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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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.

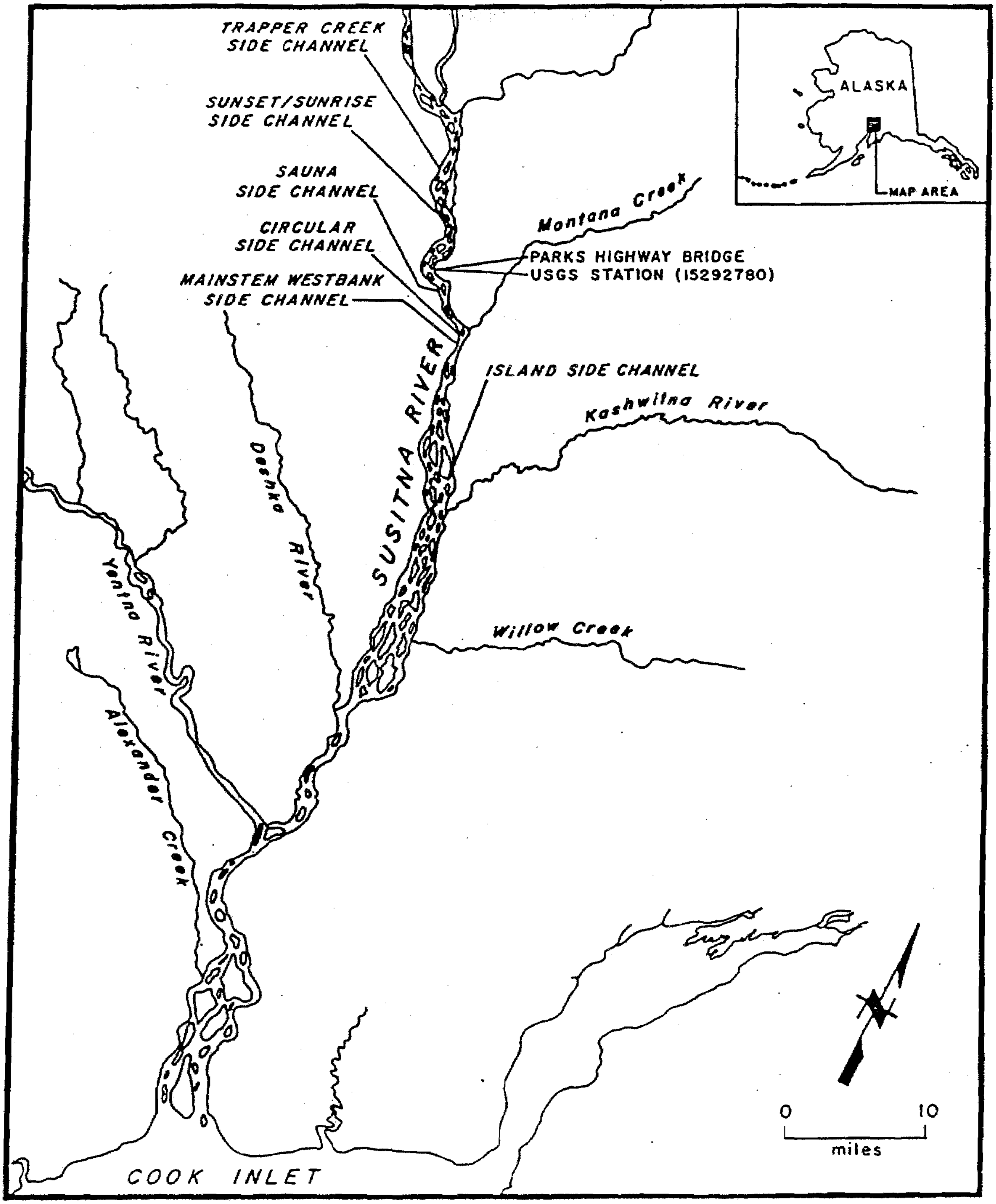
The six sites chosen for modelling complemented other sites modelled using another habitat model (see main text). All of the six sites were side channels, the majority of potential habitat in the lower river is composed of this habitat. Much of the other habitat is difficult to model with the IFIM methodology 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).

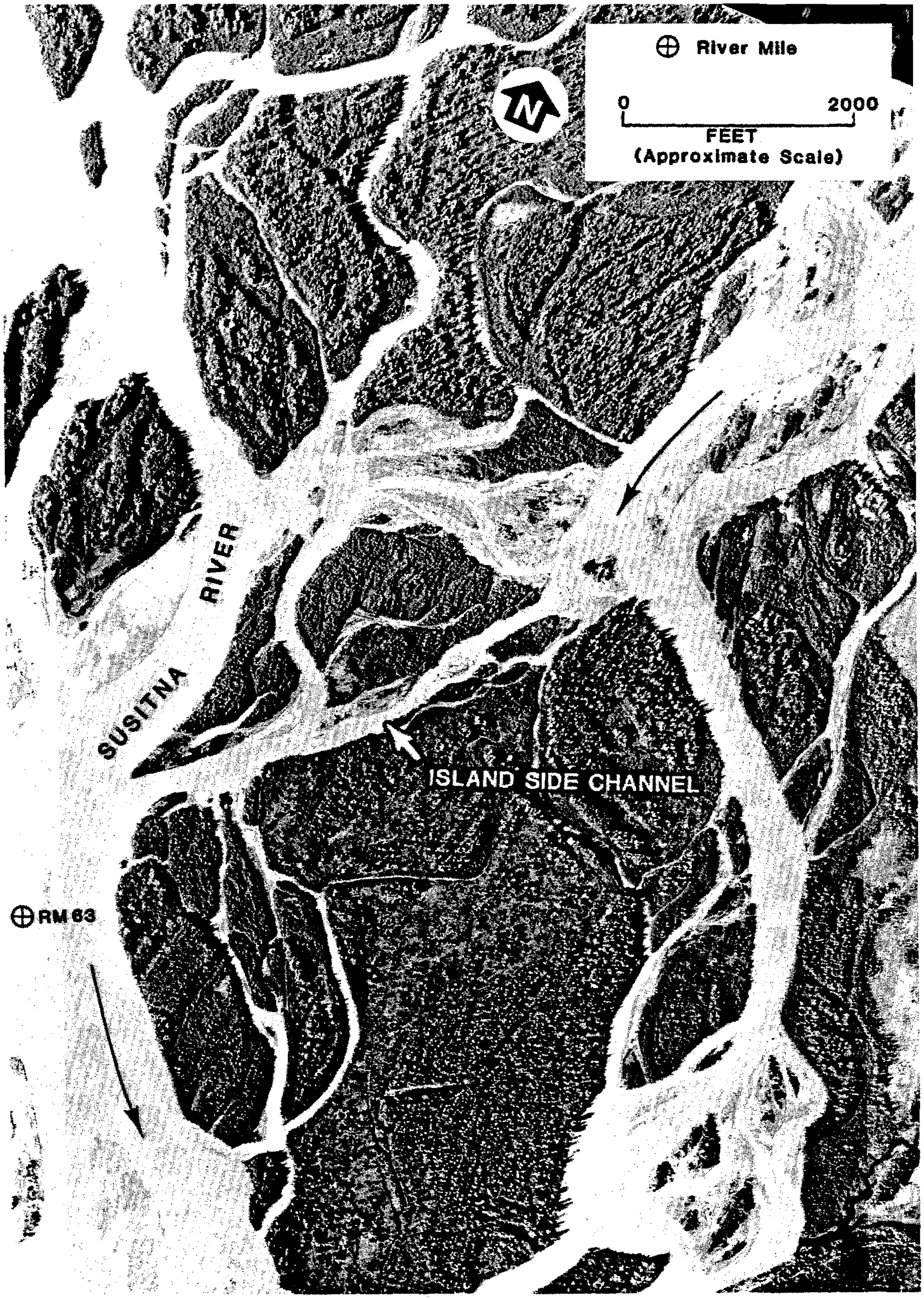
The IFG modelling site at Island Side Channel was 735 feet long and located in the lower portion of the side channel (Appendix Figure D-3). The site generally consists of a pool-riffle-pool sequence. Based on assessments by Quane et al. (1985), an area of backwater extends through the study site to a 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.

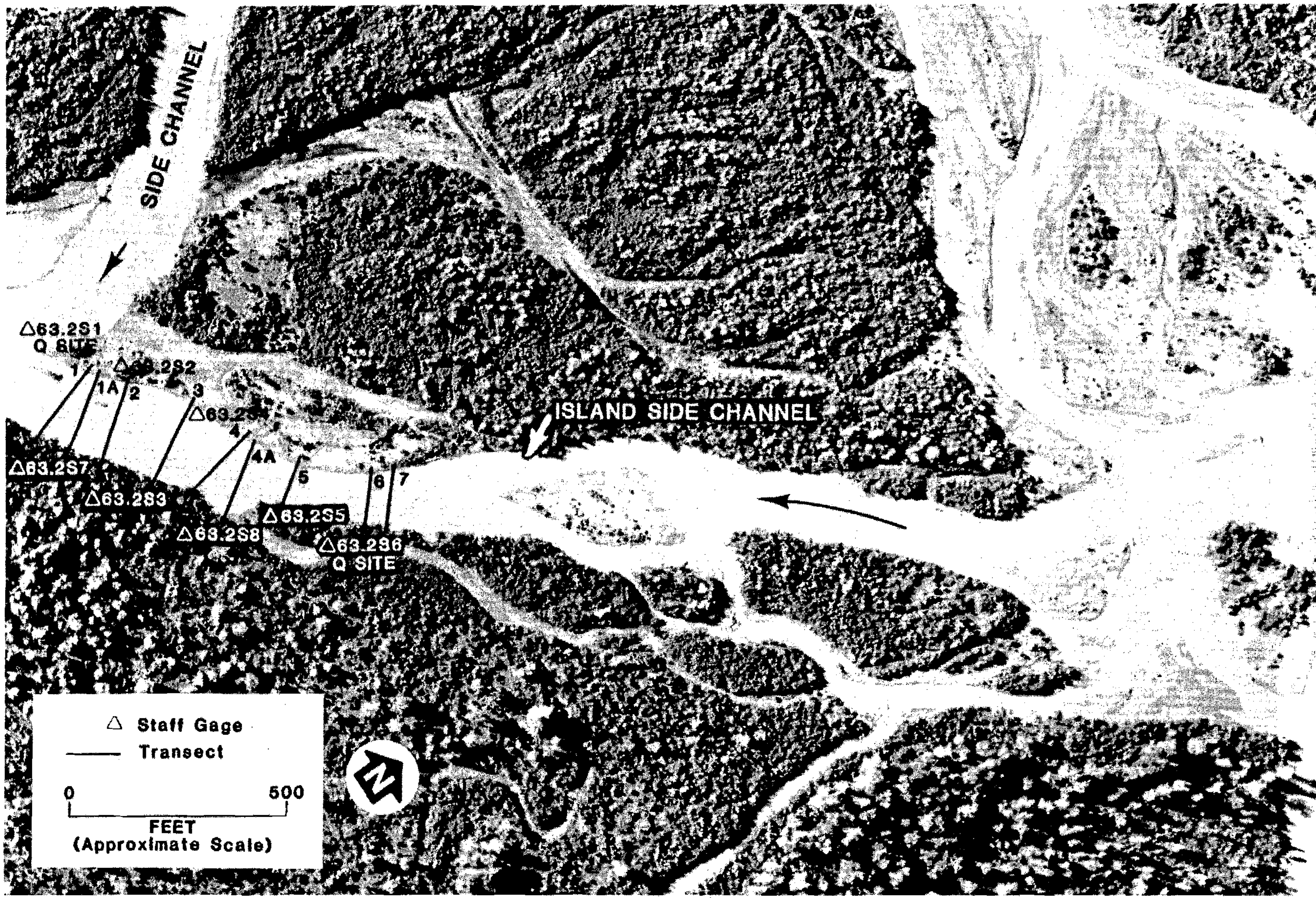
Substrate at the study site consists primarily of gravels and rubbles, with substrate changing to sand and silt in slackwater areas. The thalweg gradient of the side channel is 15.6 ft/mile (Quane et al. 1985). From an evaluation of field observations, aerial photography, and the stage/discharge relationship 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).

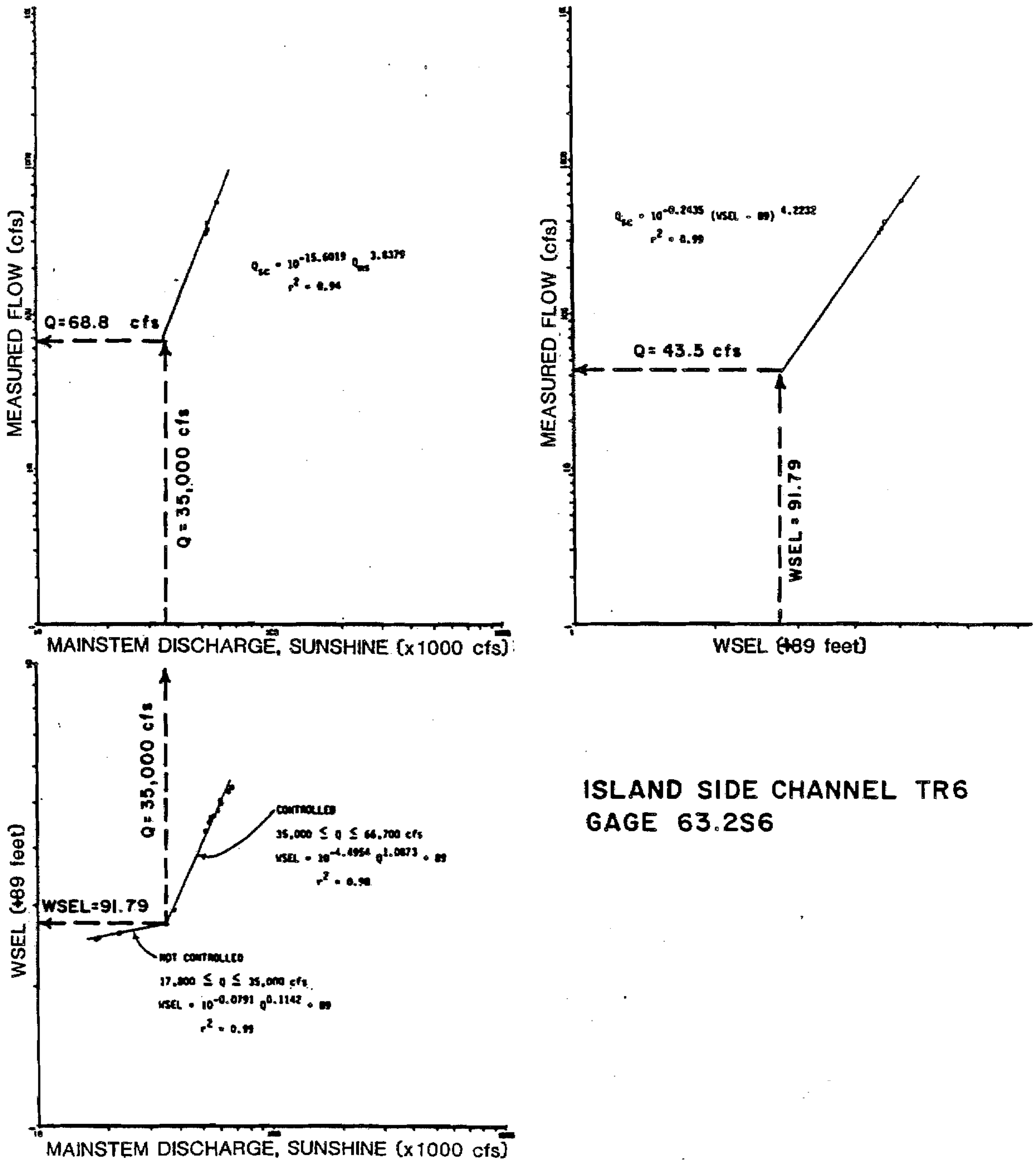
Eight cross sections were surveyed within this site during 1984 to define channel geometry (Appendix Figures D-5 & D-6). The upper two transects (5 and 6) were primarily located in pool habitat. Transects 4A and 4 primarily represent riffle habitat in the main portion of the channel. Transect 4A was 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.



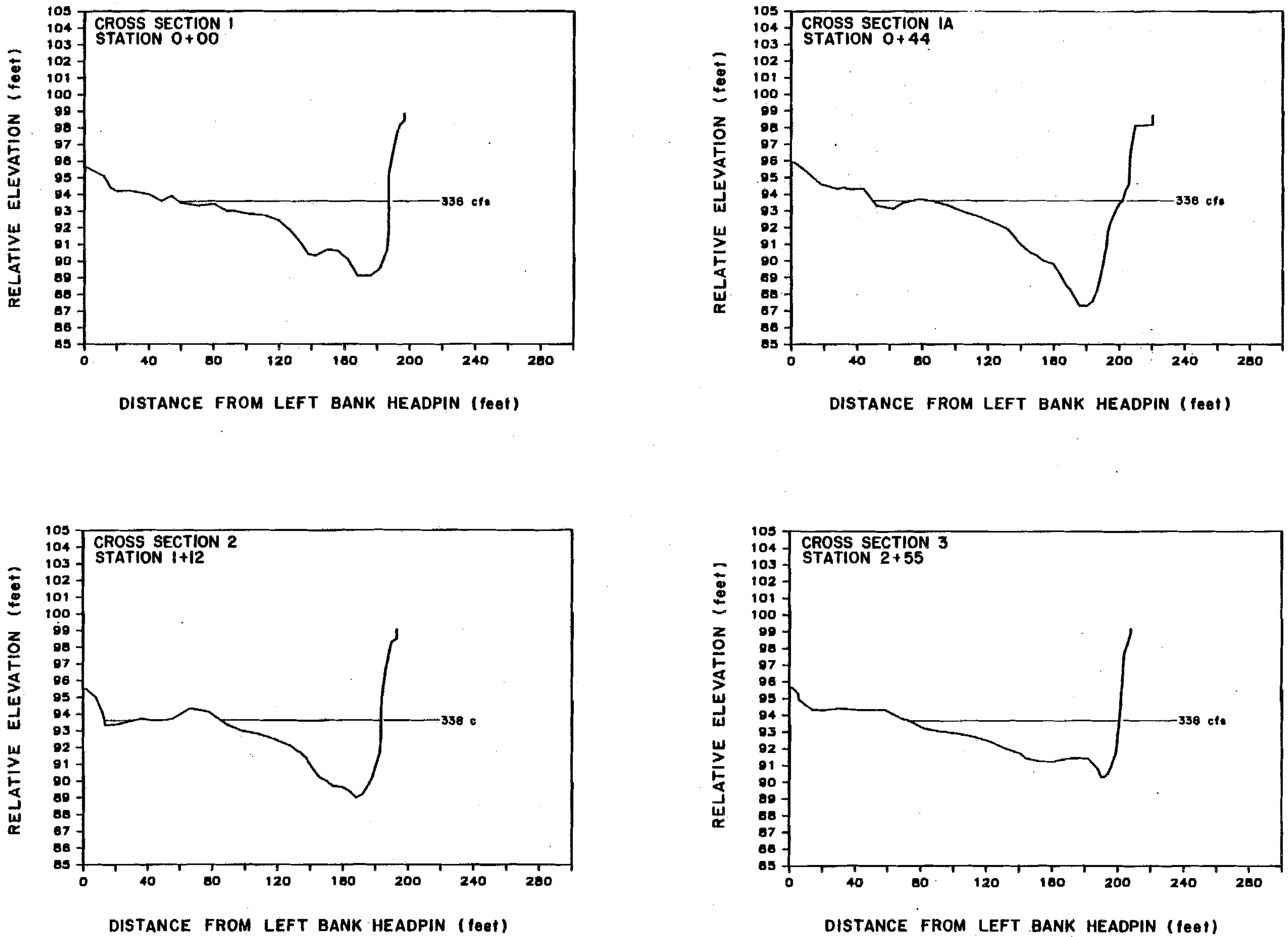
Appendix Figure D-2. Overview of Island Side Channel (RM 63.2).



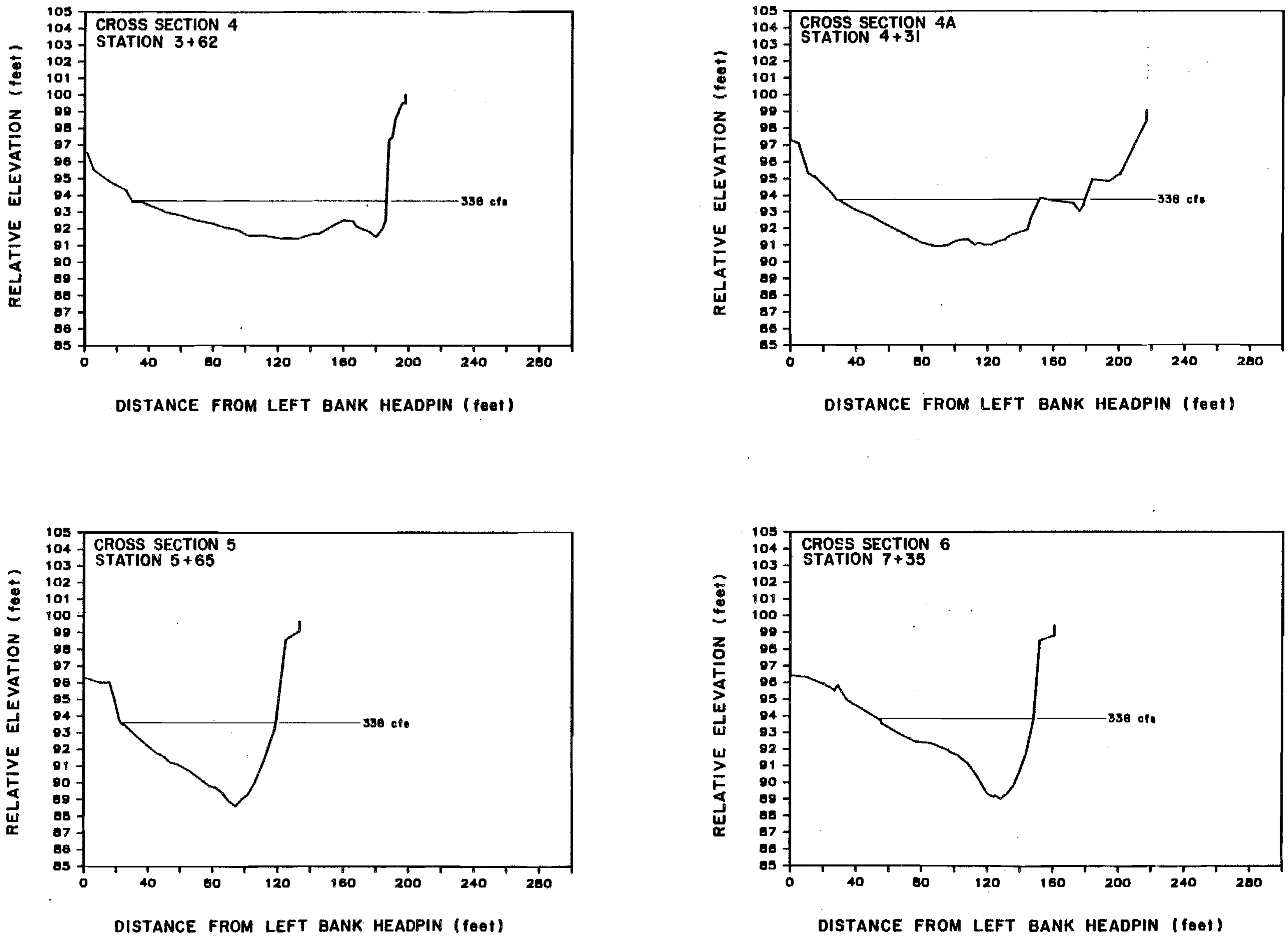
Appendix Figure D-3. Location of Island Side Channel study site (RM 63.2).



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.

