ALASKA DEPARTMENT OF FISH AND GAME
SUSITNA HYDRO AQUATIC STUDIES

ADDENDUM TO REPORT NO. 3, CH. 6

Salmon Passage Validation Studies (August -October 1984)

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PREFACE

This report is an addendum to one of a series of reports prepared for the Alaska Power Authority (APA) by the Alaska Department of Fish and Game (ADF&G) to provide information to be used in evaluating the feasibility of the proposed Susitna Hydroelectric Project. The ADF&G Susitna Hydro Aquatic Studies program was initiated in November 1980. Reports prepared by the ADF&G prior to 1983 on this subject are available from the APA.

This addendum revises and supplements portions of Chapter 6 of the 1984 ADF&G Su Hydro Studies Report Number 3, An Evaluation of Passage Conditions for Adult Salmon in Sloughs and Side Channels of the Middle Susitna River. This addendum provides the most current information on passage requirements for salmon based on the presently available information. The need for reevaluation of previously established local flows and mainstem discharges required for successful and unsuccessful salmon passage at selected slough and side channel sites in the middle reach of the Susitna River (RM 95 to 152) was necessitated based on an assessment of the results of the 1984 Passage Validation Studies (PVS). In addition, a review of presently available passage related data indicated that collection of additional data, or further evaluations of existing data, were needed to more adequately assess salmon passage conditions in these habitats. Results of the 1984 PVS, which were previously presented in a draft technical memorandum from A. Bingham to J. Ferguson (November 30, 1985), have been incorporated into this addendum along with all revised and updated data.

DRAFT

Addendum to Alaska Department of Fish and Game Report No. 3, Chapter 6: Salmon Passage Validation Studies August - October, 1984

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ABSTRACT

An interim evaluation of the effects that mainstem discharge and local flow have on passage conditions for adult chum and sockeye salmon at selected slough and side channel habitats of the middle reach of the Susitna River was previously presented in Sautner et al. (1984). Due to the limited data available for this interim evaluation, additional data

were collected during the 1984 open water field season to reevaluate the passage criteria and the local flow and mainstem discharge values required for successful and unsuccessful salmon passage within these habitats. In addition, the methodologies used for the backwater and local flow analyses were revised to reflect the additional data which were collected.

A Passage Validation Study (PVS) was initiated during the 1984 open water field season to collect additional physical and biological data to more accurately assess salmon passage conditions within slough and side channel habitats of the middle Susitna River. Physical data collected included channel cross section and thalweg profiles, substrate assessments, and local flow measurements. Biological data consisted of salmon passage criteria based on visual observations of adult chum salmon movement in selected slough and side channel habitats. The salmon passage criteria and passage reach evaluations previously presented in Sautner et al. (1984) were reevaluated and revised based on these data using a modified analytical approach. The revised analysis resulted in the development of a single set of salmon passage criteria thresholds for defining successful and unsuccessful passage conditions at study sites.

Using the revised criteria thresholds as a guidelines, 85 passage reaches were identified at slough and side channel sites during the 1984 PVS compared to 74 passage reaches identified in Sautner et al. (1984). A reevaluation of the breaching, backwater, and local flow analysis for these passage reaches indicates that mainstem discharge and local flow requirements for successful and unsuccessful passage are similar to values previously established. The most significant differences occurred in the backwater analysis for some sites, where required mainstem discharges decreased over 1,000 cfs. Water depth was determined to be the primary physical variable affecting passage conditions at passage reaches; passage conditions were not greatly affected by changes in passage reach length. Variations in channel configuration and substrate size were assumed to have no influence on the salmon passage criteria. The revised passage criteria thresholds are based on an upper thalweg depth of 0.5 feet thereby voiding all previous analyses that utilized 0.67 feet as the upper limit of thalweg depth.

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APPENDIX D

1.0 INTRODUCTION

1.1 Background

Preliminary field studies of passage conditions for adult chum salmon (Oncorhynchus keta) in selected slough and side channel spawning habitats of the middle reach of the Susitna River (Figure 1) were conducted during the 1982 (ADF&G 1983: Appendix B) and 1983 (Sautner et al. 1984) open-water field seasons. These studies evaluated the influence of selected channel geometry and hydraulic characteristics on chum salmon passage into and within these habitats. The 1982 and 1983 reports provided the basis for identifying locations presenting potential passage problems for salmon within slough and side channel habitats and for establishing interim salmon passage criteria (criteria curves) for estimating the mainstem discharges and local slough and side channel flows required to provide successful and unsuccessful passage conditions for adult chum salmon migrating into and within these habitats.

This addendum revises and supplements salmon passage data previously reported in Sautner et al. (1984) and presents the results of the 1984 Passage Validation Studies (PVS). The 1984 PVS was undertaken to verify and/or refine the interim salmon passage criteria and flow requirements previously established in Sautner et al. (1984). The initial salmon passage criteria curves presented in Sautner et al. (1984) were based on a review of limited salmon passage field data and observations collected during 1982 and 1983 combined with the professional judgement of project

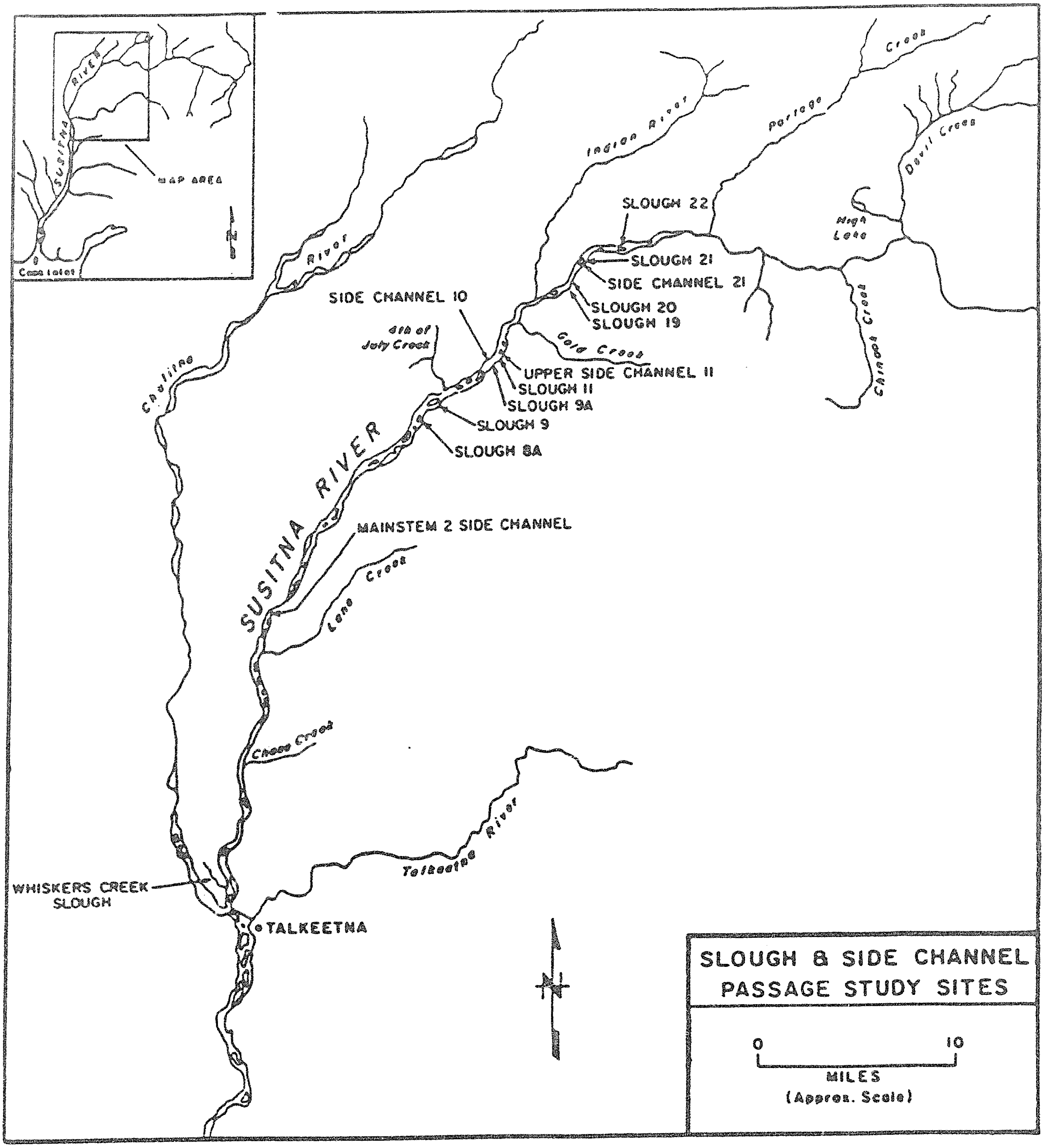

Figure 1. Geographic location of passage study sites in slough and side channel habitats of the middle Susitna River, Alaska, 1984.

fisheries biologists and hydraulic engineers. Due to the limited field data available for the development of these curves, it was necessary to obtain additional field data in 1984 to validate the 1983 salmon passage criteria. As indicated by the additional data and analyses from the 1984 PVS, the criteria curves from Sautner et al. (1984) were refined to more closely represent natural passage conditions for chum salmon in this report .

It was also necessary to refine the local flow analysis presented in Sautner et al. (1984). This analysis is primarily based on flow estimates derived from limited cross section data and associated rating curves, interpretation of aerial photography, and at some sites, from observations by field personnel. Because of these limitations, only 38 of 74 passage reaches could be evaluated for the initial local flow analysis. In addition, the accuracy of the estimates developed was questionable, as only limited flow measurements were available for comparison and validation. For these reasons, additional cross section and local flow data were collected during the 1984 PVS to provide a more complete data base to evaluate local flow requirements at all currently identified passage problem areas.

To more adequately assess the effects of mainstem discharge and local flows on salmon passage conditions in slough and side channel habitats in 1984 , it was also necessary to further evaluate the relationship between these two water sources. The available hydrologic data bases of Susitna River habitats were used to evaluate the relationship between mainstem discharges and local flows within these habitats. This information will provide more reliable local flow data for evaluating passage conditions for the local flow analyses.

1.2 Objectives

To address the deficient areas in the previous salmon passage analyses, the PVS was initiated during the 1984 open water field season to pursue the following field objectives:

1) Collect physical (hydraulic and substrate) and biological (salmon passage) data at various slough and side channel habitats in the middle Susitna River to determine if the previously established salmon passage criteria curves (Sautner et al. 1984) are valid or required revisions; and,

2) Collect additional cross section and local flow data to expand and refine the local flow analysis presented in Sautner et al. (1984).

