel hydraulic model.

Streambed Station (ft)	Water Surface Elevation Observed (ft)	Water Surface Elevation Predicted (ft)	Discharge Observed (cfs)	Discharge Predicted (cfs)	Velocity Adjustment Factor
0+00	92.85	92.86	6.0	6.3	1.005
1+66	92.86	92.87	6.9	7.2	.991
5+08	93.25	93.26	6.9	7.2	1.004
5+62	93.51	93.52	5.8	6.1	.996
9+32	95.06	95.06	5.1	5.4	1.013
			Qo = 6.0	Qp = 6.0	
0+00	94.62	94.61	312.8	315.7	1.030
1+66	94.64	94.64	301.3	307.5	1.024
5+08	94.85	94.86	306.4	318.2	1.007
5+62	94.93	94.99	292.8	288.6	.993
			Qo = 301.0	Qp = 308.0	
0+00	94.97	94.98	460.4	457.0	.974
1+66	95.00	95.00	446.1	438.2	.975
5+08	95.19	95.18	470.6	455.2	.994
5+62	95.29	95.23	409.6	415.3	1.001
9+32	96.54	96.45	473.9	451.9	.969
			Qo = 452.0	Qp = 444.0	

Qo is the mean observed calibration discharge.

Qp is the mean predicted calibration discharge.

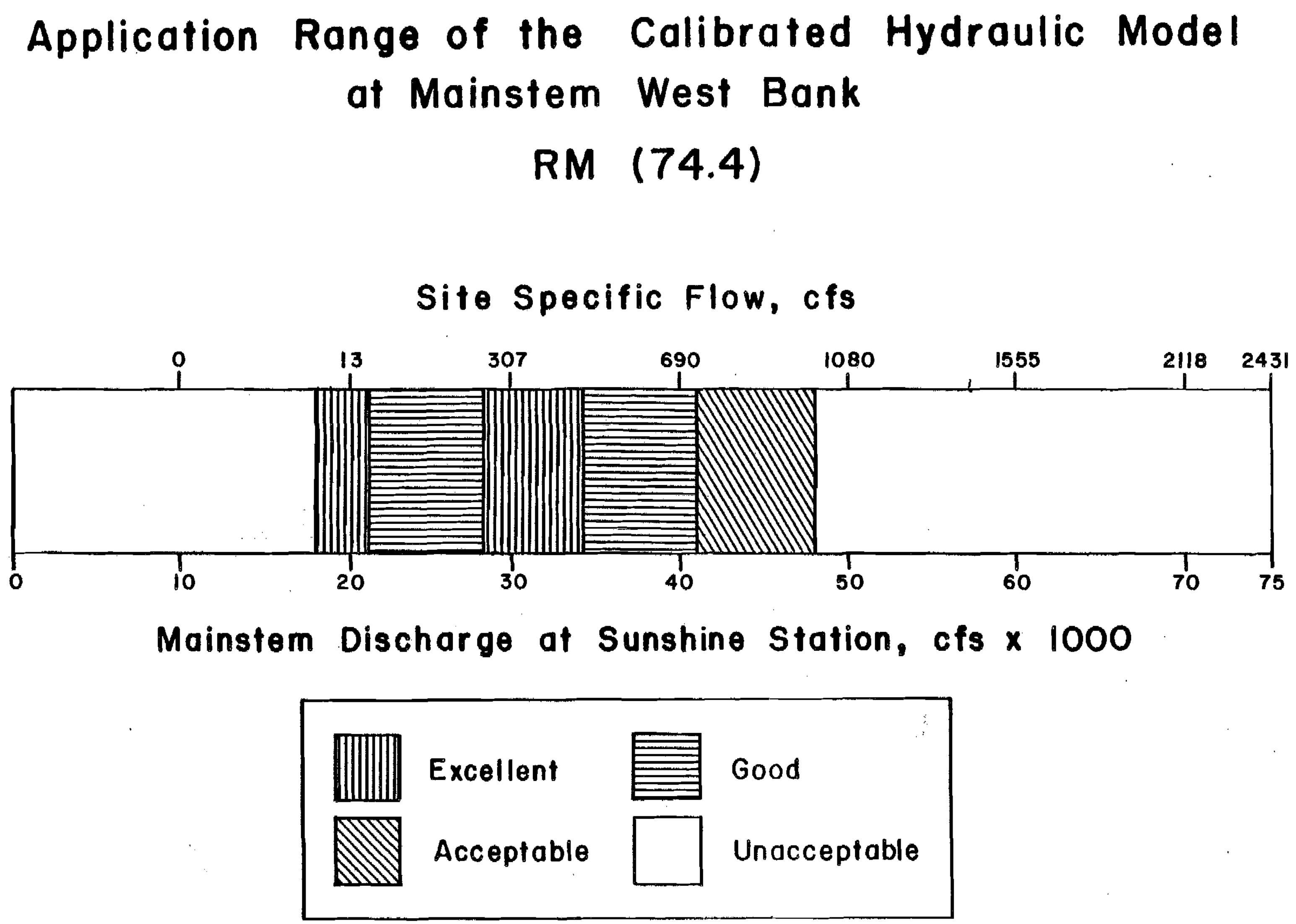
Verification

Based on the first level of verification by EWT&A, the model does an excellent job of simulating channel hydraulics between 18,000 and 21,000 cfs mainstem discharge (6 and 20 cfs site flow) (Appendix Figure D-17). Above 21,000 cfs, simulated water surface profiles deviate somewhat from field observations. As a result, the model was rated good between 21,000 and 28,000 cfs mainstem discharge (20 and 200 cfs site flow), and between 28,000 and 34,000 cfs mainstem discharge (200 and 500 cfs site flow) the model again was rated excellent. Two calibration data sets were collected within this range. Above 34,000 cfs, the quality of the hydraulic simulations begins to deteriorate as the slope of the site flow versus WSEL relationship flattens as a result of channel geometry. The deviation between the regression line developed within the model and that of the rating curve developed independently for the site increases with discharge until the model simulations are no longer acceptable. The model simulations were rated good between 34,000 and 41,000 cfs (500 and 727 cfs site flow), acceptable between 41,000 and 48,000 cfs (727 and 1000 cfs site flow), and unacceptable above 48,000 cfs mainstem discharge.

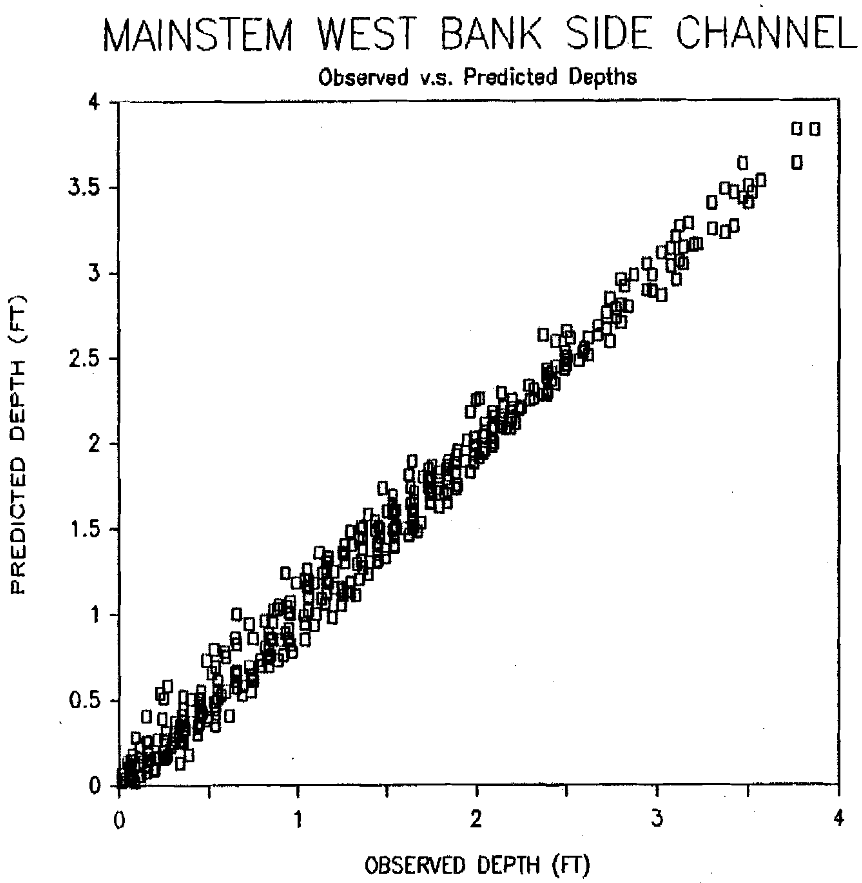
At the second level of verification there is good agreement between the predicted and observed values of depth and velocity (Appendix Figure D-18). At the higher velocities (> 2.5 ft/sec) they begin to spread apart though. In Appendix Table D-7 the results of the statistical tests are shown. There is again good agreement shown between the observed and predicted values for both velocity and depth. The index of agreement (d) is almost one, the total root mean square error (RMSE) is largely composed of the unsystematic RMSE, and the y-intercept (a) is close to zero with a slope (b) of almost one.

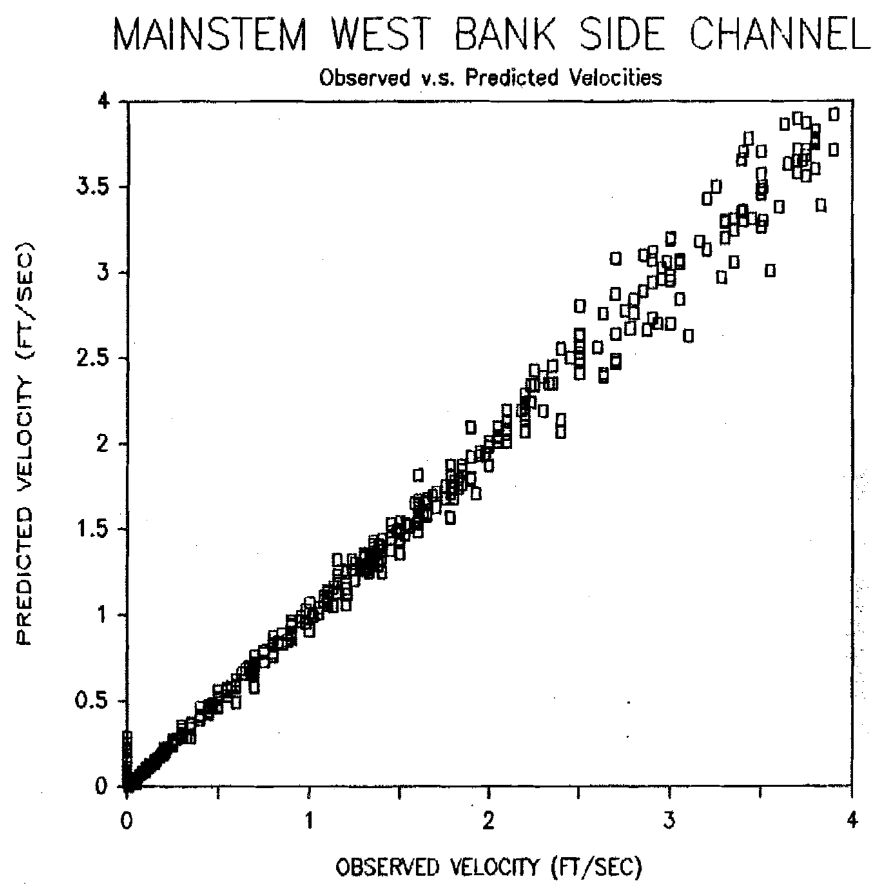
Application

For habitat simulation modelling purposes, the hydraulic simulation model developed for Mainstem West Bank Side Channel can simulate channel flows in the mainstem discharge range of 18,000 to 48,000 cfs.



Appendix Figure D-17. Application range of the calibrated hydraulic model at Mainstem West Bank Side Channel.





Appendix Figure D-18. Scatterplots of observed and predicted depths and velocities from the calibrated IFG-4 hydraulic model at Mainstem West Bank Side Channel.

Appendix Table D-7. The statistical results used to evaluate the predictive ability of the four lower river IFG-4 hydraulic models.

Side Channel Site		N	$\bar{O}$	$\bar{P}$	Std. 0	Std. P	a	b	Total RMSE	Syst RMSE	Unst RMSE	d
Mainstem	Depth	476	1.3813	1.3802	0.8602	0.8552	0.0121	0.9959	0.1013	0.0	0.1005	0.9969
West Bank	Velocity	476	1.4305	1.4367	1.5643	1.5641	0.0114	0.9910	0.1123	0.0	0.1122	0.9979
Circular	Depth	432	1.2200	1.2153	0.6147	0.6048	0.0244	0.9761	0.1392	0.0173	0.1378	0.9919
	Velocity	432	0.9080	0.9091	0.5001	0.4898	0.0127	0.9872	0.0499	0.0	0.049	0.9987
Sunset	Depth	666	1.6615	1.6580	1.8477	1.8406	0.0078	0.9935	0.1305	0.0	.1300	0.9976
	Velocity	666	1.3182	1.3230	0.8626	0.8513	0.0146	0.9926	0.0388	0.0	.0374	0.9995
Trapper	Depth	406	0.9417	0.9417	0.4027	0.3977	0.0128	0.9863	0.0773	0.0	0.0768	0.9962
Creek	Velocity	406	1.0642	1.0712	1.0583	1.0501	0.0136	0.9937	0.0718	0.0	0.0714	0.9987

N = number of observations.

0, P = mean of observed and predicted values.

Std. 0, Std. P = standard deviation of observed and predicted values.

a, b = y-intercept and slope of least squares regression between 0 and P.

RMSE = root mean square error: total, systematic, and unsystematic.

d = index of agreement.

For the use and a discussion of these statistics see Wilmott (1981).

Circular Side Channel (RM 75.3)

Site Description

Circular Side Channel is located on the west bank of the Susitna River at river mile 75.3 (Appendix Figure D-19). It is approximately 0.9 miles long and is separated from the mainstem by a large well vegetated island. An extensive backwater area occurs in the lower portion of the study site. A network of small channels at the head provide mainstem flow into the site after breaching. Prior to breaching, flow is greatly reduced and the channel is composed of large pools connected by small riffles (Quane et al. 1985).

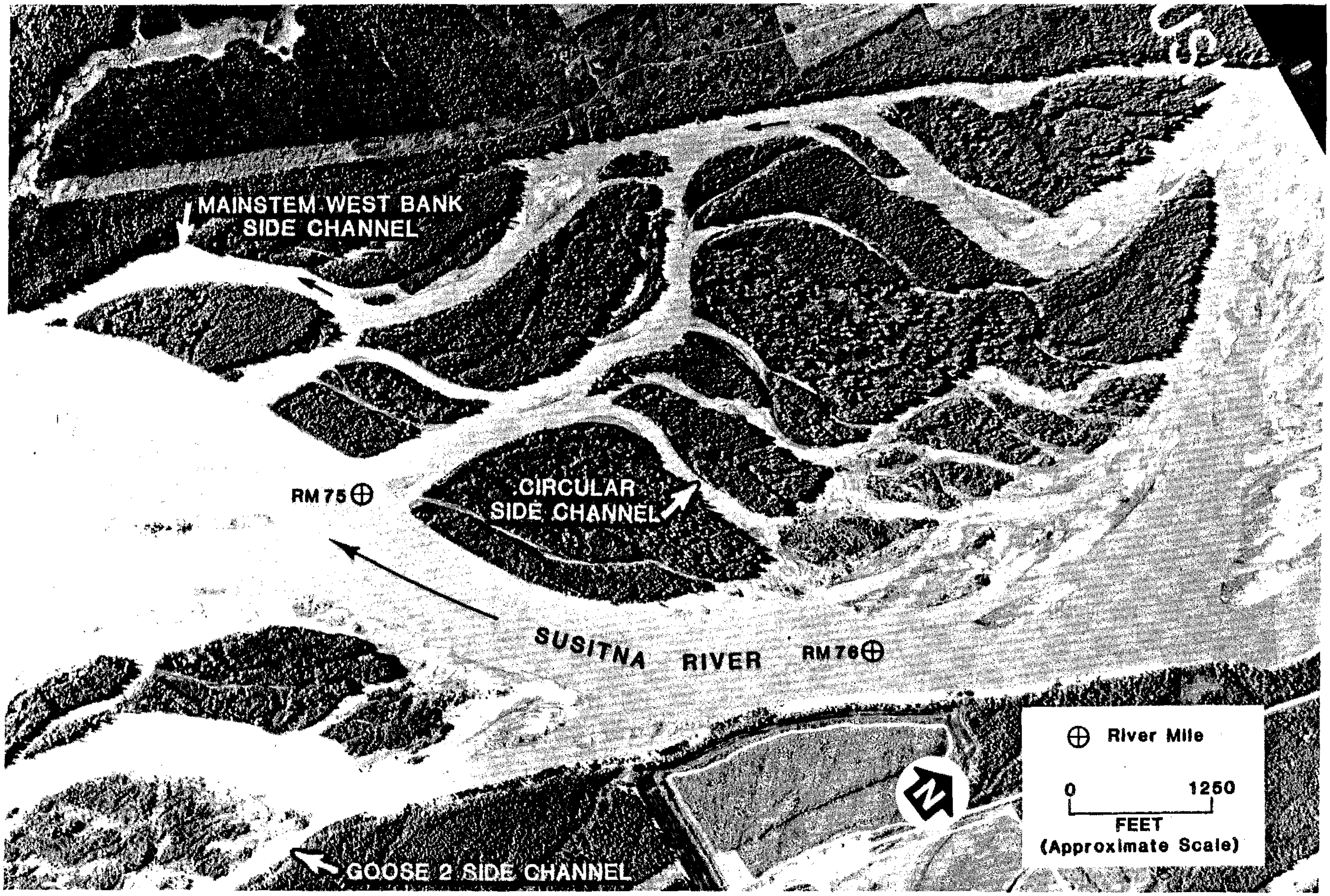
Breaching of Circular Side Channel has been estimated to occur at a mainstem discharge of 36,000 cfs (Quane et al. 1985). It has been determined that the hydraulics within this side channel are governed by mainstem discharge at mainstem discharges exceeding 36,000 cfs. The site flow that occurs at this mainstem discharge is estimated to be 26.8 cfs (Appendix Figure D-20) (Quane et al. 1985).

Based on assessments by Quane et al. (1985), backwater does not occur during non-breaching mainstem discharges. At breaching mainstem discharges of 55,200 to 66,700 cfs, however, an area of backwater was found to occur upstream to a point approximately 90 feet above transect 2A. At a mainstem discharge of 42,500 cfs, backwater has been determined to extend slightly past transect 2.