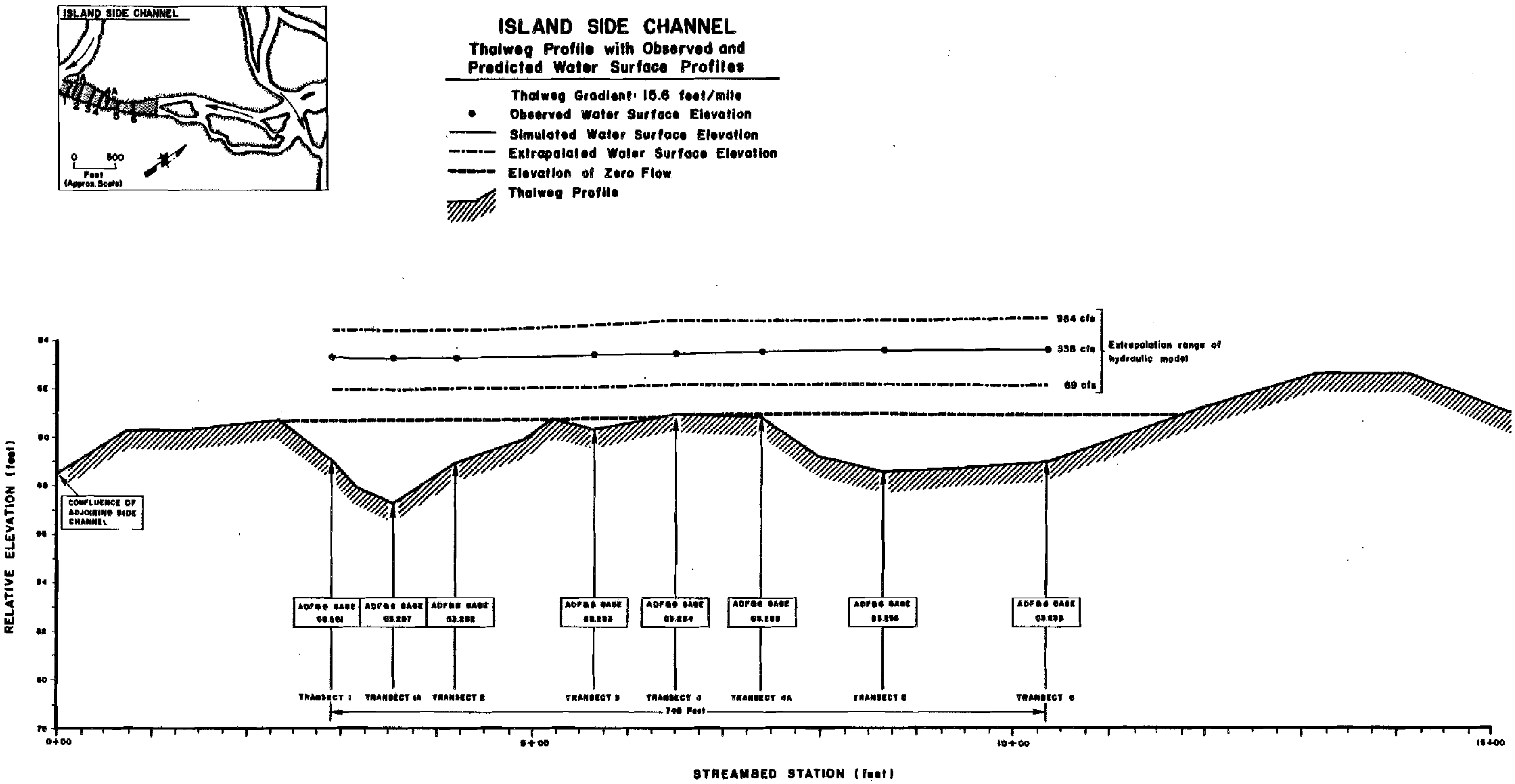
The original field water surface elevations (WSEL's) were compared to the model predicted WSEL's for the calibration flow of 338 cfs (Appendix Table D-5). At transect 1A, the original field WSEL was surveyed at 93.46 feet. In examining the WSEL's of transects 1 and 2 (93.33 and 93.41 feet in elevation 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).

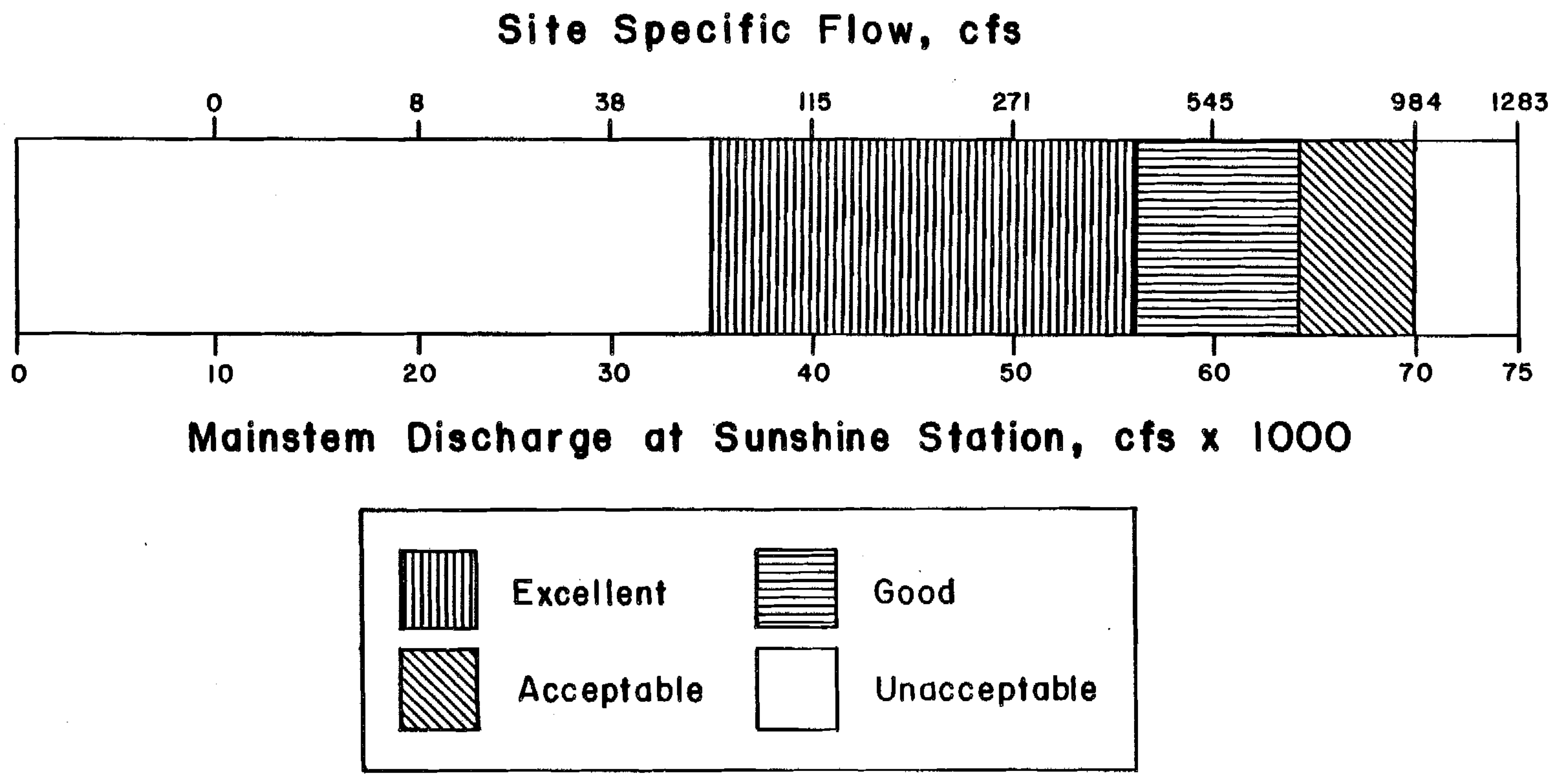
Appendix Table D-5. Comparison of field measured and model predicted water surface elevations at the calibration flow of 338 cfs for Island Side Channel.

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

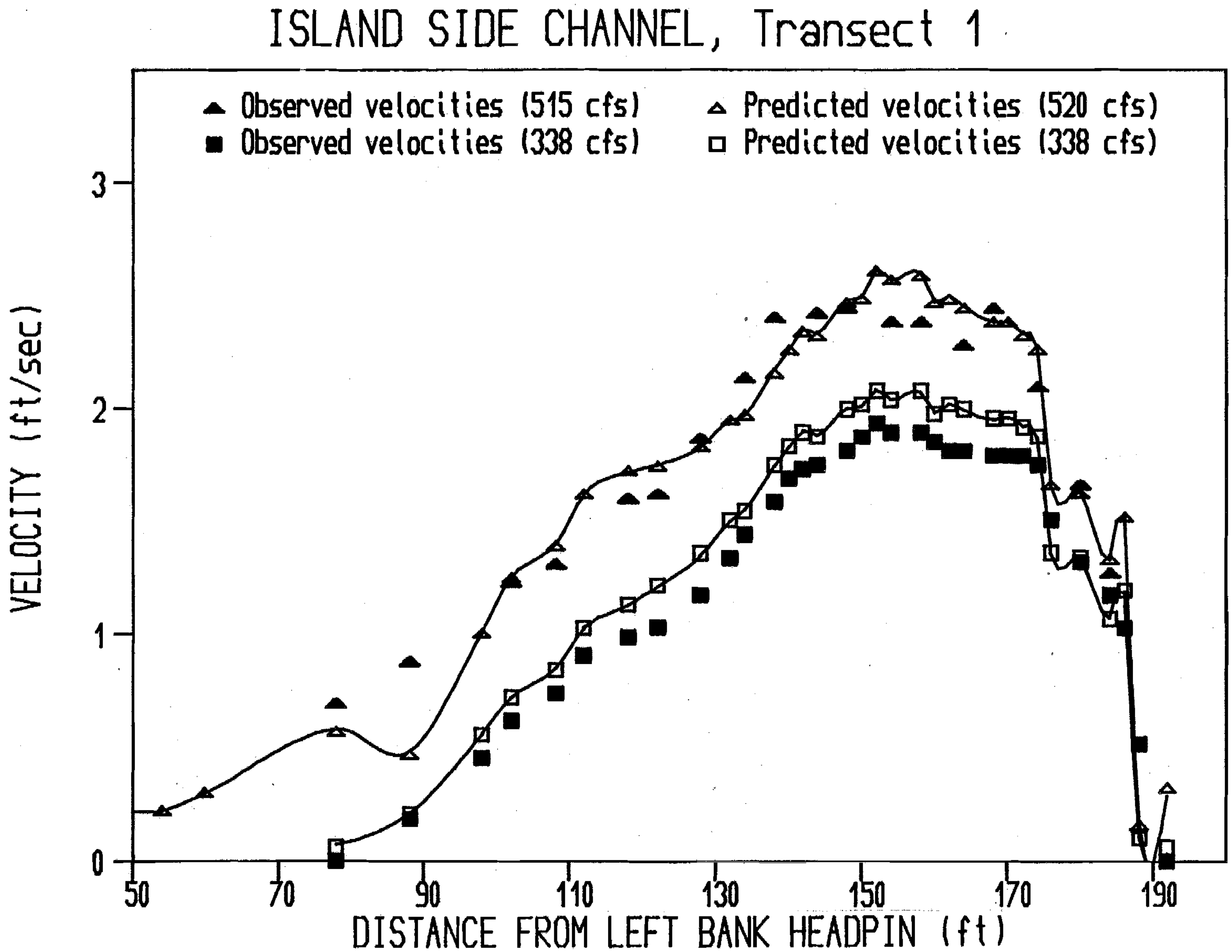
[a] Water surface elevation reduced by 0.1 feet to 93.36 feet.

Application Range of the Calibrated Hydraulic Model at Island Side Channel

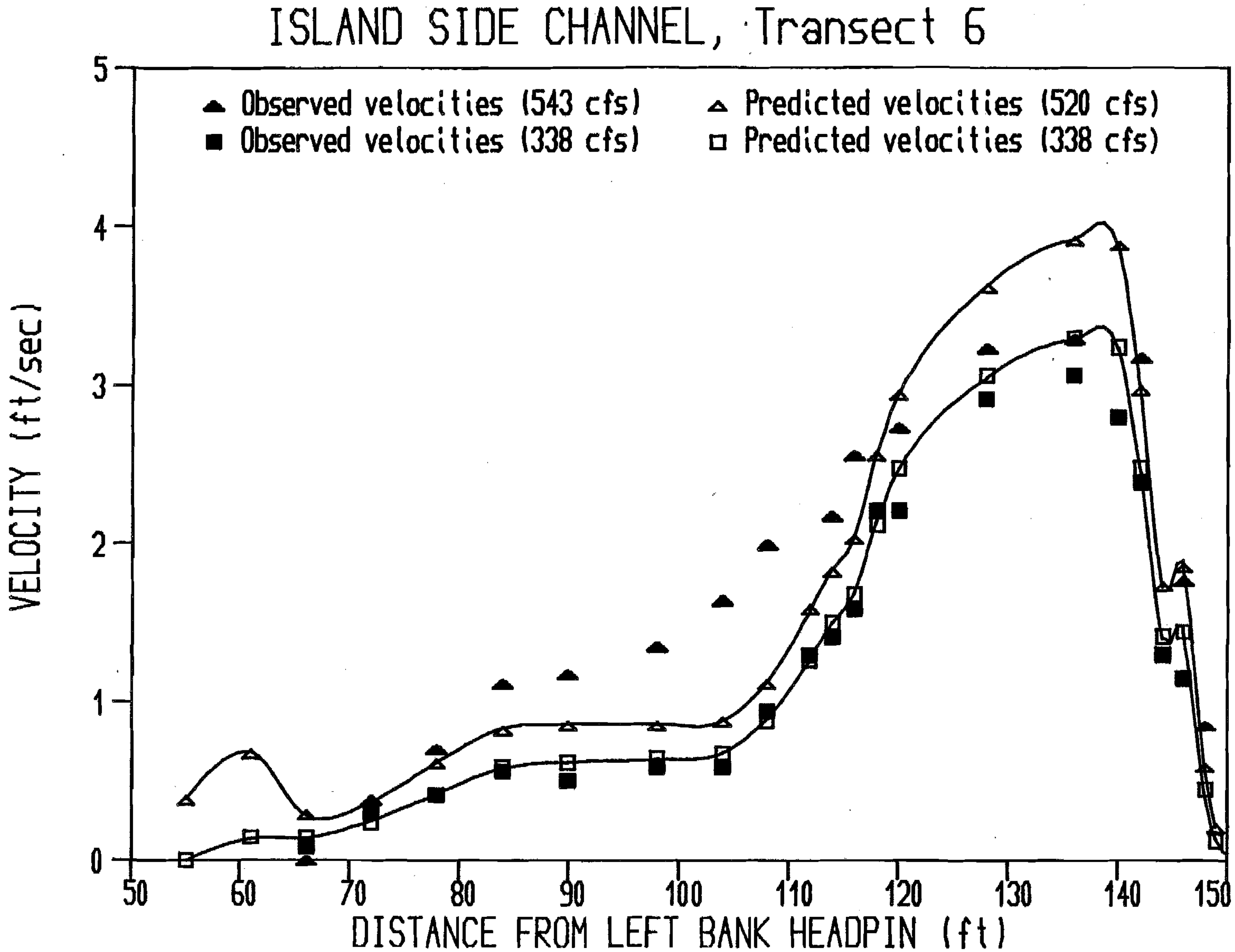
RM (63.2)



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).

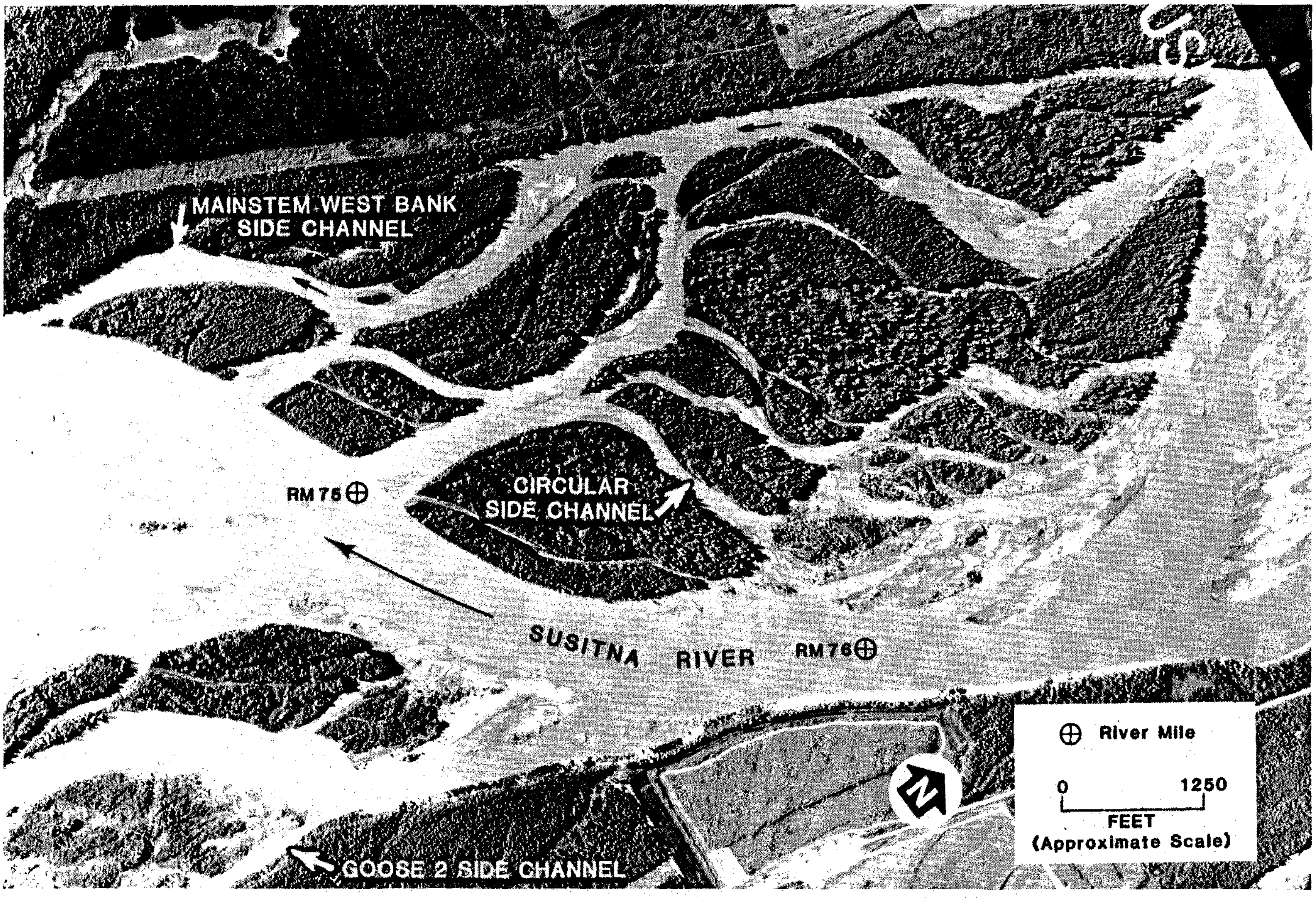
The two heads are both located approximately 1.5 miles upstream of the study site (Quane et al. 1985). Breaching of Mainstem West Bank Side Channel occurs when the mainstem overtops either of the two side channel heads. The side channel has been estimated to be initially breached at a mainstem discharge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

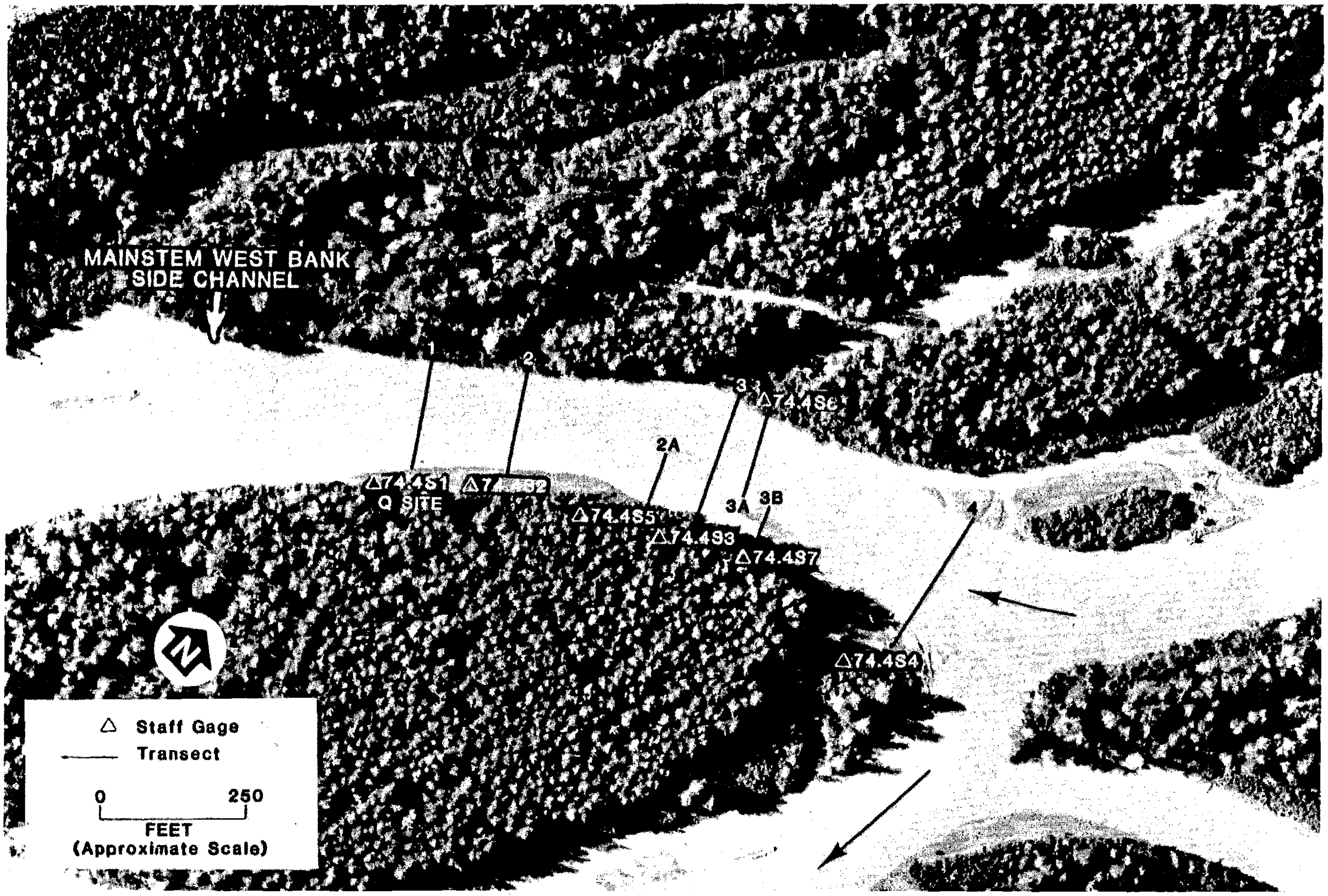
Hydraulic information was gathered from five transects (1, 2, 3, 3A, 4) in the main channel and three transects (2A, 3 in part, 3B) in a minor side channel of this study site (Appendix Figure D-12). The corresponding cross sections are presented in Appendix Figure D-14 & D-15.

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.