Preliminary results of the 1984 PVS were initially presented in a November 30, 1984 draft technical memorandum from A. Bingham to J. Ferguson. Based on these results, the following objectives were addressed in this addendum to supplement the salmon passage analyses presented in Sautner et al. (1984):

1) Refine the 1983 passage criteria curves (Sautner et al. 1984) which were developed from data collected during 1982 and 1983 and professional judgement;

2) Revise previously established mainstem discharge and local flow requirements for successful and unsuccessful chum salmon passage based on revisions to the 1983 passage criteria curves;

3) Evaluate all new passage reaches established during the 1984 PVS to determine mainstem discharges and local flows required for successful and unsuccessful passage conditions;

4) Refine and expand the local flow analysis using additional cross section and local flow data collected during the 1984 PVS; and,

5) Evaluate the presently available hydrologic data bases of the middle Susitna River to evaluate the relationship between mainstem discharges and local flows at selected slough and side channel habitats.

2.0 METHODS

2.1 Site Selection

Salmon passage conditions were evaluated at 13 slough and side channel sites in the middle reach of the Susitna River (Table 1). With the exception of Side Channel 10, these sites represent the major slough and side channel spawning locations for chum salmon in the Susitna River drainage upstream of Talkeetna. Sloughs 8A, 9, 9A, 11 and 21 are primary spawning areas for chum salmon while the remaining sites support lesser concentrations of spawning chum salmon. Although Side Channel 10 has not been utilized by spawning chum salmon in the past, it was selected for study because of its potential as a mitigation evaluation site. Discharge related passage problems have been previously identified at all the study sites (Sautner et al. 1984) with the exception of Slough 19. Slough 19 was included as a study site because spawning chum salmon had previously been observed at this site (Barrett et al. 1984) and no previous passage evaluations had been conducted.

2.2 Field Methods

2.2.1 Determination of Salmon Passage Criteria

Data from field observations of migrating chum salmon were collected within passage reaches at various slough and side channel habitats to establish minimum passage requirements (lengths and depths) necessary to provide successful and unsuccessful salmon passage conditions. Fish

Table 1. Summary of passage study sites and corresponding river miles in the middle Susitna River.

Study Site	River Mile
Whiskers Creek Slough	101.2
Mainstem 2 Side Channel	114.4
Slough 8A	125.3
Slough 9	128.3
Slough 9A	133.2
Side Channel 10	133.8
Slough 11	135.3
Upper Side Channel 11	136.1
Slough 19	140.0
Slough 20	140.1
Side Channel 21	140.6
Slough 21	141.8
Slough 22	144.2

passage observations primarily focused on chum salmon due to their more restrictive passage requirements and because they are the major salmon species presently utilizing slough and side channel habitats in the middle Susitna River.

Three conditions were defined to classify the relative degree of difficulty encountered by salmon: 1) successful passage, 2) successful passage with difficulty and exposure, and 3) unsuccessful passage. Fish passage observations were subjectively ranked into one of these three categories based on the characteristics outlined below.

Successful Passage: Fish passage into and/or within a spawning area is uninhibited. Characteristics of this category are:

1) exposure of the fish above water is negligible; and,

2) uninterrupted movement of the fish passing through a reach.

Successful passage conditions would not adversely affect natural production of salmon upstream of the area.

Successful Passage With Difficulty and Exposure: Fish passage into and/or within a spawning area is accomplished, but with stress and exposure to predation. Characteristics of this category are:

1) exposure of the dorsal surface of the fish above water;

2) one or more pauses by the fish (e.g., stranding, changing directions, or resting) within a passage reach due to shallow water conditions; or,

3) repeated attempts by the fish to navigate a passage reach before succeeding.

This condition of passage may potentially reduce the level of successful spawning in the area and, over a long period of time, may result in a decline in natural production upstream of the area.

Unsuccessful Passage: Fish passage into and/or within a spawning area may be accomplished by a limited number of fish which, because of excessive exposure, are more susceptible to increased stress and predation. Characteristics of this category are:

1) absence of fish above a passage reach;

2) exposure of the dorsal surface of the fish above water including partial exposure of eyes, gills, lateral line or caudal fin;

3) one or more pauses by the fish within a passage reach resulting in unsuccessful navigation; or,

4) death of the fish while attempting navigation of a passage reach.

Unsuccessful passage conditions may eventually eliminate or greatly reduce the natural production upstream of the area.

These field passage data were later used to develop the salmon passage criteria as described in Section 2.3.1.

2.2.2 Identification of Passage Reaches

Locations where potential salmon passage problems exist due to restrictions imposed by the physical habitat (i.e, depths, velocities) are referred to as passage reaches. A passage reach is defined as a portion of the channel at the mouth of or within a study site which is potentially limiting to salmon migration into spawning areas.

Passage reaches were initially identified in the field by locating areas where water depth was potentially limiting passage of adult chum salmon. At each identified passage reach a transect was established perpendicular to the flow of water to represent the depth characteristics of the passage reach and provide a consistent point of measurement. Representative transects were established at the shallowest or most critical point of the passage reach and marked with wood stakes and rebar headpins. The physical habitat characteristics of individual passage reaches were defined by measuring lengths, widths, and water depths using the established transect as a reference point. The criteria used to establish passage reach lengths, widths, and depths are presented below.

Passage Reach Length: The longitudinal distance of a passage reach along the thalweg channel defined by the upstream and downstream points at which water depth is no longer limiting to salmon passage. The length limits were defined at thalweg water depths of 0.50 feet and 0.67 feet which correspond to threshold passage depths presented in passage Criteria Curves I and II, respectively (Sautner et al. 1984).[1]

Passage Reach Width: The distance from left water's edge (LWE) to right water's edge (RWE) of a passage reach transect.

Passage Reach Depth: The depth of water within a passage reach which a fish must navigate through in order to proceed upstream. In the field, thalweg depth (maximum depth) was measured as an indicator of the water depth affecting passage. The point of thalweg depth at a passage reach transect was marked with a flagged spike or a staff gage for a consistent point of measurement. However, for analytical purposes it has been determined that the thalweg depth was not a representative variable of passage conditions. For this reason, passage depth, defined as an average of the mean depth and thalweg depth at a passage reach transect, was used for analytical purposes. As a result, thalweg depth measurements were converted to passage depths during the data analysis using cross section survey data (see Section 2.3.1) and were used in all subsequent passage analyses.

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1 Criteria Curve II was eliminated following an analysis of the data and all passage reach lengths previously defined in the field by the 0.67 foot depth were redefined from thalweg profiles using the 0.5 foot depth (see Section 2.3.1).

Passage reach lengths and widths were measured with a fiberglass surveyor's tape graduated in one-tenth foot increments. A standard surveying rod or staff gage was used to measure the thalweg depth at each transect. Passage reach length, width, and depth measurements were collected at the same time observations of fish passage were made.

2.2.3 Physical Habitat Variables Used to Evaluate Passage Reach Conditions

Selected physical habitat data were collected to aid in evaluating the effects of mainstem discharge and local flow on passage reach conditions at slough and side channel study sites. Habitat data collected included survey data for development of thalweg and cross section profiles, substrate and channel morphology data, and stage and flow measurements. Detailed procedures used in the collection of these data are presented in ADF&G (1983a), Quane et al. (1984), and Sautner et al. (1984).

Thalweg surveys had been completed during the 1982 and 1983 field seasons at all passage study sites except Slough 19. Therefore, survey data for the development of a thalweg profile were collected at Slough 19 to complete the set of thalweg profiles for all study sites. The Slough 19 thalweg data were surveyed to a temporary bench mark (TBM) and included additional data points at passage reaches to better define these areas.

Cross section profile data had been sporadically collected at passage reaches during the 1981, 1982 and 1983 field seasons. A primary objective of the 1984 PVS was to obtain cross section profiles at as many study sites as possible. Cross sections were surveyed at passage reach transects which were typically located at the shallowest or most critical point of the passage reach. These data were collected to provide an accurate representation of the channel morphology present at each passage reach. Included in the cross section surveys were measurements of the streambed and water surface elevations at the upstream and downstream limits of a passage reach.

Substrate conditions at each passage reach were evaluated to characterize the influence of substrate and channel configuration on salmon passage conditions. Substrate data were collected by visually classifying the substrate present in the passage reach into the two dominant size groups based on the substrate size classification system presented in Table 2.

The channel configuration of each passage reach was also subjectively ranked as either a uniform or a non-uniform channel. A uniform passage reach was characterized by a relatively straight, unbraided channel that concentrated the flow of water through one main channel. In contrast, a non-uniform passage reach was characterized by a braided, irregular channel that dispersed the flow of water over a wide area.

Stage and flow data were collected during the 1982 and 1983 open water field seasons. Additional stage and flow data were collected at

Table 2. Substrate size classification system used for the 1984 Passage Validation Studies.

Substrate Type	Symbol	Size Class
SILT	SI	very fines
SAND	SA	fines
SMALL GRAVEL	SG	1/4-1"
LARGE GRAVEL	LG	1-3"
RUBBLE	RU	3-5"
COBBLE	CO	5-10"
BOULDER	BO	> 10"

selected study sites during the 1984 field season to compliment these data. Staff gages were utilized to obtain stage data at passage reaches where backwater and/or breaching effects were not completely identified. All mainstem discharge values related to these staff gages were referenced from the USGS gaging station at Gold Creek [USGS 1984 (gage #15292000, RM 136.7)] unless otherwise indicated. Local flow measurements were collected within slough and side channel sites using either a Marsh-McBirney electrical current meter or a Scientific Instruments Pygmy flow meter following techniques described in ADF&G (1983a).

2.3 Analytical Methods

2.3.1 Salmon Passage Criteria

The analytical approach for evaluating the physical conditions affecting salmon passage in sloughs and side channels involved two steps. The first step involved the development of plots of passage criteria data (passage depth versus passage reach length) to describe successful and unsuccessful passage conditions at passage reaches. Plots were constructed for uniform passage reaches, non-uniform passage reaches, and all passage reaches combined. The second step involved a comparison of these passage criteria plots to the previously developed passage criteria curves presented in Sautner et al. (1984) to determine if revisions to the previous passage criteria were required to more accurately represent natural passage conditions.

Prior to development of the passage criteria plots, the thalweg depth data required adjustments in order to be comparable to the 1982-1983 passage criteria. Thalweg depth measurements collected in the field were converted to passage depth which is considered to be a more accurate indicator of the water depth affecting salmon passage. Passage depth is defined as an average of the mean depth and the thalweg depth of a passage reach transect.