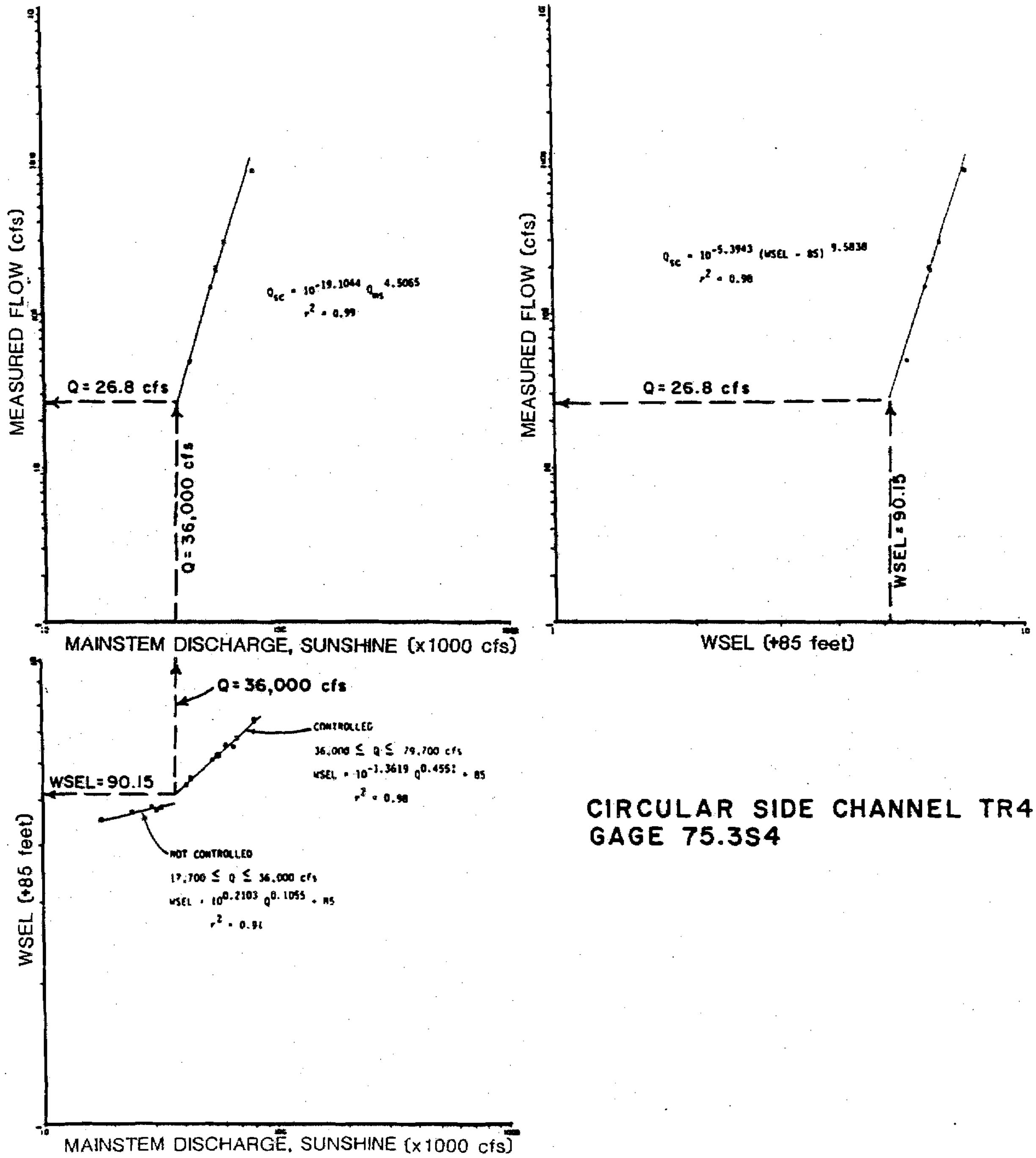
The IFG modelling study site in the upper half of Circular Side Channel is 820 feet (Appendix Figure D-21). The thalweg gradient of this study site is 14.3 ft/mile (Quane et al. 1985). Riparian vegetation along both banks consists mostly of alder and cottonwood. Substrate within the lower reaches of the Circular Side Channel site consisted predominately of silts, sands, and gravels changing to rubbles at the upper reaches. Hydraulic information was gathered from six transects established at this study site (Appendix Figure D-21). The channel is relatively straight and the cross sections are generally box shaped in configuration (Appendix Figures D-22 & D-23). Transects 1 and 2 were located in shallow backwater. Transect 2A was located in a transitional area which became run habitat at higher flows. Transect 3 was located in riffle habitat. Transect 4 was located in run habitat at the end of a pool, transect 5 bisected this pool.

Calibration

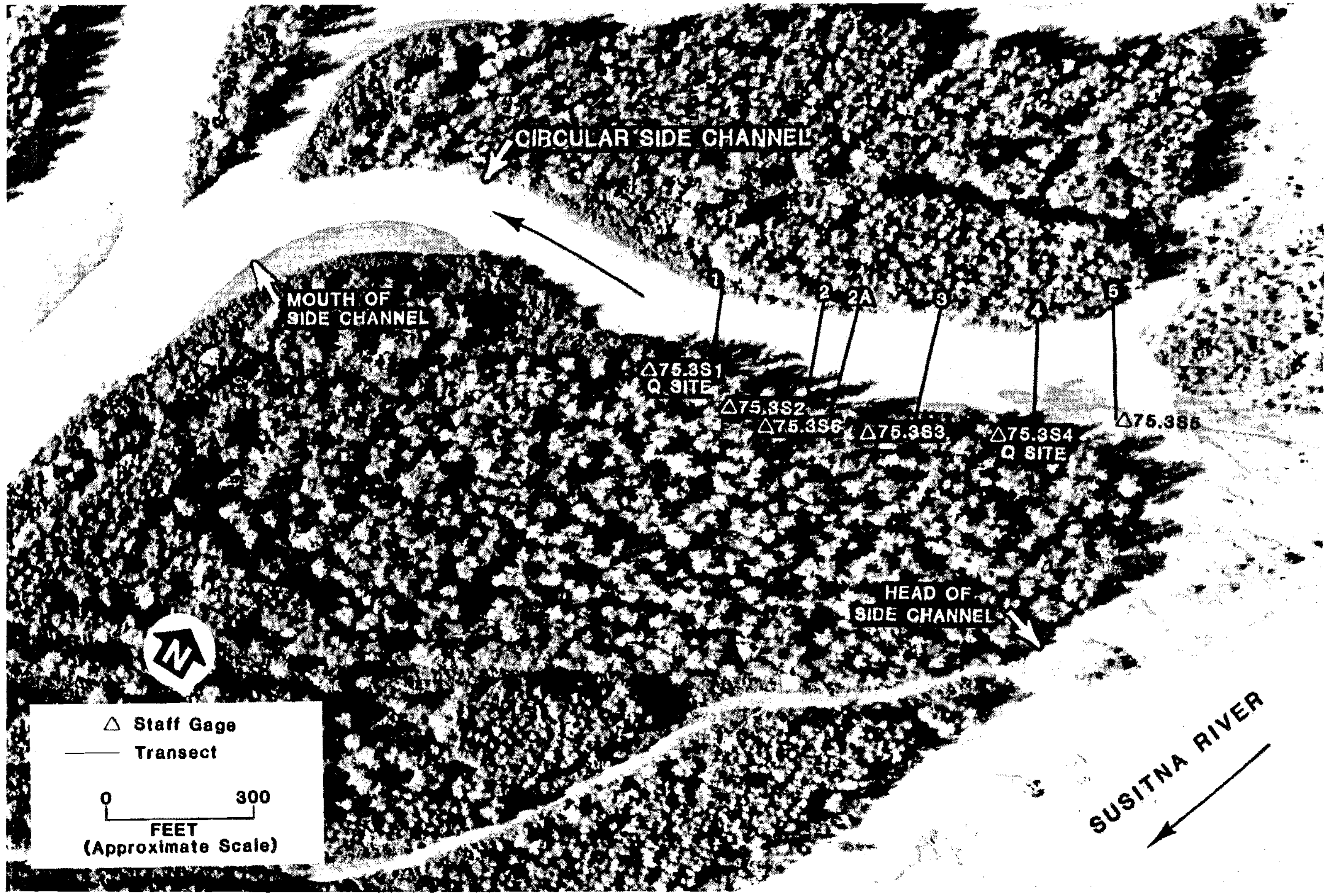
Hydraulic data were collected at two calibration flows: 50 and 204 cfs (Appendix Table D-4). Mean daily discharges for the Susitna River on the dates that calibration data were collected at the Circular Side Channel study site were 42,500 and 55,200 cfs. An IFG-4 model was used to forecast instream hydraulics based on these two calibration flows. The streambed profile, stages of zero flow, and observed and predicted water surface elevations for the study reach are plotted to scale in Appendix Figure D-24. The two data sets were used to predict hydraulic information from side channel flows of 6 to 733 cfs (mainstem discharges of 25,500 to 75,000 cfs).



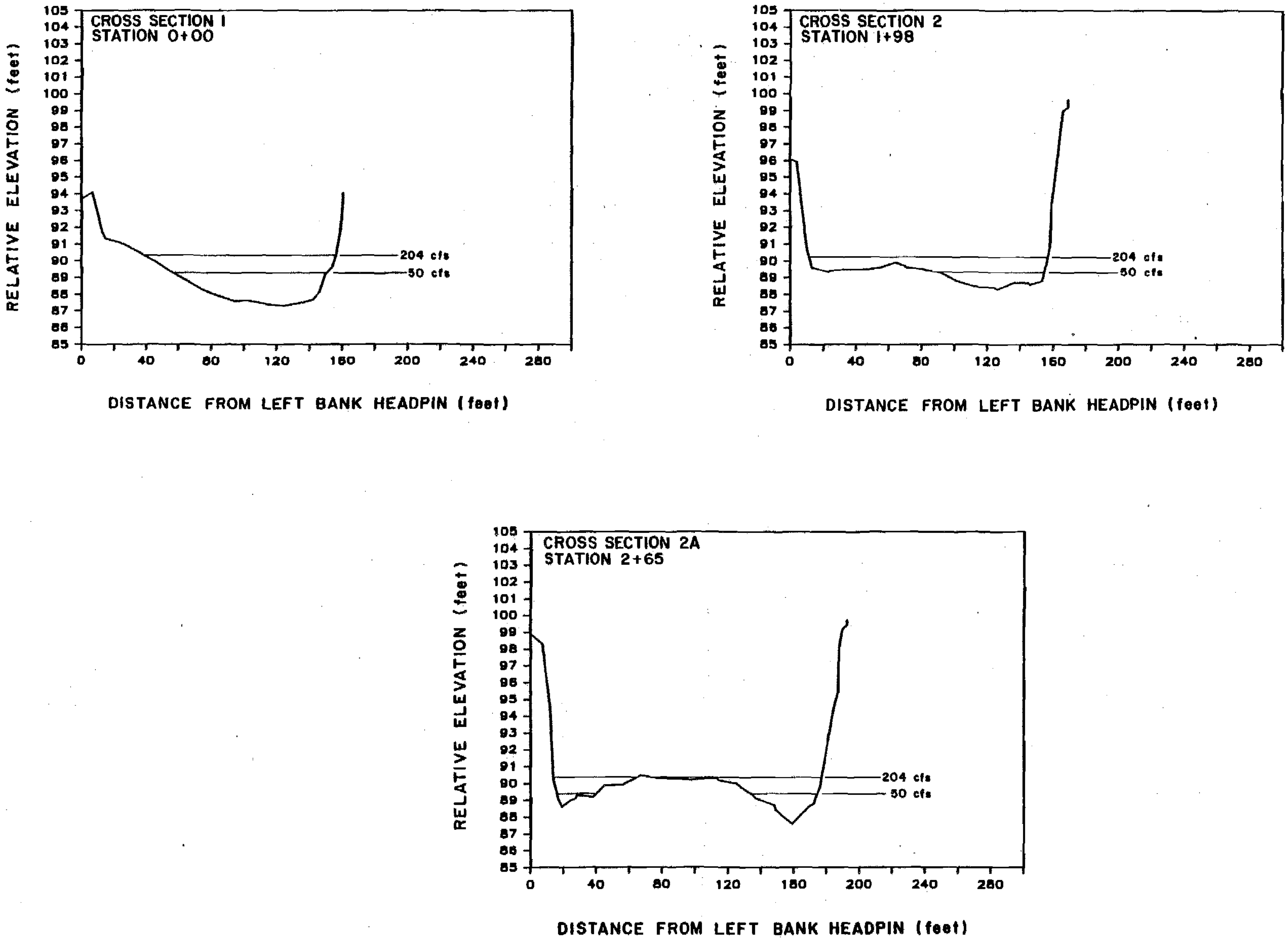
Appendix Figure D-19. Overview of Circular Side Channel (RM 75.3).



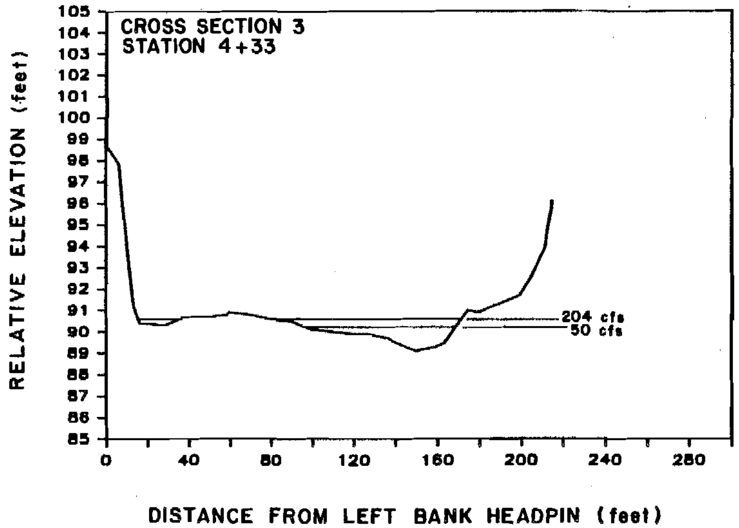
Appendix Figure D-20. Comparison of rating curves for Circular Side Channel Transect 4 (from Quane et. al. 1985).

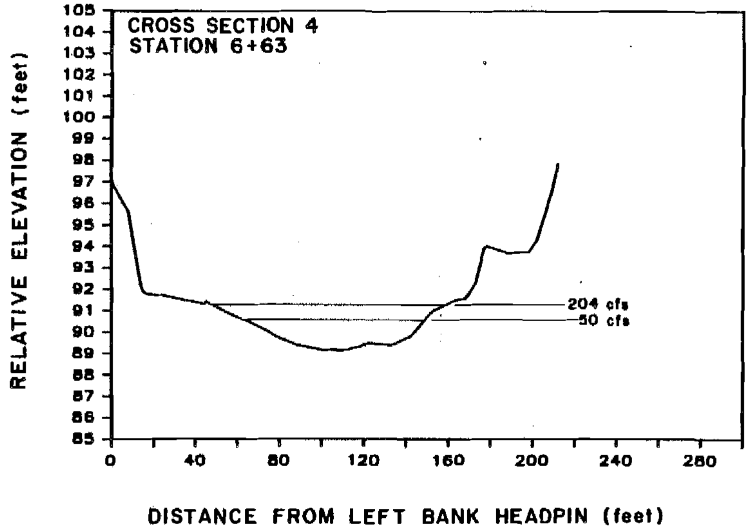


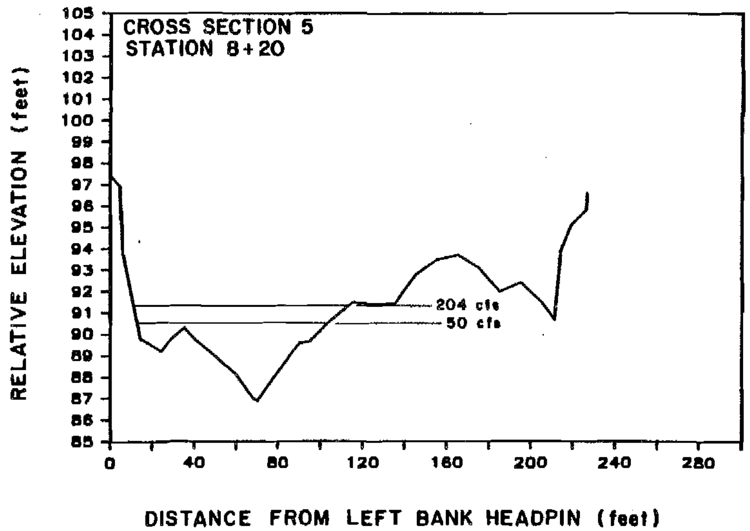
Appendix Figure D-21. Location of Circular Side Channel study site (RM 75.3).



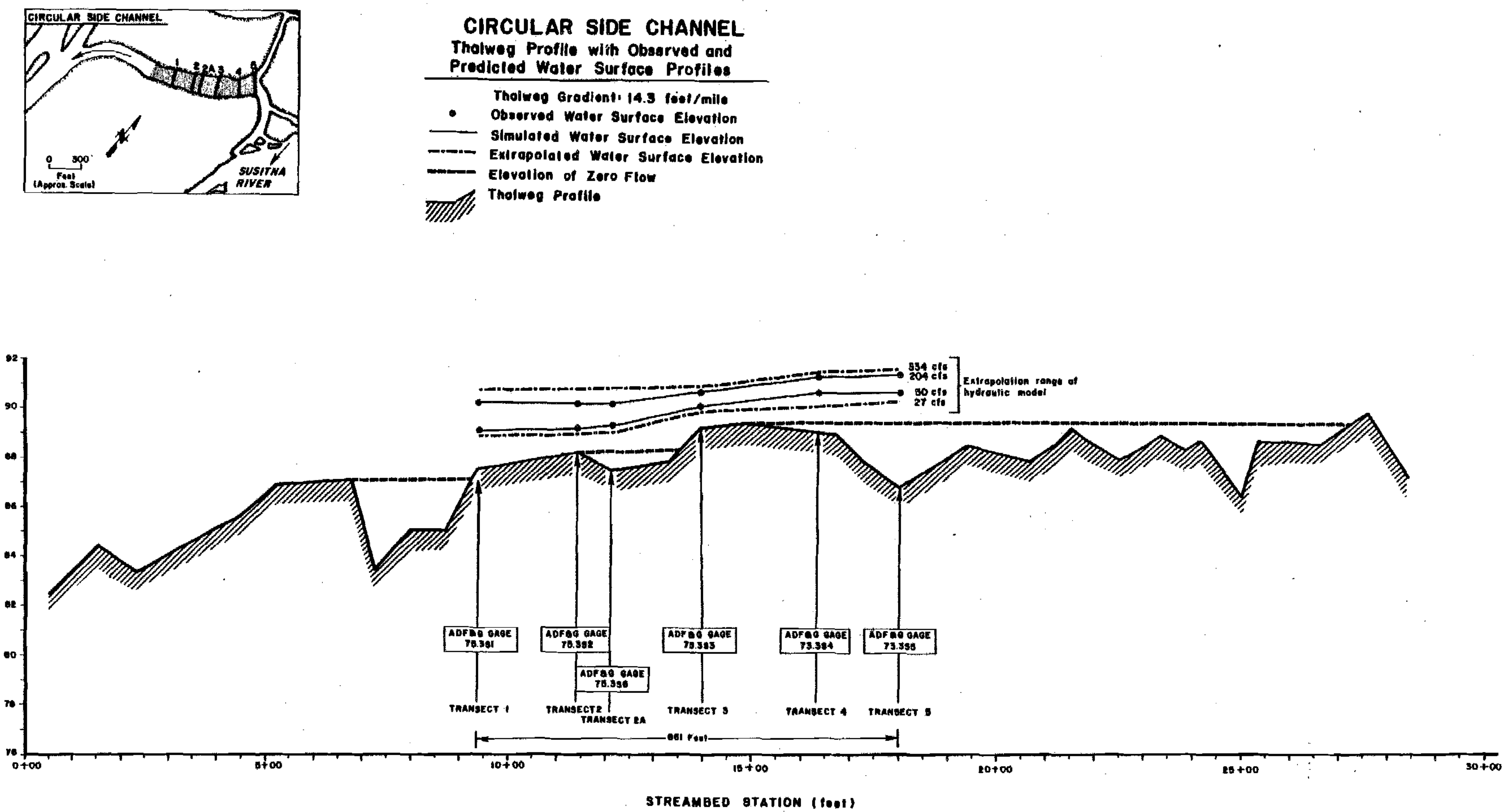
Appendix Figure D-22. Cross section of transects 1, 2, and 2A at Circular Side Channel (adapted from Quane et al. 1985).







Appendix Figure D-23. Cross section of transects 3, 4, and 5 at Circular Side Channel.



Appendix Figure D-24. Comparison of observed and predicted water surface profiles from calibrated model and surveyed thalweg profile at Circular Side Channel (adapted from Quane et al. 1985).

To evaluate the performance of the hydraulic model, observed and predicted water surface elevations, discharges, and velocity adjustment factors were compared (Appendix Table D-8). Because of the 2 calibration flows only a 2 point rating curve was formulated. In evaluating the performance of the model, observed and predicted WSEL's and discharges were the same because of this rating curve. Velocity adjustment factors were all within the good range of 0.9 to 1.1. Additionally, the stage information of the model was compared to the rating curves established by Quane et al. 1985 (Appendix Figure D-20).

At the high flow measurement of 204 cfs, the original field measured discharge at transect 2 was 34% lower than that calculated at the discharge transect. In order to use this information in the model, the individual velocity measurements were all adjusted upwards by 52%. Why there was such a large discrepancy between flows at this particular transect when the four other transect flow measurements were within 9% of the discharge transect measurement is unknown.

At transect 5 there was a change in the channel cross section from when the actual cross section survey was done and when the two calibration flows were made. Between the cross section survey of September 5, 1985, and the two calibration flow measurements July 24 and August 17, 1984, a flood event occurred on August 26, 1984. After this flood, the right side of the channel at transect 5 was scoured out. In order to avoid violating one of the underlying assumptions of the model, (i.e.,that a rigid stream channel exists) the cross section determined from the two calibration flows was used in the model.

During the 50 cfs calibration flow measurement a water surface elevation was not surveyed for transect 5. In order to obtain a water surface elevation for the model, a value was calculated from the average of the depth measurements added to the corresponding cross section elevations of the 50 cfs flow measurement.

Verification

Based on the first level of verification by EWT&A, the model does an excellent job of simulating channel hydraulics between 39,000 and 57,000 cfs, mainstem discharge (38 and 213 cfs site flow). Above 57,000 cfs, the simulated depth and velocity distributions begin to deteriorate in quality. The model simulations were therefore rated good between 57,000 and 60,000 cfs (213 and 268 cfs site flow), acceptable between 60,000 and 63,000 cfs (268 and 334 cfs site flow), and unacceptable above 63,000 cfs mainstem discharge. Below 39,000 cfs, the model simulations were also rated less than excellent as forecasted velocity and depth distributions deteriorated in quality. The model simulations were rated good between 36,000 and 39,000 cfs mainstem discharge (27 and 38 cfs site flow) (Appendix Figure D-25). Below 36,000 cfs mainstem (controlling discharge), insufficient information is available to evaluate the model.