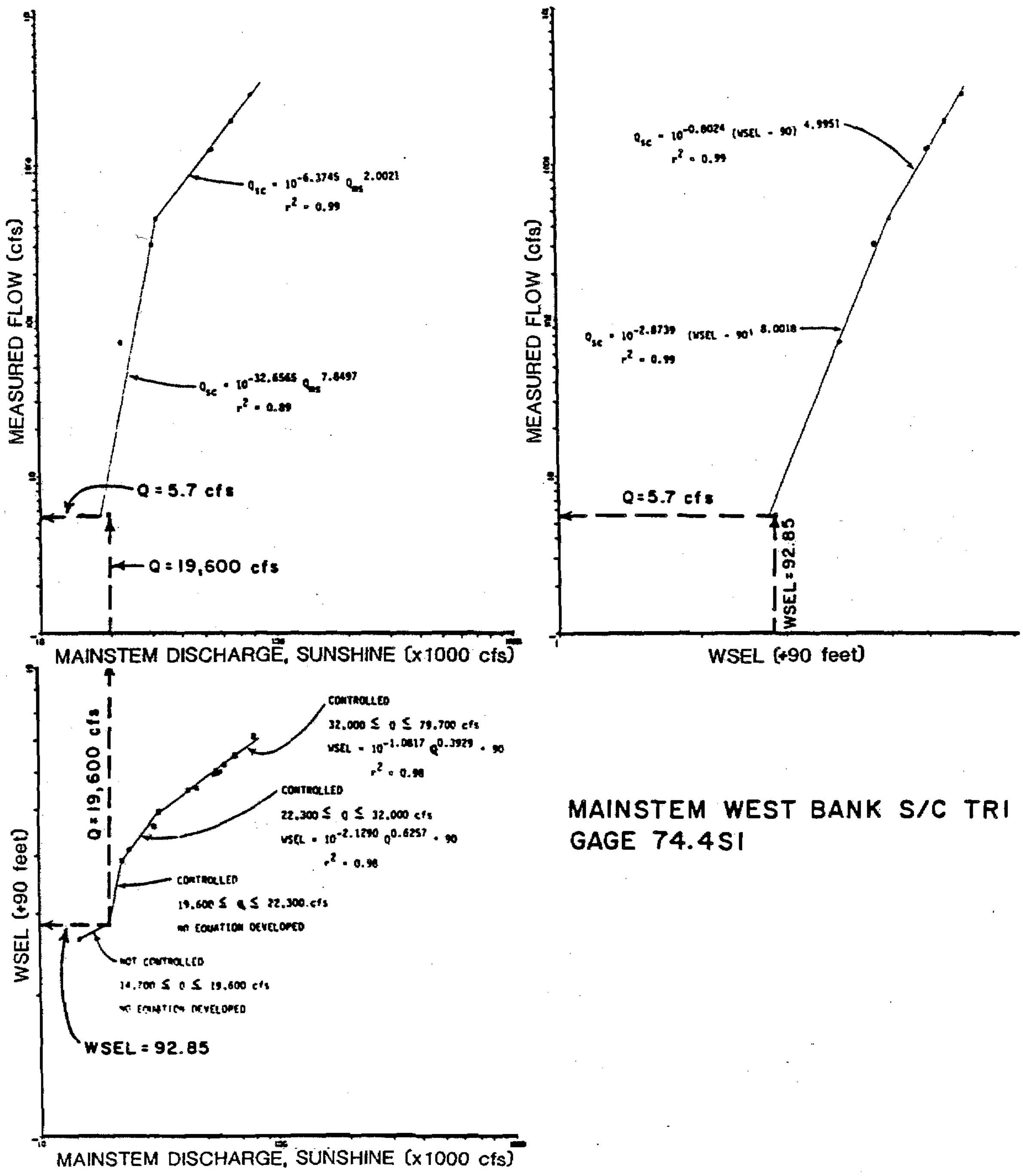
Substrate at this site primarily consisted of rubble and cobble. The thalweg gradient of the side channel is approximately 12.3 ft/mile (Quane et al. 1985).



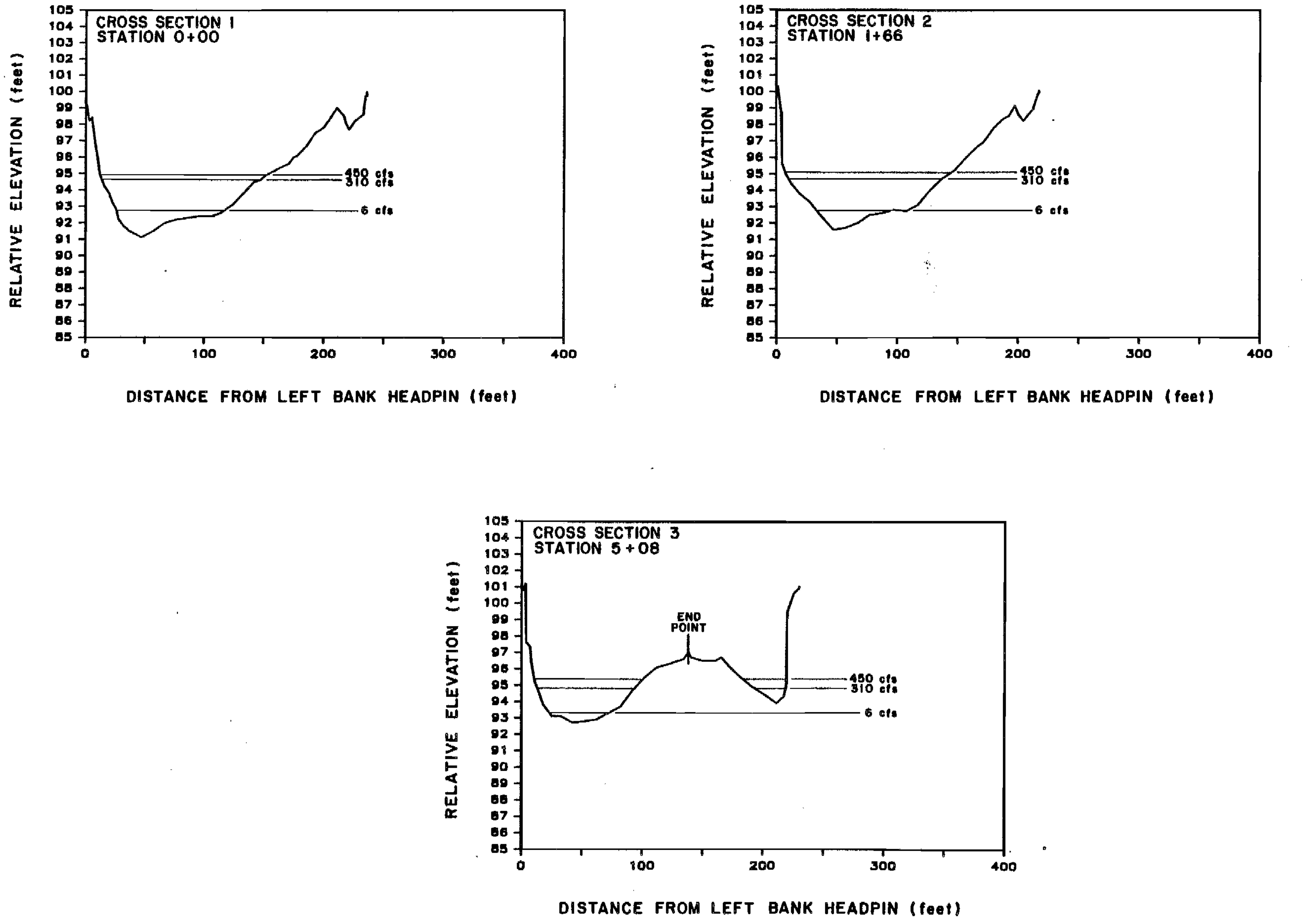
Appendix Figure D-11. Overview of Mainstem West Bank Side Channel (RM 74.4).



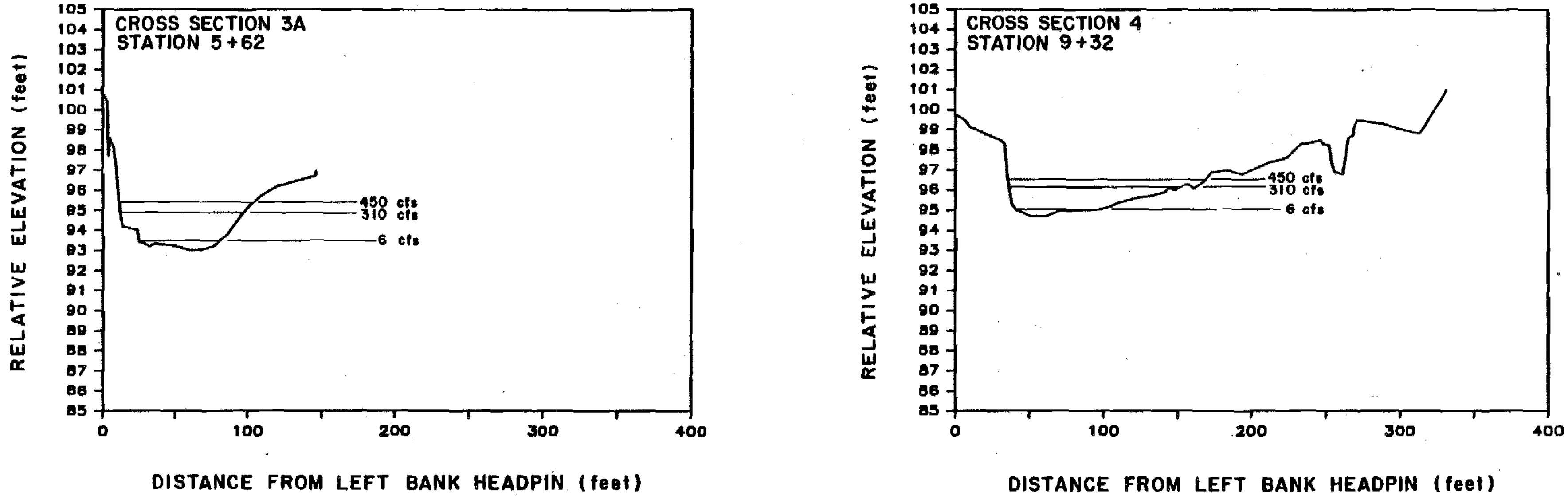
Appendix Figure D-12. Location of Mainstem West Bank Side Channel study site (RM 74.4).



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).

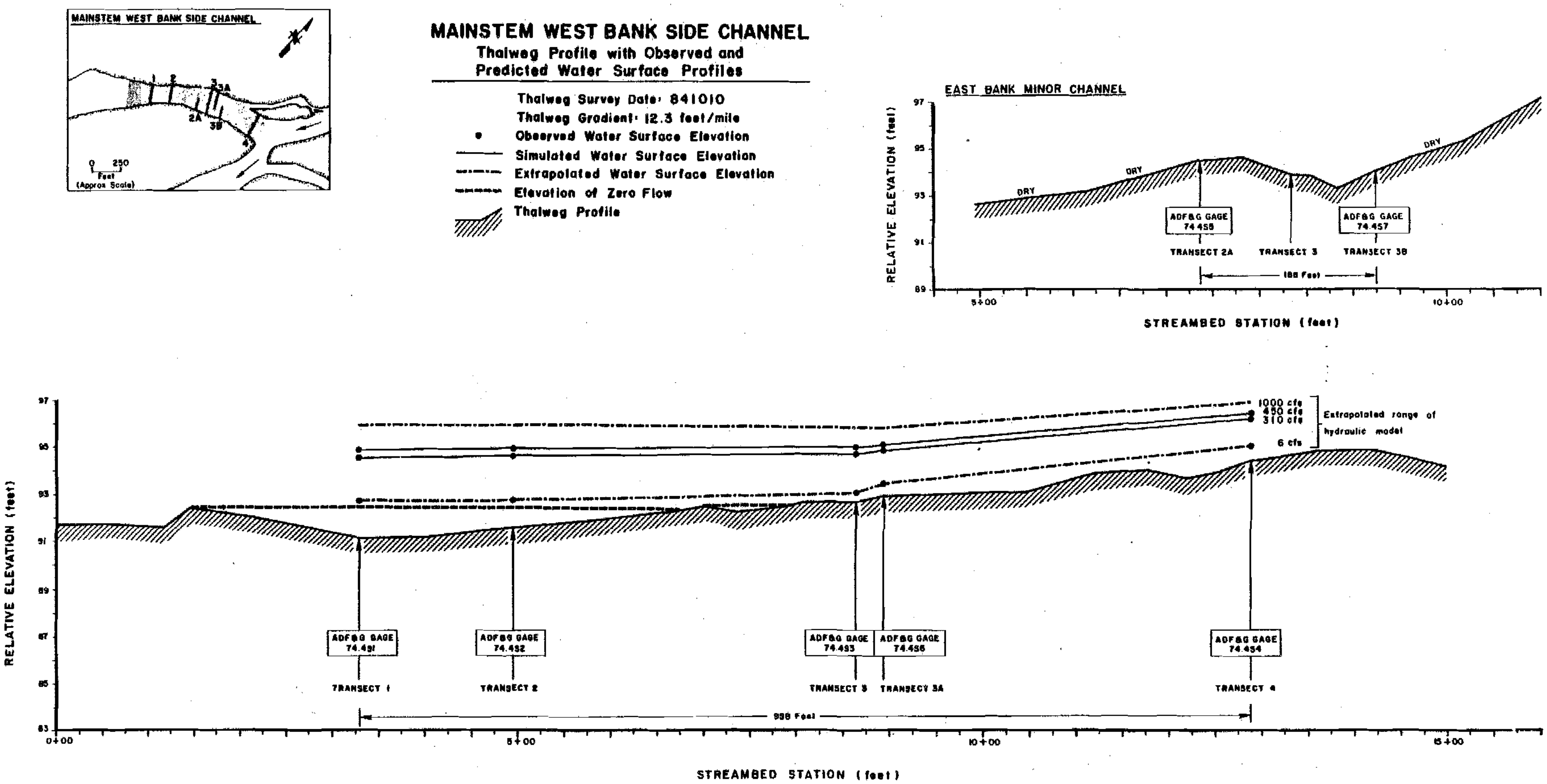
To evaluate the performance of the hydraulic model, observed and predicted water surface elevations, discharges, and velocity adjustment factors were compared (Appendix Table D-6). The 15 sets of observed and predicted WSEL's for the five transects of the 3 calibration flows were all within ± 0.02 ft. 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.

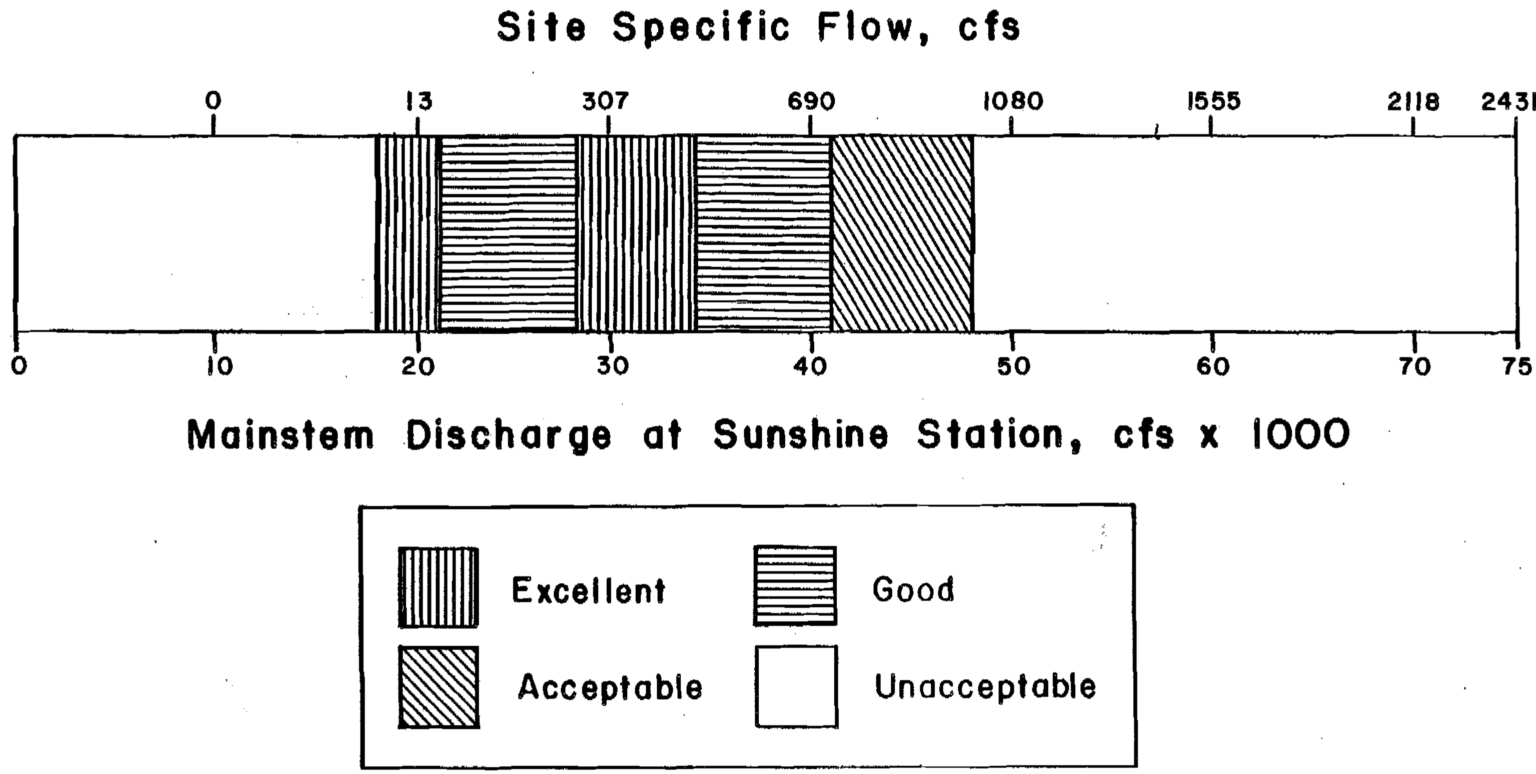
At the second level of verification there is good agreement between the predicted and observed values of depth and velocity (Appendix Figure D-18). At the higher velocities (> 2.5 ft/sec) they begin to spread apart though. In Appendix Table D-7 the results of the statistical tests are shown. There is 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

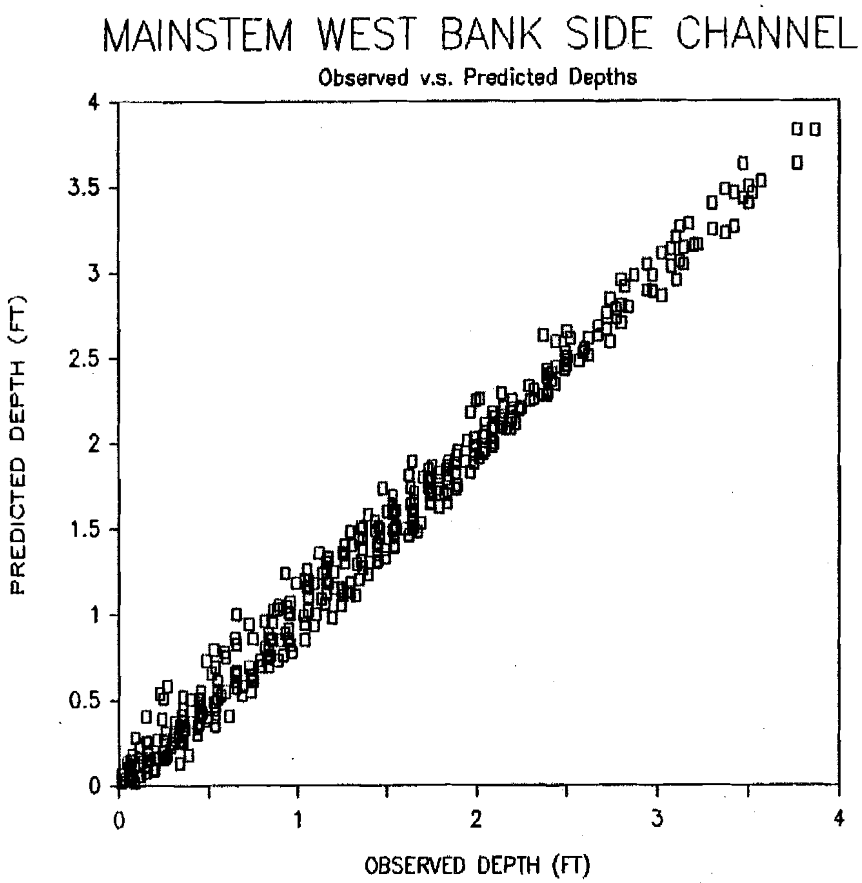
For habitat simulation modelling purposes, the hydraulic simulation model developed for Mainstem West Bank Side Channel can simulate channel flows in the mainstem discharge range of 18,000 to 48,000 cfs.

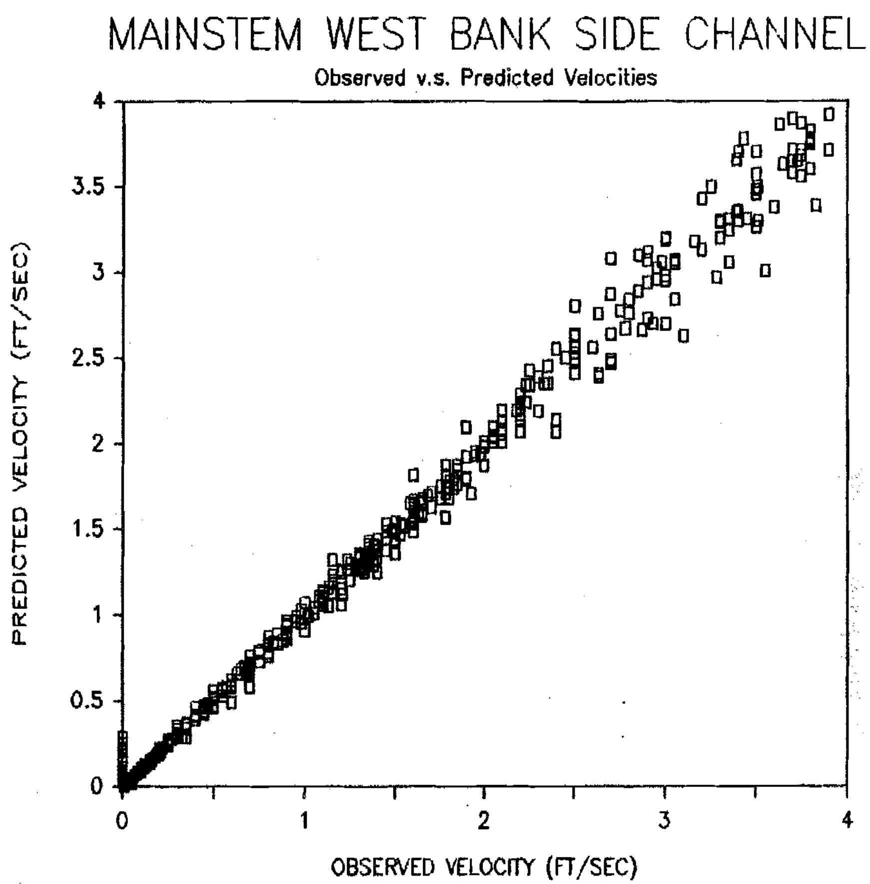
Application Range of the Calibrated Hydraulic Model at Mainstem West Bank

RM (74.4)



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. O	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.

O, P = mean of observed and predicted values.

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

a, b = y-intercept and slope of least squares regression between O 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).