A relationship between thalweg and passage depth was developed using linear regression techniques. The surveyed cross section data were used to evaluate the mean depth corresponding to a specified thalweg depth. The mean and thalweg depths were averaged to obtain the passage depth. Thalweg depths were selected to range from 0.1 to 1.0 feet to represent a typical range of conditions at passage reaches. Passage reaches within Sloughs 8A, 9, 9A, 11 and 21, Upper Side Channel 11 and Slough 21 were used in the analysis. Cross sections where multiple channels existed (e.g. braided channels) were excluded due to their non-uniformity resulting in varying water surface elevations within the cross section.

The following equation was derived, based on the above data, to estimate passage depths (d_p) from thalweg depths (d_t). The relationship has a correlation coefficient (r) equal to .995.

$d_p = 0.75\ d_t^{\ 1.02}$ where d_p = Passage Depth and

d_t = Thalweg Depth

An adjustment was also required for a portion of the passage length data collected in the field. Initially, passage reach lengths were measured based on thalweg water depth limits of 0.50 feet and 0.67 feet which correspond to threshold passage depths presented in Criteria Curves I and II, respectively (Sautner et al. 1984). However, during the 1984 field season it became apparent that passage reach length measurements using the Criteria Curve II thalweg water depth limit of 0.67 feet included areas which did not present passage problems to migrating salmon. Field observations during 1984 indicated that a thalweg water depth of 0.50 feet was a more appropriate upper limit. Subsequent analysis of the data also supported the elimination of 0.67 feet as a thalweg water depth limit in the passage analysis. Therefore, those lengths measured using a thalweg water depth limit of 0.67 feet were adjusted to represent lengths established by using a thalweg water depth of 0.50 feet. This was accomplished by drawing a scaled diagram of each affected passage reach including appropriate streambed and water surface elevations based on thalweg and cross section survey data. A new passage reach length was then measured directly from each diagram using an upstream and downstream thalweg water depth limit of 0.50 feet.

Following the appropriate adjustments to passage length and depth values, all data points were plotted by categories of fish passage (successful, successful with difficulty and exposure and unsuccessful). Three plots of the passage data were developed depicting 1) data collected at uniform passage reaches, 2) data collected at non-uniform passage reaches, and 3) all data combined.

The original criteria curves were then superimposed on these passage criteria plots to evaluate the accuracy of these previously established curves by comparing the distribution of the passage data in relation to the criteria curves. Based on the results of these comparisons, appropriate revisions were made to the passage criteria to better represent the relationship between passage reach length and passage depth.

2.3.2 Passage Reach Evaluations

This study utilizes the same basic analytical approach for evaluating passage conditions in the middle Susitna River as was presented in Sautner et al. (1984). This conceptual approach is based on a procedure involving three steps.

1) Definition of the salmon passage criteria (water depth and reach length) required for successful and unsuccessful salmon passage (The analytical methods utilized to complete this step are presented in the preceding section, 2.3.1.).

2) Identification of all the passage reaches within the selected study sites which do not provide successful passage conditions for migrating salmon under all flow conditions based upon the passage criteria established in step one.

3) Evaluation of each passage reach in terms of its hydraulic characteristics, and determination of mainstem discharges and/or local flows required to provide successful passage conditions as defined in step one.

The final step consists of three hydraulic analyses: a breaching analysis, a backwater analysis, and a local flow analysis. The first two of these analyses evaluate the independent effects of mainstem breaching and backwater on passage conditions at passage reaches. The third analysis evaluates the independent effects of local flow on passage conditions at selected passage reaches only. The combined effect of two or more of these conditions acting together was not evaluated; the relative influence of one condition on another is quite small.

In each of the three analyses, length and depth of passage reaches were used as the primary criteria to evaluate salmon passage conditions. The discharge and/or flow requirements resulting from each analysis are defined for conditions that fulfill threshold passage conditions for successful and unsuccessful passage. By defining these upper and lower boundaries, the middle condition of "successful with difficulty and exposure" is also defined.

A flow duration curve [presented in Sautner et al. (1984)] was developed for the period from August 20 to September 20 based on mainstem discharge data collected at Gold Creek over a 35 year period (USGS gage

#15292000). This curve was used to evaluate the percentage of time that the discharge requirements for passage reaches are equalled or exceeded. The mainstem discharge data collected at Gold Creek were also used to evaluate the number of years that the discharge requirements for passage reaches were equalled or exceeded for at least one day during the study period.

2.3.2.1 <u>Verification of Passage Reaches</u>

Passage reaches were initially identified in this study from field observations made during the 1984 open water season (see Section 2.2.2) using salmon passage criteria previously established in Sautner et al. (1984). As a result, it was necessary to reevaluate the passage reaches initially identified in the field based on the revised 1984 passage criteria thresholds to determine if they still qualified as passage reaches under the new passage criteria. The verification process consisted of comparing the range of physical conditions observed at each passage reach with the revised passage criteria thresholds. Passage reaches which fell below the successful passage threshold for at least one set of flow conditions were verified as passage reaches for further analysis. Passage reaches which consistently fell above the successful passage threshold for the observed range of physical conditions were eliminated from further consideration since this was an indication that passage problems did not exist at these sites.

All passage reaches thus identified and verified were sequentially numbered in ascending order beginning at the downstream end of each site. The upstream limit of the identification procedure was defined as the first passage reach beyond the upstream limit of utilization by spawning salmon.

2.3.2.2 Breaching Analysis

The breaching analysis in this study follows the same methods that were presented in Sautner et al. (1984). Since breaching affects all passage reaches within a site, the breaching analysis for each site is applicable to the entire study site. Initial breaching and controlling discharge values have been previously determined for each slough and side channel study site with the exception of Slough 9A (Quane et al. 1984; Sautner et al. 1984). Estimates of the initial breaching and controlling discharge values for Slough 9A were determined from stage data, aerial photos and field observations. Passage reach conditions are considered to be successful under controlling discharge conditions.

2.3.2.3 Backwater Analysis

The backwater analysis utilized in this study is conceptually similar to the analysis presented in Sautner et al. (1984) with the exception that specific steps involved in the analysis were modified to fit the revised passage criteria. This analysis evaluates the influence that mainstem backwater has on passage conditions at passage reaches located in or near the mouth area of each study site prior to breaching. As in the 1984 analysis, local flow was considered to be an insignificant factor affecting backwater relative to the effects of mainstem discharge and was therefore not considered in the analysis.

Successful passage conditions are provided by backwater at a passage reach when the water surface elevation of the mainstem influenced backwater submerges the highest point of elevation within a passage reach by a water depth corresponding to successful passage over a passage reach length of zero feet using the revised passage criteria. Thus, the first part of the backwater analysis involved computing the appropriate water surface elevations required to provide successful and unsuccessful passage conditions at each passage reach affected prior to breaching. Mainstem discharges corresponding to these water surface elevations were calculated from rating curve equations representing the hydraulic relationships in the mouth areas of each study site. These mainstem discharge values represent the minimum discharges required to meet the threshold conditions for successful and unsuccessful passage.

2.3.2.4 Local Flow Analysis

The primary objective of the local flow analysis was to estimate the amount and frequency of occurrence of the local flow which is required to provide successful or unsuccessful salmon passage conditions at a passage reach. The specific analysis followed is outlined below and is depicted schematically in Figure 2.

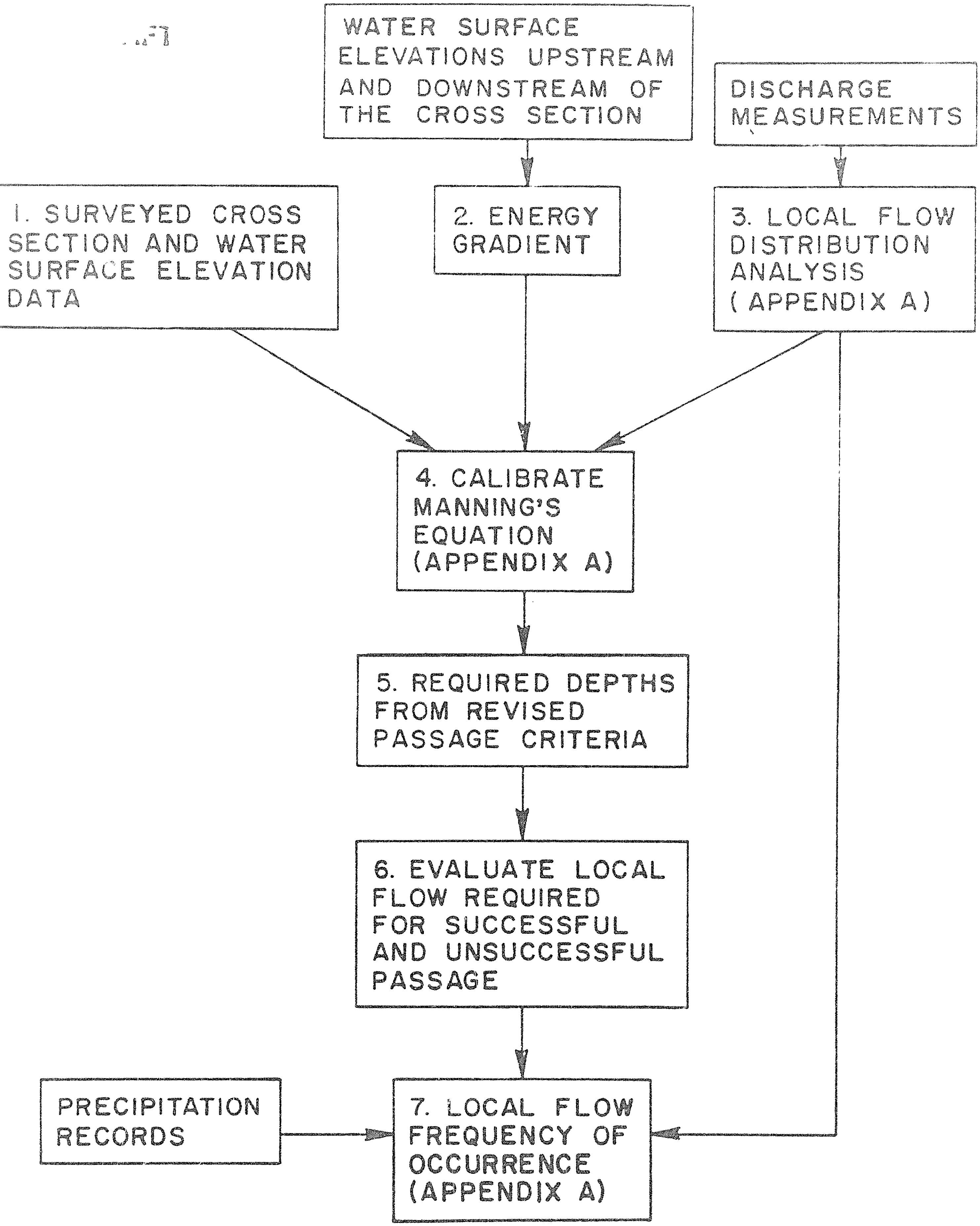

Figure 2. Schematic diagram of steps followed in the local flow analysis at a passage reach.