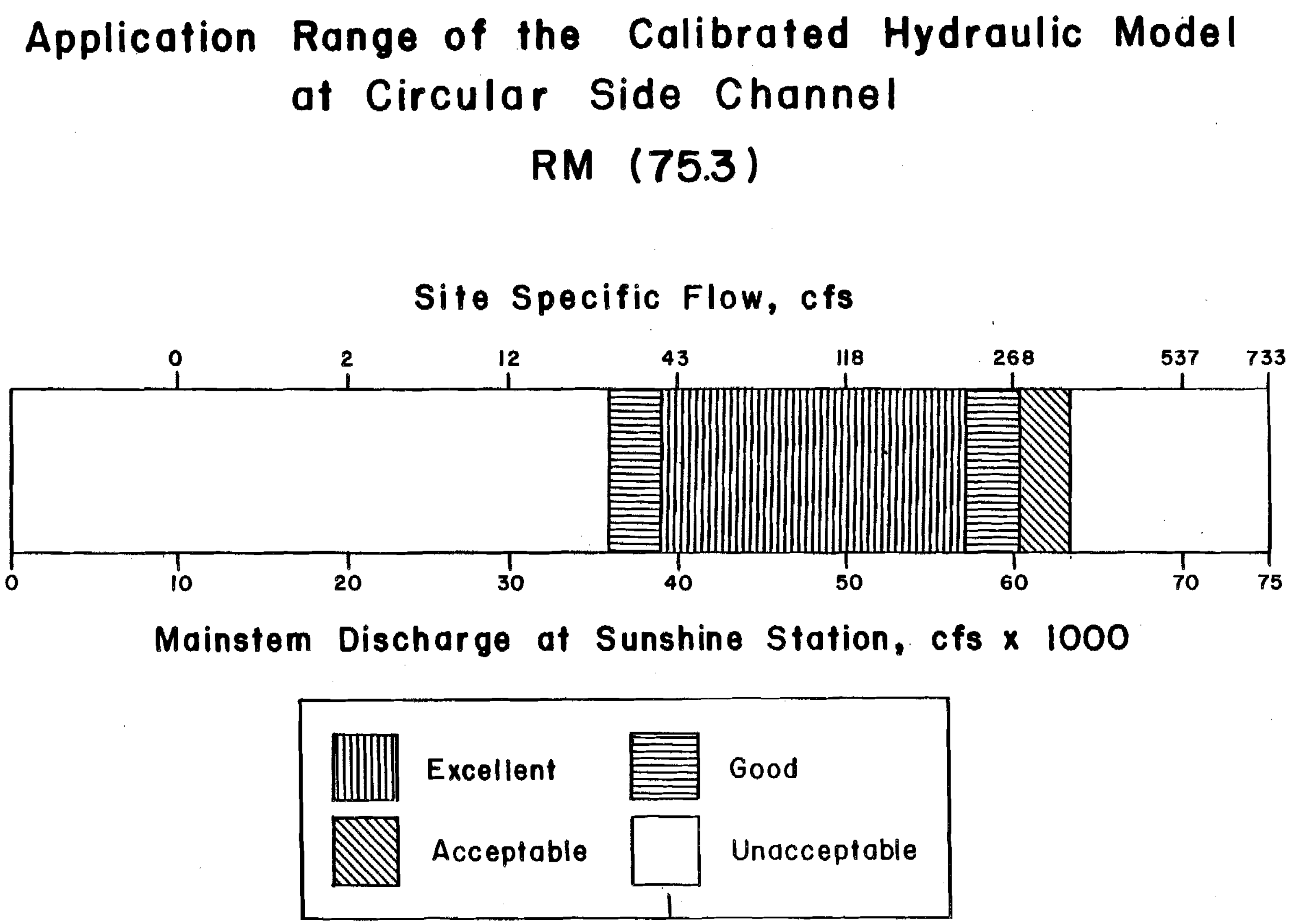
At the second level of verification there is excellent agreement between the observed and predicted velocities and good agreement between the

Appendix Table D-8. Comparison between observed and predicted water surface elevations, discharges, and velocities for 1984 Circular Side Channel hydraulic model.

Streambed Station (ft)	Water Surface Elevation Observed (ft)	Water Surface Elevation Predicted (ft)	Discharge Observed (cfs)	Discharge Predicted (cfs)	Velocity Adjustment Factor
0+00	89.28	89.28	44.4	44.4	1.000
1+98	89.30	89.30	47.9	47.9	.998
2+65	89.41	89.41	56.0	56.0	1.000
4+33	90.20	90.20	43.7	43.7	1.000
6+63	90.60	90.60	50.9	50.9	.997
8+20	90.62	90.63	53.6	53.6	1.000
			Qo = 49.0	Qp = 49.0	
0+00	90.29	90.29	202.8	202.8	.998
1+98	90.27	90.27	203.1	203.1	.987
2+65	90.31	90.31	198.4	198.4	.999
4+33	90.66	90.66	176.9	176.9	.998
6+63	91.29	91.29	199.9	199.9	1.000
8+20	91.32	91.32	194.2	194.2	1.000
			Qo = 196.0	Qp = 196.0	

Qo is the mean observed calibration discharge.

Qp is the mean predicted calibration discharage.

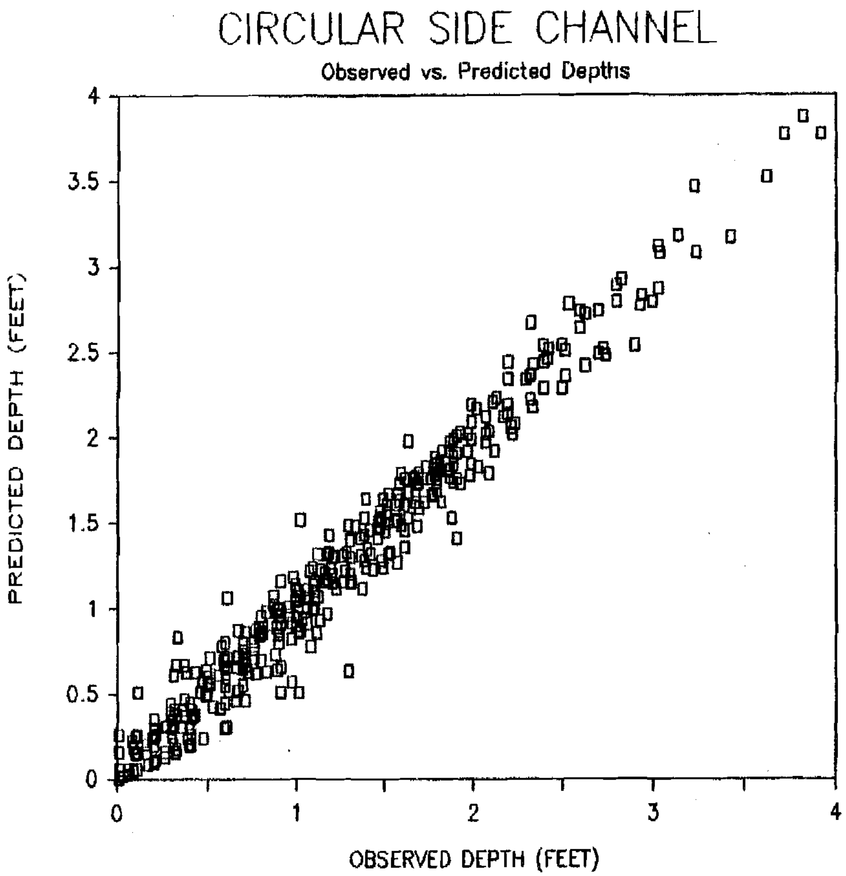


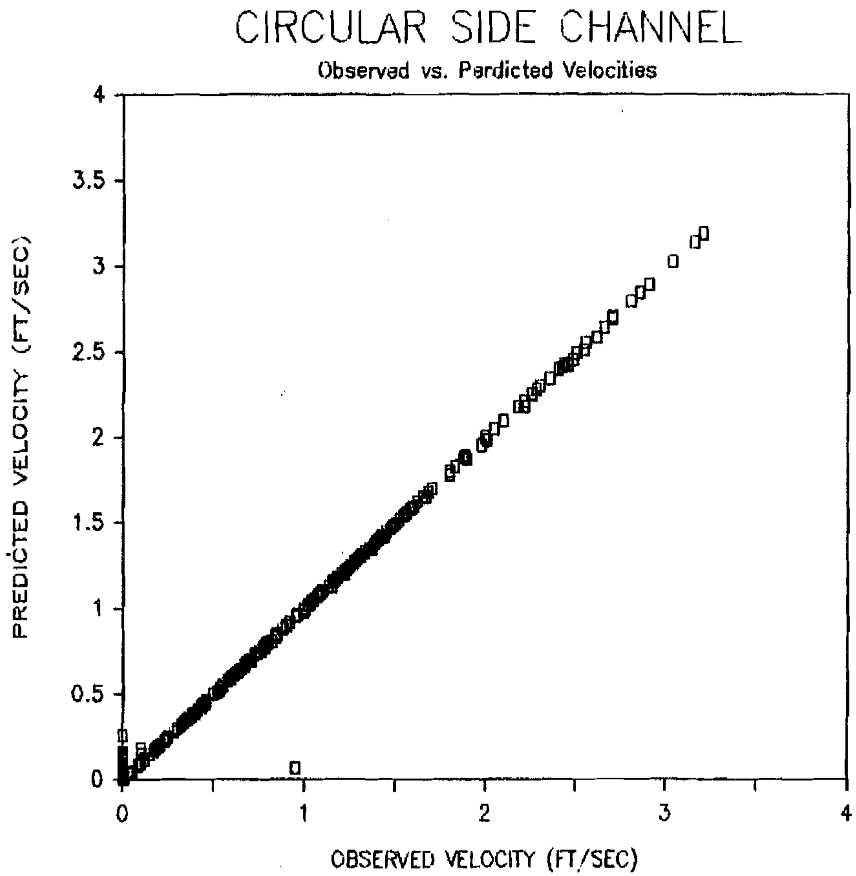
Appendix Figure D-25. Application range of the calibrated hydraulic model at Circular Side Channel.

observed and predicted depths (Appendix Figure D-26). The results of the statistical tests also indicate good agreement between the predicted and observed values for both velocity and depth (Appendix Table D-7). The index of agreement is near one, the total RMSE is mostly composed of the unsystematic RMSE, and the y-intercept is close to zero with a slope of almost one.

Application

For habitat simulation modelling purposes, the hydraulic simulation model developed for Circular Side Channel can simulate channel flows in the mainstem discharge range of 36,000 to 63,000 cfs.





Appendix Figure D-26. Scatterplots of observed and predicted depths and velocities from the calibrated IFG-4 hydraulic model at Circular Side Channel.

Sauna Side Channel (RM 79.8)

Site Description

Sauna Side Channel is located on the west bank of the Susitna River at river mile 79.8 (Appendix Figure D-27). It is approximately 0.2 miles long. Both the mouth and head of the side channel are connected to a larger side channel of the mainstem Susitna River. For the most part, the side channel is confined on the west side by a high bank and on the east by a large sparsely vegetated gravel bar. A smaller side channel enters just below the head of Sauna Side Channel on its west bank. This side channel conducts flow to the study site during high mainstem discharges, but dewaters before the head of Sauna Side Channel becomes unbreached. Breaching flows result from overtopping of the side channel that adjoins the head on the east bank of Sauna Side Channel. Prior to breaching, the channel is composed of two large interconnected pools whose water levels are maintained from ground water seepage originating from the vicinity of the head. An extensive log jam at the head of Sauna Side Channel influences the flow into this side channel.

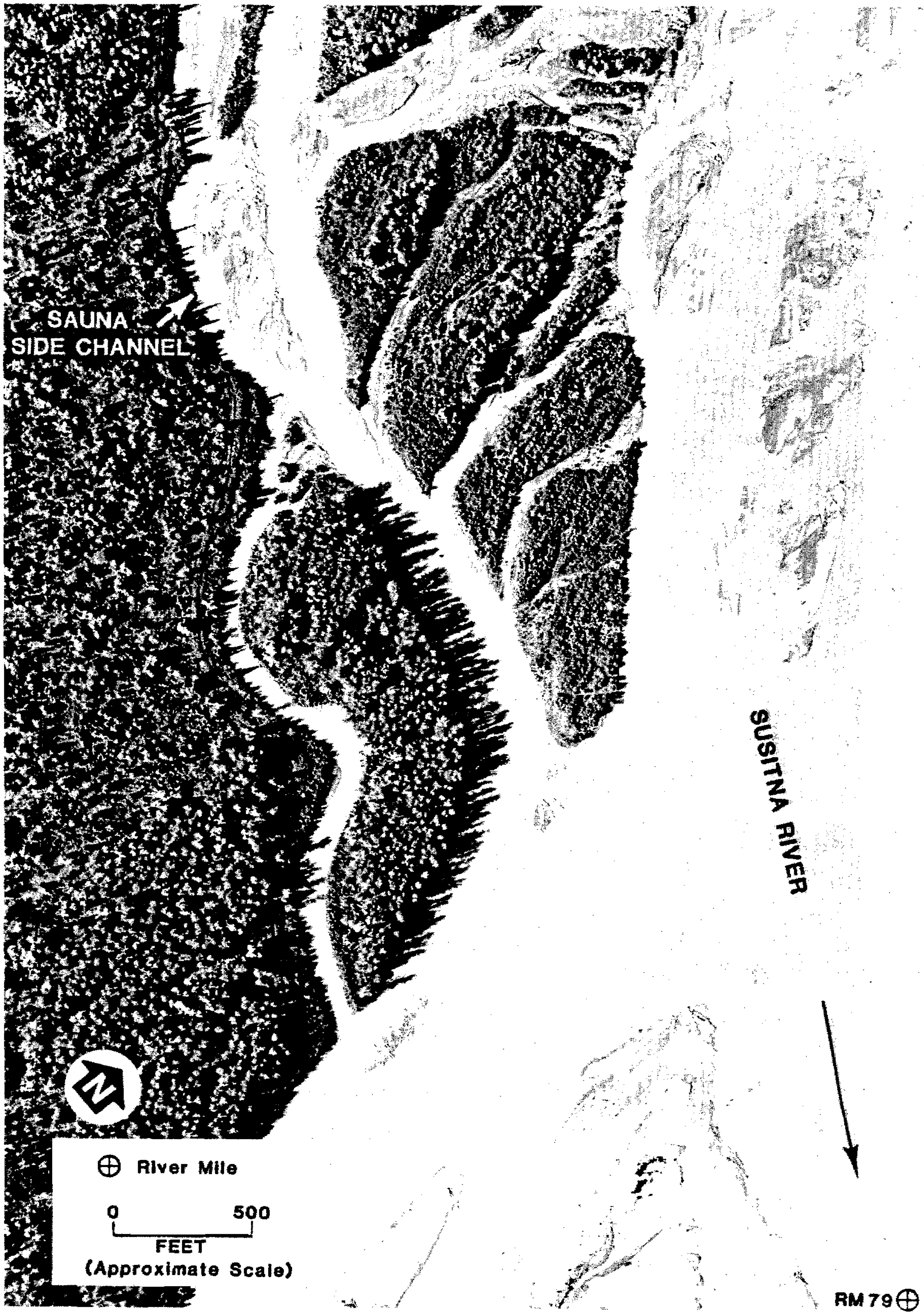
Based on field observations and stage/discharge relationships, the mainstem discharge estimated to initially breach Sauna Side Channel was 37,000 cfs (Quane et al. 1985). A controlling discharge of 38,000 cfs was determined for this side channel also based on this stage/discharge relationship. A side channel flow of 22.5 cfs was estimated to occur at the 38,000 cfs mainstem discharge as derived from the stage versus streamflow rating curve (Appendix Figure D-28). Quane et al. (1985) determined that backwater does not occur in Sauna Side Channel during non-breaching mainstem discharges. During breaching discharges of 54,600 to 56,700 cfs, however, backwater was observed to occur throughout the Sauna Side Channel study site.

The IFG modelling site, located approximately 2,000 feet from the mouth of this side channel, was 480 feet long (Appendix Figure D-29). The thalweg gradient at this site is 10.4 ft/mile (Quane et al. 1985). Substrates throughout this site consist primarily of sands and silts. The water is slow moving with velocities usually less than 1.0 ft/sec. The left bank at the site is an erosional bank with a height exceeding five feet; riparian vegetation along this bank consists of alder and birch. In contrast, the left bank is a depositional bank with no riparian vegetation.

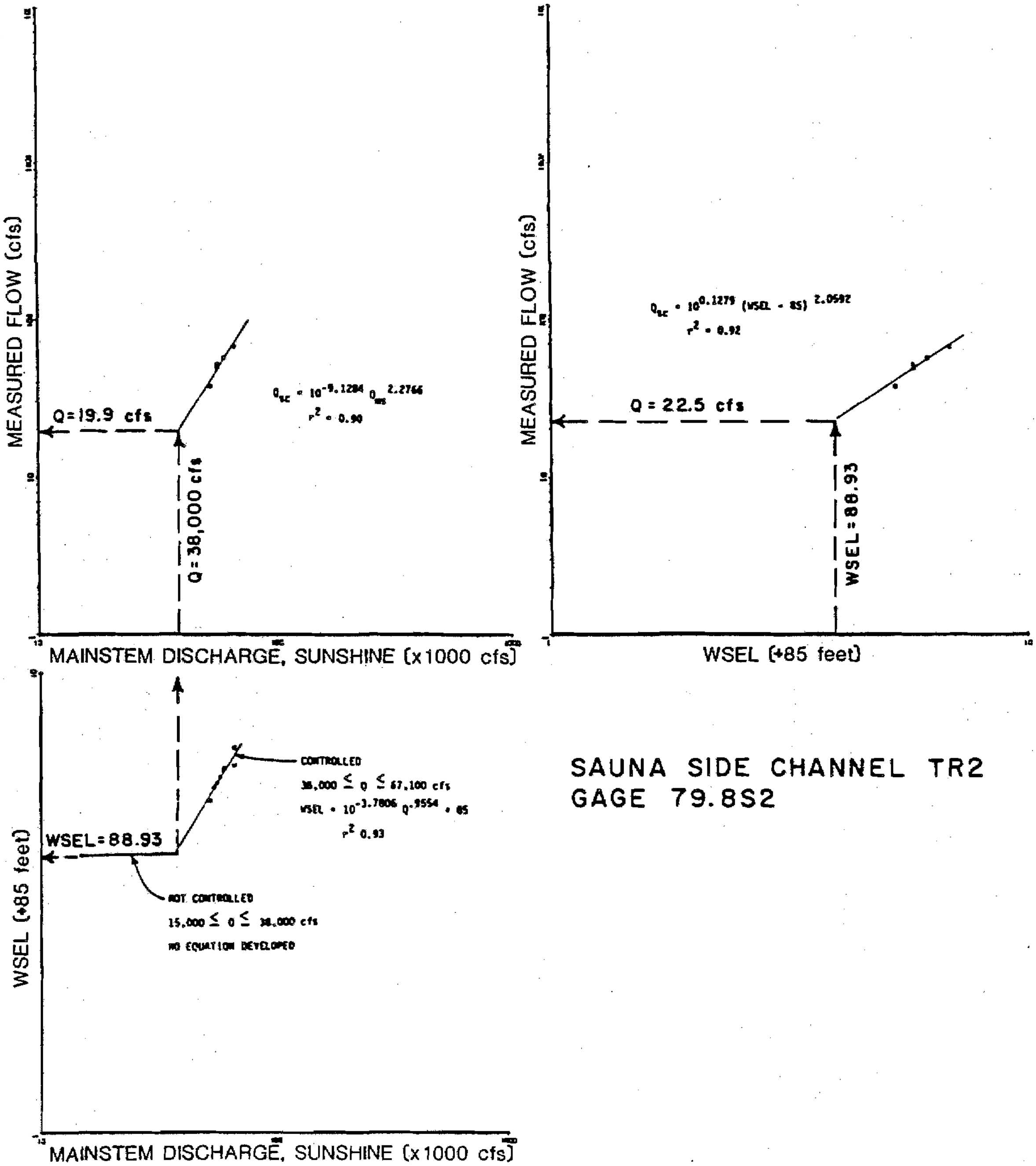
Four transects were located within this study site (Appendix Figure D-30) . Transects 1 and 2 were located in shallow pool habitat whereas transects 3 and 4 were located in deeper pools.