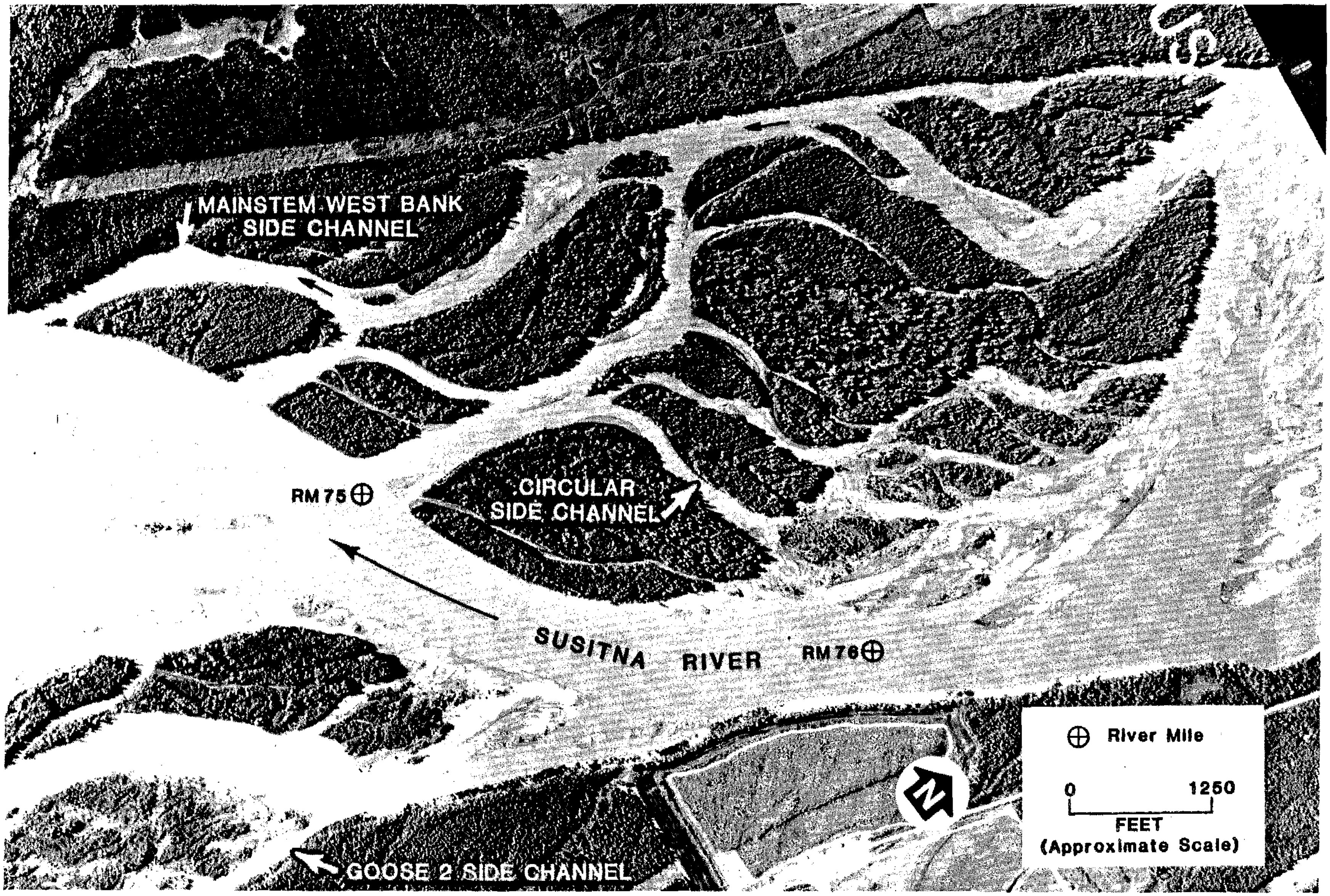
Breaching of Circular Side Channel has been estimated to occur at a mainstem discharge of 36,000 cfs (Quane et al. 1985). It has been determined that the hydraulics within this side channel are governed by mainstem discharge at mainstem discharges exceeding 36,000 cfs. The site flow that occurs at this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

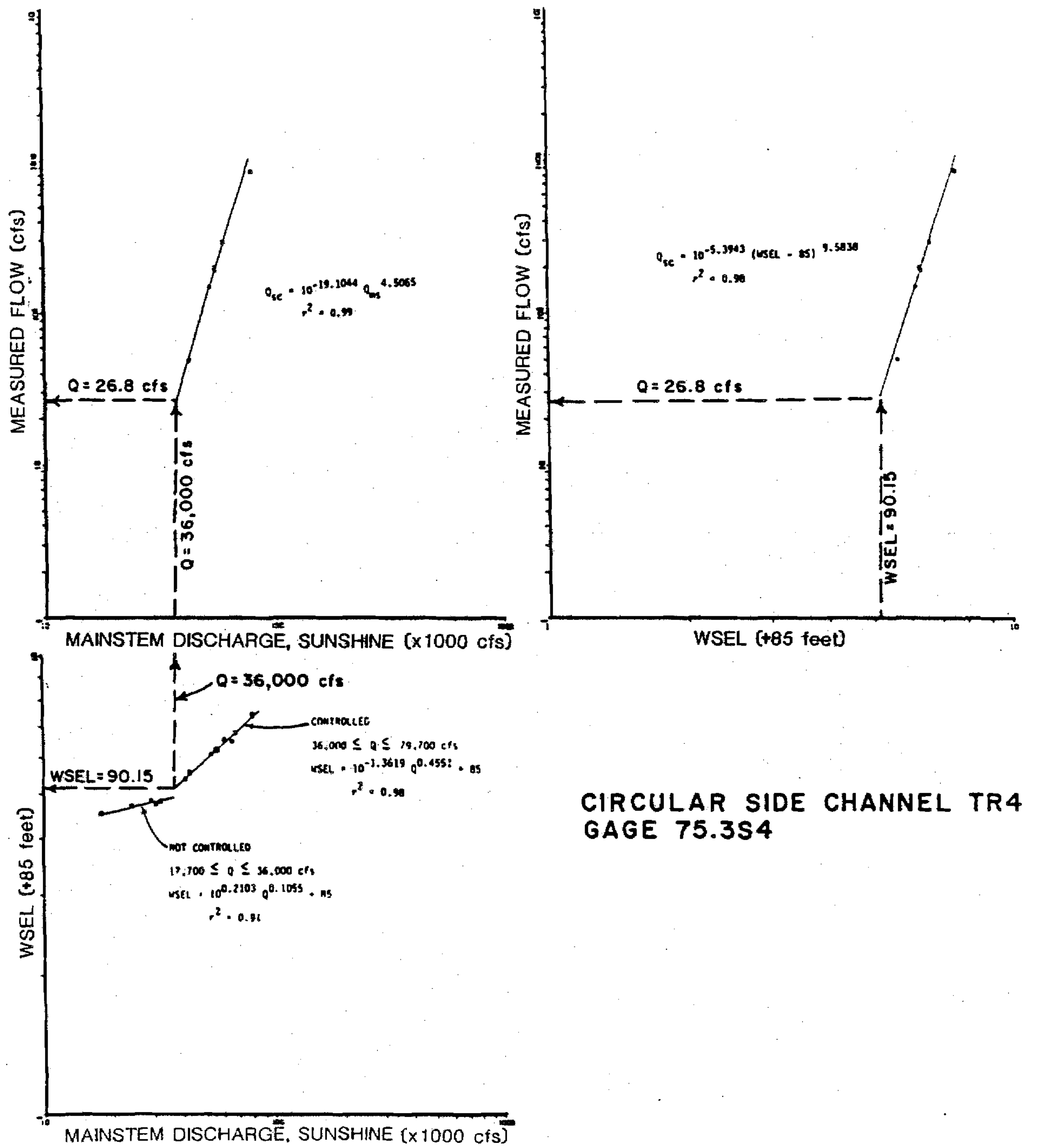
The IFG modelling study site in the upper half of Circular Side Channel is 820 feet (Appendix Figure D-21). The thalweg gradient of this study site is 14.3 ft/mile (Quane et al. 1985). Riparian vegetation along both banks consists mostly of alder and cottonwood. Substrate within the lower reaches of 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

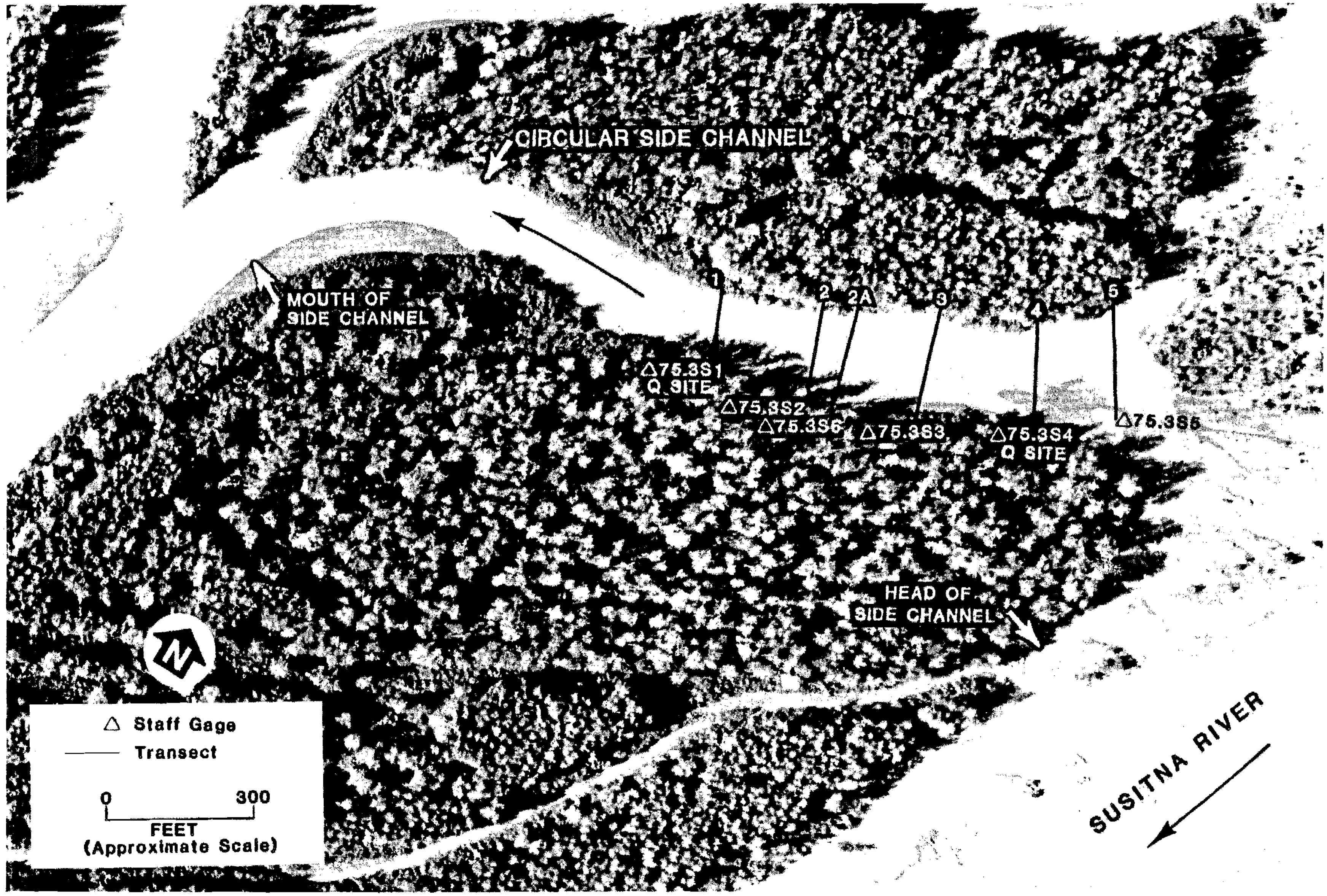
Hydraulic data were collected at two calibration flows: 50 and 204 cfs (Appendix Table D-4). Mean daily discharges for the Susitna River on the dates that calibration data were collected at the Circular Side Channel study site were 42,500 and 55,200 cfs. An IFG-4 model was used to forecast instream hydraulics 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).



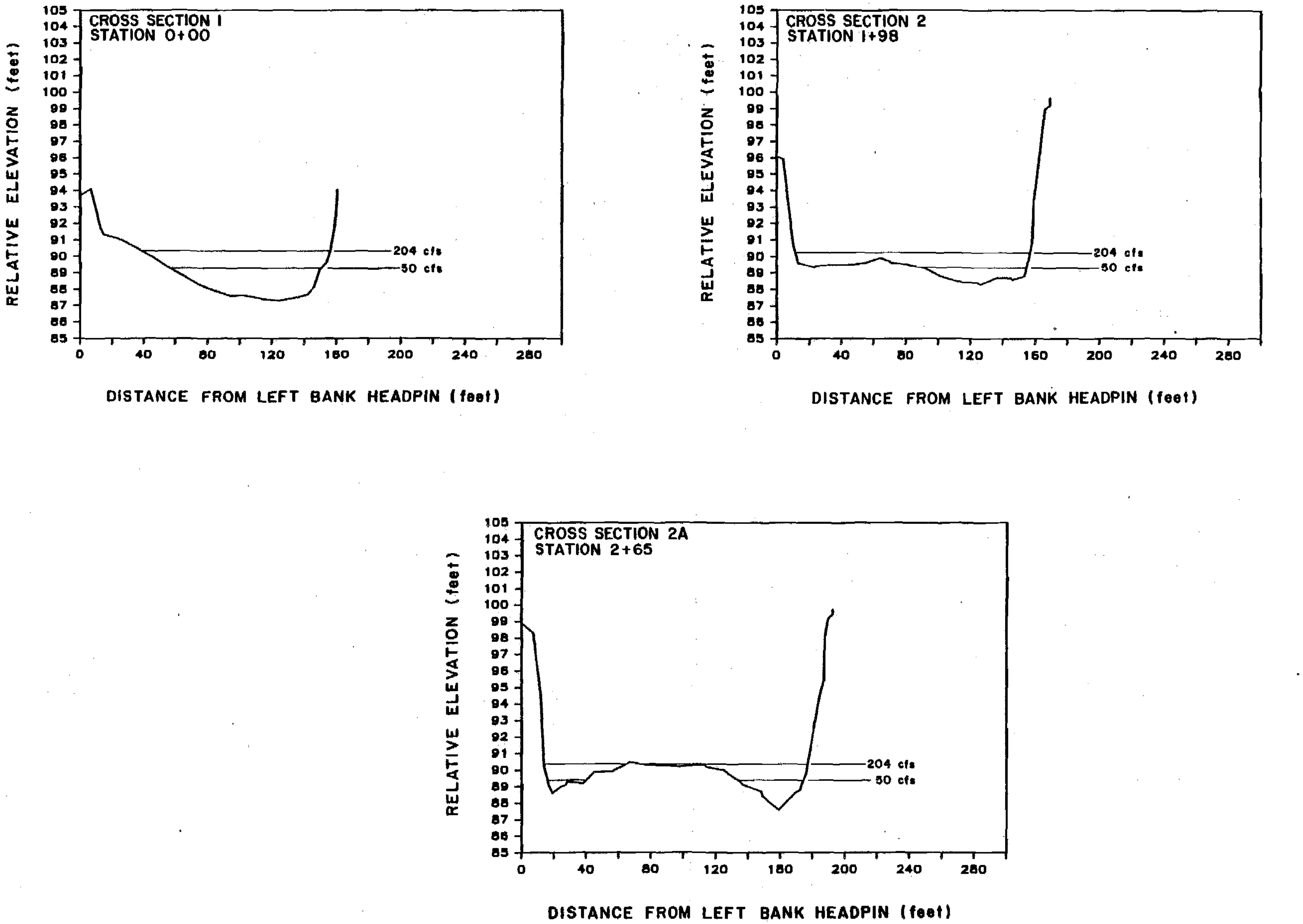
Appendix Figure D-19. Overview of Circular Side Channel (RM 75.3).



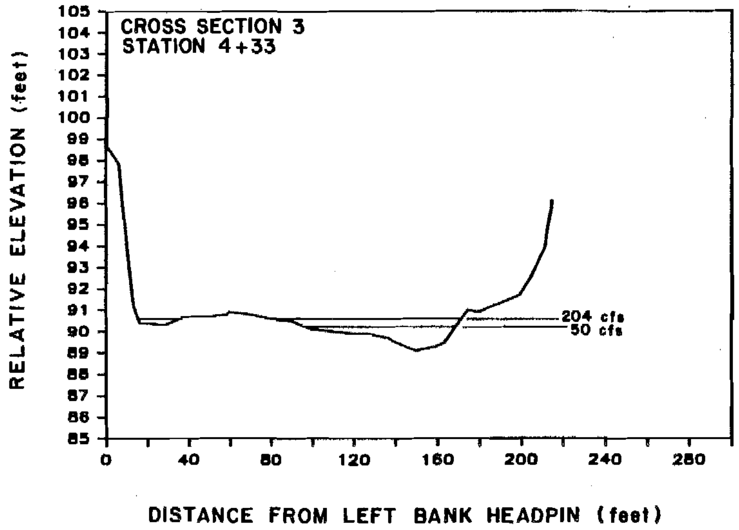
Appendix Figure D-20. Comparison of rating curves for Circular Side Channel Transect 4 (from Quane et. al. 1985).

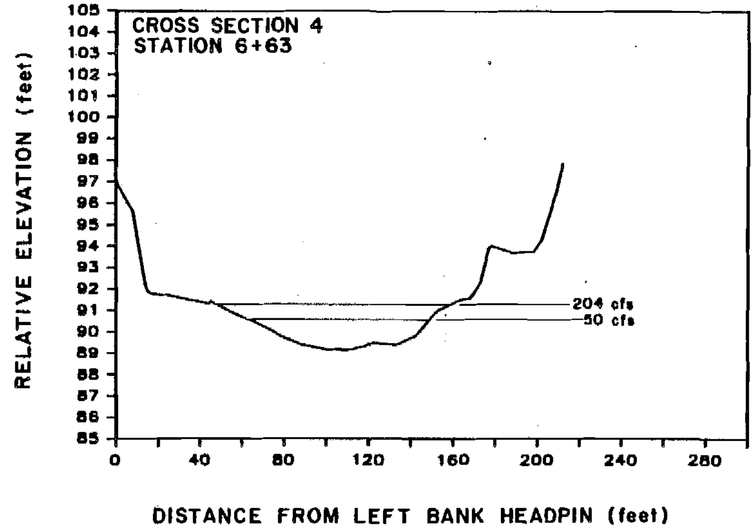


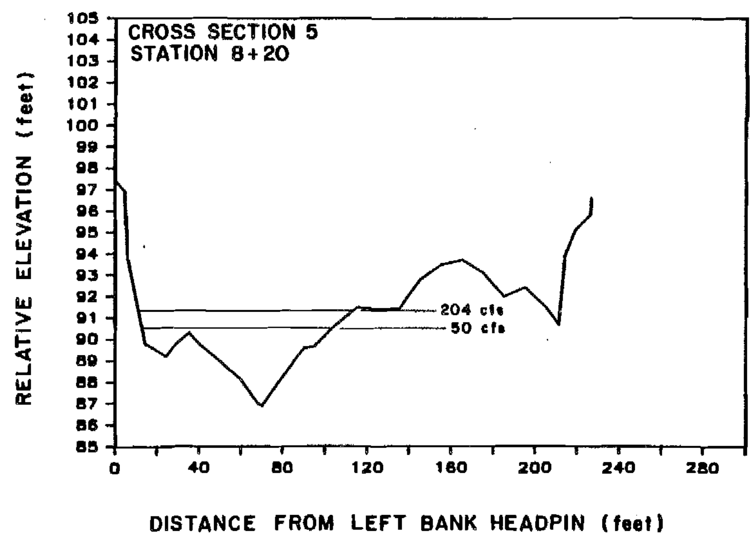
Appendix Figure D-21. Location of Circular Side Channel study site (RM 75.3).



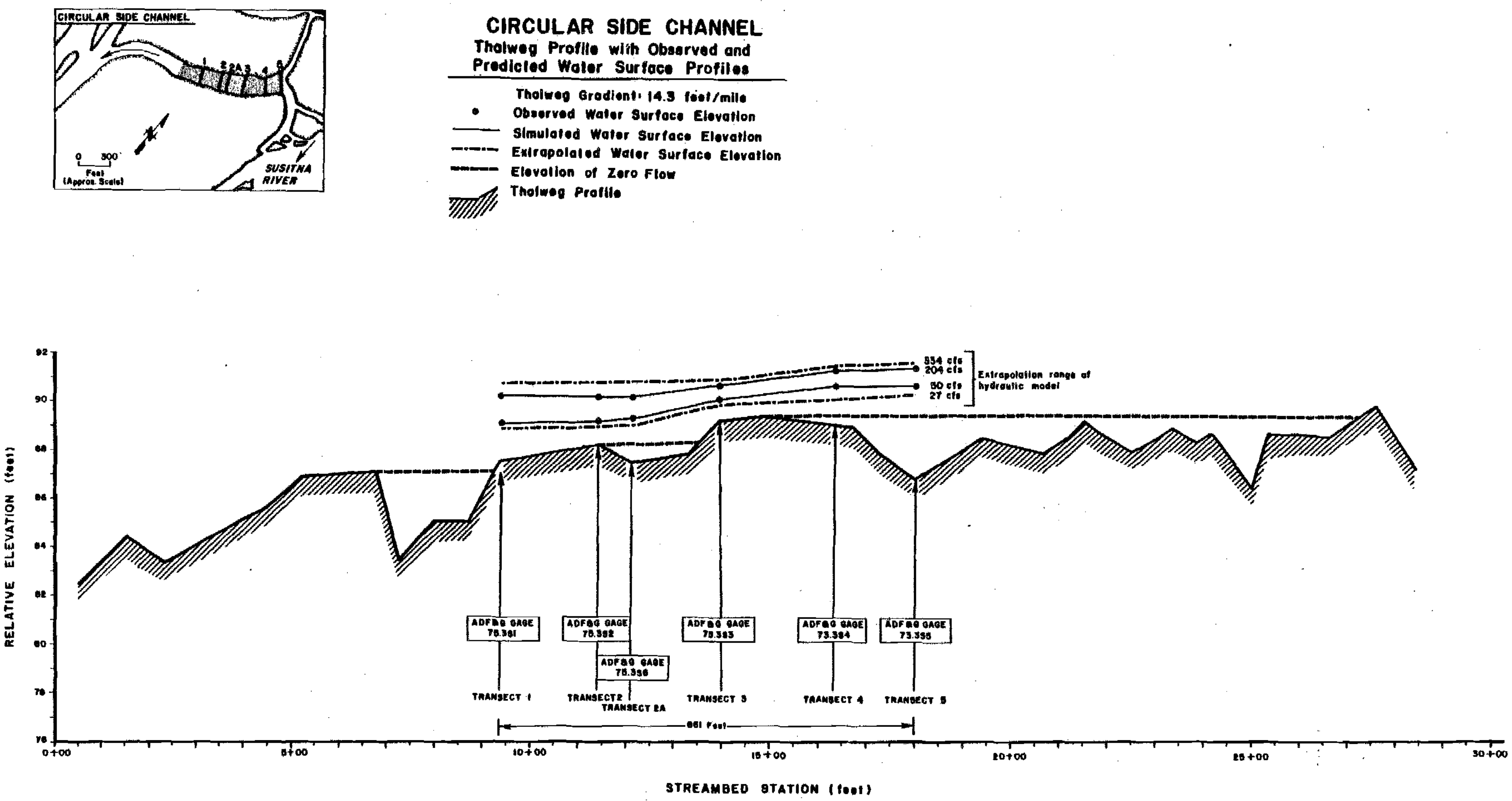
Appendix Figure D-22. Cross section of transects 1, 2, and 2A at Circular Side Channel (adapted from Quane et al. 1985).







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.