1. Obtain a surveyed cross section and water surface elevation that are representative of the most difficult passage condition within a passage reach.

2. Determine the energy gradient at each passage reach which is assumed equal to the steeper of the water surface slopes upstream and downstream of the cross section.

3. Determine the local flow corresponding to the surveyed water surface elevation at each passage reach.

4. Given passage reach substrate size and channel uniformity, calibrate Manning's equation to the surveyed water surface elevation and to the corresponding local flow by selecting a Manning's roughness coefficient from a range of acceptable values.

5. Select the required passage depths from the given reach length and the revised passage criteria for successful and unsuccessful passage.

6. Determine the local flows corresponding to the required passage depths for successful and unsuccessful passage using the calibrated Manning's Equation.

7. Estimate the frequencies of occurrence of these local flows which correspond to successful and unsuccessful passage conditions.

Cross section and water surface elevation survey data were collected following methods presented in Section 2.2.3. For assumed uniform flow conditions at passage reaches, the water surface slope is equal to the energy gradient. The energy gradient was generally taken to be the steeper of the upstream and downstream water surface slopes. In cases where the slope was not measured in the field, the water surface slope was obtained from thalweg profile data.

To provide estimates of the local flow corresponding to the surveyed water surface elevation at a passage reach, local flow measurements were collected at selected study sites as described in Section 2.2.3. At some passage reaches, flow was measured concurrently with the water surface elevation measurements. At passage reaches lacking corresponding flow measurements, a local flow distribution analysis was conducted to relate known flows at other passage reaches and discharge gages to the flow at these passage reaches. A detailed description of this analysis is provided in Appendix A.

Manning's Equation provides a relation between required passage depths and local flows at the passage reaches. The equation was calibrated for each passage reach where measured water surface elevation data were available. At sites where water surface elevations were not obtained, the equation was calibrated by comparison with equations from nearby and

Table 4 (Continued).

Study Site (River Mile)	Passage Reach[a] 1984 Report	1985 Addendum	Physical Characteristics of Passage Reach: Shallowest Depth (ft)[b] Thalweg	Passage	Length[c] (ft)	Passage[d] Evaluation
Slough 9A (133.2)	--	I	0.19	0.14	74	Unsuccessful
	'	II	0.43	0.32	15	Successful/Difficult
	II	III	0.37	0.27	78	Successful/Difficult
	III	IV	0.38	0.28	27	Successful/Difficult
	III	V	0.35	0.26	54	Successful/Difficult
	IV	VI	0.33	0.24	54	Successful/Difficult
	V	VII	0.35	0.26	19	Successful/Difficult
	VI	VIII	0.32	0.23	223	Unsuccessful
	VII	--	--	--	--	--
	VIII	IX	0.38	0.28	22	Successful/Difficult
	IX	X	0.10	0.07	119	Unsuccessful
	X	XI	0.15	0.11	203	Unsuccessful
Side Channel 10 (133.8)	I	I	0.00	0.00	304	Unsuccessful
	II	II	0.00	0.00	365	Unsuccessful
	III	III	0.00	0.00	40	Unsuccessful
	IV	IV	0.00	0.00	35	Unsuccessful
	V	V	0.30	0.22	10	Successful/Difficult
	VI	VI	0.00	0.00	200	Unsuccessful
	VII	VII	0.00	0.00	263	Unsuccessful
Slough 11 (135.3)	I	I	0.29	0.21	189	Unsuccessful
	II	II	0.45	0.33	313	Successful/Difficult
	II	III	0.26	0.19	121	Unsuccessful
	III	IV	0.36	0.26	40	Successful/Difficult
	IV	V	0.30	0.22	85	Unsuccessful
	V	VI	0.39	0.29	75	Successful/Difficult
	V	VII	0.19	0.14	62	Unsuccessful
Upper Side Channel 11 (136.1)	I	--	--	--	--	--
	II	I	0.32	0.23	580	Unsuccessful
	III	II	0.00	0.00	880	Unsuccessful
Slough 19 (140.0)	--	I	0.17	0.12	47	Unsuccessful
	--	II	0.15	0.11	13	Unsuccessful
	--	III	0.33	0.24	18	Successful/Difficult
	--	IV	0.12	0.09	121	Unsuccessful
	--	V	0.13	0.09	44	Unsuccessful
	--	VI	0.30	0.22	63	Successful/Difficult
	--	VII	0.12	0.09	66	Unsuccessful
	--	VIII	0.00	0.00	126	Unsuccessful
	--	IX	0.00	0.00	108	Unsuccessful

Table 4 (Continued).

Study Site (River Mile)	Passage Reach[a] 1984 Report	Passage Reach[a] 1985 Addendum	Physical Characteristics of Passage Reach: Shallowest Depth (ft)[b] Thalweg	Shallowest Depth (ft)[b] Passage	Length[c] (ft)	Passage[d] Evaluation
Slough 20 (140.1)	--	I	0.43	0.32	19	Successful/Difficult
	I	II	0.44	0.32	43	Successful/Difficult
	II	--	--	--	--	--
	III	III	0.30	0.22	20	Successful/Difficult
	IV	IV	0.42	0.31	43	Successful/Difficult
	V	V	0.36	0.26	31	Successful/Difficult
	VI	VI	0.00	0.00	383	Unsuccessful
Side Channel 21 (140.6)	I	I	0.33	0.24	55	Successful/Difficult
	II	II	0.32	0.23	29	Successful/Difficult
	III	--	--	--	--	--
	IV	III	0.36	0.26	63	Successful/Difficult
	V	IV	0.34	0.25	132	Successful/Difficult
	VI	V	0.41	0.30	62	Successful/Difficult
	VII	--	--	--	--	--
	VIII	VI	0.35	0.26	138	Successful/Difficult
	IX	--	--	--	--	--
	X	VII	0.25	0.18	800	Unsuccessful
	--	VIII	0.25	0.18	50	Unsuccessful
	--	IX	0.34	0.25	52	Successful/Difficult
Slough 21 (141.8)	I	I	0.30	0.22	256	Unsuccessful
	--	II	0.31	0.23	263	Unsuccessful
	IIL	IIIL	0.00	0.00	460	Unsuccessful
	IIR	IIIR	0.00	0.00	244	Unsuccessful
Slough 22 (144.3)	I	I	0.36	0.26	115	Successful/Difficult
	II	--	--	--	--	--
	III	II	0.32	0.23	76	Successful/Difficult
	IV	III	0.12	0.09	157	Unsuccessful

[a] Passage reaches located in left and right channels of site (facing upstream) are indicated as "L" and "R", respectively.

[b] Thalweg and passage depth values correspond to the shallowest measurements collected in the field at each passage reach.

[c] Length values correspond to the length of a passage at the specified shallowest depth as measured in the field.

[d] Evaluation of passage based on the revised passage criteria for the given set of passage reach conditions.

Table 5. A summary of initial breaching and controlling mainstem discharges affecting passage reaches within selected study sites in the middle Susitna River.

		Breaching Analysis[a]			
				Controlling Discharge Exceedence Frequency	
Study Site (River Mile)	Passage Reaches Affected	Initial Breaching Discharge (cfs)	Controlling[b] Discharge (cfs)	Percent Total Time[e]	Percent Total Years[f]
Whiskers Creek Slough (101.2)	I - II	22,000	23,000	16	69
Mainstem 2 Side Channel (114.4)	I - IVL	12,000	16,000	45	94
	IVR - VIIIR	23,000	25,000	10	57
Slough 8A (125.3)	I - VIL	27,000	27,000	7	46
	VIR - XR	33,000	33,000	2	11
Slough 9 (128.3)	I - V	16,000	19,000	29	77
Slough 9A (133.2)	I - XI	11,500	13,500[c]	60	97
Side Channel 10 (133.8)	I - VI	19,000	19,000	29	77
Slough 11 (135.3)	I - VII	42,000	42,000	1	9
Upper Side Channel 11 (136.1)	I - II	13,000	16,000	45	94
Slough 19 (140.0)	I - V	13,000[d]	13,000[d]	63	97
	VI - IX	Upland	Upland	--	--
Slough 20 (140.1)	I - VI	22,000	23,000	16	69
Side Channel 21 (140.6)	I - VII	9,200	12,000	71	97
	VIII - IX	18,000	24,000	13	66
Slough 21 (141.8)	I - IIIL	23,000	25,000	10	57
	IIIR	26,000	No Data	--	--
Slough 22 (144.3)	I - III	20,000	23,000	16	69

[a] Passage reach conditions are considered to be successful under controlling discharge conditions.

[b] Controlling mainstem discharge values where determined by the project hydraulic engineer using available hydraulic data.

[c] This mainstem discharge value is an estimate based on a mean increase of approximately 2,000 cfs over the initial breaching discharge.

[d] Corresponds to breaching of overflow channel #2 (Figure B-9) located at the mouth of Slough 19.

[e] Percentage of total time for a 35 year flow record that the indicated discharge is equalled or exceeded during the period 20 August - 20 September (USGS gage at Gold Creek, gage #15292000).

[f] Percentage of total years for a 35 year flow record that the indicated discharge is equalled or exceeded during the period 20 August - 20 September (USGS gage at Gold Creek, gage #15292000).

Table 6. Summary of mainstem discharges required to provide successful and unsuccessful salmon passage conditions from backwater effects at selected study sites in the middle Susitna River.