Calibration

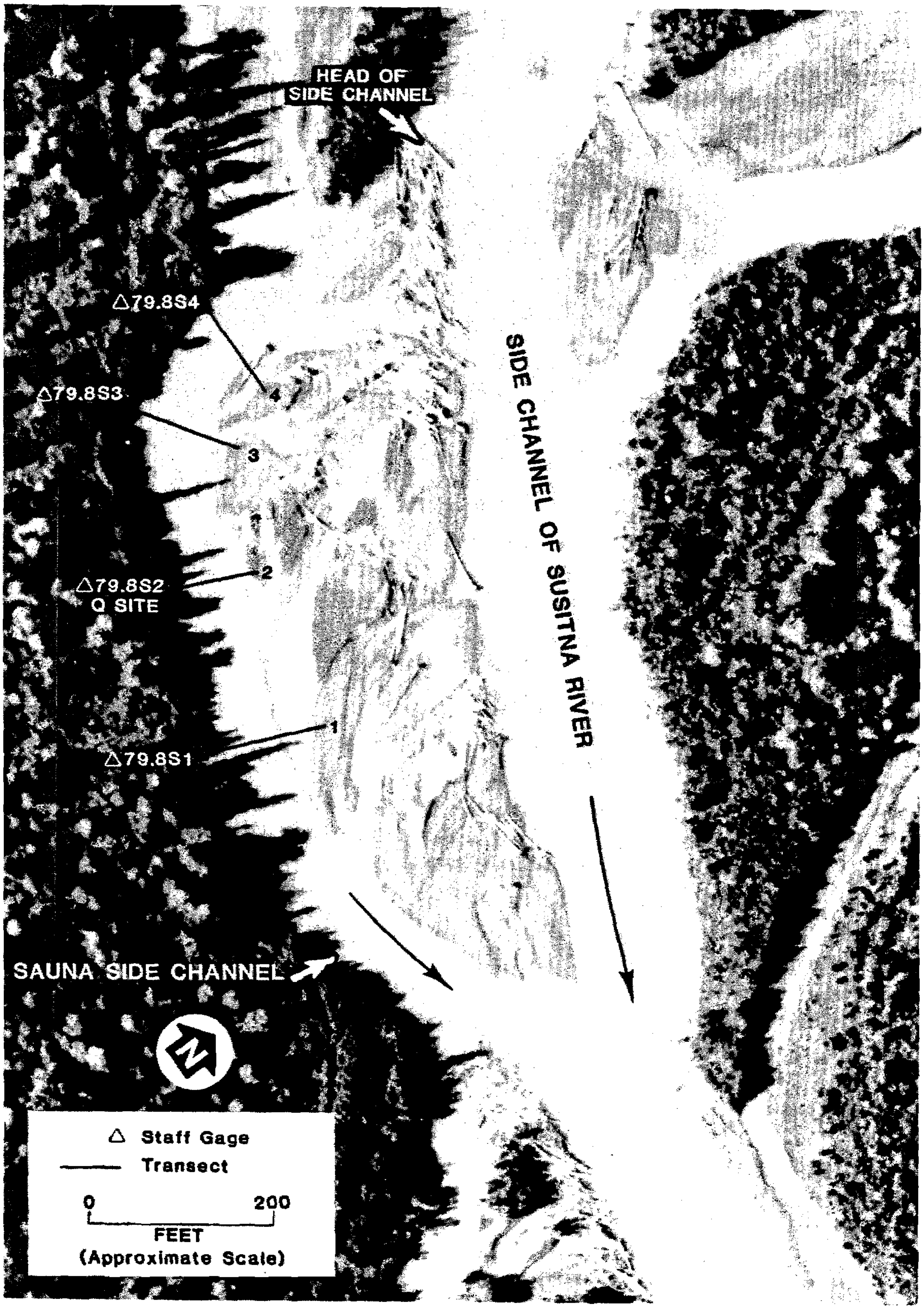
Hydraulic data were collected at a calibration flow of 52 cfs corresponding to a mainstem discharge of 52,000 cfs (Appendix Table D-4). Based on this single calibration flow, an IFG-2 model was used to forecast instream hydraulics of this study site. The streambed profile, stage of zero flow, and observed and predicted water surface elevations for the study reach are plotted in Appendix Figure D-31. This data set



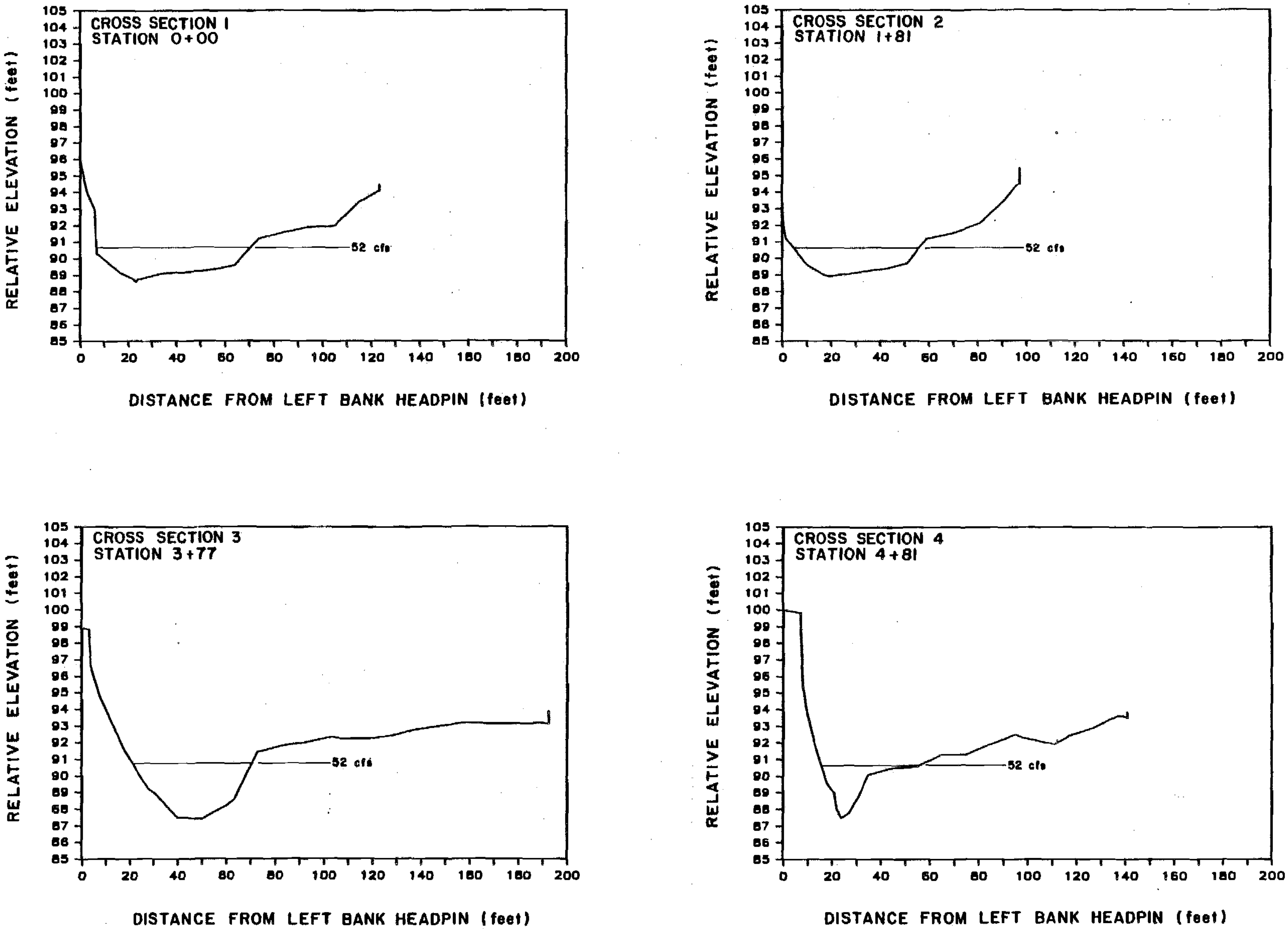
Appendix Figure D-27. Overview of Sauna Side Channel (RM 79.8).



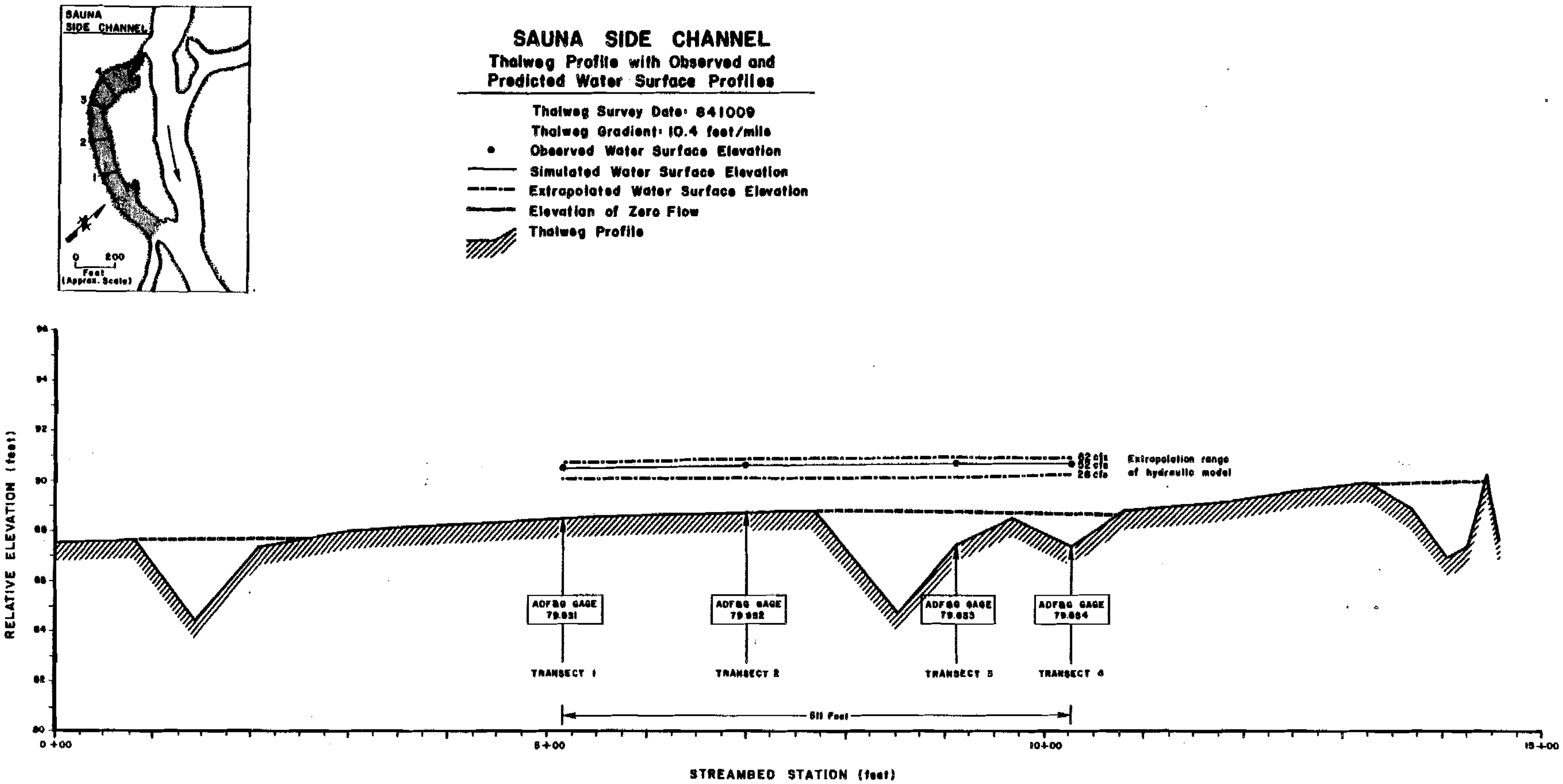
Appendix Figure D-28. Comparison of rating curves from Sauna Side Channel transect 2 (from Quane et. at. 1985).



Appendix Figure D-29. Location of Sauna Side Channel study site (RM 79.8).



Appendix Figure D-30. Cross section of transects 1, 2, 3, and 4 at Sauna Side Channel (adapted from Quane et al. 1985).



Appendix Figure D-31. Comparison of observed and predicted water surface profiles from calibrated model and surveyed thalweg profile at Sauna Side Channel (adapted from Quane et al. 1985).

was used to predict hydraulic information from side channel flows of 5 to 93 cfs (mainstem discharges of 21,000 to 75,000 cfs). To evaluate the performance of the hydraulic model, observed and predicted water surface elevations were compared (Appendix Table D-9). Additionally, the stage information of the model was compared to the rating curves established by Quane et al. (1985) (Appendix Figure D-28).

It was difficult to calibrate hydraulic information at this site because very limited field data were available. A site flow versus WSEL rating curve could only be developed for transect 2 (Appendix Figure D-28). The IFG-2 model is essentially a water surface profile model and a critical variable for calibrating it, is the water surface elevations of simulated flows. Data, however, is only available for transect 2 and not for any of the other three transects. The actual velocity measurements from other measured flows at the discharge transect, however, can be compared to the model predicted velocities for those same flows. At the discharge measurement for transect 2, however, there were only two flows that were far enough away from the 52 cfs measurement to be usable (38 and 68 cfs). Thus, the information available to hydraulically calibrate the IFG-2 model for this site consists of the water surface elevations and velocity measurements for all four transects at the calibrating flow of 52 cfs, and water surface elevations and velocities for the two other site flows of 38 and 68 cfs at transect 2.

This site is influenced by backwater and the effects are more pronounced at the 68 cfs flow. From the field data, the observed top width is greater by 20 feet, the water surface elevation is 0.93 feet higher, and the average velocity is 0.20 ft/sec slower than predicted by the model. At the 38 cfs flow, the effect seems to have reversed, with the observed widths being similar, the WSEL 0.08 feet lower, and the average velocity 0.09 ft/sec faster than predicted by the model (Appendix Table D-10).

In the calibration process, the original field WSEL was reduced by 0.1 feet. This adjustment was made in order to obtain water surface elevations that agreed more closely to the lower site flows. It was felt that this adjustment would make the model, in terms of predictability, more sensitive at the lower site flows. By reducing the WSEL of transect 1 by 0.1 feet, the difference between the field and the model WSEL at the 38 cfs flow was reduced from 0.18 feet, when the calibration discharge WSEL was 90.71, to 0.08 feet, when the calibration discharge WSEL was 90.61 feet (Appendix Table D-10).

As a result of a flood on August 26, sediments were deposited in the study site resulting in changes in all the cross sections derived from the calibration flow on July 23. As a result, the cross sections obtained during the September 15 survey were used in the model until the water's edge of the calibration flow was reached, then the cross sections from the calibration flow were used.

When measuring the velocities and depths at each of the transects, the discharge calculated at transect 4 was 16% lower than the 52 cfs site flow calculated at the discharge transect. In order to utilize this information in the model, the velocities were adjusted upwards by 16%.

Appendix Table D-9. Comparison of field measured and model predicted water surface elevations at the calibration flow of 52 cfs for Sauna Side Channel.

	Water Surface Elevation (ft)		
Transect	Original Field	Modified Field*	Model Predicted
1	90.70	90.60	90.61
2	90.71	90.61	90.62
3	90.72	90.62	90.63
4	90.69	90.59	90.63

* Field water surface elevations were reduced by 0.1 feet.

Appendix Table D-10. The effects of the backwater at Sauna Side Channel, information obtained from transect 2.

Site Flow (cfs)	Original WSEL (ft)		Modified WSEL (ft)		Top Width (ft)		Average Velocity (ft/sec)	
	Field	Model	Field	Model	Field	Model	Field	Model
68	91.85	91.06	91.85	90.92	77.0	55.0	0.32	0.52
52[a]	90.71[b]	90.74	90.61[c]	90.62	53.5	53.0	0.53	0.49
38	90.24	90.42	90.24	90.32	50.5	52.0	0.51	0.42

[a] Calibration flow

[b] Original field WSEL input into model

[c] Field WSEL reduced by 0.1 ft

No stage-site flow rating curve was developed for transect 1. When inputting other flows into the model, the IFG-2 requires either the associated WSEL for this flow or the slope. Because the WSEL could not be obtained for other flows at this transect, a slope value of 0.00005 was input instead. This value was generated by the model from transect 1 at the calibration flow of 52 cfs.

Verification

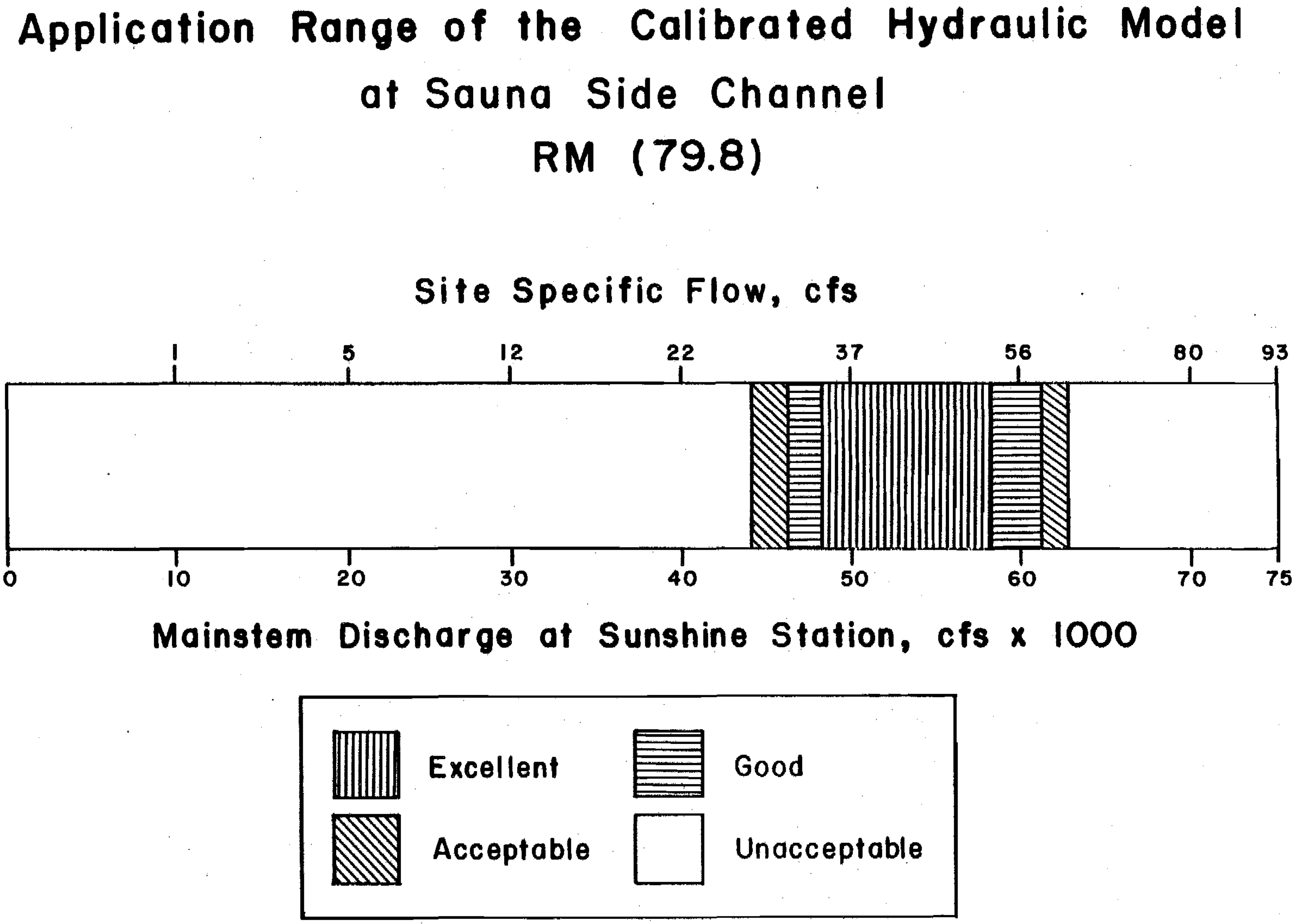
The dominant influence of backwater on channel hydraulics makes the site a poor candidate for application of IFG-2 modeling techniques. However, because only one data set was collected, application of the IFG-4 hydraulic model was not possible.

Based on the first level of verification by EWT&A, the IFG-2 model for this site does an excellent job of simulating channel hydraulics between 48,000 cfs and 58,000 cfs mainstem discharge (34 to 52 cfs site flow) (Appendix Figure D-32). Within this range, predicted WSEL's, depths, and velocities are in close agreement with field information (evaluated at 38 cfs by discharge measurement made by Quane et al. (1985). The predictive capability of the model within this range provides evidence that the backwater influence within the study site is lessening with decreasing discharge.