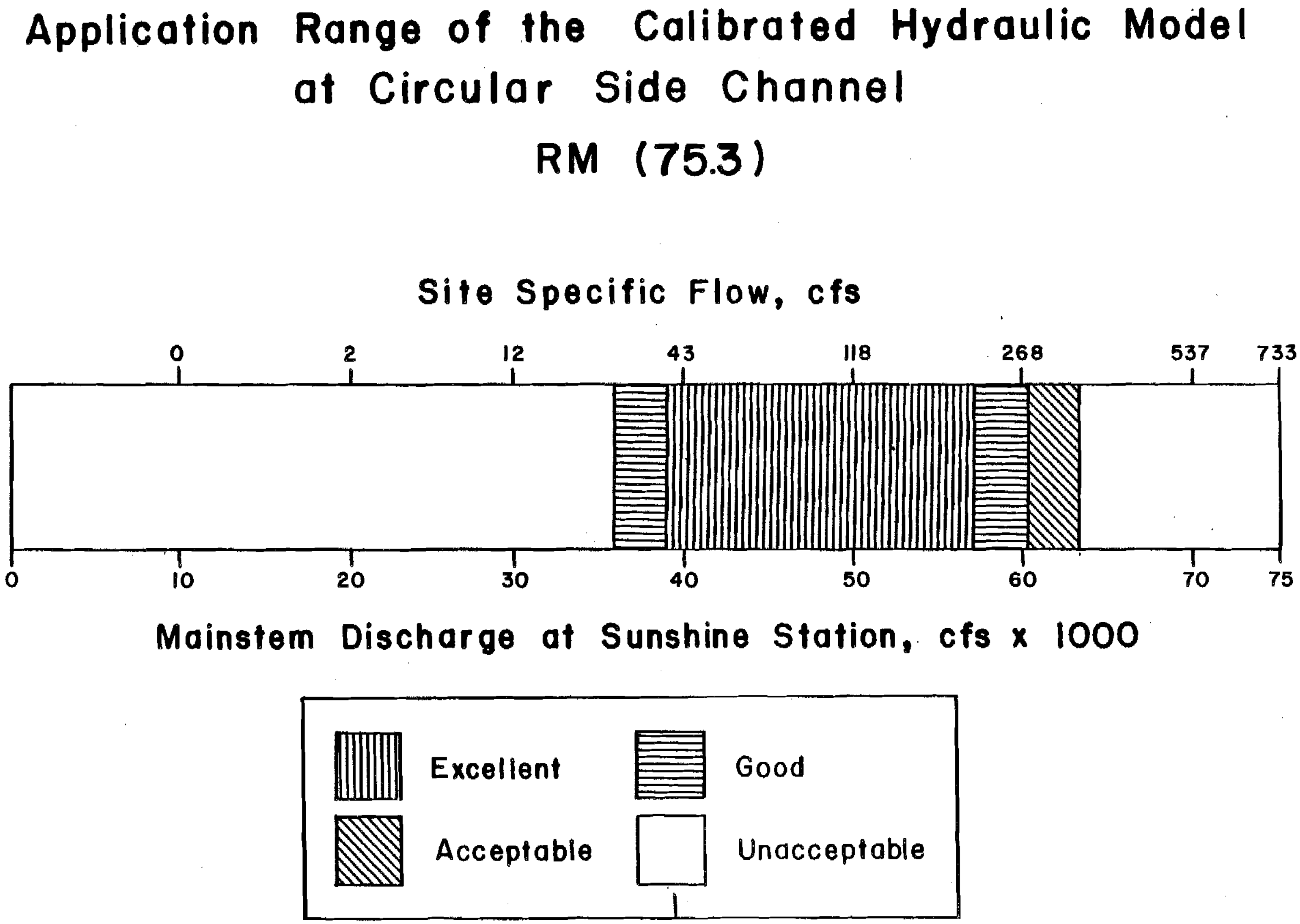
At the second level of verification there is excellent agreement between the observed and predicted velocities and good agreement between the

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.

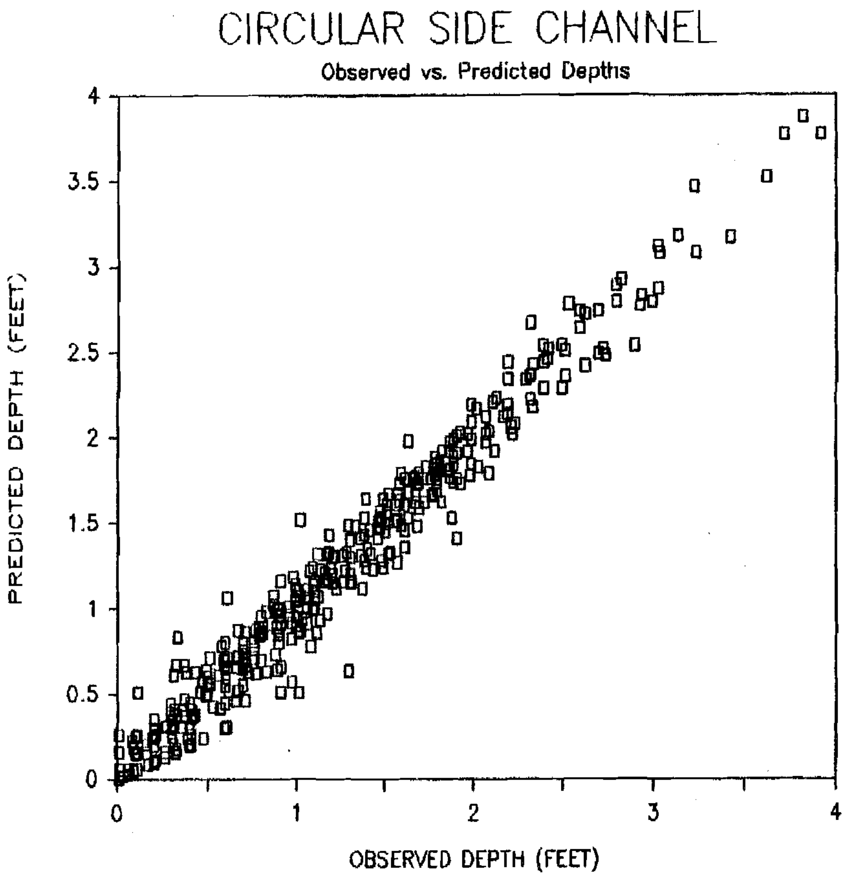


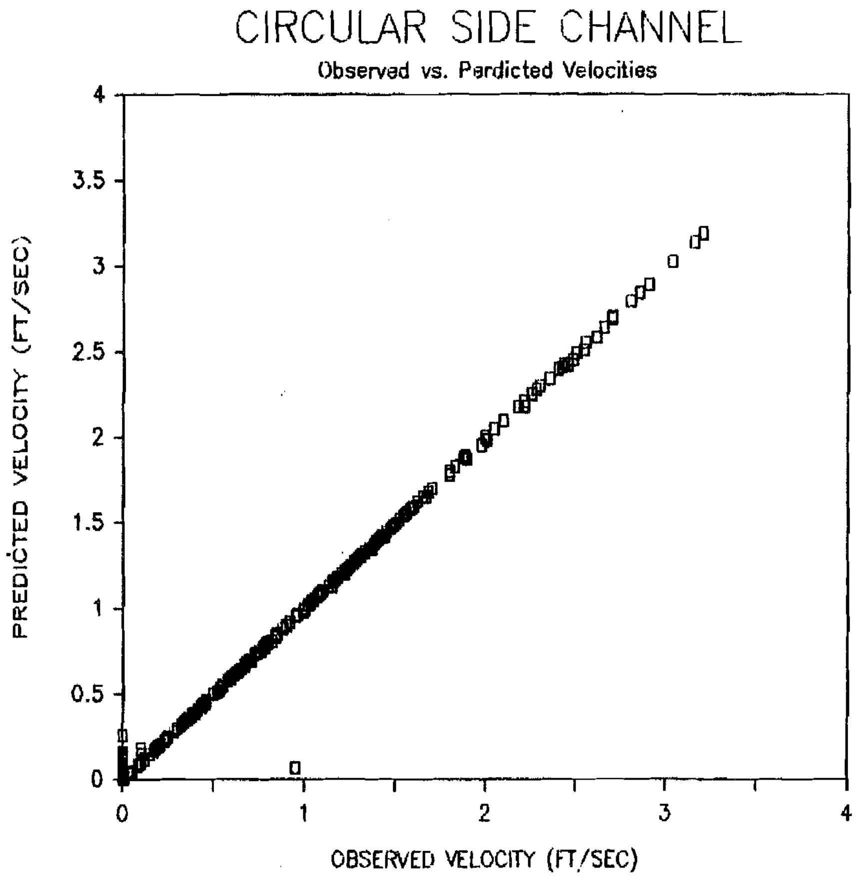
Appendix Figure D-25. Application range of the calibrated hydraulic model at Circular Side Channel.

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.

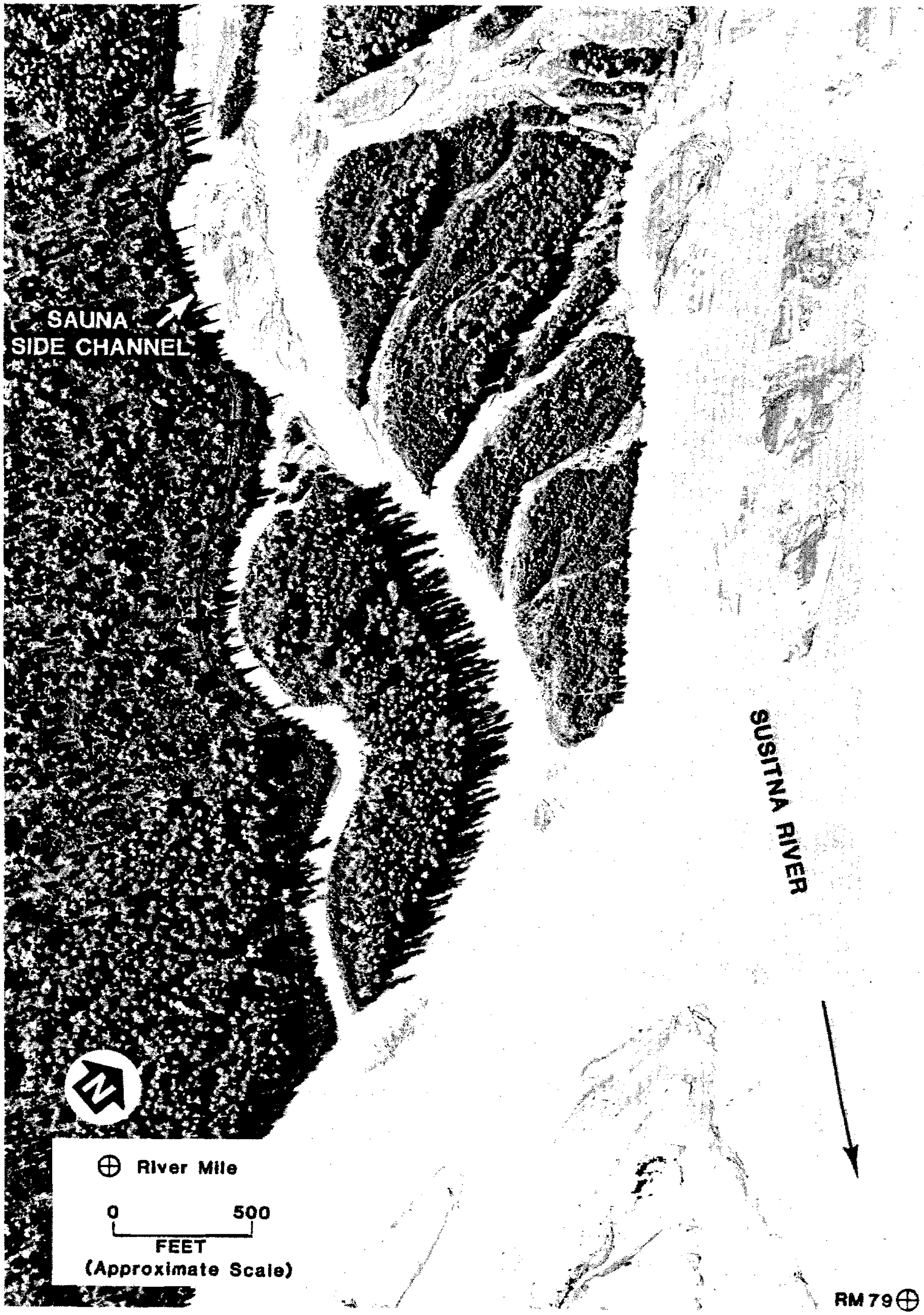
Based on field observations and stage/discharge relationships, the mainstem discharge estimated to initially breach Sauna Side Channel was 37,000 cfs (Quane et al. 1985). A controlling discharge of 38,000 cfs was determined for this side channel also based on this stage/discharge relationship. A side 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.

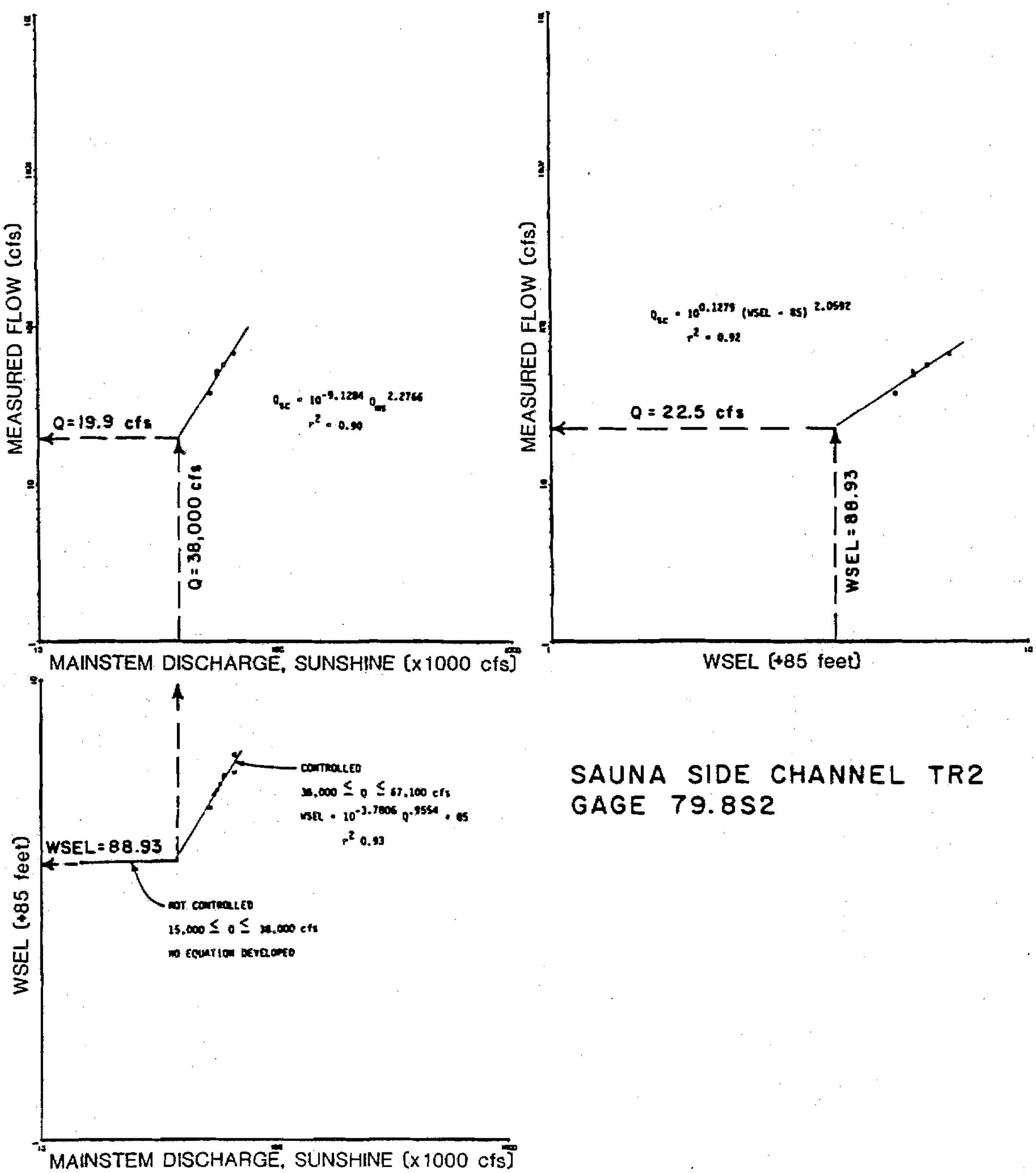
Four transects were located within this study site (Appendix Figure D-30) . Transects 1 and 2 were located in shallow pool habitat whereas transects 3 and 4 were located in deeper pools.

Calibration

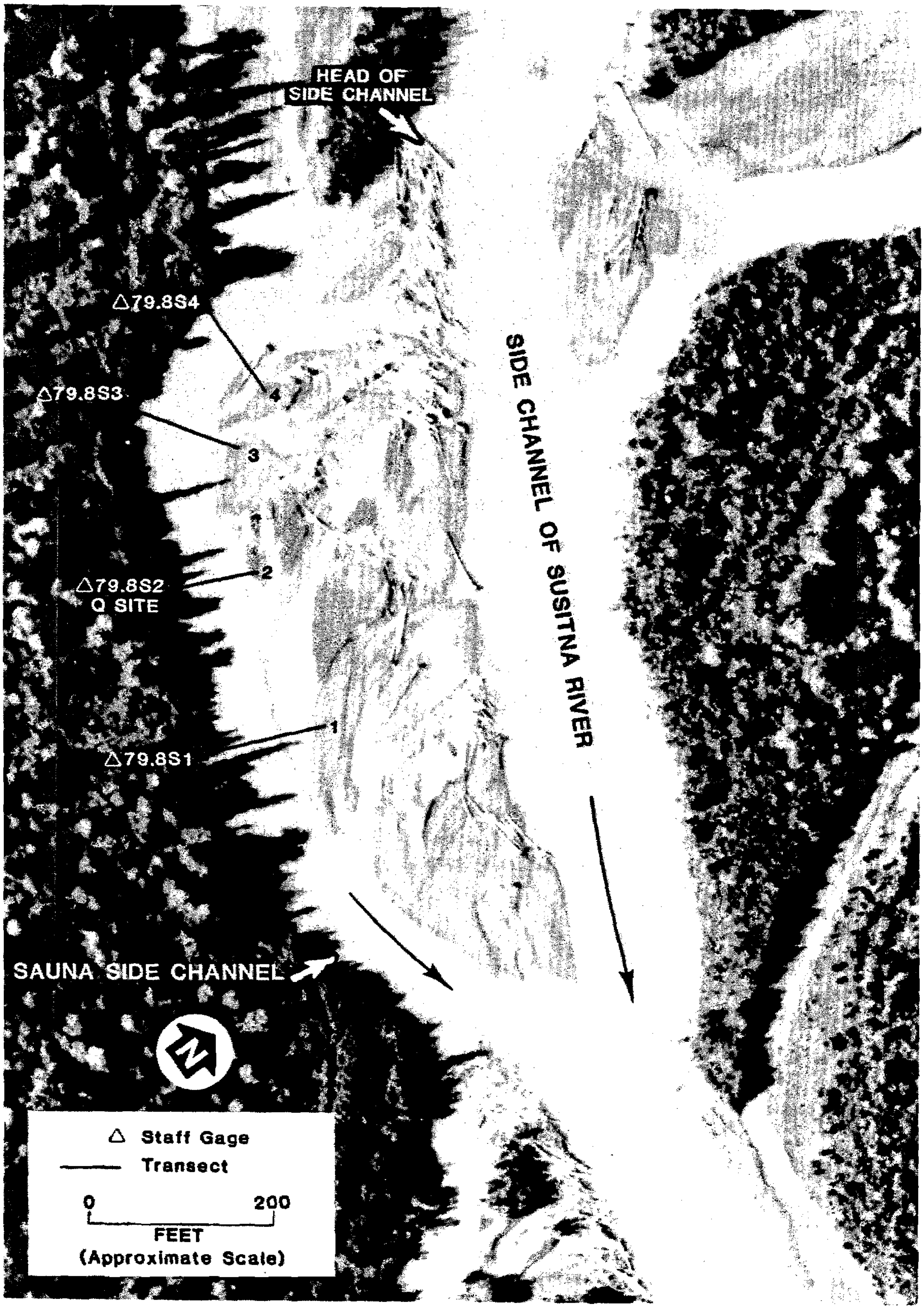
Hydraulic data were collected at a calibration flow of 52 cfs corresponding to a mainstem discharge of 52,000 cfs (Appendix Table D-4). Based on this single calibration flow, an IFG-2 model was used to forecast instream hydraulics of this study site. The streambed profile, stage of zero flow, and observed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



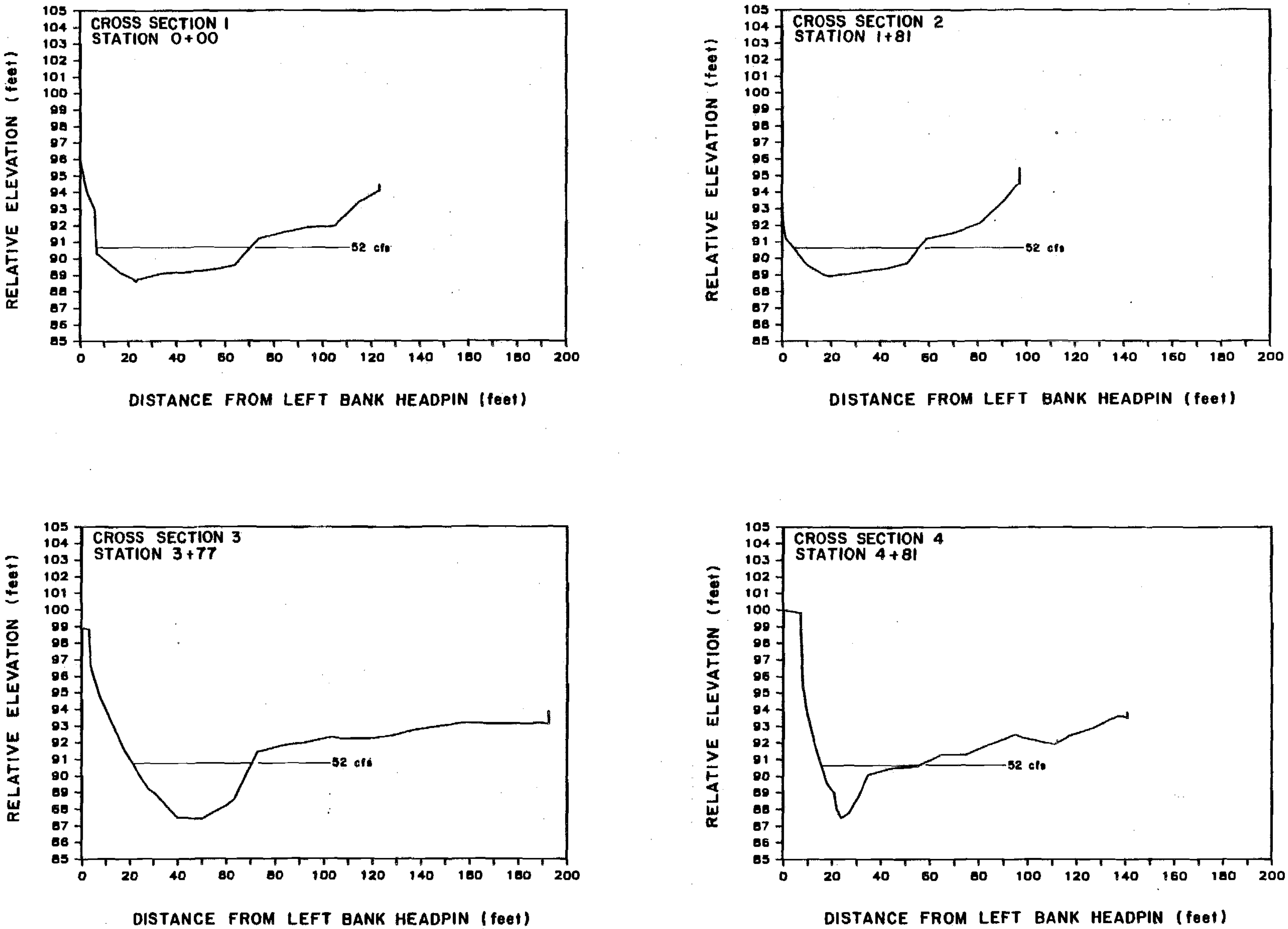
Appendix Figure D-27. Overview of Sauna Side Channel (RM 79.8).