		Backwater Analysis[a]				
				Successful Passage Exceedence Frequency		
Study Site (River Mile)	Passage Reach[b]	Unsuccessful Passage (cfs)	Successful Passage (cfs)	Percent Total Time[c]	Percent Total Years[d]	Staff Gage Used
Whiskers Creek Slough (101.2)	I	e	e	--	--	101.2W1
	II	e	e	--	--	--
Mainstem 2 Side Channel (114.4)	I	8,600	9,200	87	97	114.4W6
	II	11,800	12,500	67	97	114.4W6
	III	e	e	--	--	--
	IVL	e	e	--	--	--
	IVR	18,800	19,700	26	77	114.4S7
	VR	e	e	--	--	--
	VIR	e	e	--	--	--
	VIIR	e	e	--	--	--
	VIIIR	e	e	--	--	--
Slough 8A (125.3)	I	7,200	7,700	94	97	125.3S1
	II	14,600	16,000	45	94	125.3W5
	III	17,600	19,000	29	77	125.3W5
	IV	23,600	25,000	10	57	125.3W5
	V	e	e	--	--	--
	VIL	e	e	--	--	--
	VIR	e	e	--	--	--
	VIIR	e	e	--	--	--
	VIIIR	e	e	--	--	--
	IXR	e	e	--	--	--
	XR	e	e	--	--	--
Slough 9 (128.3)	I	10,900	11,600	74	97	128.3W3
	II	e	e	--	--	--
	III	e	e	--	--	--
	IV	e	e	--	--	--
	V	e	e	--	--	--
Slough 9A (133.2)	I	10,800	11,500	74	97	133.2S1
	II	e	e	--	--	--
	III	e	e	--	--	--
	IV	e	e	--	--	--
	V	e	e	--	--	--
	VI	e	e	--	--	--
	VII	e	e	--	--	--
	VIII	e	e	--	--	--
	IX	e	e	--	--	--
	X	e	e	--	--	--
	XI	e	e	--	--	--

Table 6 (Continued)

Study Site (River Mile)	Passage Reach[b]	Backwater Analysis[a]				Staff Gage Used
		Unsuccessful Passage (cfs)	Successful Passage (cfs)	Successful Passage Exceedence Frequency		
				Percent Total Time[c]	Percent Total Years[d]	
Side Channel 10	I	17,700	18,500	31	80	133.8W5
(133.8)	II	e	e	--	--	--
	III	e	e	--	--	--
	IV	e	e	--	--	--
	V	e	e	--	--	--
	VI	e	e	--	--	--
Slough 11	I	15,400	16,500	42	94	135.3W1
(135.3)	II	18,300	19,400	27	77	135.3W1
	III	32,000	33,400	2	11	135.3W1
	IV	38,800	40,300	1	9	135.3W1
	V	e	e	--	--	--
	VI	e	e	--	--	--
	VII	e	e	--	--	--
Upper Side Channel 11	I	e	e	--	--	136.2W3
(136.1)	II	e	e	--	--	--
Slough 19	I	e	e	--	--	140.04S
(140.0)	II	e	e	--	--	--
	III	e	e	--	--	--
	IV	e	e	--	--	--
	V	e	e	--	--	--
	VI	13,000	13,000	63	97	140.0S3
	VII	14,500	15,300	48	97	140.0S3
	VIII	18,100	19,000	29	77	140.0S3
	IX	24,800	25,600	8	54	140.0S3
Slough 20	I	12,300	13,200	62	97	140.1W4
(140.1)	II	20,000	21,100	22	77	140.1W4
	III	e	e	--	--	--
	IV	e	e	--	--	--
	V	e	e	--	--	--
	VI	e	e	--	--	--
Side Channel 21	I	7,100	7,800	94	97	140.6S8
(140.6)	II	9,700	10,300	82	97	140.6S8
	III	e	e	--	--	--
	IV	e	e	--	--	--
	V	e	e	--	--	--

Table 6 (Continued)

Study Site (River Mile)	Passage Reach[b]	Backwater Analysis[a]: Unsuccessful Passage (cfs)	Successful Passage (cfs)	Successful Passage Exceedence Frequency: Percent Total Time[c]	Percent Total Years[d]	Staff Gage Used
Side Channel 21 (continued)	VI	e	e	--	--	--
(140.6)	VII	e	e	--	--	--
	VIII	e	e	--	--	--
	IX	e	e	--	--	--
Slough 21	I	e	e	--	--	142.0W5
(141.8)	II	e	e	--	--	--
	IIIL	e	e	--	--	--
	IIIR	e	e	--	--	--
Slough 22	I	16,000	17,800	35	89	144.3S7
(144.3)	II	21,900	22,700	17	69	144.3W3
	III	e	e	--	--	--

a This analysis assumes that local flows are negligible.

b Passage reaches located in left and right channels of sites (facing upstream) are indicated as "L" and "R", respectively.

c Percentage of total time for a 35 year flow record, that the indicated discharge is equalled or exceeded during the period 20 August - 20 September (USGS gage at Gold Creek, gage #15292000).

d Percentage of total years for a 35 year flow record that the indicated discharge is equalled or exceeded during the period 20 August - 20 September (USGS gage at Gold Creek, gage #15292000).

e Influence of backwater was not evaluated since breaching occurs at discharges lower than those required for providing backwater influence.

spawning period. The percent of total time values were taken from the flow duration curve, whereas, the percent of years frequency values indicate the relative number of years that the mean daily flow exceeded the indicated flow for at least one day during the period.

The exceedence frequency based on time reflects the length of time in an average year that the indicated flow is equalled or exceeded. For example, since the period of August 20 to September 20 contains 32 days (including start and end dates), then an exceedence frequency of 50 percent, which corresponds to a discharge of 15,000 cfs, would indicate that in an average year, 16 days (50 percent of 32 days) would have daily discharges equal to or in excess of 15,000 cfs. The daily mainstem discharge exceedence curves for 10%, 50% and 90% of the time are presented in Figure 9.

The exceedence frequency based on years reflects the number of years that the indicated flow is equalled or exceeded for at least one day during the study period. For the example above using 15,000 cfs, the exceedence frequency based on years is 97 percent. That is, 34 of 35 years had at least one day during the study period with a mean daily discharge equal to or greater than 15,000 cfs.

3.2.2 Local Flow Analysis

Estimates of local flow corresponding to successful and unsuccessful passage conditions at selected passage reaches within study sites are

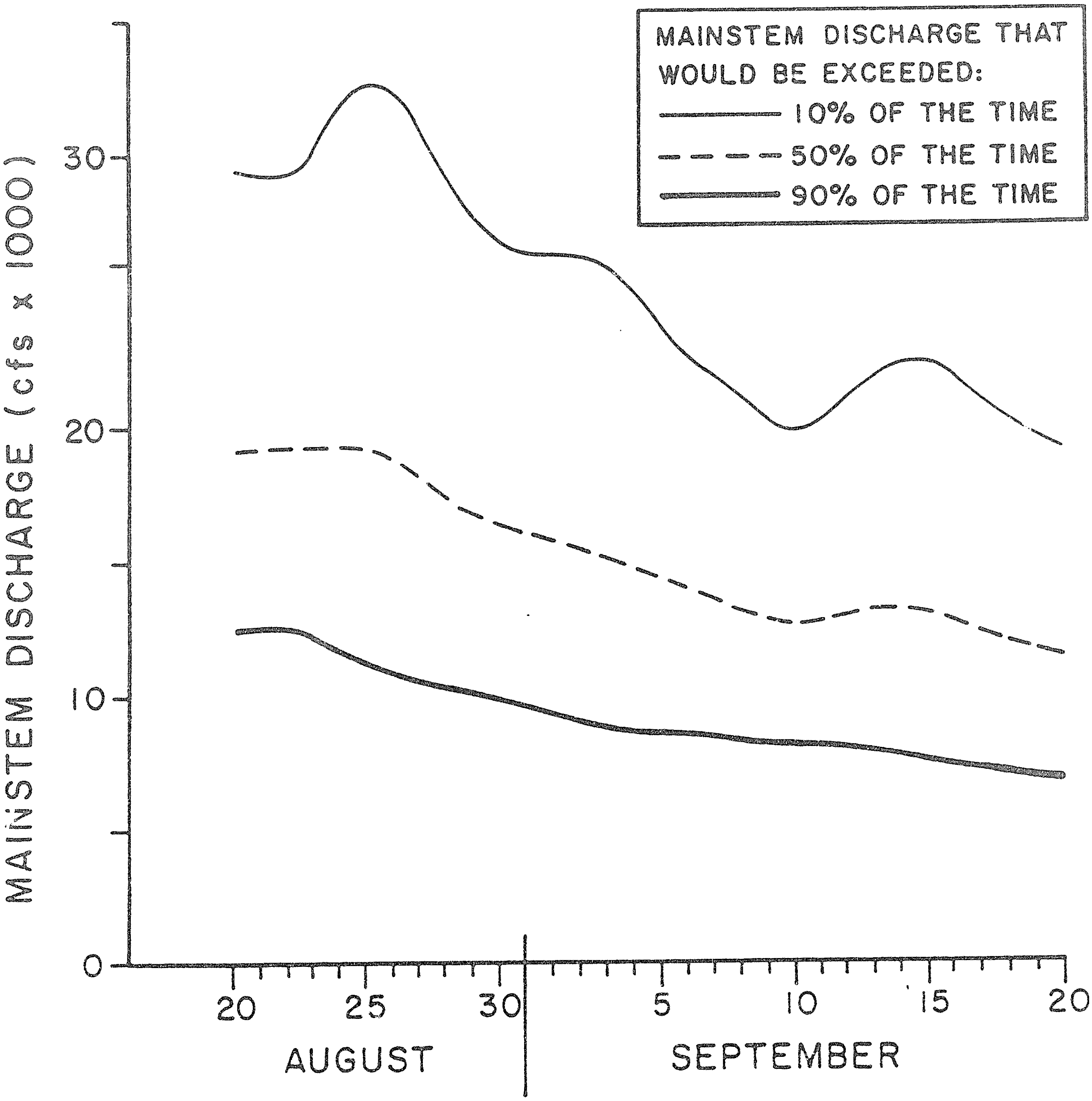

Figure 9. Daily mainstem discharge exceedence curves for the August 20 to September 20 salmon spawning period in the middle Susitna River. Exceedence curves were developed from 35 years of USGS discharge data at Gold Creek (Station No. 15292000) using methods described in Chapman (1982).

provided in Table 7. These estimates provide an indication of the quantity of local flow required for passage in the absence of the direct effects of mainstem influenced backwater and breaching.

Exceedence frequencies are provided at those sites for which a relationship between mainstem discharge and groundwater contributions to local flow can be established. Local flow in sloughs and side channels is comprised mainly of groundwater upwelling (driven largely by mainstem water levels) and runoff from precipitation events. The exceedence values reflect the percent of time that the passage condition is met or exceeded during the period from August 20 to September 20 as a result of precipitation events that generate local flows sufficient to supplement groundwater upwelling flow corresponding to a median mainstem discharge of 15,000 cfs for the period.