Below 48,000 cfs mainstem, there is increasing disagreement between the WSEL's predicted by the model and those extrapolated from the rating curve. At a 23 cfs site flow, the difference in predicted WSEL between model and rating curve equation has increased to approximately one foot at transects 1 and 2. Although there is evidence that suggests that the model may be a more accurate predictor of WSEL's than the rating curve equations below 48,000 cfs mainstem, insufficient information exists to resolve the difference with confidence. Since depths become shallow within this range, predictive errors in WSEL can result in significant errors in predicted depths and velocities. For this reason, the recommended extrapolation range is limited below 48,000 cfs.

Above a 48,000 cfs mainstem discharge, there is increasing, disagreement between the WSEL's predicted by the model and those observed in the field. One of the premises of the hydraulic theory that is the basis of the IFG-2 model is that the water surface profile of the study reach is controlled by its slope. This premise is violated when the water surface profile is influenced by mainstem backwater. From examination of discharge measurements made at 48 and 68 cfs it is apparent that the influence of backwater is increasing with stage above 58,000 cfs mainstem.

Overall, the recommended extrapolation range is limited above 58,000 cfs. The model simulations were rated excellent between 48,000 and 58,000 mainstem discharge (34 to 52 cfs site flow). Good between 46,000 and 48,000 (31 to 34 cfs) and from 58,000 to 60,000 cfs (52 to 58 cfs). Acceptable between 44,000 and 46,000 cfs (28 to 31 cfs) and 60,000 to 63,000 cfs (58 to 62 cfs). The model was rated unacceptable below 44,000 cfs and above 63,000 cfs mainstem discharge (Appendix Figure D-32).

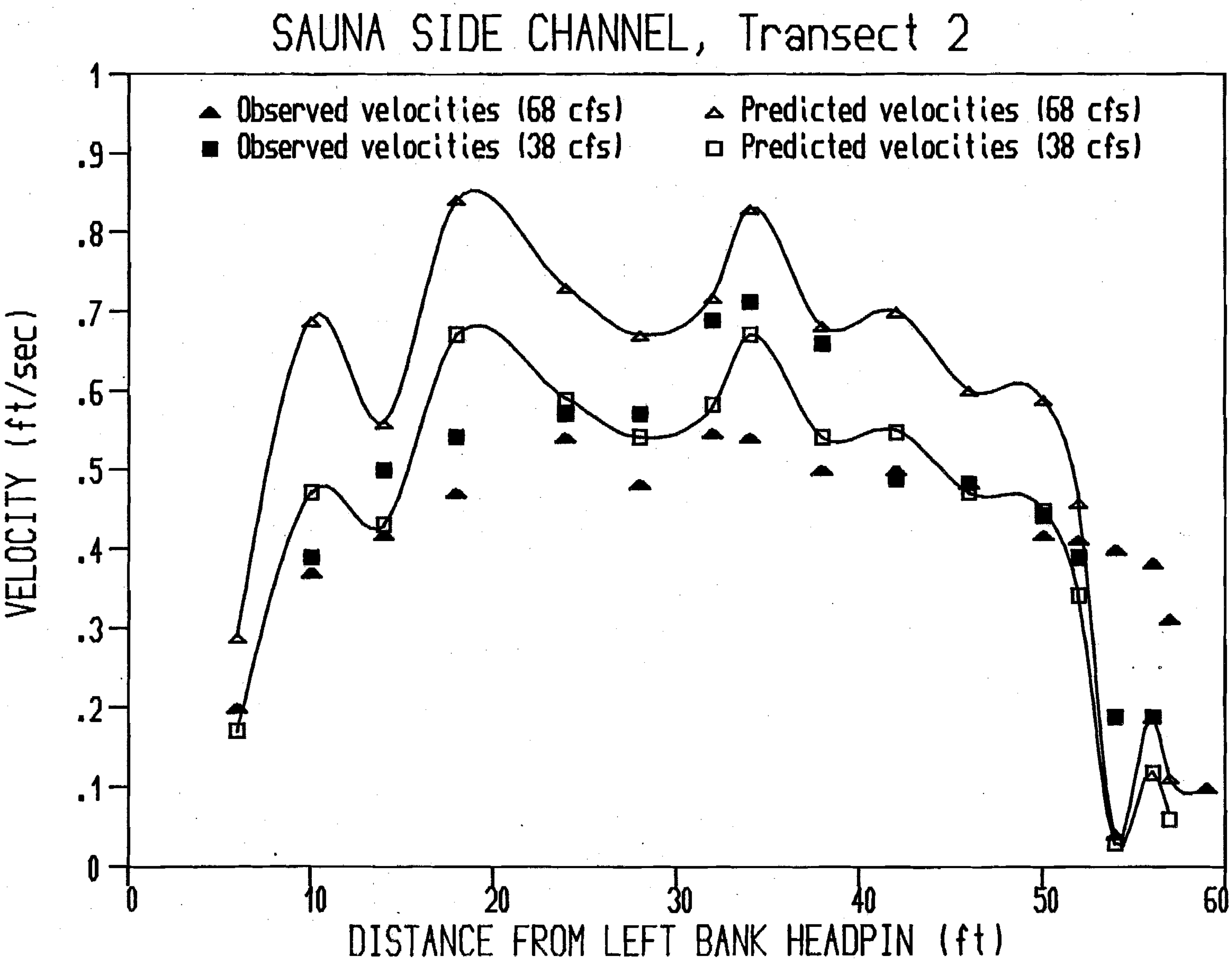


Appendix Figure D-32. Application range of the calibrated hydraulic model at Sauna Side Channel.

The velocity profiles produced by the IFG-2 model at transect 2 were compared to the observed velocities at flows of 38 and 68 cfs (Appendix Figure D-33). Because this site is primarily a backwater area and the IFG-2 hydraulic model is not a backwater model it was thought that calibrating the model to more accurately predict at the lower flows would be more critical than at the higher flows. Thus at the 38 cfs flow there is found a better correspondence between the observed and predicted velocities. At the 68 cfs flow the backwater becomes more apparent. A majority of the observed velocities are lower than the predicted velocities and many of these values are lower than individual 38 cfs flow velocities. Because of the overall low velocities, 1.0 ft/sec, it was felt that this was the best compromise in applying this model to the Sauna Side Channel site.

Application

For habitat simulation modelling purposes the hydraulic simulation model developed for Sauna Side Channel can simulate channel flows in the mainstem discharge range of 44,000 to 63,000 cfs.



Appendix Figure D-33. Comparison of observed and predicted velocities from the IFG-2 hydraulic model at Sauna Side Channel using two flows at the discharge transect.

Sunset Side Channel (RM 86.9)

Site Description

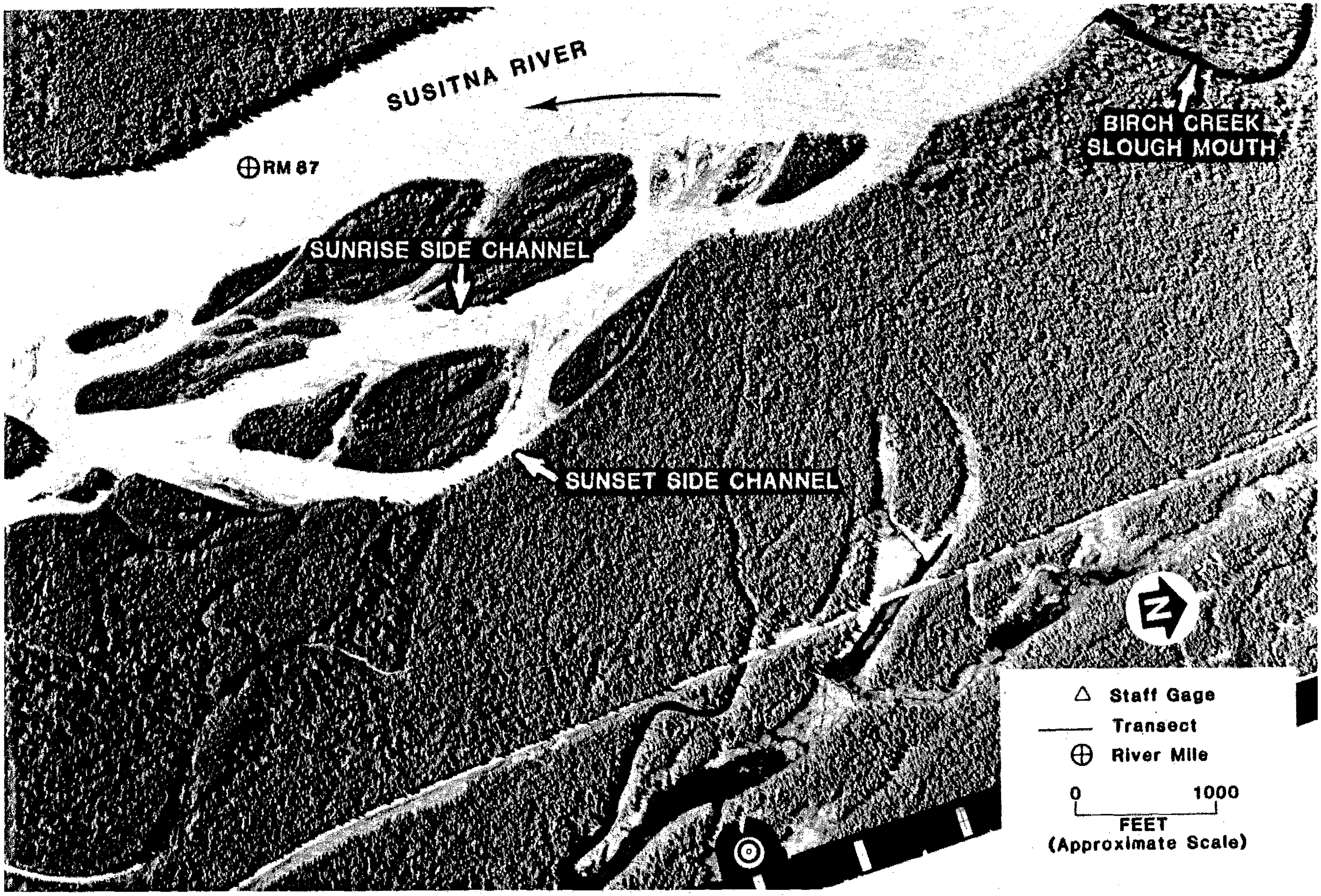
Sunset Side Channel is located on the east bank of the Susitna River at river mile 86.9 (Appendix Figure D-34). It is approximately 1.1 miles long and is separated from the main channel of the Susitna River on the west by a network of vegetated islands and side channels. The channel is confined on the east by a high cut bank. Prior to breaching, the side channel is composed of a sequence of pools and riffles. During this period, flow is maintained in the main channel by groundwater seepage and upwelling. After breaching, flows up to 3,900 cfs have been measured (Quane et al. 1985).

Breaching of Sunset Side Channel results from the direct overtopping of the head of the side channel by the mainstem Susitna River. Based on assessments by Quane et al. (1985) the side channel initially breached at 31,000 cfs and controlled at a mainstem discharge of 32,000 cfs. The associated site flow at the controlling discharge has been estimated to be 45.8 cfs while a flow of 41.1 cfs is derived from the flow versus mainstem discharge rating curve (Appendix Figure D-35).

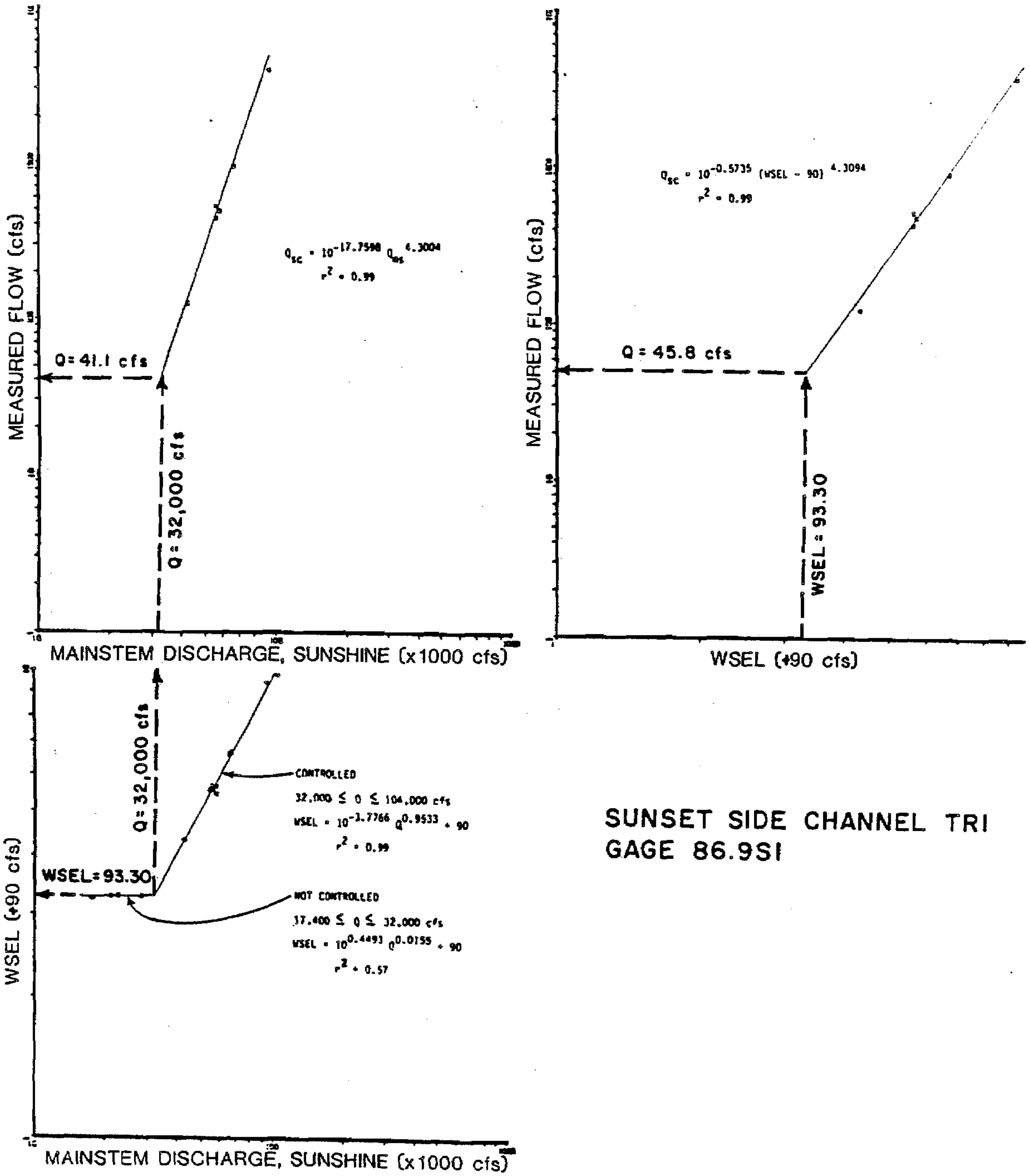
Based on assessments by Quane et al. (1985) a backwater area does not occur in this side channel during unbreached conditions. But at breaching mainstem discharges ranging from 56,000-66,700 cfs, an area of backwater was observed to extend upstream approximately 1,100 feet to a point between transects 1 and 2.

The IFG modelling site within Sunset Side Channel was located in the lower portion of the side channel and was 1410 feet long (Appendix Figure D-36). Hydraulic information was collected from seven transects within this study site (Appendix Figures D-37 & D-38). The channel within the study site has a gradual bend. The right bank from transects 2 to 6 is erosional, becoming less steep and depositional at transects 0 and 1. On the left bank, transects 2 through 6 are primarily depositional in nature. In the areas of transects 0 and 1, the left bank becomes steep and erosional. At transect 2 on the left bank a small dewatered channel enters but water was never observed running in it (Appendix Figure D-36). The thalweg gradient within the study site is 9.5 ft/mile (Quane et al. 1985). Riparian vegetation along the right bank is primarily birch and spruce, whereas on the left bank it is alder.

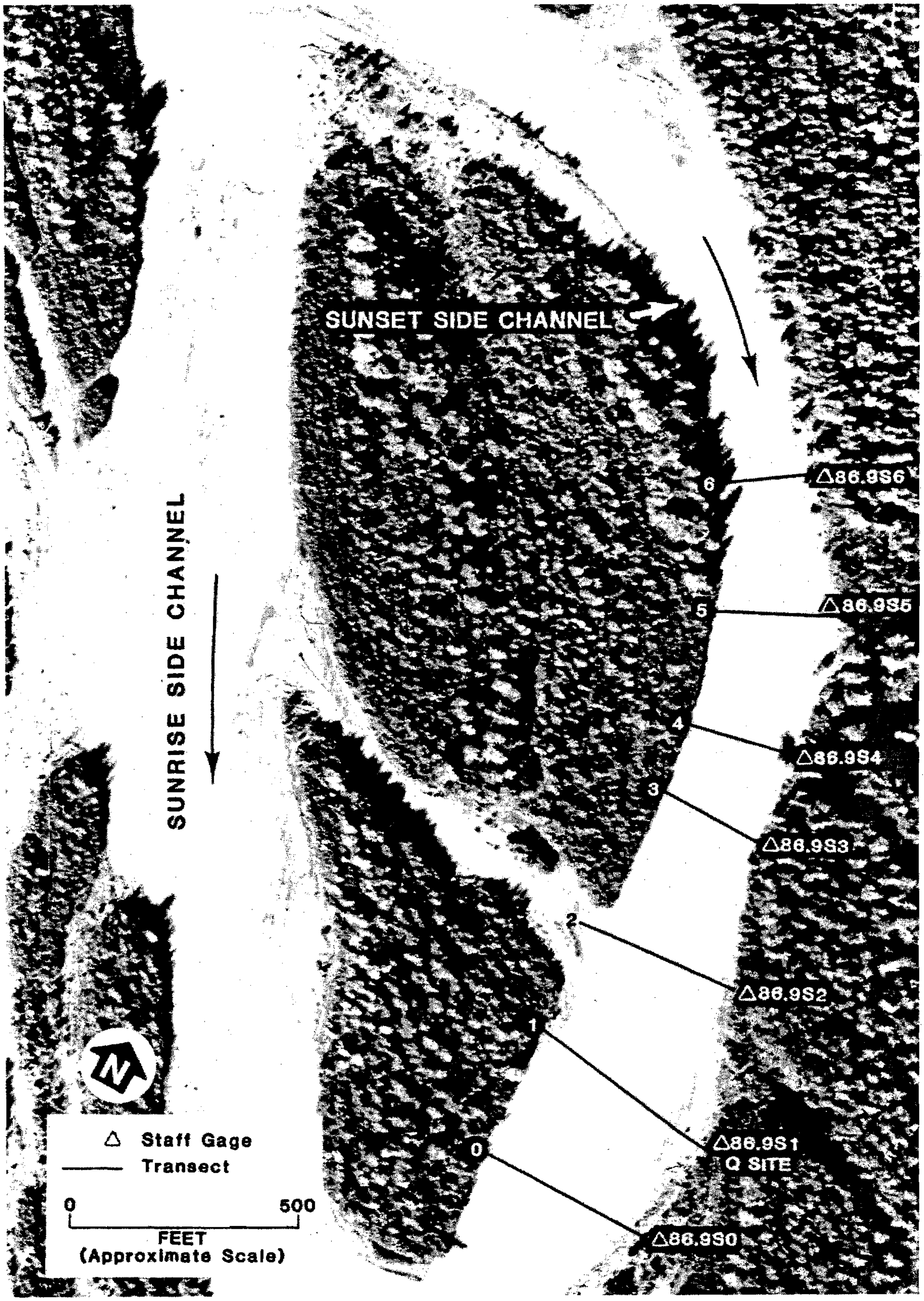
Transect 0 is located in a shallow pool habitat and has a substrate of sand and small gravel. Transects 1 (the discharge site) and 2 are primarily run habitat, and the substrate is small gravel. At transect 3, the habitat changes to run and shallow pool habitat, the predominant substrate is small and large gravel. The hydraulic control for transects 5 and 6 is transect 4. This transect represents riffle habitat, with substrates composed mostly of small and large gravels. Transects 5 and 6 are located in deep pool habitat, with small and large gravel substrate.