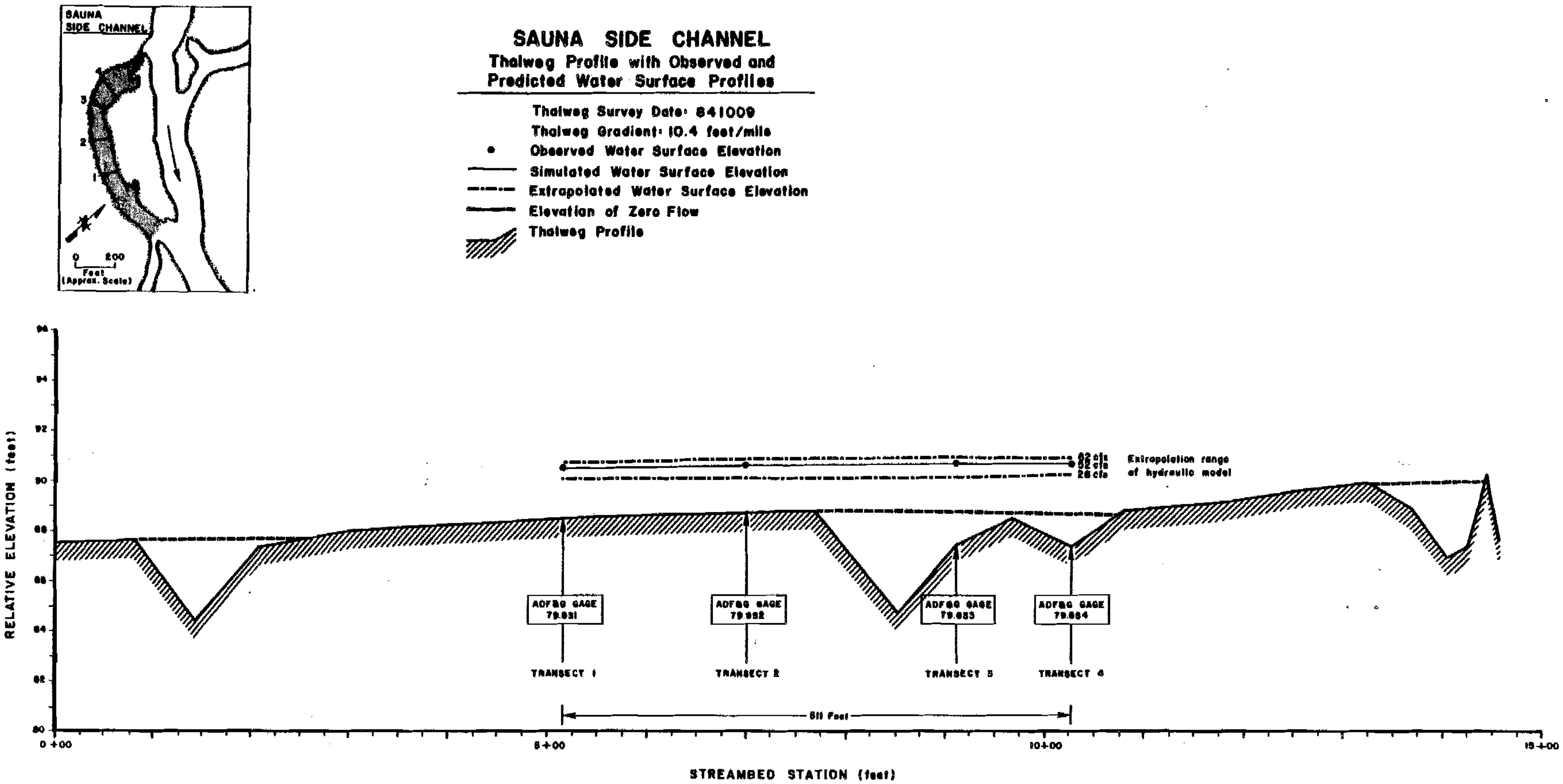
Appendix Figure D-28. Comparison of rating curves from Sauna Side Channel transect 2 (from Quane et. at. 1985).



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.

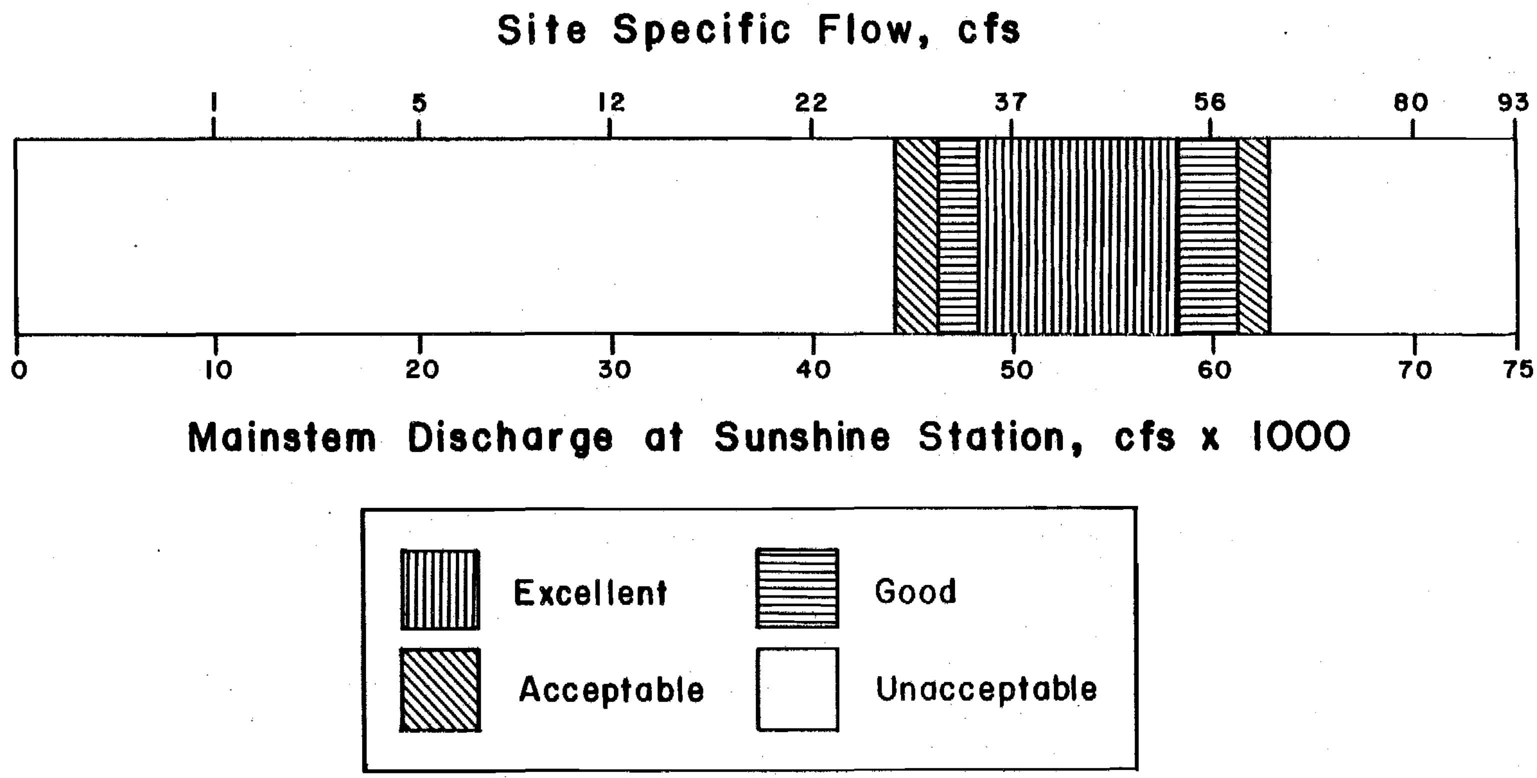
Based on the first level of verification by EWT&A, the IFG-2 model for this site does an excellent job of simulating channel hydraulics between 48,000 cfs and 58,000 cfs mainstem discharge (34 to 52 cfs site flow) (Appendix Figure D-32). Within this range, predicted WSEL's, depths, and velocities are 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).

Application Range of the Calibrated Hydraulic Model at Sauna Side Channel RM (79.8)

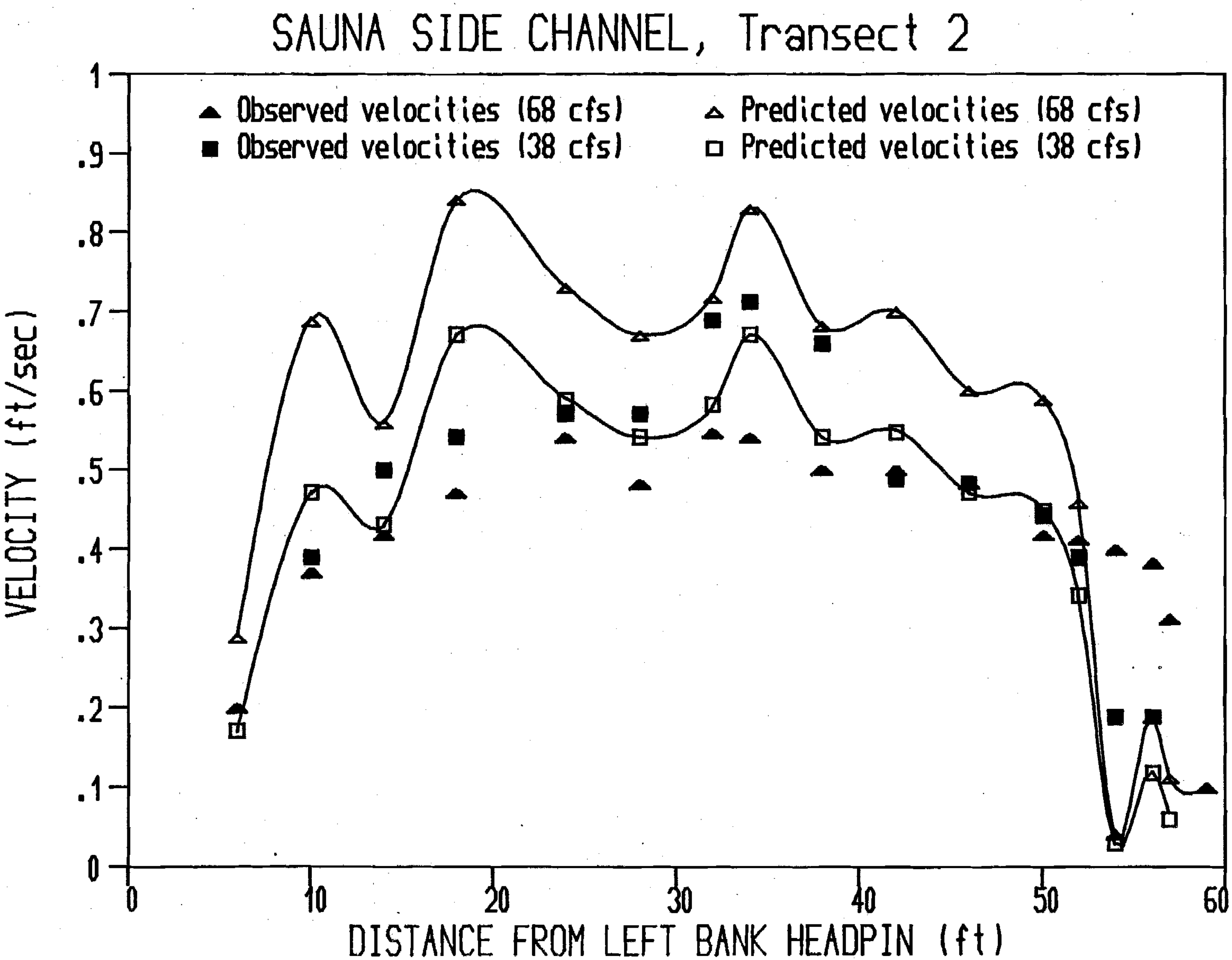


Appendix Figure D-32. Application range of the calibrated hydraulic model at Sauna Side Channel.

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

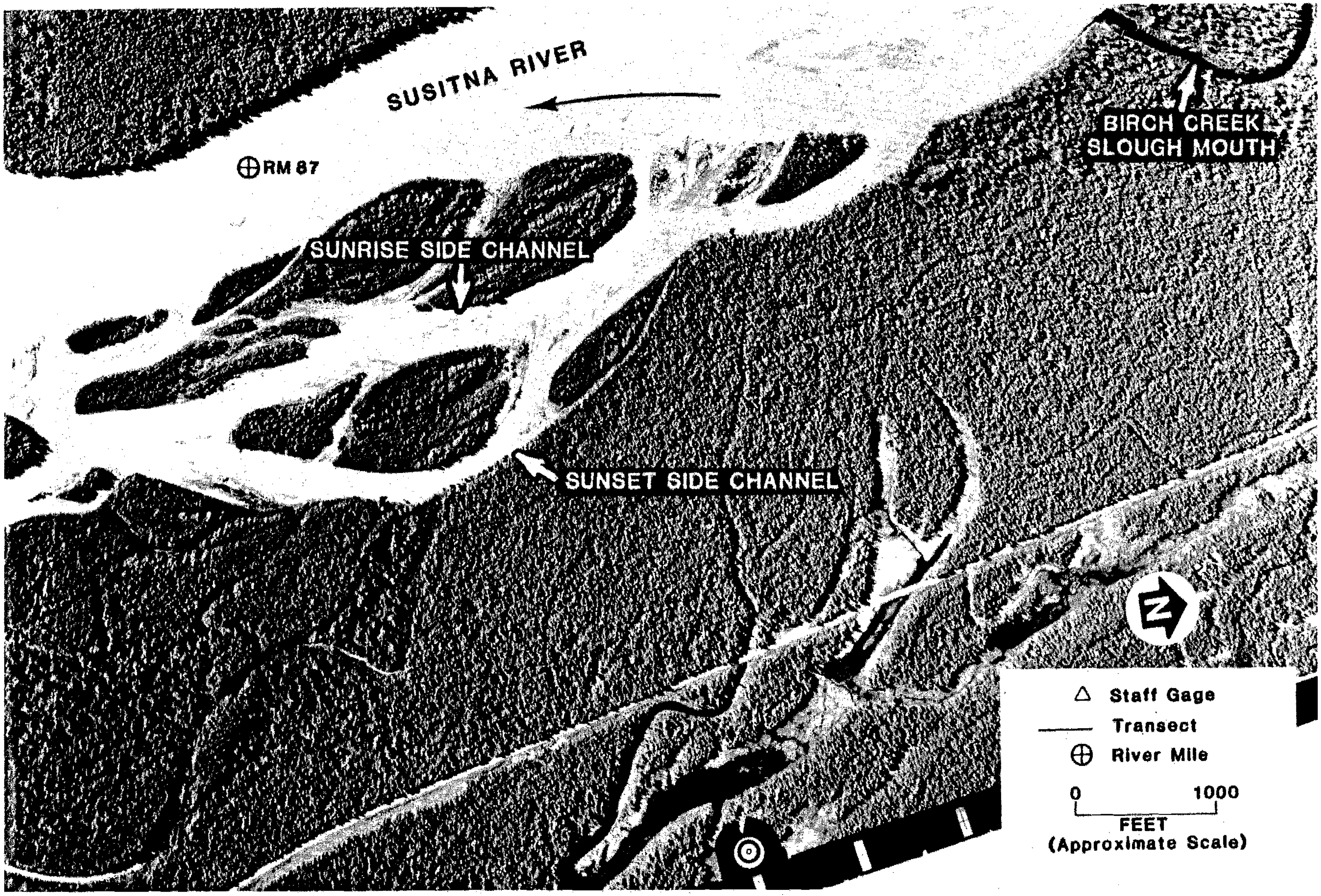
Sunset Side Channel is located on the east bank of the Susitna River at river mile 86.9 (Appendix Figure D-34). It is approximately 1.1 miles long and is separated from the main channel of the Susitna River on the west by a network of vegetated islands and side channels. The channel is confined on the 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).

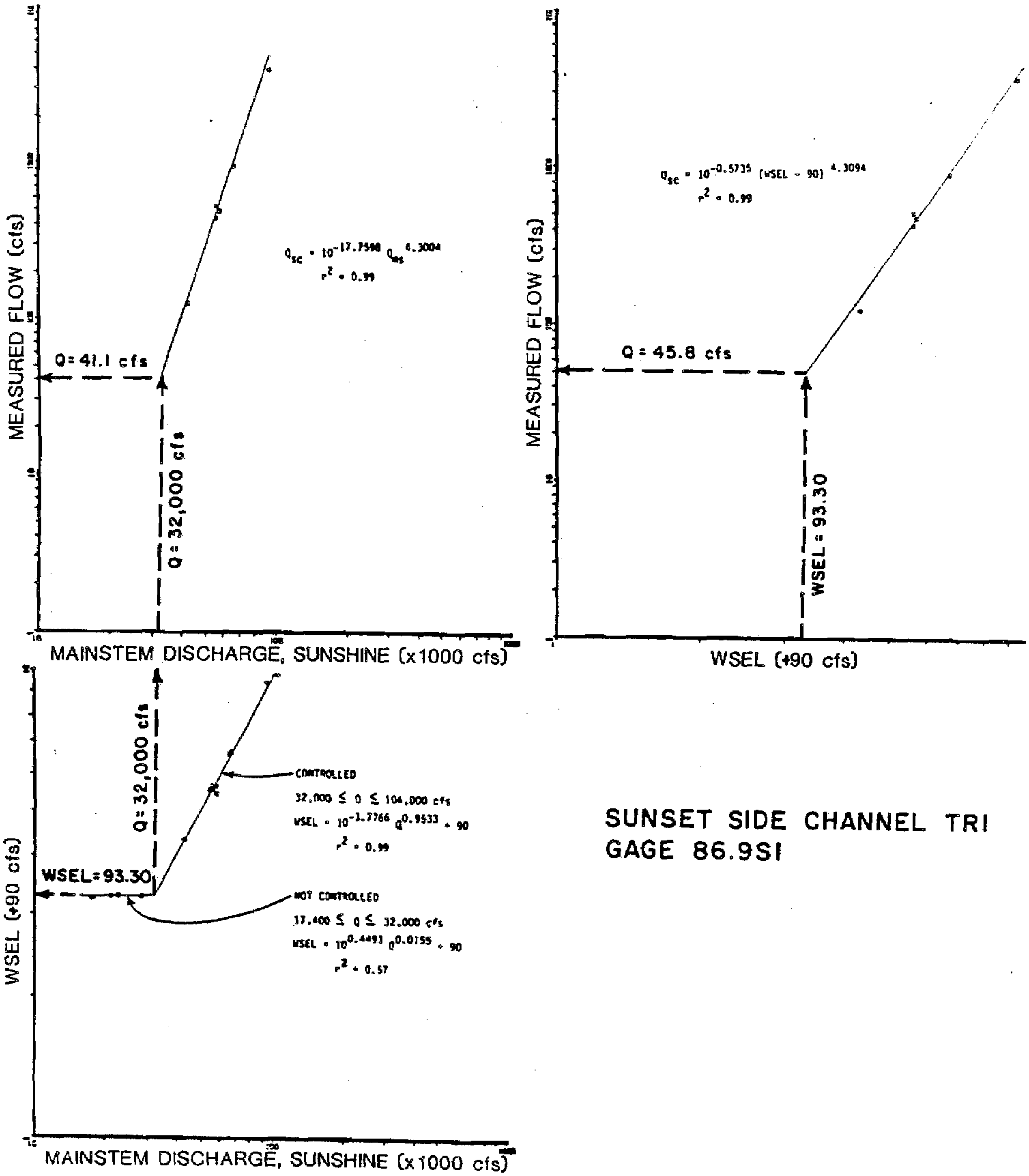
Based on assessments by Quane et al. (1985) a backwater area does not occur in this side channel during unbreached conditions. But at breaching mainstem discharges ranging from 56,000-66,700 cfs, an area of backwater was observed to extend upstream approximately 1,100 feet to a point between transects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

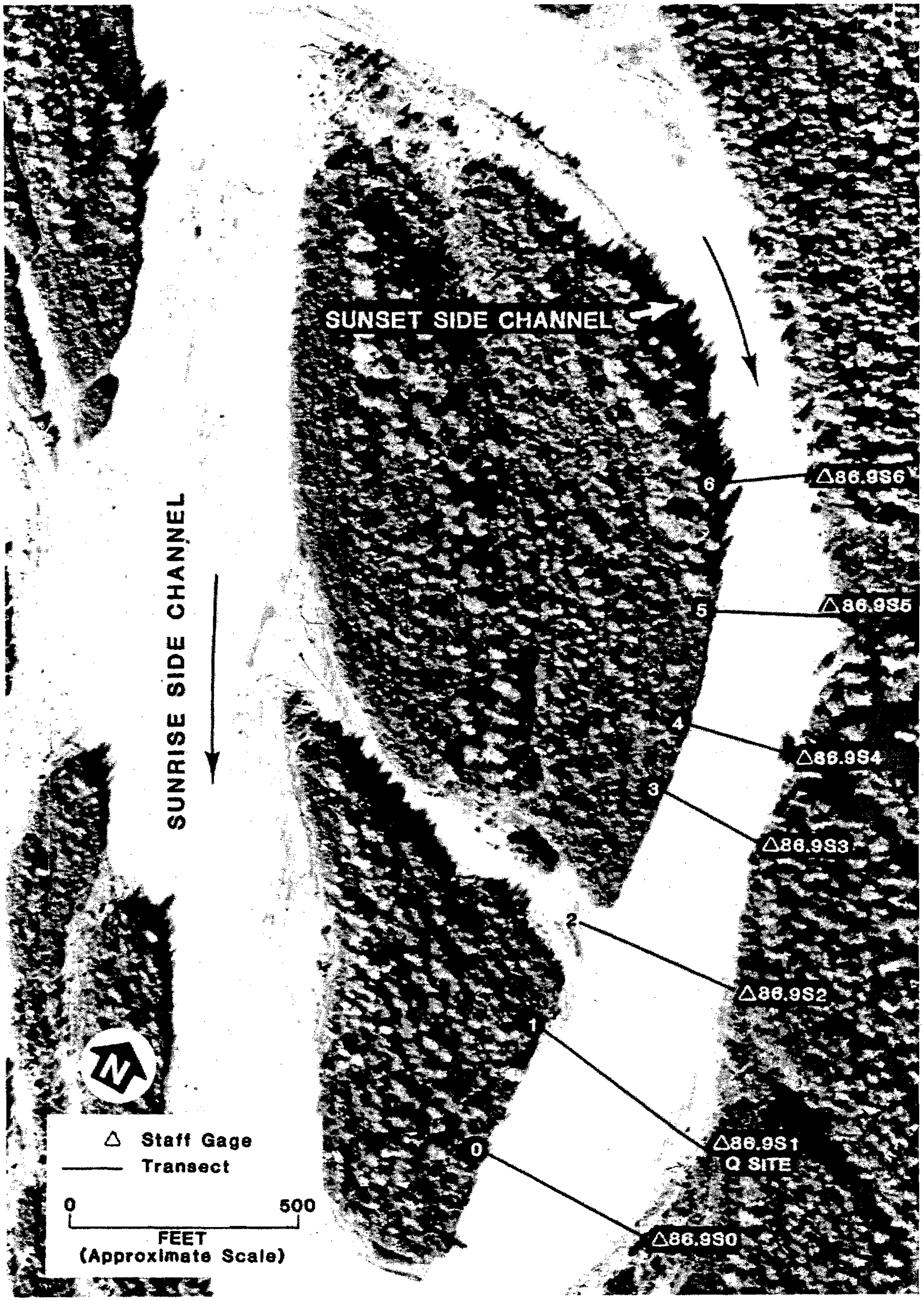
Transect 0 is located in a shallow pool habitat and has a substrate of sand and small gravel. Transects 1 (the discharge site) and 2 are primarily run habitat, and the substrate is small gravel. At transect 3, the habitat changes to run and shallow pool habitat, the predominant substrate is small and 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.