Since precipitation records illustrate that precipitation in any amount falls only half of the time during this period, exceedence values range from 0 to 50 percent. A 0 percent frequency means that the amount of precipitation required to produce local flow to supplement groundwater generated flow corresponding to a median mainstem flow for the period is so large that it occurs very infrequently (e.g. 1 in 10 years). An intermediate exceedence frequency such as 22 percent indicates that the combination of groundwater generated flow corresponding to a mainstem discharge of 15,000 cfs and runoff from a precipitation event which is equalled or exceeded 22 percent of the time is sufficient to provide the required passage flow. An exceedence of 50 percent or greater indicates

Table 7. Summary of local flows required for successful and unsuccessful passage conditions and the frequencies of occurrence based on precipitation and groundwater contributions at an average Susitna River discharge of 15,000 cfs during the August 20 to September 20 period.

Study Site (River Mile)	Passage Reach		Successful Conditions			Unsuccessful Conditions		
	Number	Length (ft)	Passage Depth (ft)	Local Flow (cfs)	Percent Exceedence	Passage Depth (ft)	Local Flow (cfs)	Percent Exceedence
Whiskers Creek	I	34	0.33	14.0	a	0.21	6.0	a
(101.2)	II	63	0.34	5.0	a	0.22	1.0	a
Mainstem II	I	32	0.33	1.0	a	0.21	0.5	a
(114.4)	II	168	0.36	5.0	a	0.24	1.0	a
	III	209	0.37	13.0	a	0.25	4.0	a
	IVL	310	0.37	4.0	a	0.25	1.0	a
	IVR	34	0.33	11.0	a	0.21	3.0	a
	VR	243	0.37	4.0	a	0.25	2.0	a
	VIR	84	0.34	2.0	a	0.22	0.8	a
	VIIR	84	0.34	7.0	a	0.22	3.0	a
	VIIIR	318	0.37	2.0	a	0.25	0.7	a
Slough 8A	I	160	0.36	2.0	>50	0.24	0.8	>50
(125.9)	II	229	0.37	5.0	14	0.25	2.0	33
	III	27	0.33	4.0	19	0.21	1.0	>50
	IV	116	0.35	6.0	8	0.22	2.0	31
	V	174	0.36	6.0	7	0.24	2.0	30
	VI	26	0.33	3.0	31	0.21	0.6	>50
	VII	213	0.37	7.0	< 5	0.25	3.0	23
	VIII	150	0.35	11.0	< 5	0.23	3.0	20
	IX	136	0.35	4.0	< 5	0.23	0.8	>50
	X	171	0.36	2.0	< 5	0.24	0.8	16
Slough 9	I	342	0.37	5.0	33	0.25	4.0	>50
(128.3)	II	340	0.37	6.0	17	0.25	3.0	>50
	III	421	0.37	5.0	11	0.25	2.0	>50
	IV	35	0.33	3.0	17	0.21	1.0	>50
	V	219	0.37	0.9	8	0.25	0.9	37
Slough 9A	I	74	0.34	9.0	22	0.22	4.0	>50
(133.6)	II	15	0.32	3.0	>50	0.20	2.0	>50
	III	78	0.34	4.0	>50	0.22	2.0	>50
	IV	27	0.33	4.0	22	0.21	2.0	>50
	V	54	0.34	4.0	20	0.22	3.0	>50
	VI	54	0.34	6.0	< 5	0.22	3.0	>50
	VII	19	0.33	4.0	< 5	0.21	1.0	>50
	VIII	223	0.37	9.0	< 5	0.25	3.0	7

Table 7 (Continued).

Study Site (River Mile)	Passage Reach: Number	Passage Reach: Length (ft)	Successful Conditions: Passage Depth (ft)	Successful Conditions: Local Flow (cfs)	Successful Conditions: Percent Exceedence	Unsuccessful Conditions: Passage Depth (ft)	Unsuccessful Conditions: Local Flow (cfs)	Unsuccessful Conditions: Percent Exceedence
Slough 9A (Continued)	IX	22	0.33	3.0	< 5	0.21	0.8	> 50
	X	119	0.35	2.0	8	0.23	0.6	> 50
	XI	203	0.37	9.0	< 5	0.25	3.0	< 5
Slough 11 (135.3)	I	189	0.37	4.0	< 5	0.25	1.0	> 50
	II	313	0.37	1.4	>50	0.25	b	b
	III	121	0.35	9.0	< 5	0.23	3.0	< 5
	IV	40	0.33	3.0	< 5	0.21	1.0	> 50
	V	85	0.34	3.0	< 5	0.22	1.0	> 50
	VI	75	0.34	2.0	< 5	0.22	0.6	> 50
	VII	62	0.34	0.5	< 5	0.22	0.4	< 5
Upper Side Channel 11 (136.1)	I	580	0.37	8.0	>50	0.25	2.0	> 50
	II	880	0.37	b	b	0.25	b	b
Sough 19 (140.0)	I	47	0.33	b	b	0.21	b	b
	II	13	0.32	b	b	0.20	b	b
	III	18	0.32	b	b	0.20	b	b
	IV	121	0.35	b	b	0.23	b	b
	V	44	0.33	b	b	0.21	b	b
	VI	63	0.34	2.0	a	0.22	0.6	a
	VII	66	0.34	2.0	a	0.22	0.7	a
	VIII	126	0.35	2.0	a	0.23	0.9	a
	IX	108	0.35	4.0	a	0.23	1.0	a
Slough 20 (140.1)	I	19	0.32	2.0	a	0.20	0.6	a
	II	43	0.33	2.0	a	0.21	0.5	a
	III	20	0.32	3.0	a	0.20	1.0	a
	IV	43	0.33	b	b	0.21	b	b
	V	31	0.33	b	b	0.21	b	b
	VI	383	0.37	10.0	a	0.25	4.0	a
Side Channel 21 (140.6)	I	55	0.34	5.0	> 50	0.22	2.0	> 50
	II	29	0.33	7.0	> 50	0.21	3.0	> 50
	III	63	0.34	7.0	> 50	0.22	3.0	> 50
	IV	132	0.35	4.0	24	0.23	1.0	> 50
	V	62	0.34	4.0	21	0.22	1.0	> 50
	VI	138	0.35	17.0	< 5	0.23	4.0	> 50
	VII	800	0.37	20.0	< 5	0.25	5.0	> 50
	VIII	50	0.33	7.0	< 5	0.21	2.0	> 50
	IX	52	0.34	5.0	9	0.22	2.0	> 50

Table 7 (Continued).

Study Site (River Mile)	Passage Reach Number	Passage Reach Length (ft)	Successful Conditions Passage Depth (ft)	Successful Conditions Local Flow (cfs)	Successful Conditions Percent Exceedence	Unsuccessful Conditions Passage Depth (ft)	Unsuccessful Conditions Local Flow (cfs)	Unsuccessful Conditions Percent Exceedence
Slough 21	I	256	0.37	4.0	< 5	0.25	1.0	>50
(141.8)	II	263	0.37	2.0	>50	0.25	0.4	>50
	IIIR	244	0.37	3.0	< 5	0.25	0.8	>50
	IIIL	460	0.37	b	< 5	0.25	b	< 5
Slough 22	I	115	0.35	3.0	a	0.23	1.0	a
(144.2)	II	76	0.34	2.0	a	0.22	0.7	a
	III	157	0.36	4.0	a	0.24	2.0	a

[a] Frequencies not evaluated.

[b] No cross section data available.

that the flow resulting from groundwater upwelling at a median mainstem discharge of 15,000 cfs is sufficient to provide the required flow for passage without precipitation input. The mainstem discharge and associated frequency that would be required for successful and unsuccessful passage conditions at passage reaches in Sloughs 8A, 9, and 11 in the absence of any precipitation input is given in Table 8.

Table 8. Frequencies of occurrence of local flows evaluated through the use of mainstem versus local flow relationships in Sloughs 8A, 9 and 11 excluding the effects of breaching and backwater.

Site	Passage Reach	Required Local Flow (cfs)		Required Mainstem Discharge (cfs)		Frequency of Occurrence (%)	
		Successful	Unsuccessful	Successful	Unsuccessful	Successful	Unsuccessful
Slough 8A	I	2.0	0.8	5,000	3,500	100	100
	II	5.0	2.0	> 60,000	25,000	0	10
	III	4.0	1.0	> 60,000	8,500	0	88
	IV	6.0	2.0	> 60,000	25,000	0	10
	V	6.0	2.0	> 60,000	31,500	0	6
	VI	3.0	0.6	17,500	3,500	35	100
	VII	7.0	3.0	> 60,000	22,500	0	15
	VIII	11.0	3.0	> 60,000	26,000	0	9
	IX	4.0	0.8	> 60,000	10,000	0	82
	X	2.0	0.4	> 60,000	13,500	0	60
Slough 9	I	5.0	4.0	27,500	14,500	7	52
	II	6.0	3.0	57,000	8,000	0	90
	III	5.0	2.0	> 60,000	9,500	0	83
	IV	3.0	1.0	51,000	2,500	0	100
	V	2.0	0.8	> 60,000	19,500	0	25
Slough 11	I	4.0	1.0	34,000	7,500	4	93
	II	< 1.4	< 1.4	< 10,000	10,000	> 81	> 81
	III	9.0	3.0	> 60,000	28,000	0	7
	IV	3.0	1.0	44,000	< 10,500	1	79
	V	3.0	1.0	> 60,000	13,500	0	65
	VI	2.0	0.6	> 60,000	12,000	0	70
	VII	0.5	0.4	> 60,000	48,000	0	0

4.0 DISCUSSION

4.1 Salmon Passage Criteria

The analysis of the salmon passage data collected during the 1984 open water season resulted in revisions of the passage criteria curves developed from the 1982 and 1983 passage data (Sautner et al. 1984). The final product of the analysis was the development of a single set of salmon passage criteria thresholds for establishing successful and unsuccessful salmon passage conditions (Figure 7). In general, the same assumptions corresponding to the original criteria curves in Sautner et al. (1984) are applicable to the revised passage criteria thresholds. However, based on field observations of salmon passage, one of the important assumptions regarding the passage criteria required modification. This assumption was originally stated as follows:

1. All passage reaches can be described as either uniform, straight channels with small substrate (less than or equal to 3 inches in diameter), or non-uniform braided channels with large substrate (greater than 3 inches in diameter).