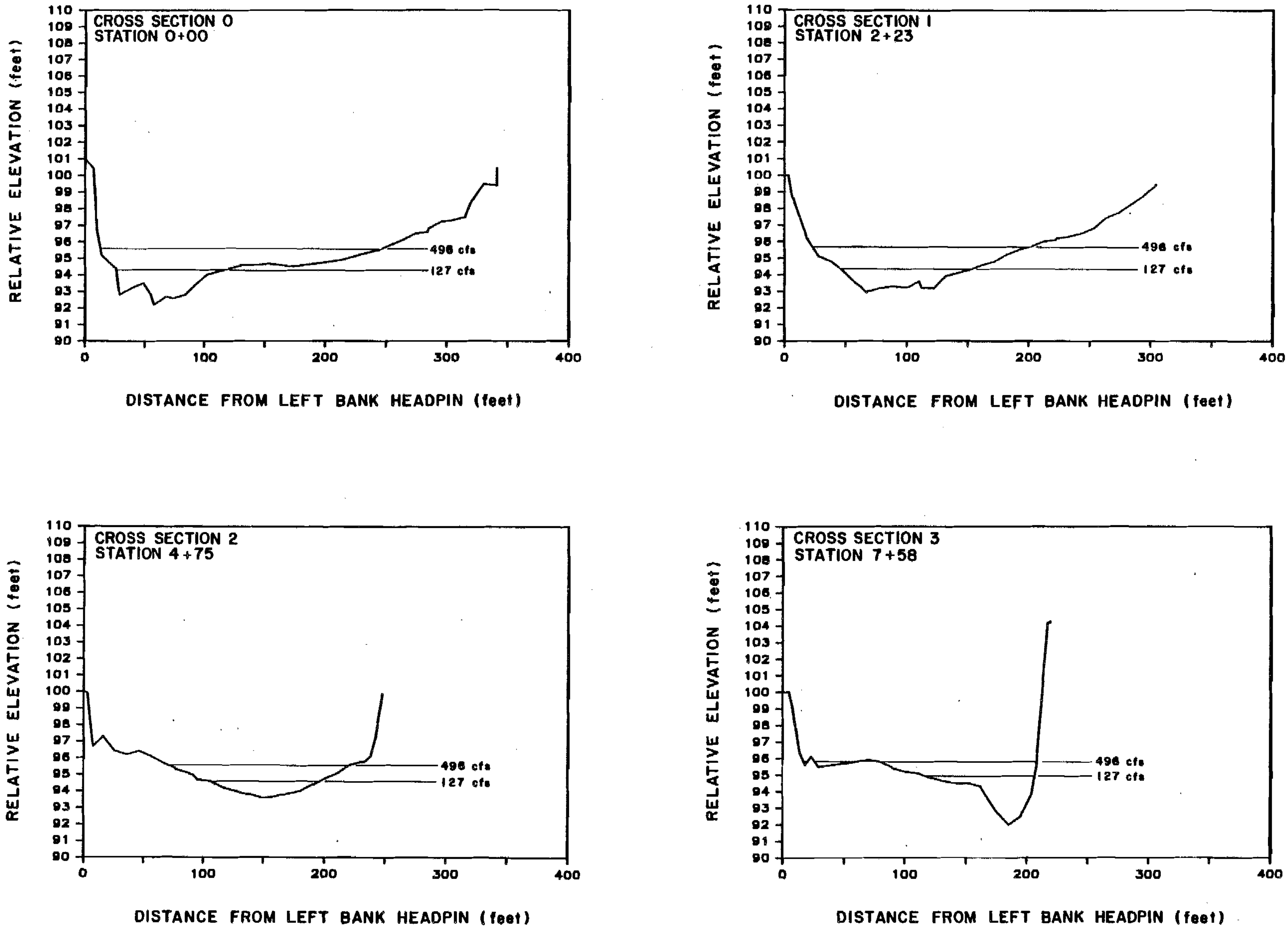
Appendix Figure D-34. Overview of Sunset Side Channel (RM 86.4).



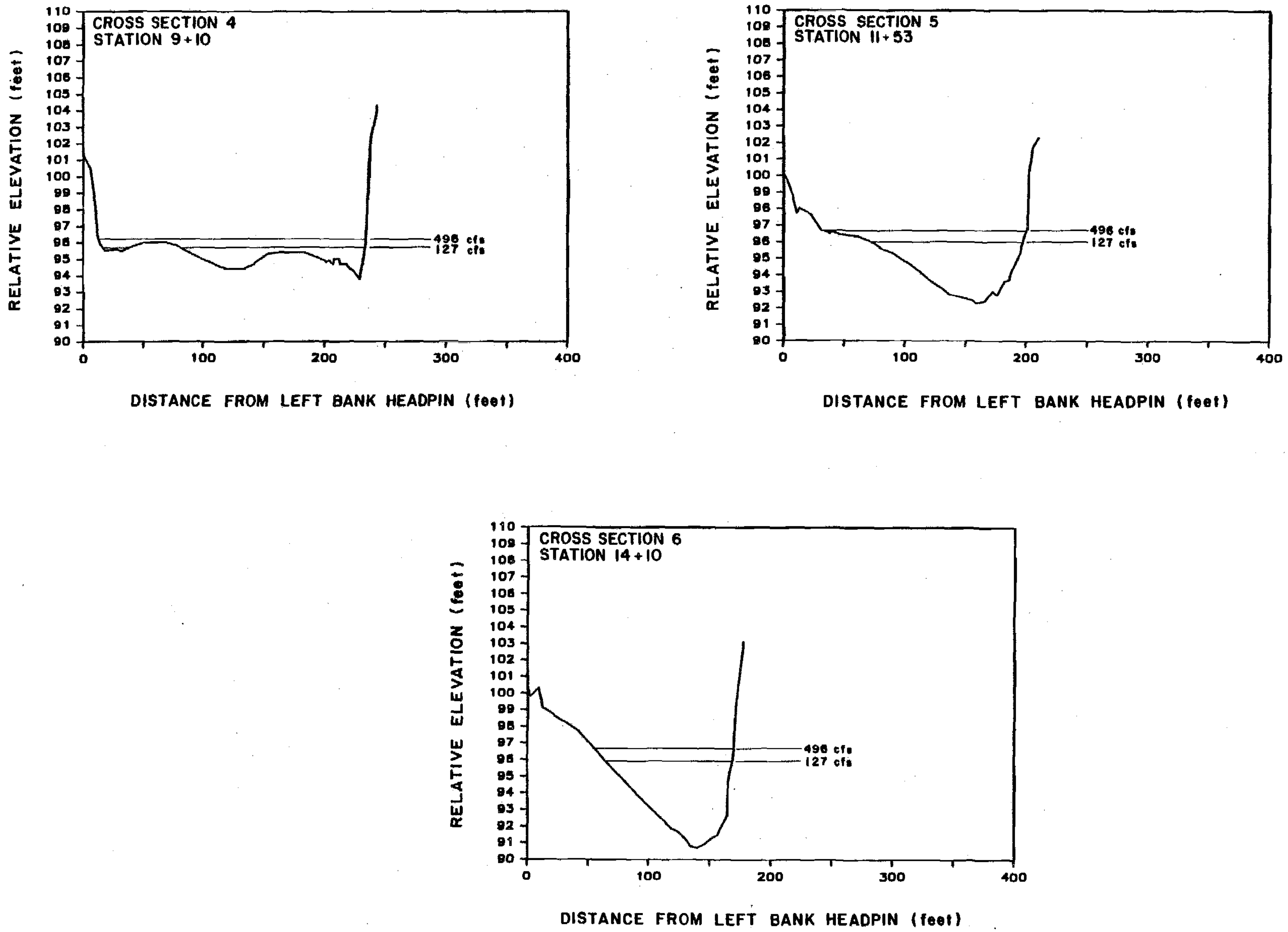
Appendix Fugure D-35. Comparison of rating curves from Sunset Side Channel at transect 1 (from Quane et. al. 1985).



Appendix Figure D-36. Location of Sunset Side Channel study site (RM 86.9).



Appendix Figure D-37. Cross section of transects 0, 1, 2, and 3 at Sunset Side Channel (adapted from Quane et al. 1985).



Appendix Figure D-38. Cross section of transects 4, 5, and 6 at Sunset Side Channel (adapted from Quane et al. 1985).

Calibration

Hydraulic data were collected at two calibration flows: 127 and 496 cfs (Appendix Table D-4). Mean daily discharges for the Susitna River on the dates that calibration data were collected at the Sunset Site Channel study site were 42,500 and 57,800 cfs, respectively. Based on these two calibration flows, an IFG-4 model was used to forecast instream hydraulics at this study site. The streambed profile, stage of zero flow, and observed and predicted water surface elevations for the study reach are plotted to scale in Appendix Figure D-39. Both calibration data sets were used to predict hydraulic information from side channel flows of 7 to 1,603 cfs (mainstem discharges of 21,000 to 75,000 cfs).

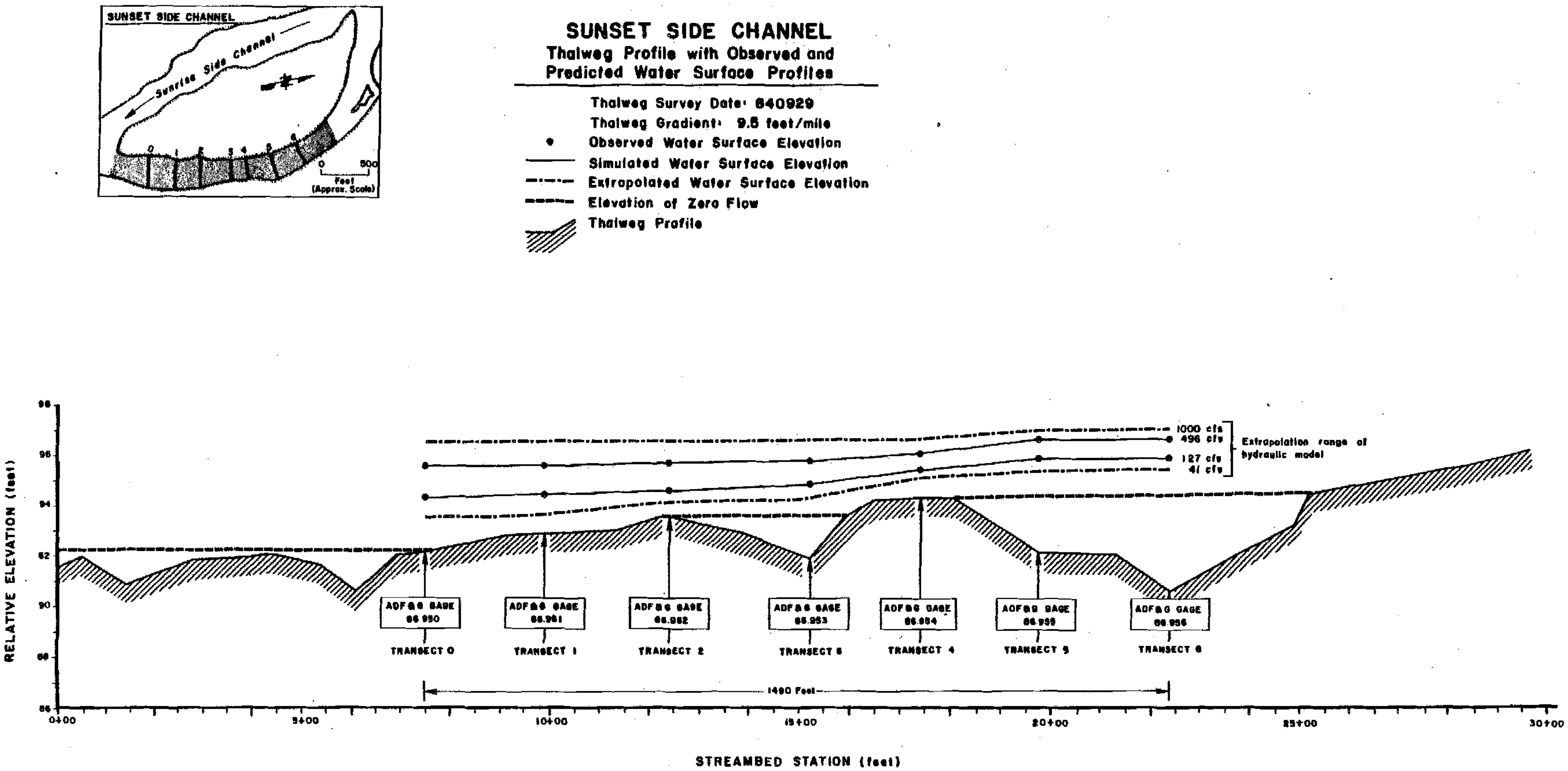
To evaluate the performance of the hydraulic model, observed and predicted water surface elevations, discharges, and velocity adjustment factors were compared (Appendix Table D-11). The hydraulic model at Sunset Side Channel is similar to Circular Side Channel. Because of the 2 calibration flows, only a 2 point rating curve was formulated. In evaluating the performance of the model, observed and predicted WSEL's and discharges were the same because of this rating curve. Velocity adjustment factors were all within the good range of 0.9 to 1.1. Additionally, the stage information of the model was compared to the rating curves established by Quane et al. (1985) (Appendix Figure D-35).

In the model, the stages of zero flow are not the same as those determined from the thalweg survey by Quane et al. 1985 (Appendix Table D-12). The stage of zero flow values, input into the model, were derived from the thalweg points of the model input cross sections of transects 0, 1, 2, and 4. The reason for this change in thalweg elevations is likely the result of the flood event. All the points used in the model were from measurements made before the flood, whereas the Quane et al. (1985) thalweg survey was done after the flood event.

At transect 6, the velocities at the high calibration flow measurement (496 cfs) were adjusted upwards by 15% and at the low calibration flow measurement (127 cfs) adjusted downwards by 21%. Because this transect bisects a deep pool with eddies, it is difficult to obtain an accurate discharge measurement. The eddy effect was much more pronounced at the high calibration flow measurement, as there was about a 40 foot a section in which the velocities were negative. Because of its depth and slow velocities, this area was considered valuable habitat for rearing juvenile salmon. In order to facilitate using these negative velocity values in the model these measurements were treated as positive.

At transect 3, there was a difference in WSEL's at the 127 cfs calibration flow. WSEL at the left bank was 95.03 feet, whereas at the right bank it was 94.90 feet. As the staff gage WSEL was 94.93 feet and the majority of flow occurred along this right side, a WSEL of 94.93 feet was used in the model.

At transect 4, there was a large discrepancy (0.54 ft) in WSEL's across the transect at the calibration flow of 127 cfs. This occurred because



Appendix Figure D-39. Comparison of observed and predicted water surface profiles from calibrated model and surveyed thalweg profile at Sunset Side Channel (adapted from Quane et al. 1985).

Appendix Table D-11. Comparison between observed and predicted water surface elevations, discharges, and velocities for 1984 Sunset Side Channel hydraulic model.

Streambed Station (ft)	Water Surface Elevation Observed (ft)	Water Surface Elevation Predicted (ft)	Discharge Observed (cfs)	Discharge Predicted (cfs)	Velocity Adjustment Factor
0+00	94.27	94.27	132.7	132.4	1.000
2+23	94.34	94.34	131.7	131.3	.999
4+75	94.69	94.69	133.6	133.3	1.000
7+58	94.97	94.97	127.2	126.9	.998
9+10	95.54	95.54	136.4	136.3	1.000
11+53	95.98	95.98	125.5	125.2	.999
14+10	95.97	95.97	129.9	129.6	
			Qo = 131.0	Qp = 131.0	
0+00	95.62	95.62	462.3	462.3	1.000
2+23	95.67	95.67	500.0	500.0	.999
4+75	95.75	95.75	504.6	504.6	1.000
7+58	95.87	95.87	438.1	438.1	1.000
9+10	96.18	96.18	507.2	507.2	.993
11+53	96.64	96.64	469.9	469.9	.999
14+10	96.63	96.63	492.0	492.0	1.000
			Qo = 482.0	Qp = 482.0	

Qo is the mean observed calibration discharge.

Qp is the mean predicted calibration discharge.

Appendix Table D-12. Differences between stages of zero flow input into the model and Quane et al. (1985) thalweg survey at Sunset Side Channel.

Transect	Stage of Zero Flow (ft)	
	Model Input	Thalweg Survey
0	92.30	92.50
1	92.60	93.00
2	93.40	93.60
3	93.40	93.60
4	94.20	94.40
5	94.20	94.40
6	94.20	94.40

the section of the channel where a majority of the flow occurred was higher in elevation and separated by a gravel berm from a lower elevation minor channel where the staff gage was located. In order to utilize this cross section in the model, the channel cross section of the minor channel was elevated upwards by 0.6 feet.

At a section of transect 3, because of channel configuration, the individual velocity measurements for the 127 cfs site flow were greater than the corresponding velocity measurements at the higher 496 cfs site flow. If these original values were to be used in the model the simulated velocities would decrease with increasing site flows rather than increase as expected under normal circumstances. In order to amend this situation, the velocities were adjusted such that the relationship would simulate a positive increase in velocities with corresponding increases in site flow.

Verification

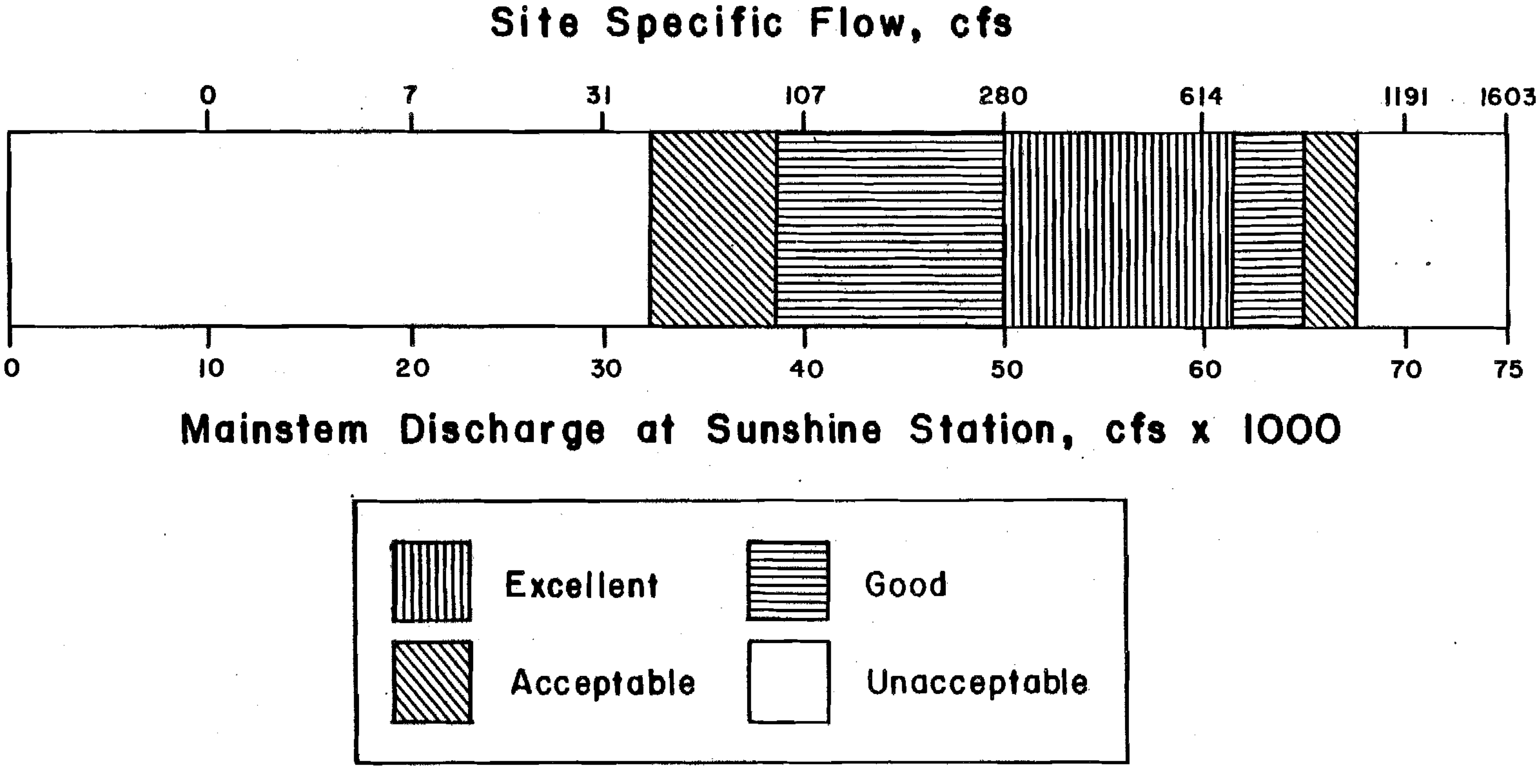
Based on the first level of verification by EWT&A, the model does an excellent job of simulating channel hydraulics between 50,000 and 61,000 cfs, mainstem discharge(275 and 649 cfs site flow). Above 61,000 cfs, the realiability of the simulated depth and velocity distributions begin to decrease. The model simulations were rated good between 61,000 and 64,500 cfs (649 and 850 cfs site flow), acceptable between 64,500 and 67,000 cfs (850 and 1,000 cfs site flow), and unacceptable above 67,000 cfs mainstem discharge. Below 50,000 cfs, the model simulations were also rated less than excellent, primarily because of reduced effectiveness in predicting water surface profiles as compared to field observations. The model simulations were rated good between 38,000 and 50,000 cfs (89 and 275 cfs site flow), acceptable between 32,000 and 38,000 cfs (41 and 89 cfs site flow), and unacceptable below 32,000 cfs mainstem discharge (Appendix Figure D-40).