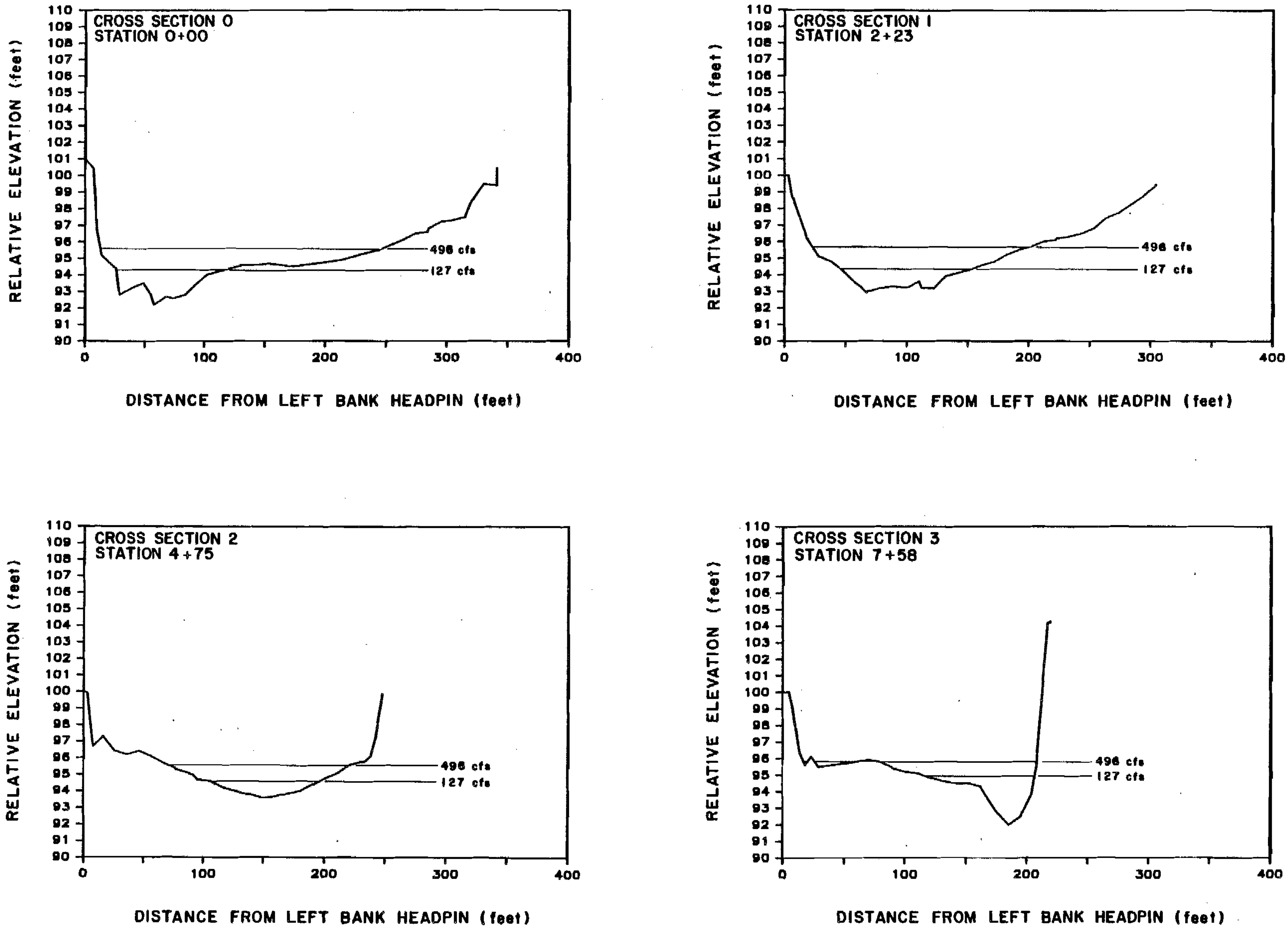
Appendix Figure D-34. Overview of Sunset Side Channel (RM 86.4).



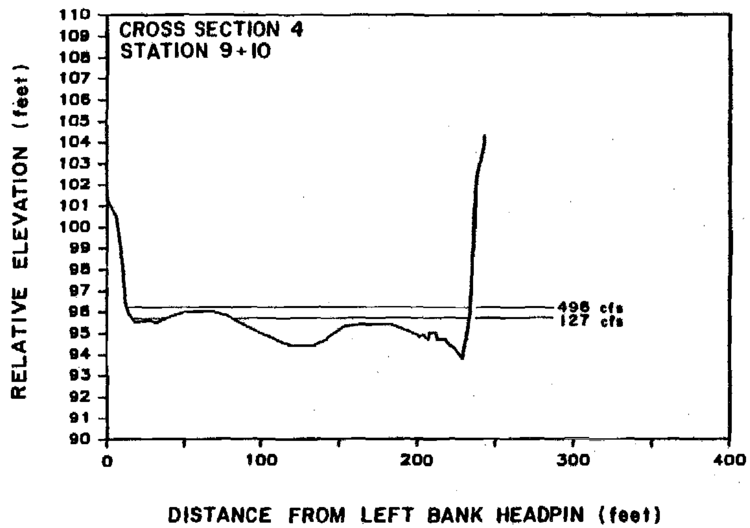
Appendix Fugure D-35. Comparison of rating curves from Sunset Side Channel at transect 1 (from Quane et. al. 1985).

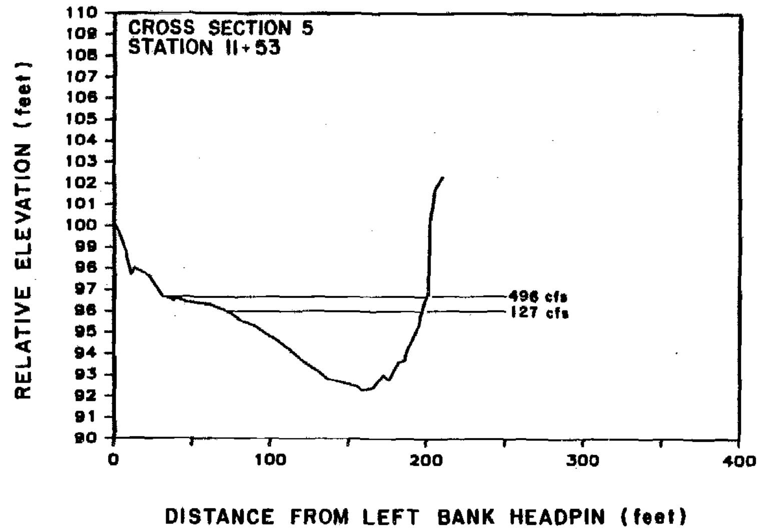


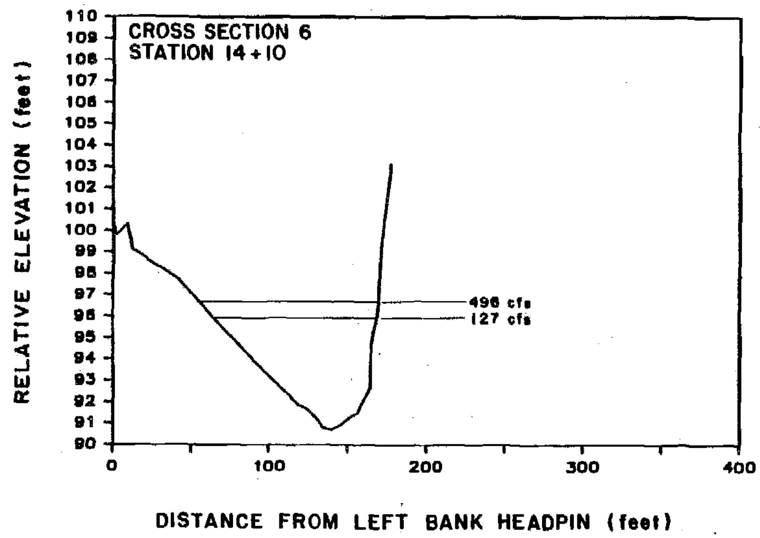
Appendix Figure D-36. Location of Sunset Side Channel study site (RM 86.9).



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).

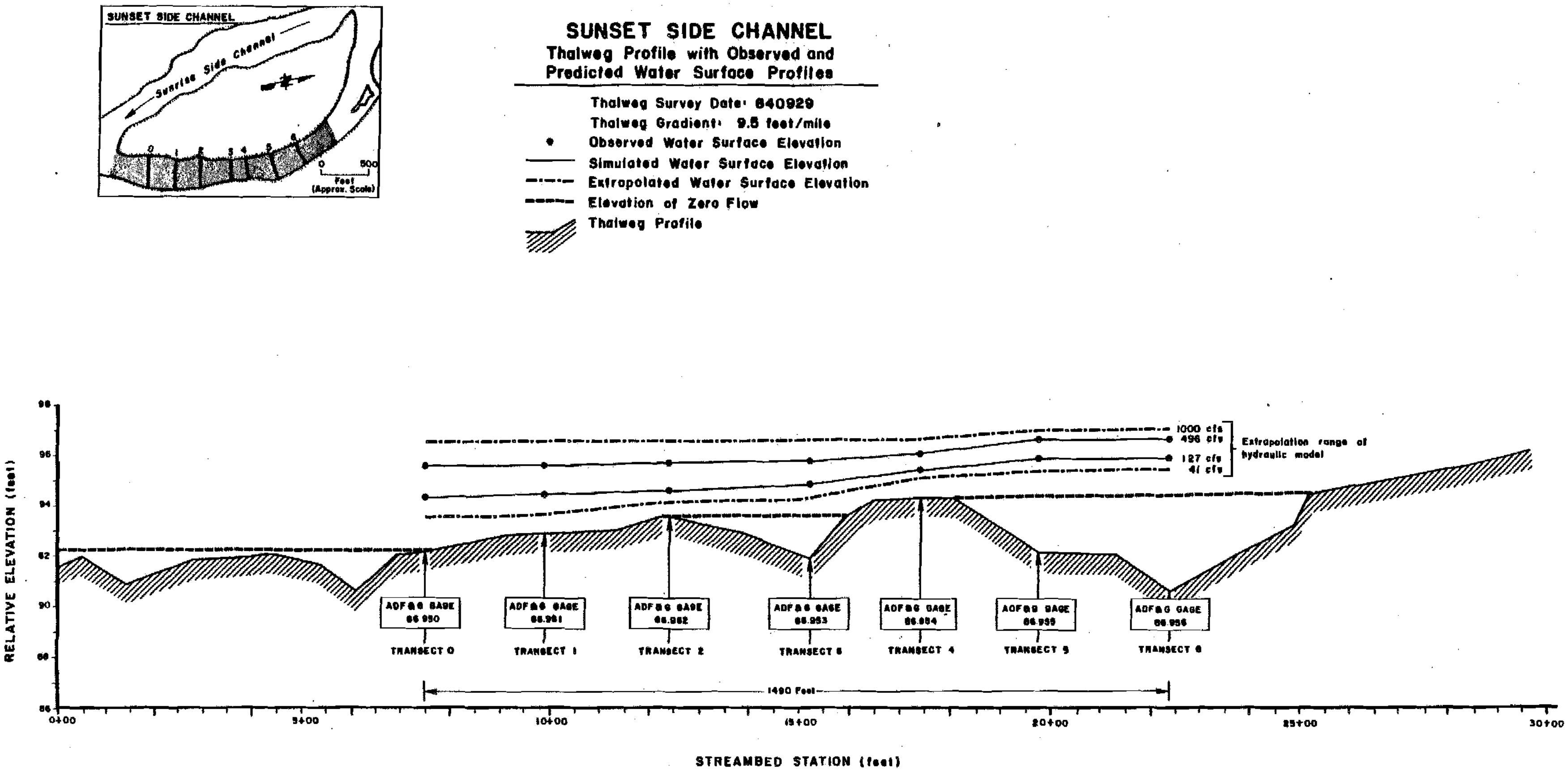
To evaluate the performance of the hydraulic model, observed and predicted water surface elevations, discharges, and velocity adjustment factors were compared (Appendix Table D-11). The hydraulic model at Sunset Side Channel is similar to Circular Side Channel. Because of the 2 calibration flows, only 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	Stage of Zero Flow (ft) 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.

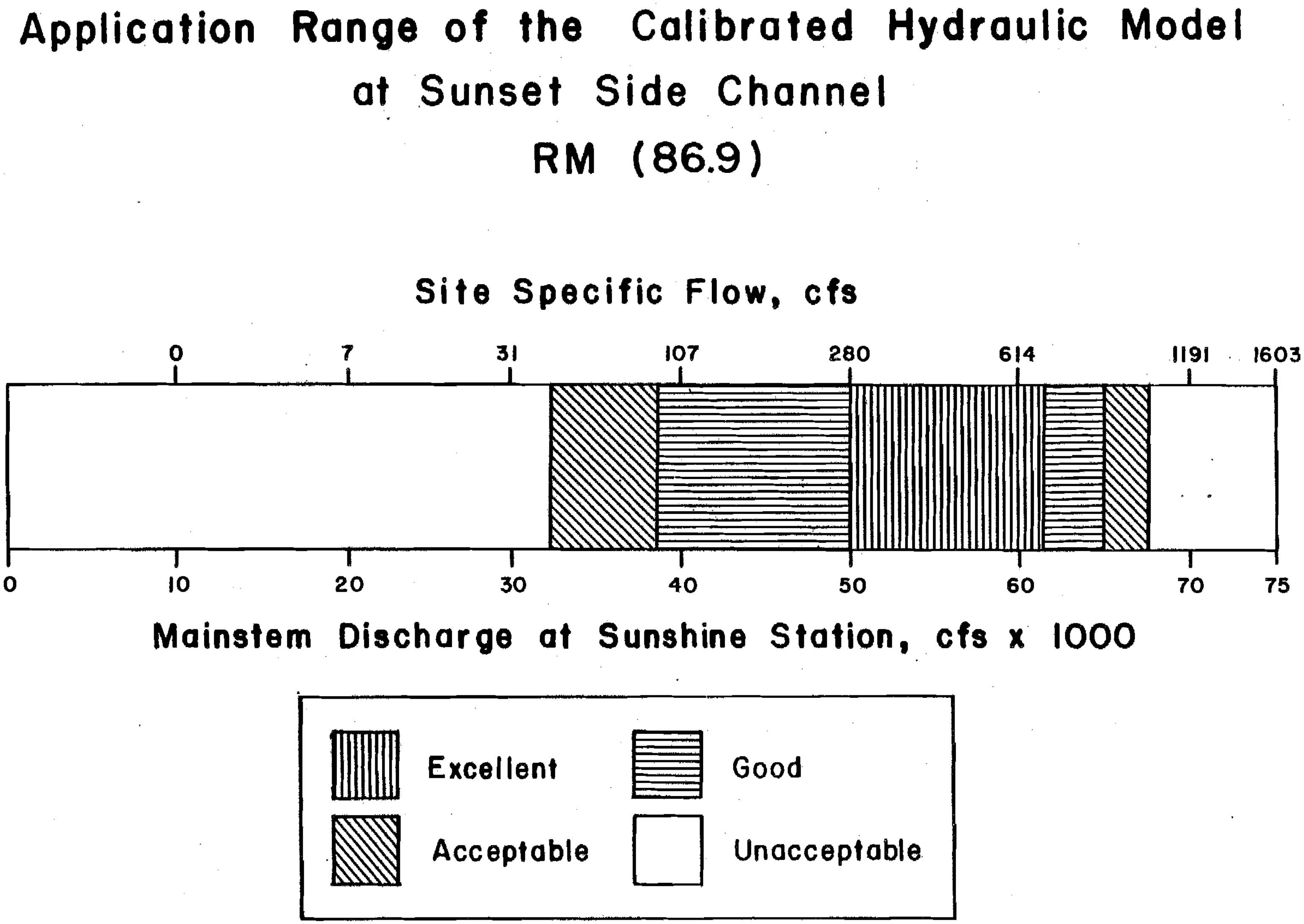
Verification

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).

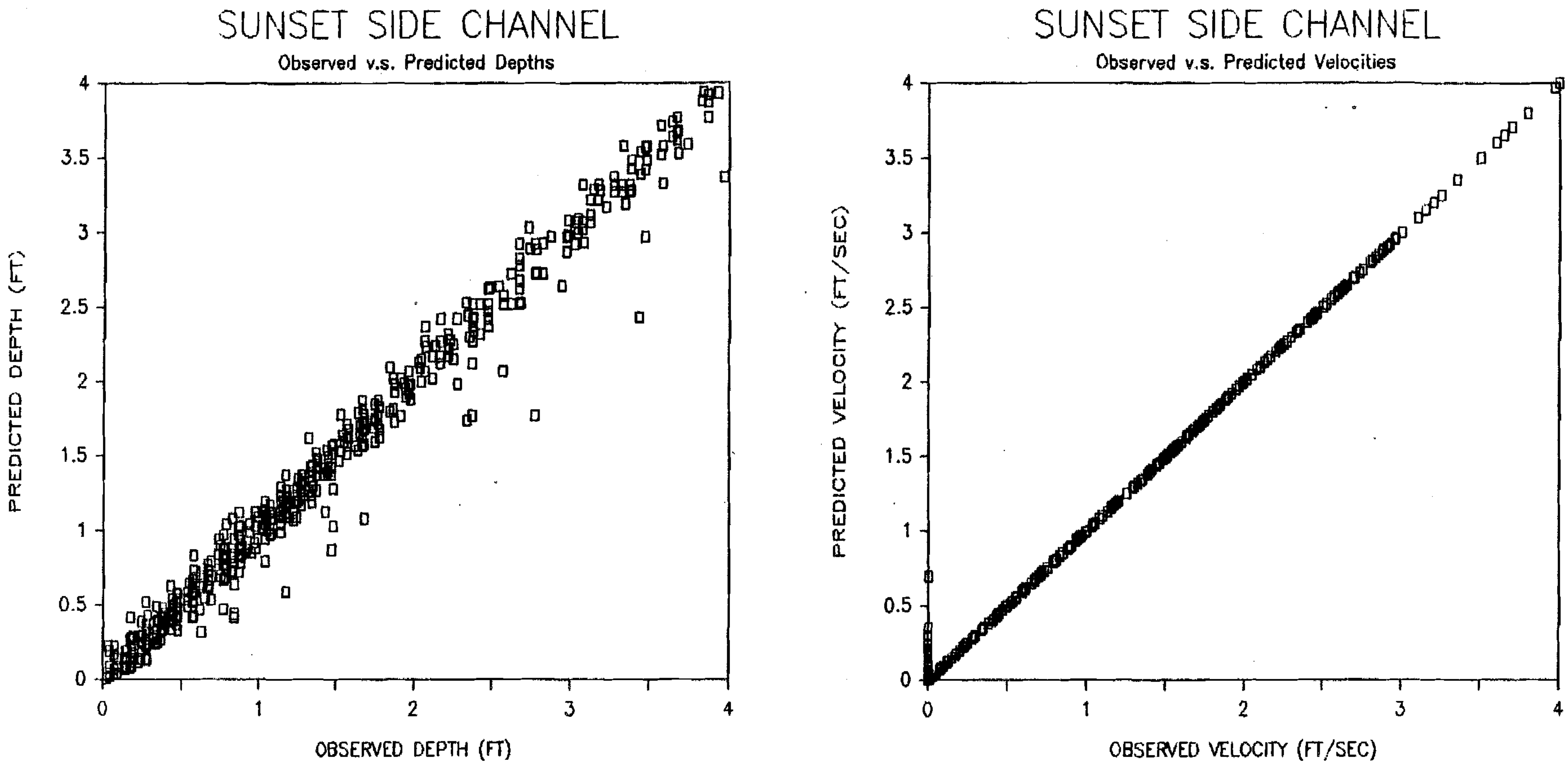
At the second level of verification there is excellent agreement for velocity and good agreement for depth between observed and predicted values (Appendix Figure D-41). For a small number of depths there is a deviation away from the expected one to one relationship and this maybe attributable to the 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.



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).

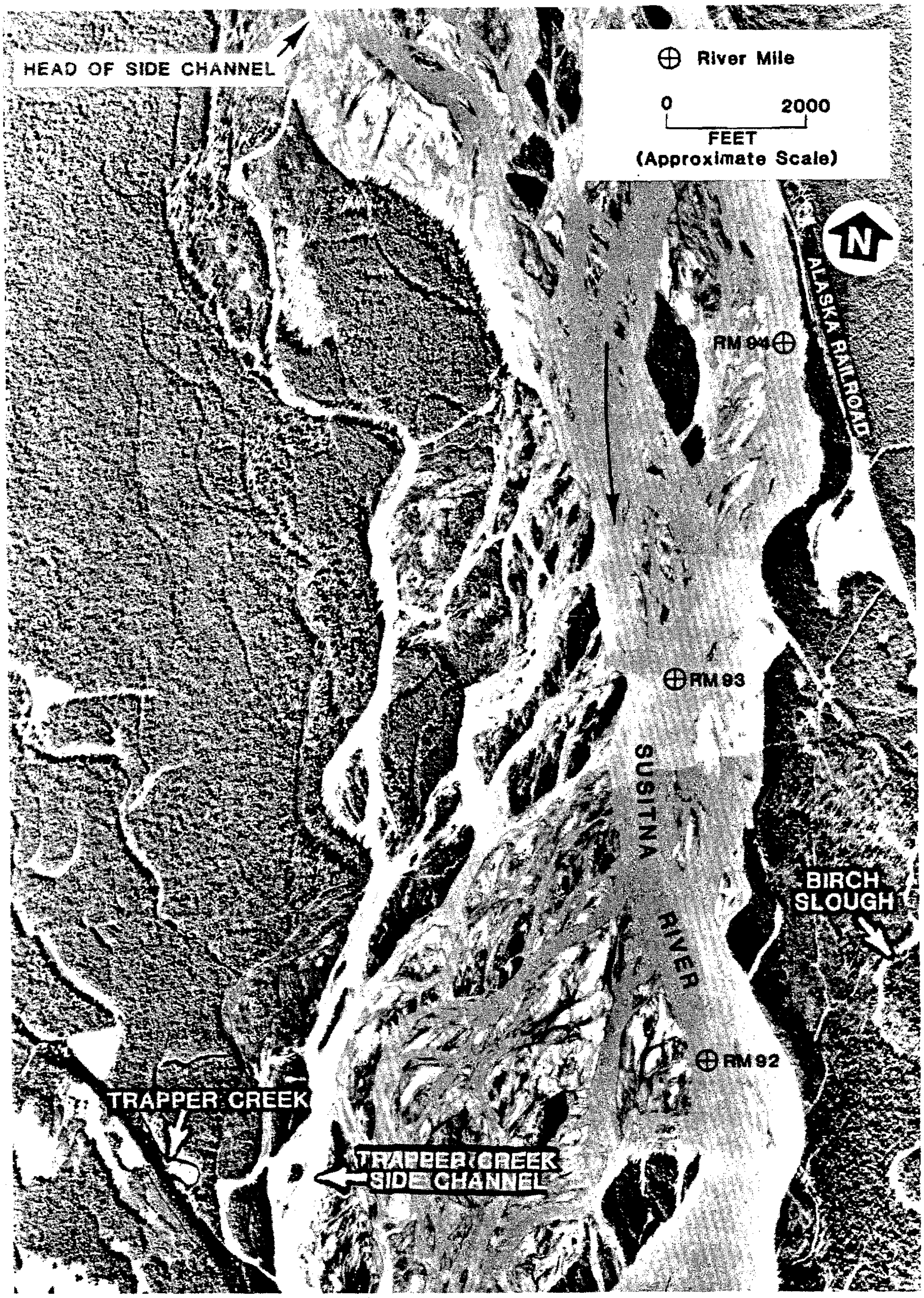
During unbreached conditions, flows in Trapper Creek Side Channel are principally due to Cache Creek and groundwater from the upper reaches of the side channel. Breaching of Trapper Creek Side Channel is the result of the direct overtopping of the multiple heads of the side channel by the mainstem Susitna 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.