Exceptions to this assumption were encountered at several passage reaches (e.g. Sloughs 20 and 21) during the past field season. Non-uniform channels were observed at passage reaches with predominantly small substrate, and passage reaches with predominantly large substrate and uniform channels were also encountered (Table 3). In these situations it was often very difficult to classify certain passage reaches under one of the original criteria curves. This required that the relative importance of channel configuration and substrate size be reevaluated. Based on field observations, differences in channel configuration appeared to have a greater overall influence on flow, and therefore on salmon passage conditions, than substrate size. Therefore, if substrate is disregarded as a factor in the salmon passage criteria analysis, the above assumption can be rewritten as follows:

1. All passage reaches can be described as either uniform, straight channels, or as non-uniform, braided channels.

This assumption indicates that passage reaches can still be classified into two categories which would theoretically require two separate sets of criteria curves as in Sautner et al. (1984). However, when length and depth data for both uniform and non-uniform passage reaches were plotted separately and together, there was no distinct evidence to indicate the requirement of two sets of criteria curves. The combined passage data (collected from both uniform and non-uniform channels) closely fit Criteria Curve I for uniform channels, whereas Criteria Curve II, for non-uniform channels, overestimates water depths required for successful passage. This was verified in the field when measuring lengths of passage reaches using the Criteria Curve II thalweg water depth of 0.67 feet. Passage reaches for which this depth value was used for establishing the upstream and downstream limits included water depths where fish did not appear to have any passage problems. A thalweg water depth of approximately 0.50 feet, which corresponds to

Criteria Curve I, appeared to be a more accurate indicator of the depth of water at which salmon first encounter passage difficulty.

Based on these reasons, and supported with field observations, it was determined that only a single set of passage criteria thresholds is necessary to accurately describe natural salmon passage conditions. Hence, the previous assumption was modified to read as follows:

1. All passage reaches influence salmon passage conditions in a similar manner regardless of channel configuration and substrate size.

The salmon passage criteria thresholds developed in this addendum are similar to Criteria Curve I from Sautner et al. (1984) with some modifications based on the 1984 data. The most significant modification to the passage criteria involved the 0-20 feet range of the curves for both successful and unsuccessful passage. When the original criteria curves were developed in 1984, the sharp downward inflections in this range of the criteria curves were assumed to reflect an intuitive idea that salmon are able to swim through very shallow depths for short lengths. This adaptation was based solely on intuition and the professional judgement of several project personnel with various backgrounds. However, the salmon passage data collected during the 1984 field season were not sufficient to support the sharp, downward inflections in the 0-20 feet range of the original curves. General field observations of chum salmon passage also did not support this adaptation in the original curves (Blakely pers. comm. 1984). In addition, very few passage reaches identified during the 1984 field season had passage reach lengths that fit into the 0-20 feet range of the passage criteria. Thus, the original criteria curves were modified to reflect these field observations and additional data, resulting in the development of two straight lines, referred to as salmon passage criteria thresholds, which more accurately reflect salmon passage conditions.

The assumption that salmon are able to swim through shallower depths at shorter reach lengths may be falsely based on the well known ability of salmon to leap over obstacles such as waterfalls. However this ability is only characteristic with the physical and hydraulic features present at waterfalls (eg., plunge pool depths, water velocities). These conditions are not characteristic of passage reaches in sloughs and side channels of the middle Susitna River and thus there were no observations of salmon "jumping" over passage reaches of shorter reach lengths.

The salmon passage criteria thresholds developed in this addendum are represented by two straight lines which best fit the salmon passage data collected during 1984. Placement of the threshold lines for successful and unsuccessful salmon passage indicates that passage depth appears to be the critical physical factor affecting passage conditions. Passage reach length is not as critical in relation since passage depth increases only 0.05 feet over lengths up to 200 feet.

4.2 Passage Evaluations

During the 1984 open water field season, 85 passage reaches were identified at selected slough and side channel study sites of the middle Susitna River compared to 74 passage reaches previously identified in Sautner et al. (1984). The difference in the number of passage reaches is primarily related to the specific methods employed to identify passage reaches. In Sautner et al. (1984), passage reaches were identified strictly from surveyed thalweg profiles of each study site. However, the majority of these thalwegs were not surveyed for the purposes of analyzing salmon passage conditions. Thus, certain passage reaches within some study sites were not adequately defined on the thalweg profiles. In contrast, identification of passage reaches during the 1984 PVS were based on actual field observations. This method resulted in the identification of new passage reaches, the elimination of some previously identified passage reaches, and in some cases, the division of a single, previously identified passage reach into two separate passage reaches. In addition, Slough 19 was included as an additional study site to be evaluated for passage. Therefore, the methods employed in this addendum result in a more accurate and complete identification of passage reaches compared to the methods utilized in Sautner et al. (1984).

Mainstem discharge estimates resulting from the backwater and breaching analyses were also presented as percent exceedence frequencies based on time and years. Although these percent exceedence values are supposed to represent the entire period of interest, they may contain an inherent bias towards the first two weeks of the August 20 to September 20 salmon spawning period. An evaluation of the daily mainstem discharge exceedence curves for 10%, 50% and 90% of the time (Figure 9) indicates that the middle Susitna River discharge generally decreases through the period of interest. It is also apparent that higher discharges occur with greater frequency during the first half of the period of interest. Discharges generally decrease in the latter half of this period. The decreasing trend in mainstem discharge values is generally consistent during the entire period with few periodic spikes or peaks. Although the percent exceedence values presented in this addendum are for the entire August 20 to September 20 period, these values are more indicative of the first half of the salmon spawning period rather than the last half because this is the period when the higher discharges can be expected to be equalled or exceeded.

4.2.1 Mainstem Breaching

The mainstem Susitna River directly influences salmon passage conditions within a slough or side channel when the head of a site becomes breached. This event is significant since after mainstem breaching has occurred all the passage reaches within a site are affected in a similar manner. The breaching analysis in this addendum provides a summary of the mainstem discharges which are required to breach selected study sites in the middle Susitna River. These results are essentially the same values that were reported in Sautner et al. (1984) with the addition of mainstem discharge estimates for Sloughs 9A and 19. Although two breaching discharges are presented for each study site, controlling discharge values are of primary importance since field observations have shown that successful salmon passage conditions exist at all passage reaches within a site when controlling mainstem breaching has occurred. Initial breaching discharges are only presented to provide an indication of when a study site is initially overtopped by mainstem water and may be considered to approximate the discharge representing the unsuccessful threshold value.

A review of the results of the breaching analysis (Table 5) indicates that the majority of study sites breach at relatively high mainstem discharges (19,000 to 42,000 cfs). This includes Sloughs 8A, 9, 11 and 21 which comprise a major portion of the primary spawning areas for chum salmon in the middle Susitna River. Under natural flow conditions, these relatively high mainstem discharges (19,000 to 42,000 cfs) are equalled or exceeded less than a third (29%-1%, respectively) of the total time for the period August 20 to September 20 (Table 5). These discharge values of 19,000 to 42,000 cfs also correspond to 77%-9%, respectively, of the total number of years in which the breaching discharge is equalled or exceeded at least once during the August 20 to September 20 period. However, the exceedence frequencies for the total number of years contains an inherent bias towards the first two weeks of the period of interest.

4.2.2 Mainstem Backwater

In addition to breaching effects, the mainstem Susitna River directly affects salmon passage in the mouth area of a slough or side channel by creating backwater pools. As mainstem discharge increases, the stage of the backwater pool progressively rises and inundates the lower portion of the site. This effect is important in regulating the passage of salmon into a slough or side channel spawning site at mainstem discharges less than those required for breaching.

The backwater analysis in this addendum presents a summary of the mainstem discharges which provide successful salmon passage conditions from backwater effects at selected study sites in the middle Susitna River. It is evident from the results that, in general, only the initial few passage reaches located in the mouth regions of study sites are inundated by backwater prior to breaching. However, at three sites (Whiskers Creek Slough, Upper Side Channel 11 and Slough 21), the influence of backwater on passage conditions is completely absent prior to breaching. In these cases, the effects of breaching and local flow become increasingly more critical in providing successful passage conditions.

A comparison of the results of the backwater analysis in this addendum to the results previously reported in Sautner et al. (1984) is presented in Table 9. It is evident from the comparison that the mainstem discharge values for successful passage conditions from both studies are in

Table 9. Comparison of the results of the backwater analysis presented in this addendum to the results previously reported in Sautner et al. (1984) for sloughs and side channels in the middle Susitna River.

Study Site (River Mile)	Passage Reach	Mainstem Discharges (cfs)			
		Present Addendum		Sautner et al. (1984)	
		Unsuccessful	Successful	Unsuccessful	Successful
Mainstem 2 Side Channel (114.4)	I	8,600	9,200	a	a
	II	11,800	12,500	11,500	12,200
	IVR	18,800	19,700	18,400	19,200
Slough 8A (125.3)	I	7,200	7,700	< 10,600	< 10,600
	II	14,600	16,000	14,600	15,600
	III	17,600	19,000	a	a
	IV	23,600	25,000	a	a
Slough 9 (128.3)	I	10,900	11,600	< 12,200	< 12,200
Slough 9A (133.2)	I	10,800	11,500	a	a
Side Channel 10 (133.8)	I	17,700	18,500	17,400	18,200
Slough 11 (135.3)	I	15,400	16,500	15,200	16,200
	II	18,300	19,400	a	a
	III	32,000	33,400	31,900	33,200
	IV	38,800	40,300	38,300	39,600
Slough 20 (140.1)	I	12,300	13,200	a	a
	II	20,000	21,100	20,800	22,100
Side Channel 21 (140.6)	I	7,100	7,800	< 12,000	< 12,000
	II	9,700	10,300	b	b
Slough 22 (144.3)	I	16,000	17,800	< 23,000	< 23,000
	II	21,900	22,700	b	b

[a] This site not evaluated.

[b] Breaching occurs at mainstem discharges lower than those required for providing backwater influence.

general agreement. The discharge values established in this addendum constitute a general increase of less than 1,000 cfs over values reported in Sautner et al. (1984). However in a few cases (eg., Passage Reach I in Slough 8A), values differ more than 1,000 cfs for successful passage. These larger differences are due to better defined rating curves established during the 1984 field season which provide more accurate estimates of mainstem discharge.

Overall, discrepancies between the mainstem discharge values reported in both studies are a reflection of the revised passage criteria thresholds and their application in the backwater analysis. The methods which comprise the backwater analysis include the determination of the depth requirements for successful passage for a reach length of zero feet from the revised passage criteria thresholds. In this addendum, a passage depth of 0.32 feet corresponds to the zero reach length for successful salmon passage. In Sautner et al. (1984), the comparative passage depth from Criteria Curve I was 0.26 feet. Although the difference in the passage depth values is only 0.06 feet, it accounts for the general increase in mainstem discharge values reported in this addendum. In general, where discrepancies in the results of both studies occur, it should be noted that the results of this addendum are refinements of those reported earlier and are therefore considered more reliable.