At the second level of verification there is excellent agreement for velocity and good agreement for depth between observed and predicted values (Appendix Figure D-41). For a small number of depths there is a deviation away from the expected one to one relationship and this maybe attributable to the adjustments in the channel cross section at transect 4. The statistical tests show good agreement between these predicted and observed values (Appendix Table D-7). The index of agreement is almost one, the total RMSE is mostly composed of the unsystematic RMSE, and the y-intercept is essentially zero with a slope of 0.99.

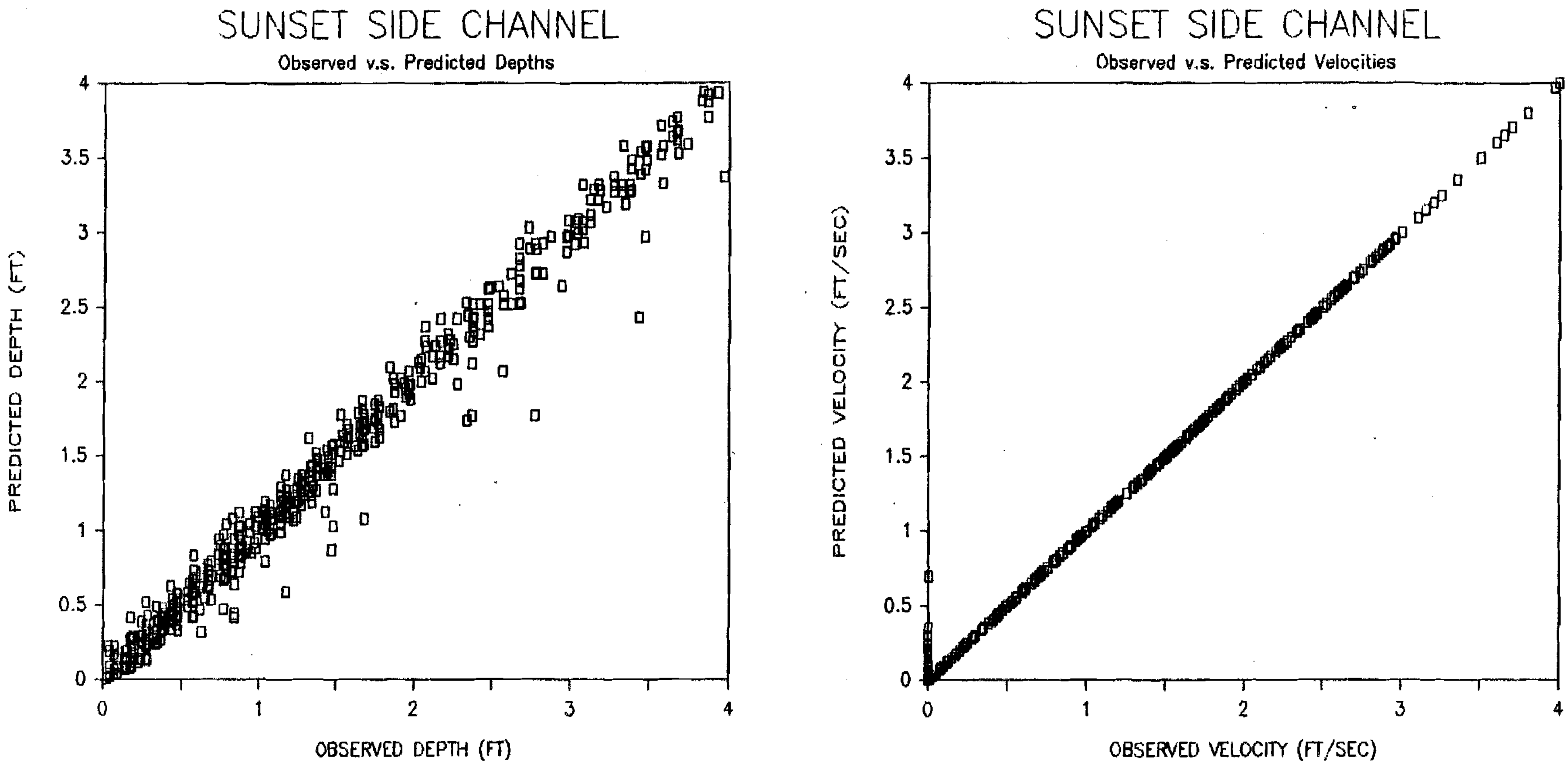
Application

For habitat simulation modelling purposes the hydraulic simulation model developed for Sunset Side Channel can simulate channel flows in the mainstem discharge range of 32,000 to 67,000 cfs.

Application Range of the Calibrated Hydraulic Model at Sunset Side Channel RM (86.9)



Appendix Figure D-40. Application range of calibrated hydraulic model at Sunset Side Channel.



Appendix Figure D-41. Scatterplots of observed and predicted depths and velocities from the calibrated IFG-4 hydraulic model at Sunset Side Channel.

Trapper Creek Side Channel (RM 91.6)

Site Description

Trapper Creek Side Channel is located on the west bank of the Susitna River and is approximately 5.0 miles long (Appendix Figure D-42). It has a relatively uniform, broad, and flat bottomed alluvial channel which is fed by multiple heads. It is separated from the mainstem Susitna River by a complex of sand bars, small channels, and vegetated islands. The head portion of this side channel is located in a complex of small channels and vegetated islands making it difficult to identify the origin of breaching flows (Quane et al. 1985).

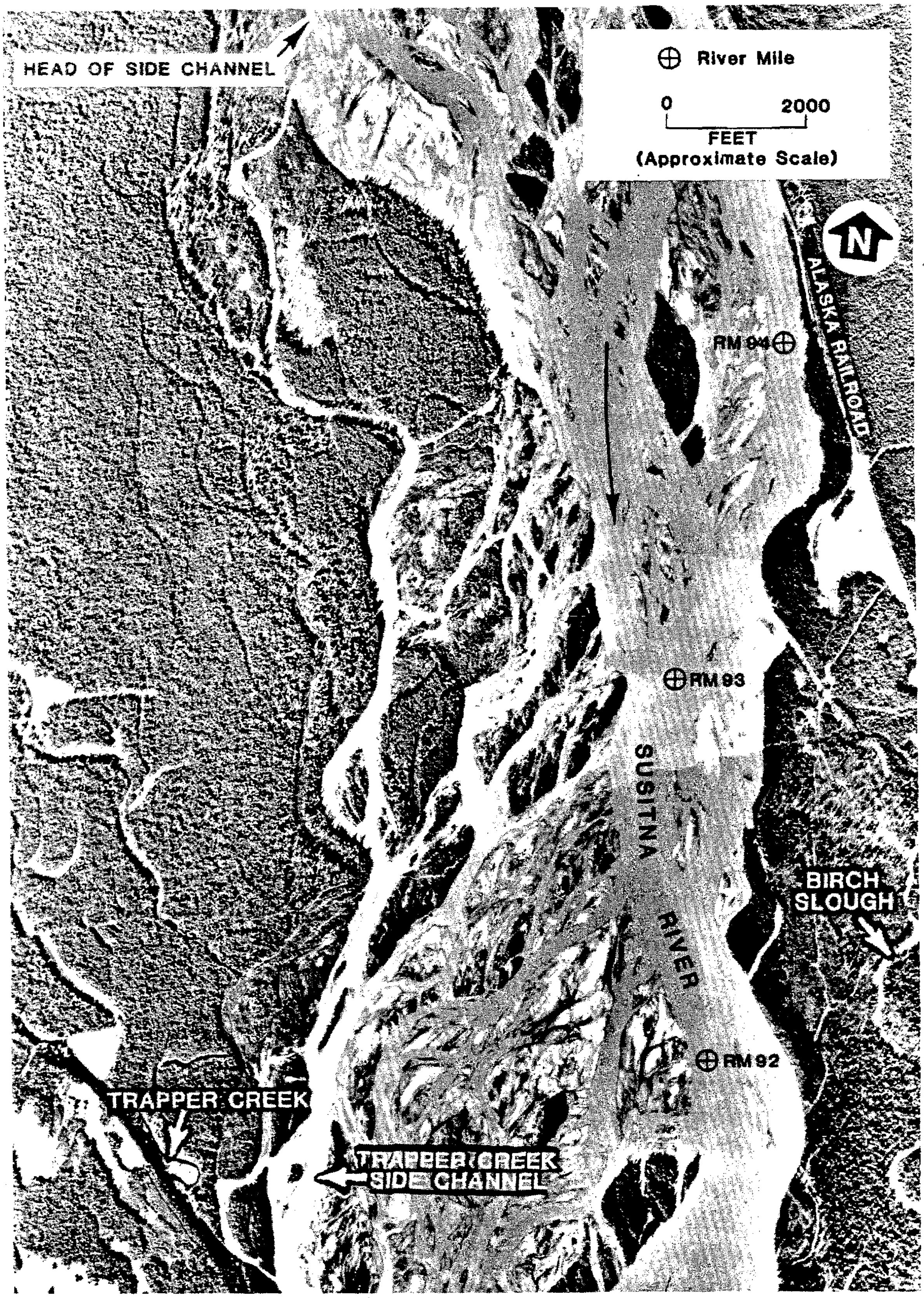
During unbreached conditions, flows in Trapper Creek Side Channel are principally due to Cache Creek and groundwater from the upper reaches of the side channel. Breaching of Trapper Creek Side Channel is the result of the direct overtopping of the multiple heads of the side channel by the mainstem Susitna River. Based on assessments by Quane et al. (1985), the channel is estimated to be initially breached at a mainstem discharge of 43,000 cfs. Based on the comparison of the stage versus mainstem discharge rating curve for transect 4 (Appendix Figure D-43) by Quane et al. 1985, a discharge of 44,000 cfs was selected as the controlling breaching discharge. This mainstem discharge corresponds to a streamflow measurement of 31.4 cfs.

Based on assessments by Quane et al. (1985), backwater has not been observed. But at mainstem discharges ranging from 15,700 to 22,700 cfs, pooling was observed at transects 1, 2, and 3 which resulted from the control located about 370 feet downstream from transect 1.

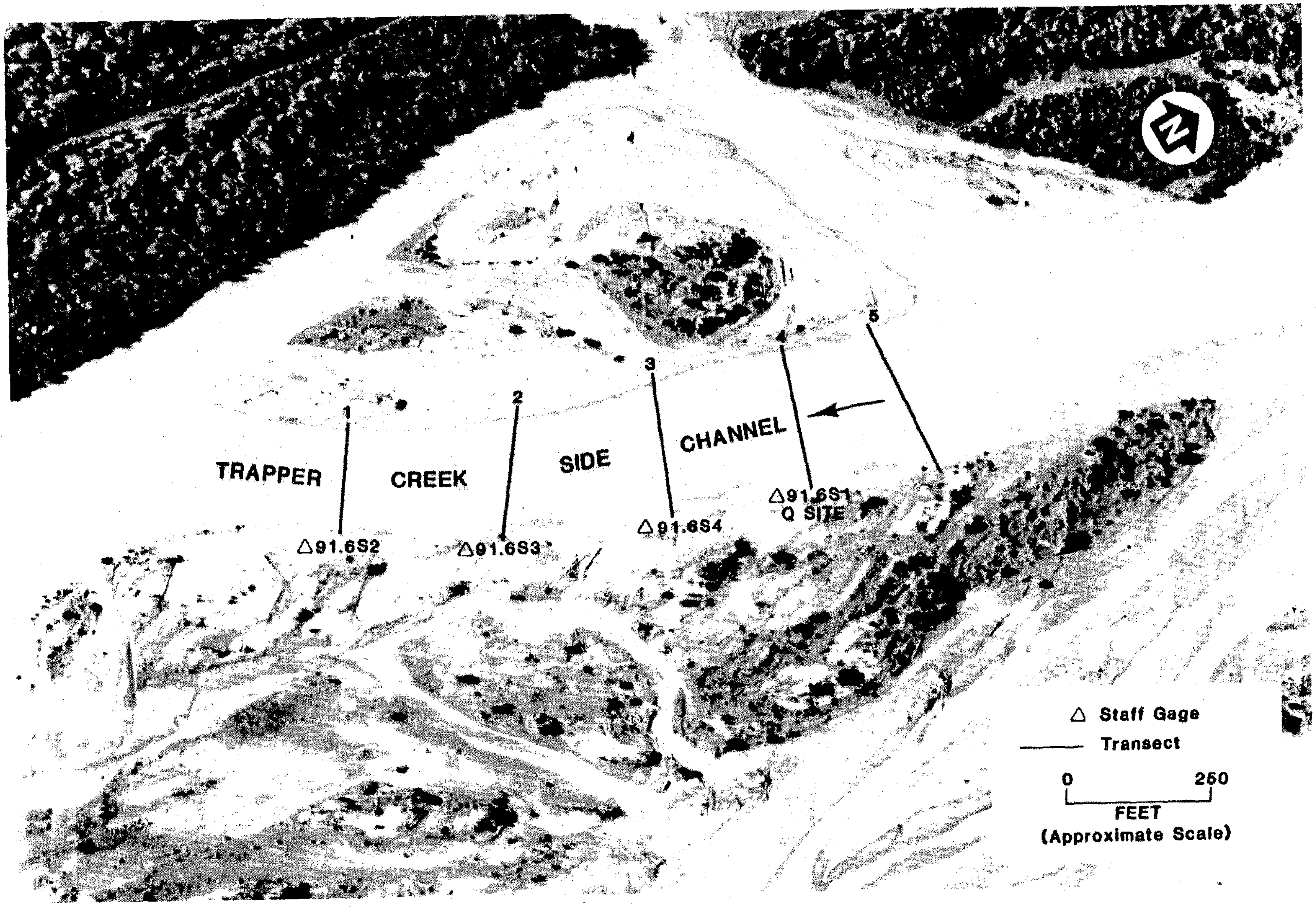
The 790 foot long IFG modelling site at Trapper Creek Side Channel was located in the lower portion of the side channel in a broad open channel area (Appendix Figure D-44). Four cross sections were surveyed within this area to define channel geometry (Appendix Figure D-45). The upper two transects were situated in a run, whereas the lower two transects were in a pool influenced by a downstream control. Substrate consisted primarily of rubble and gravels with some sand at the first transect. The thalweg gradient of the side channel is 12.1 ft/mile (Quane et al. 1985).

Calibration

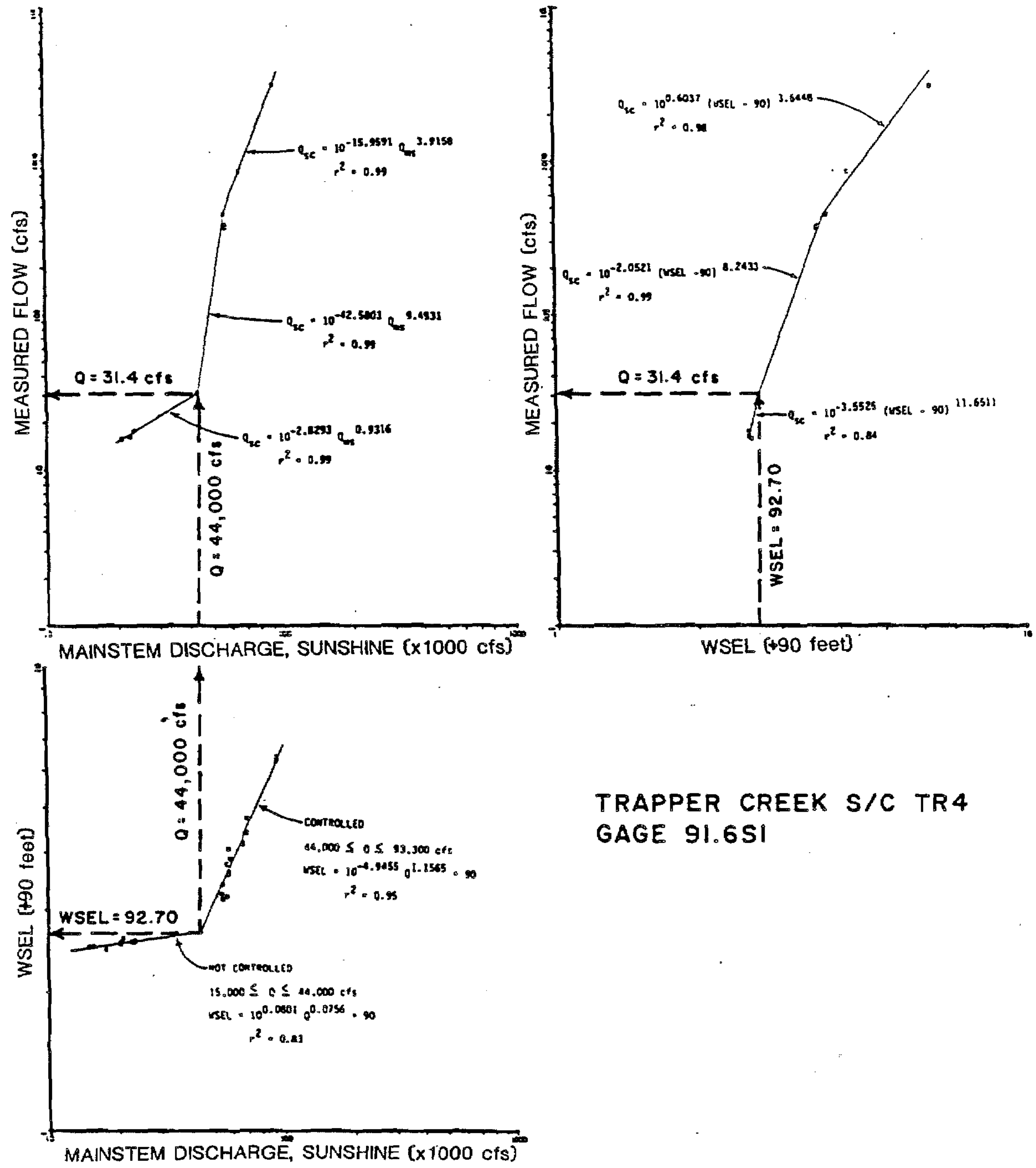
Hydraulic data were collected at three calibration flows: 16, 32, and 389 cfs (Appendix Table D-4). Mean daily discharges for the Susitna River on the dates that calibration data were collected at the Trapper Creek study site were 20,900 cfs, 44,000 cfs, and 57,700 cfs respectively. Based on these calibration flows an IFG-4 model was used to forecast instream hydraulics for this study site. The streambed profile, stages of zero flow, and observed and predicted water surface elevations for the study reach are plotted to scale in Appendix Figure D-46. All three data sets were used to predict hydraulic information for side channel flows from 9 to 1,351 cfs (mainstem discharges of 12,000 to 75,000 cfs).