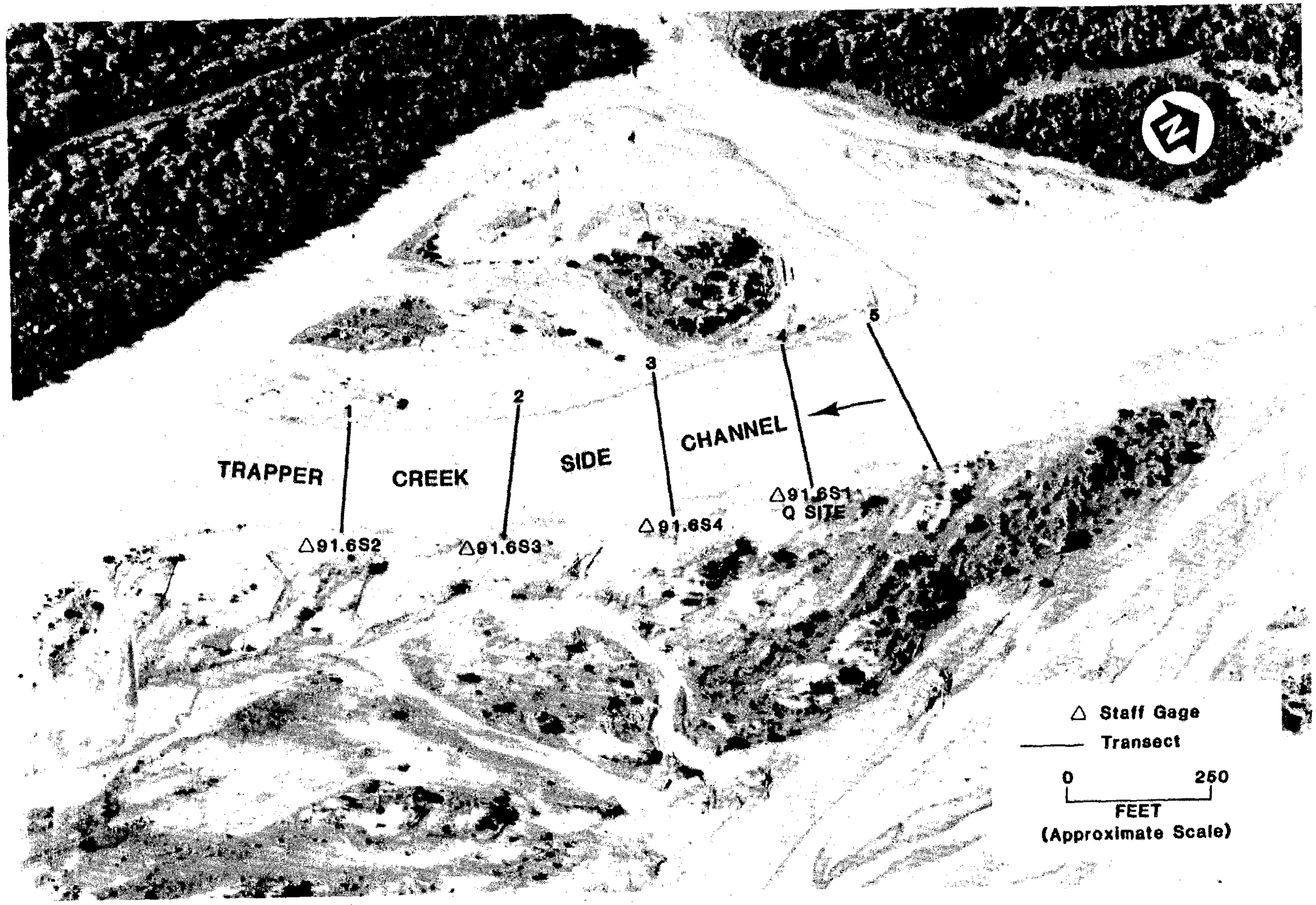
The 790 foot long IFG modelling site at Trapper Creek Side Channel was located in the lower portion of the side channel in a broad open channel area (Appendix Figure D-44). Four cross sections were surveyed within this area to define channel geometry (Appendix Figure D-45). The upper two transects were 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

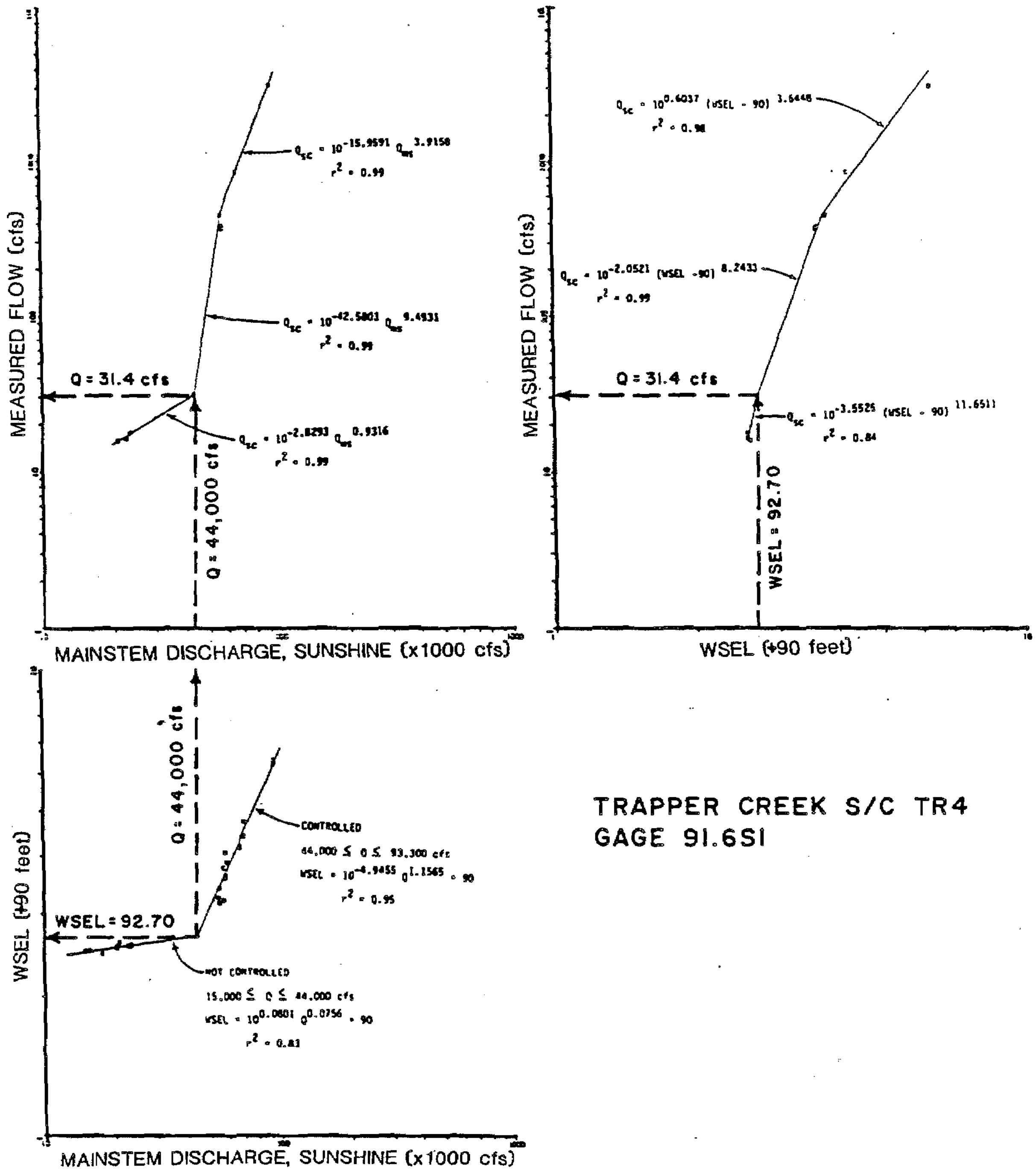
Hydraulic data were collected at three calibration flows: 16, 32, and 389 cfs (Appendix Table D-4). Mean daily discharges for the Susitna River on the dates that calibration data were collected at the Trapper Creek study site were 20,900 cfs, 44,000 cfs, and 57,700 cfs respectively. Based on these calibration 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).



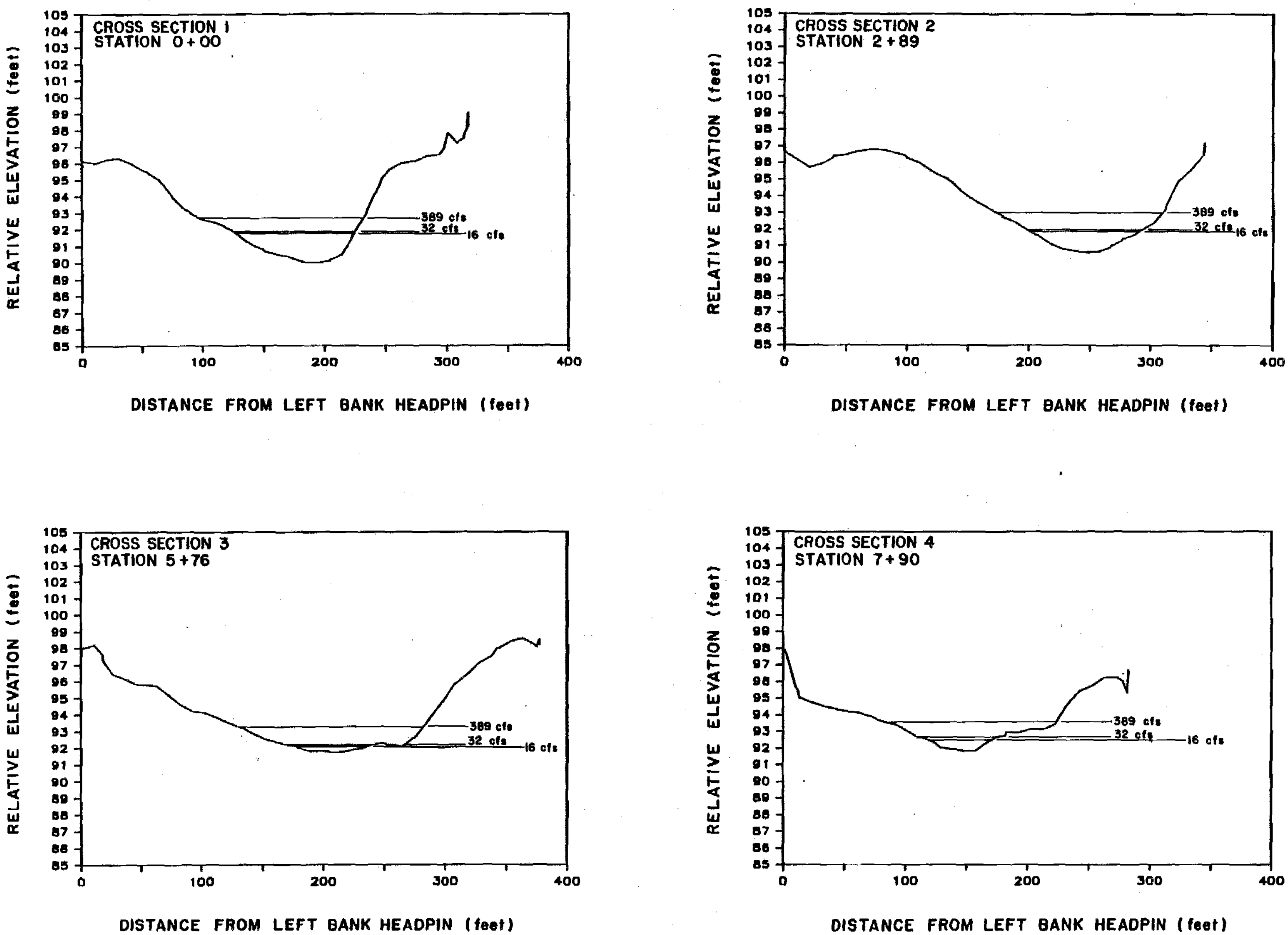
Appendix Figure D-42. Overview of Trapper Creek Side Channel (RM 91.6).



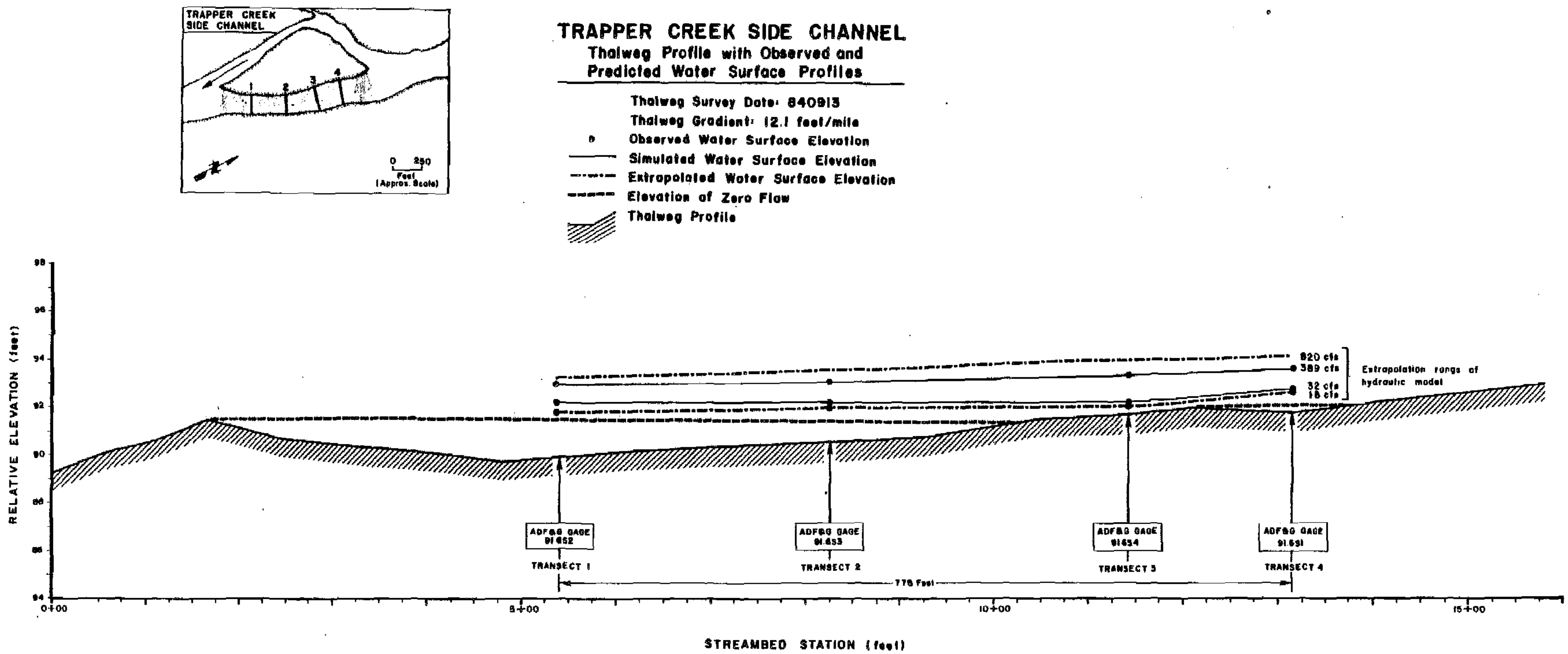
Appendix Figure D-44. Location of Trapper Creek Side Channel study site (RM 91.6).



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.

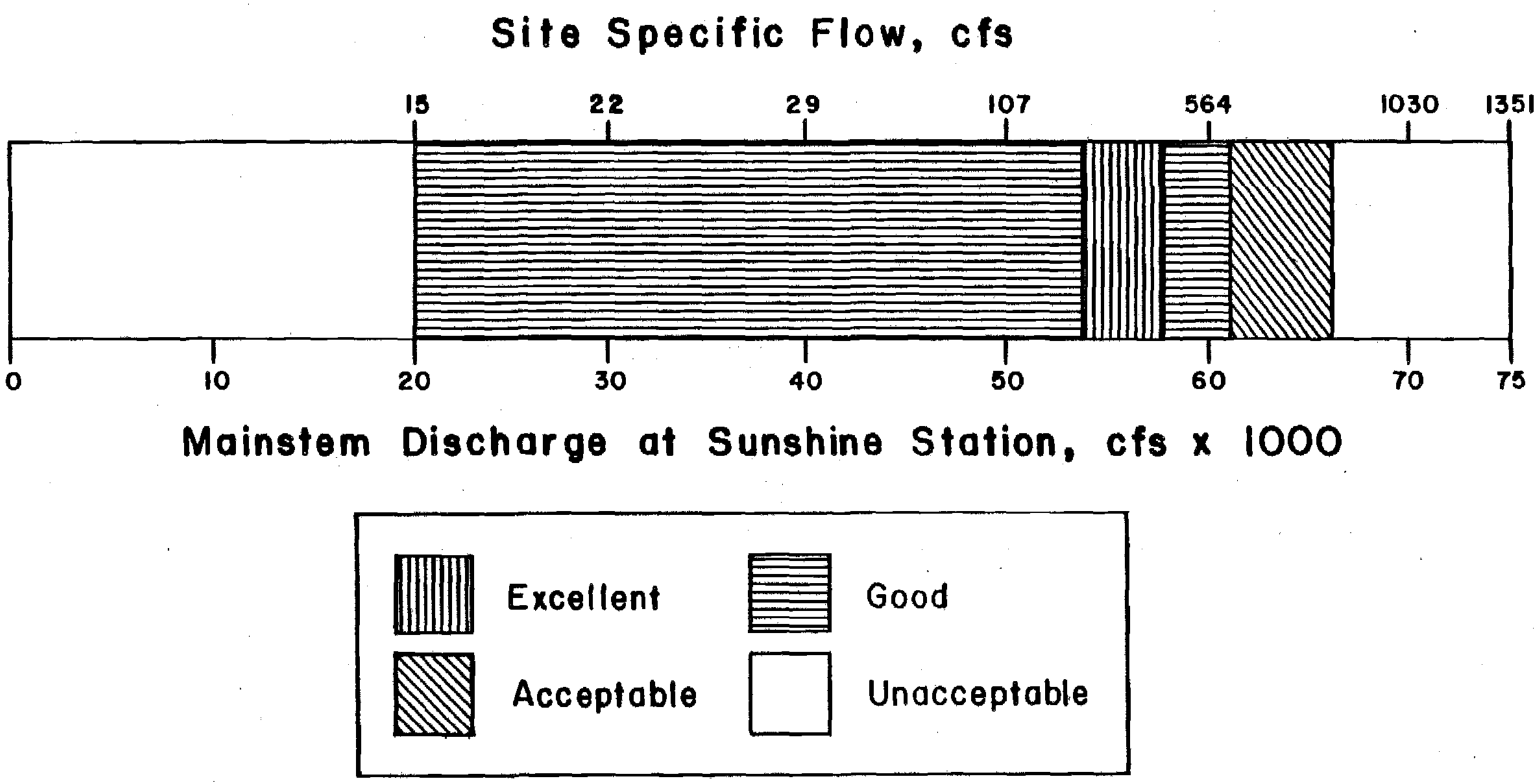
Appendix Table D-13. Comparison between observed and predicted water surface elevations, discharges, and velocities for 1984 Trapper Creek Side Channel hydraulic model.

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	

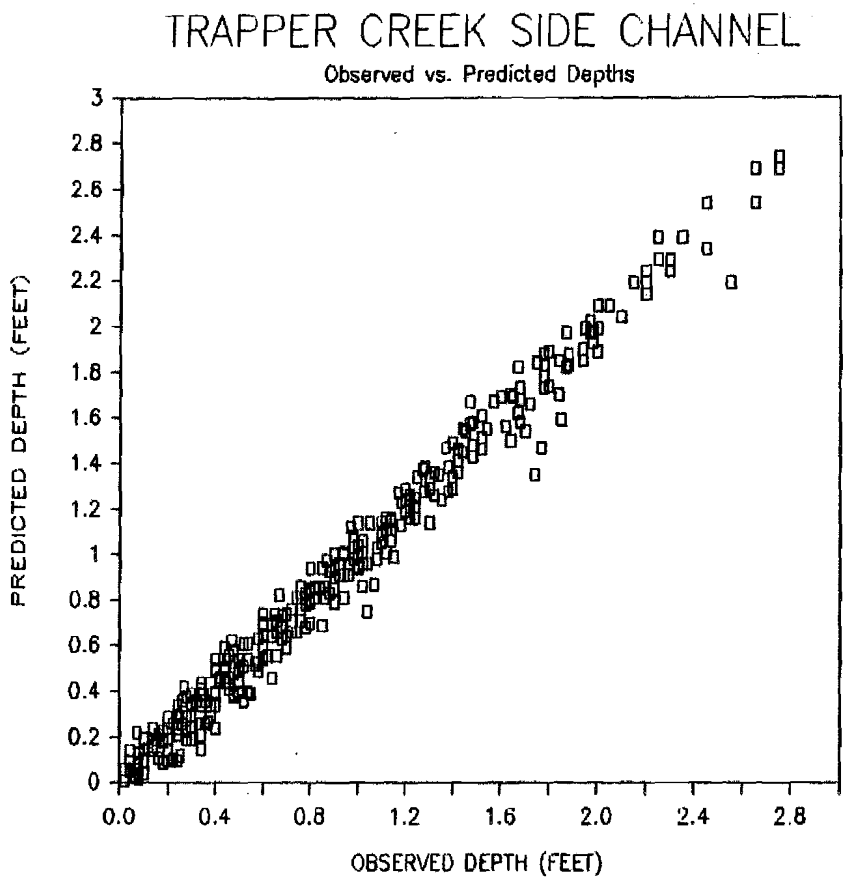
Qo is the mean observed calibration discharge.

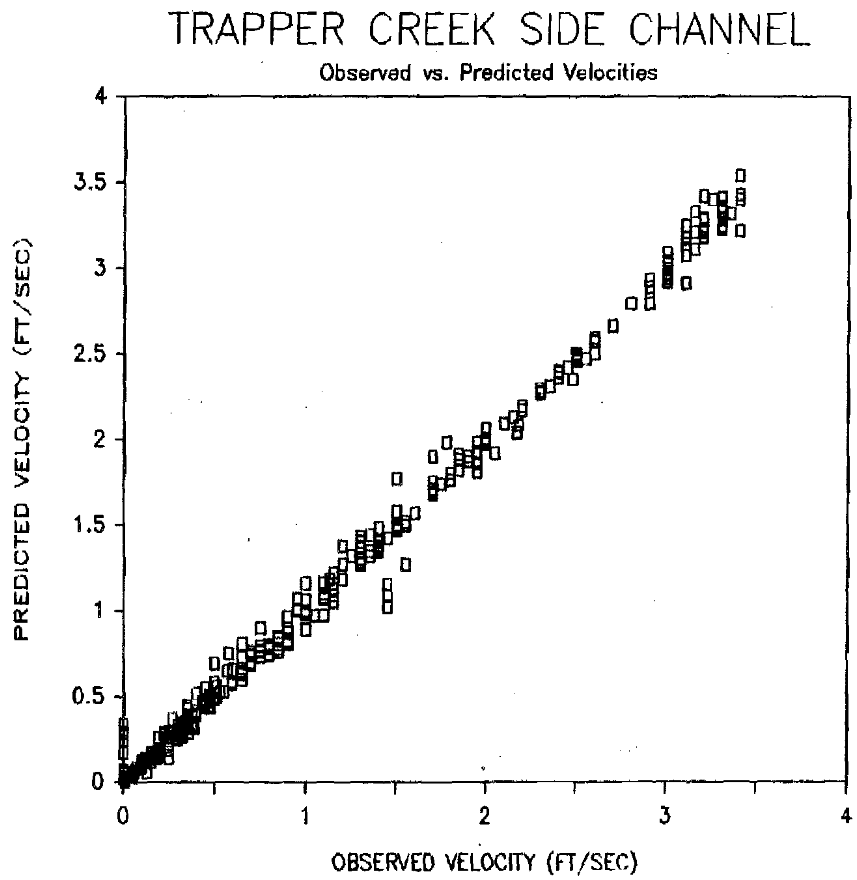
Qp is the mean predicted calibration discharge.

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

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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.

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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