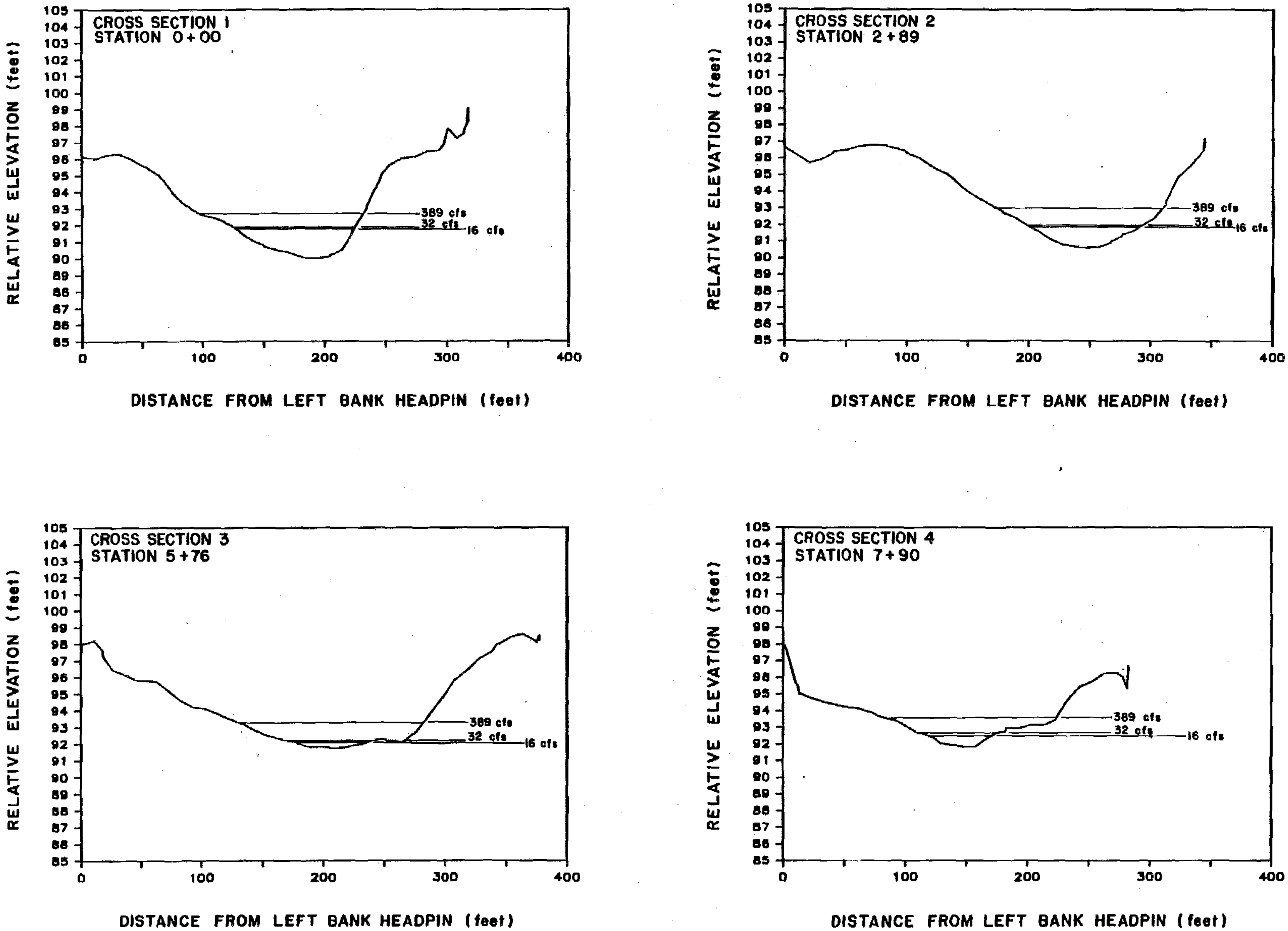
Appendix Figure D-42. Overview of Trapper Creek Side Channel (RM 91.6).



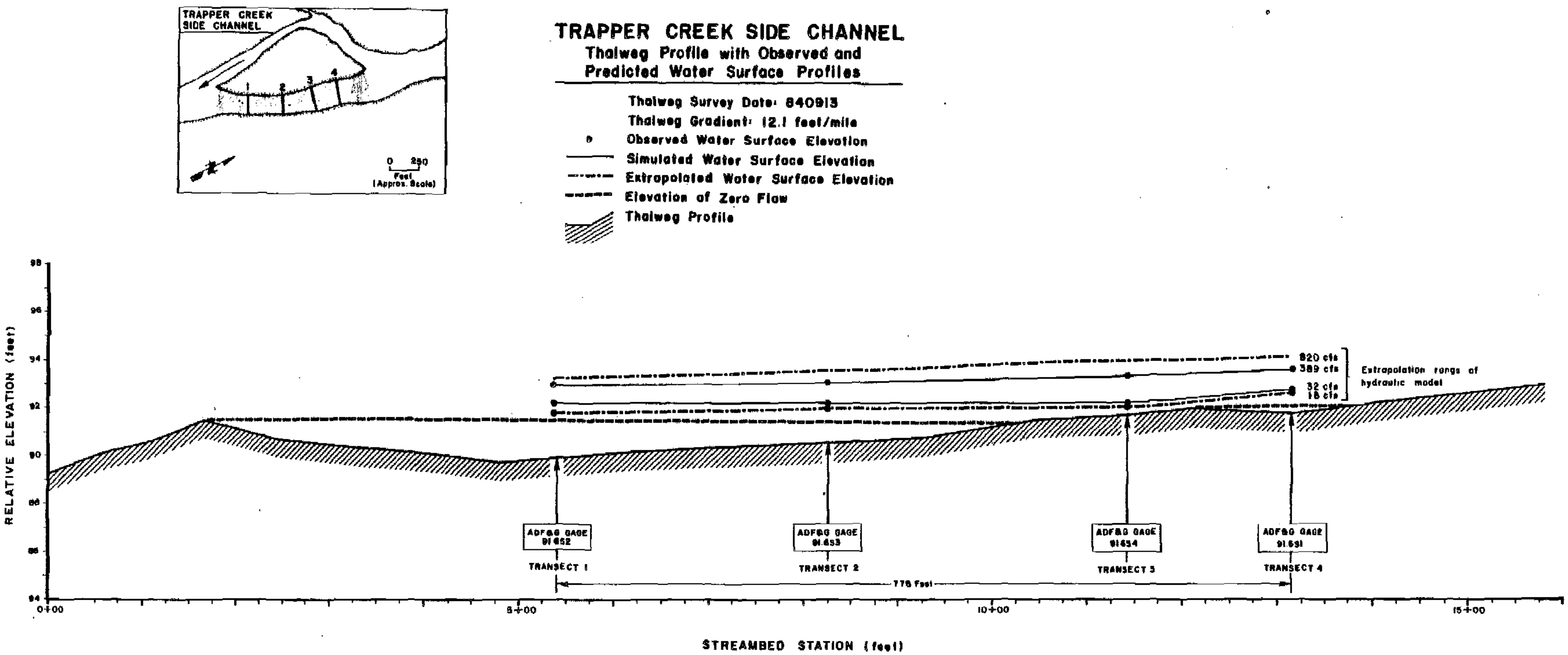
Appendix Figure D-44. Location of Trapper Creek Side Channel study site (RM 91.6).



Appendix Figure D-43. Comparison of rating curves from Trapper Creek Side Channel transect 4 (from Quane et. al. 1985).



Appendix Figure D-45. Cross section of transects 1, 2, 3, and 4 at Trapper Creek Side Channel (adapted from Quane et al. 1985).



Appendix Figure D-46. Comparison of observed and predicted water surface profiles from calibrated model and surveyed thalweg profile for Trapper Creek Side Channel (adapted from Quane et al. 1985).

To evaluate the performance of the hydraulic model, observed and predicted water surface elevations, discharges, and velocity adjustment factors were compared (Appendix Table D-13). Of the 12 sets of observed and predicted WSEL's, six sets were within ±0.02 feet of each other and the other six sets were within ±0.05 feet of each other. All the observed and predicted discharges were within 10% of each other except for one set in which there was an 11% difference. All velocity adjustment factors were within the good range of 0.9 to 1.1. Additionally, the stage information of the model was compared to the rating curves established by Quane et al. (1985) (Appendix Figure D-43).

Between the time that the first two calibration flows (389 and 32 cfs) were made and the last calibration flow of 16 cfs was made, the channel cross section at transect 1 was scoured by a flood event. In order to utilize this information in the model, the cross section determined from the survey and the 16 cfs flow measurement were used, and the WSEL's of the two calibration flows (389 and 32 cfs) were then reduced by 0.37 feet.

Transect 1 was determined to be a poor site for measuring discharge because it was a pool area affected by a downstream control. The velocities for the 32 cfs calibration flow were therefore adjusted upwards by 27%, and at the 16 cfs calibration flow were also adjusted upwards by 20%.

Verification

Based on the first level of verification by EWT&A the model does a good job of simulating channel hydraulics between 20,000 cfs and 54,000 cfs mainstem discharge (15 and 220 cfs site flow) (Appendix Figure D-47). There are sufficient deviations in water surface elevation and discharge between predicted and observed values within this range to preclude attainment of the excellent rating. This occurs because the model is approximating a portion of the rating curve described by two adjoining linear relationships with a single line.

Between 54,000 cfs and 58,000 cfs mainstem (220 and 460 cfs site flow) the model does an excellent job of simulating channel hydraulics. Beyond 58,000 cfs mainstem, the quality of the simulations begins to deteriorate as the slope of the stage/discharge relationship for the site flattens with a change in channel geometry. The deviation between the regression line developed within the model and that of the rating curve increases with discharge until the model simulations are no longer acceptable. The model simulations were rated good between 58,000 cfs and 61,000 cfs (460 and 600 cfs site flow), acceptable between 61,000 cfs and 66,000 cfs (600 and 820 cfs site flow), and unacceptable above 66,000 cfs mainstem (Appendix Figure D-47).

At the second level of verification there is good agreement between the observed and predicted values for velocity and depth (Appendix Figure D-48). The statistical tests also show good agreement between the predicted and observed values (Appendix Table D-7). The index of agreement is 0.99, the total RMSE is largely composed of the unsystematic RMSE, and the y-intercept is almost zero with a slope near one.

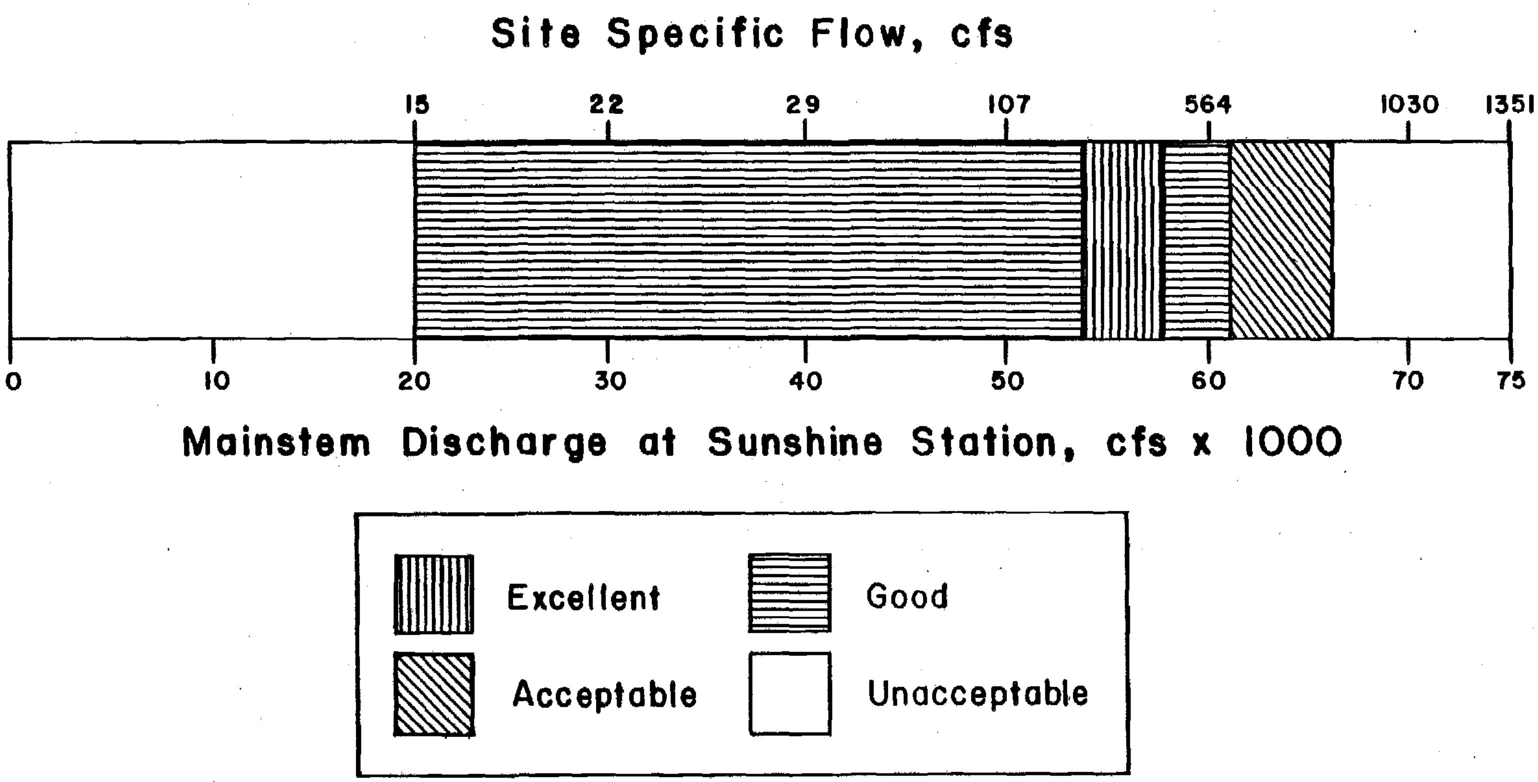
Appendix Table D-13. Comparison between observed and predicted water surface elevations, discharges, and velocities for 1984 Trapper Creek Side Channel hydraulic model.

Streambed Station (ft)	Water Surface Elevation Observed (ft)	Water Surface Elevation Predicted (ft)	Discharge Observed (cfs)	Discharge Predicted (cfs)	Velocity Adjustment Factor
0+00	91.94	91.90	15.4	15.1	.985
2+89	91.94	91.91	15.5	14.1	.962
5+76	92.18	92.14	16.7	15.6	.995
7+90	92.56	92.56	15.1	15.1	.976
			Qo = 16.0	Qp = 15.0	
0+00	91.97	92.92	30.1	30.8	1.041
2+89	92.00	92.04	26.0	28.9	1.033
5+76	92.24	92.29	29.6	31.8	1.043
7+90	92.70	92.70	30.2	30.2	1.042
			Qo = 29.0	Qp = 30.0	
0+00	92.75	92.74	397.8	397.3	.980
2+89	93.00	92.99	392.3	387.9	.995
5+76	93.32	93.31	413.4	410.7	.994
7+90	93.58	83.58	367.2	367.2	.997
			Qo = 393.0	Qp = 391.00	

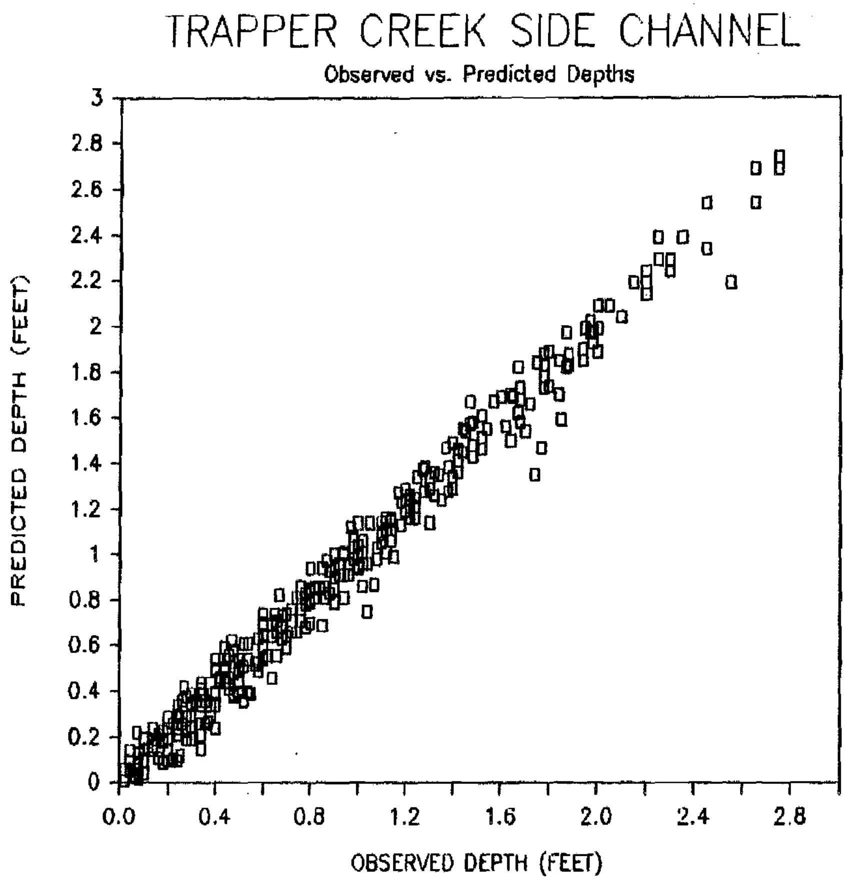
Qo is the mean observed calibration discharge.

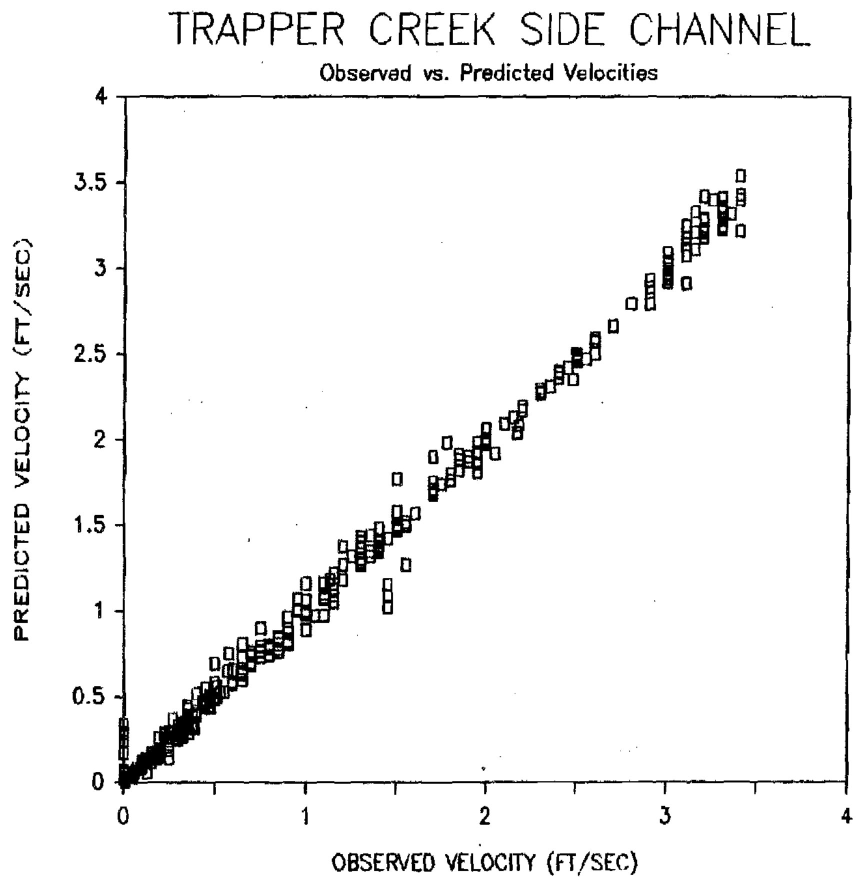
Qp is the mean predicted calibration discharge.

Application Range of the Calibrated Hydraulic Model at Trapper Creek Side Channel RM (91.6)



Appendix Figure D-47. Application range of the calibrated hydraulic model at Trapper Creek Side Channel.





Appendix Figure D-48. Scatterplots of observed and predicted depths and velocities from the calibrated IFG-4 model at Trapper Creek Side Channel.

Application

For habitat simulation modelling purposes the hydraulic simulation model developed for Trapper Creek Side Channel can simulate channel flows in the mainstem discharge range of 20,000 to 66,000 cfs.

SUMMARY

A summary of the range of mainstem discharges that the hydraulic models can simulate for the rearing habitats of salmon at the six lower river IFG modelling sites is presented in Appendix Table D-14.

Appendix Table D-14. Summarization of the range of mainstem discharges that the hydraulic models can simulate for the rearing habitats of salmon at the six lower river IFG modelling sites.

Site (RM)	Mainstem Discharge Range (cfs)
Island Side Channel (63.2)	35,000 to 70,000
Mainstem West Bank (74.4)	18,000 to 48,000
Circular Side Channel (75.3)	36,000 to 63,000
Sauna Side Channel (79.8)	44,000 to 63,000
Sunset Side Channel (86.9)	32,000 to 67,000
Trapper Creek Side Channel (91.6)	20,000 to 66,000

ACKNOWLEDGEMENTS

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

-- The other ADF&G Su Hydro Aquatic Studies Program staff who provided their support to this study. For collection of field data: Fred Metzler, Pat Morrow, Isaac Queral, Glenn Freeman, and John McConnaughey. To Paul Suchanek for collection of the cover information used in assessing the weighted usable areas of the models. In reduction of the data, making the many computer runs, and helping prepare this appendix: Fred Metzler, Mary Shiffer, Dan Kingsley, and Kathy Sheehan Dugan. To Tim Quane, Pat Morrow, and Isaac Queral for use of much of their findings and figures from Task 36 support technical report - Hydrological Investigations at Selected Lower Susitna River Study Sites. To the editors: Doug Vincent-Lang, Tim Quane, and Drew Crawford. For the cartography on the final figures: Carol R. Hepler and Roxann Peterson.

-- To E.W. Trihey and Associates; particularly Bob Aaserude and Diane Hilliard for their valuable expertise in the collection of data, the calibration, and the verification of the hydraulic models.

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ALASKA DEPARTMENT OF FISH AND GAME

SUSITNA RIVER AQUATIC STUDIES PROGRAM

REPORT NO. 7

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PARTS 1 AND 2

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334 W. Fifth Avenue, Second Floor
Anchorage, Alaska 99501

July 1985