4.2.3 Local Flow

The local flow analysis has been refined and expanded considerably from the analysis presented in Sautner et al. (1984). The limited data available for the previous analysis resulted in a few general assumptions. Data were collected during the 1984 open water season to eliminate most of these assumptions and allow a more thorough analysis of the local flow required for passage in sloughs and side channels. The refined analysis necessitated detailed assumptions. In addition, neither the groundwater distribution analysis nor the local flow frequency analysis were conducted for the passage evaluations presented in Sautner et al. (1984). These additional analyses and refinement of the methods used to evaluate local flows resulted in the following additional assumptions which are more specific and expanded from the assumptions presented in Sautner et al. (1984).

1. The surveyed cross section is representative of the most difficult passage condition within the passage reach.

2. Local flow in passage reaches is composed of surface water runoff and upwelling contributions from identified upwelling sites and upwelling distributed uniformly along the channel bed.

3. The local flow distribution analysis evaluates flow at a passage reach which is representative of field conditions.

4. The percent groundwater values are constant at a site for all slough and mainstem flows.

5. The groundwater flows can be represented by local flows measured during a period of low rainfall.

6. Antecedent moisture conditions are invariable and have a negligible effect on surface water runoff.

7. The August precipitation duration curve at Talkeetna is applicable to the August 20 to September 20 salmon spawning period.

8. Precipitation at Talkeetna may be adjusted to represent rainfall conditions at sloughs and side channels of the middle river by using precipitation coefficients.

9. Basin areas contributed surface water in accordance with identified percent runoff factors. The factors are constant for all rainfall amounts.

10. Manning's Equation is applicable to the low flow and shallow depth conditions at passage reaches.

11. Manning's Equation can be calibrated at a known flow and corresponding water surface elevation; the calibrated equation may be applied to thalweg depths up to one foot.

12. Local flow in passage reaches is uniform; for uniform flow, the energy gradient is equal to the slope of the water surface.

13. The flow characteristics at a passage reach are governed by the maximum of the upstream and downstream water surface slopes at the cross section.

14. Manning's roughness coefficients are uniformly greater at the shallow depths associated with the passage analysis in comparison to the flood flow roughness values found in the literature (Chow 1959).

15. Flow excluded by flow computations using surveyed cross section data is a constant amount that is continuously underpredicted at all depths.

Required local flow values for successful and unsuccessful salmon passage conditions presented in this addendum are fairly similar to previous values (Table 10). Variations between the addendum results and previous values may be partially explained by variations in the calibration of Manning's Equation. In Sautner et al. (1984) constant Manning's roughness coefficient was used at all passage reaches. In the addendum, a site-specific Manning's roughness coefficient reflected variations in passage reach substrate and channel uniformity. The energy gradient was approximated in the previous study from the water

Table 10. Comparison of the results of the local flow analysis presented in this addendum to the results previously reported in Sautner et al. (1984) for sloughs and side channels in the middle Susitna River.

Study Site (River Mile)	Passage Reach	Local Flow (cfs)			
		Present Addendum		Sautner et al. (1984)	
		Unsuccessful	Successful	Unsuccessful	Successful
Whiskers Creek Slough (101.2)	I	6.0	14.0	8.0	16.0
Mainstem 2 Side Channel (114.4)	VR	2.0	4.0	3.0	5.0
	VIR	0.8	2.0	3.0	5.0
	VIIR	2.0	7.0	3.0	5.0
	VIIIR	0.7	2.0	3.0	5.0
Slough 8A (125.3)	I	0.8	2.0	1.0	2.0
	VIIR	3.0	7.0	3.0	5.0
	IXR	0.8	4.0	2.0	4.0
	XR	0.8	2.0	2.0	4.0
Slough 9 (128.3)	I	4.0	5.0	1.0	2.0
	II	3.0	6.0	1.0	1.0
	III	2.0	5.0	4.0	6.0
Slough 9A (133.2)	II	2.0	3.0	1.0	1.0
	III	2.0	4.0	2.0	3.0
	VI	3.0	6.0	0.5	1.0
	X	0.6	2.0	0.5	2.0
	XI	3.0	9.0	0.5	3.0
Slough 11 (135.3)	I	1.0	4.0	3.0	4.0
	IV	1.0	3.0	3.0	4.0
	V	1.0	3.0	5.0	8.0
Upper Side Channel 11 (136.1)	I	2.0	8.0	7.0	12.0
Slough 20 (140.1)	II	0.5	2.0	3.0	6.0
	III	1.0	3.0	3.0	6.0
Side Channel 21 (140.6)	II	3.0	7.0	4.0	8.0
	III	3.0	7.0	2.0	7.0
	IV	1.0	4.0	10.0	18.0
Slough 22 (144.3)	I	1.0	3.0	6.0	11.0
	III	2.0	4.0	1.0	2.0

surface gradient evaluated over large reaches on the thalweg profile. In the addendum, the water surface gradient was predominantly obtained from field measurements of the water surface upstream and downstream from the cross-section. The cross-section database was much smaller previously; cross-sections were often unavailable within passage reaches and nearby cross-sections were used in the analysis. Cross-section data collected within passage reaches during the 1984 field season enlarged the database and permitted a more thorough analysis of local flows required for passage.

4.3 Influence of Mainstem Discharge on Local Flow

The two principal sources of local flow in sloughs and side channels of the middle Susitna River are surface water runoff and groundwater upwelling. These sources of local flow are influenced by mainstem discharge and by precipitation events. Surface water runoff is a function of precipitation and basin characteristics, and is not influenced by fluctuations in mainstem discharge. Since precipitation in any amount falls roughly half of the time during the spawning period, surface runoff is generally periodic during this time. Most drainage areas contributing to sloughs and side channels are quite small and steep; thus surface runoff decreases substantially or stops soon after the precipitation stops. As a result of the intermittent nature of the surface runoff component of local flow, groundwater upwelling plays a major role in sustaining flow in sloughs and side channels during unbreached periods.

Groundwater upwelling during the spawning period originates from any of three sources: 1) shallow localized infiltration from the mainstem; 2) localized infiltration from precipitation events; and 3) regional groundwater transport in the down valley direction (AEIDC 1985). Of these three sources, only the first is directly influenced by short term fluctuations in mainstem stage. This localized source fluctuates daily in response to daily fluctuations in mainstem stage. This direct influence is demonstrated in a set of linear regression equations that relate the apparent groundwater component of slough flow to mainstem stage or mainstem discharge (e.g., H-E 1984, Beaver 1984, R&M 1984). The most recent version of these equations, developed as a function of mainstem stage (Gemperline pers. comm. 1984), were used in the frequency of occurrence; analysis presented in Appendix A. Such relations have only been developed for Sloughs 8A, 9 and 11 and cannot be generalized for application to other sloughs and side channels. A relation has been developed for Slough 21 but is not applicable at mainstem discharges in the range considered in these passage analyses.

Another localized and fluctuating component of groundwater upwelling is that generated from precipitation events. This component generally enters from the valley wall side of the slough or side channel and is not all causally related to mainst[illegible] discharges. This component of groundwater upwelling is directly related to surface water runoff from precipitation. However, the response of infiltrating precipitation would be delayed in comparison with the rapid response of surface water runoff. The influence of this source of groundwater upwelling has not been quantified.

The regional groundwater transport component of groundwater upwelling provides the base flow in the slough or side channel. This component may fluctuate slightly on a seasonal time scale, but would remain fairly constant during the spawning period. The amount of local flow provided by this source depends upon the length and characteristics of the slough channel that intersects this source. Base flows in sloughs and side channels have not been quantified as a separate entity, but are incorporated in the local flow values resulting from the regression equations discussed above.

4.4 Conclusions/Recommendations

The mainstem discharge and local flow values presented in this addendum differ in some cases with values previously reported in Sautner et al. (1984). In general, where discrepancies between the results of both studies occur, the results presented in this addendum are considered more reliable since they are based on refinements of both field and analytical methods.

The evaluation of salmon passage conditions presented in this report is based on the present hydraulic and morphologic characteristics of slough and side channel habitats. An important consideration that should be examined in future application of these data relates to physical changes that may occur within these habitats in the future. Changes in the natural sediment load of the Susitna River may result in aggradation or degradation of the streambed of slough or side channel habitats. Ice conditions may also result in changes in present channel morphology. Any changes in the present channel morphology may result in changes in the mainstem discharge and local flow values required for salmon passage as presented in this report. With these limitations in mind, the following conclusions were derived from this study.

1. All designated passage reaches influence salmon passage conditions in a similar manner regardless of channel configuration and substrate size.

2. The passage criteria data indicate that two separate sets of criteria curves are not required to describe passage requirements for chum salmon.

3. The thalweg depth threshold of 0.67 feet from Criteria Curve II is an overestimate of the water depth required for successful passage for chum salmon. A thalweg depth of 0.5 feet is a more accurate indicator of the depth at which salmon would first encounter passage difficulty.

4. The revised salmon passage criteria are represented by two straight lines, referred to as threshold limits, which best fit the passage criteria data collected during 1984. The threshold limits represent the criteria for successful and unsuccessful passage of chum salmon in the middle reach of the Susitna River.

5. The distribution of fish passage field observations in relation to the threshold limits for successful and unsuccessful passage of chum salmon support the revision of the original criteria curves.

6. Field observations and passage data collected during 1984 do not support the downward inflection represented by the first 20 feet of the original criteria curves. Extensions of straight line threshold criteria for reach lengths greater than 20 feet continued through this 0 to 20 feet range in the revised passage criteria threshold limits.

7. Passage depth appears to be the critical physical factor affecting salmon passage. Based on the threshold limits for successful and unsuccessful passage of chum salmon, passage depth increases only slightly over passage reach lengths up to 200 feet and is assumed constant for lengths greater than 200 feet.

8. A total of 85 passage reaches were identified at selected slough and side channel study sites of the middle Susitna River based on field observations.

9. Breaching is important in providing successful passage conditions, but only at relatively high mainstem discharges at the majority of slough and side channel study sites in the Middle Susitna River.

10. Backwater is a dominant factor in providing successful passage conditions from the mainstem into some slough and side channel sites by inundating the lower most passage reaches in each site.

11. Local flow is influenced largely by mainstem discharge levels and by precipitation events.

12. Local flow is important in providing periodic conditions for successful passage and more frequent conditions for successful passage with difficulty and exposure at those sites infrequently receiving direct mainstem influence through breaching or backwater.

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8.0 APPENDICES

APPENDIX A

Supplement to Local Flow Methods

APPENDIX A

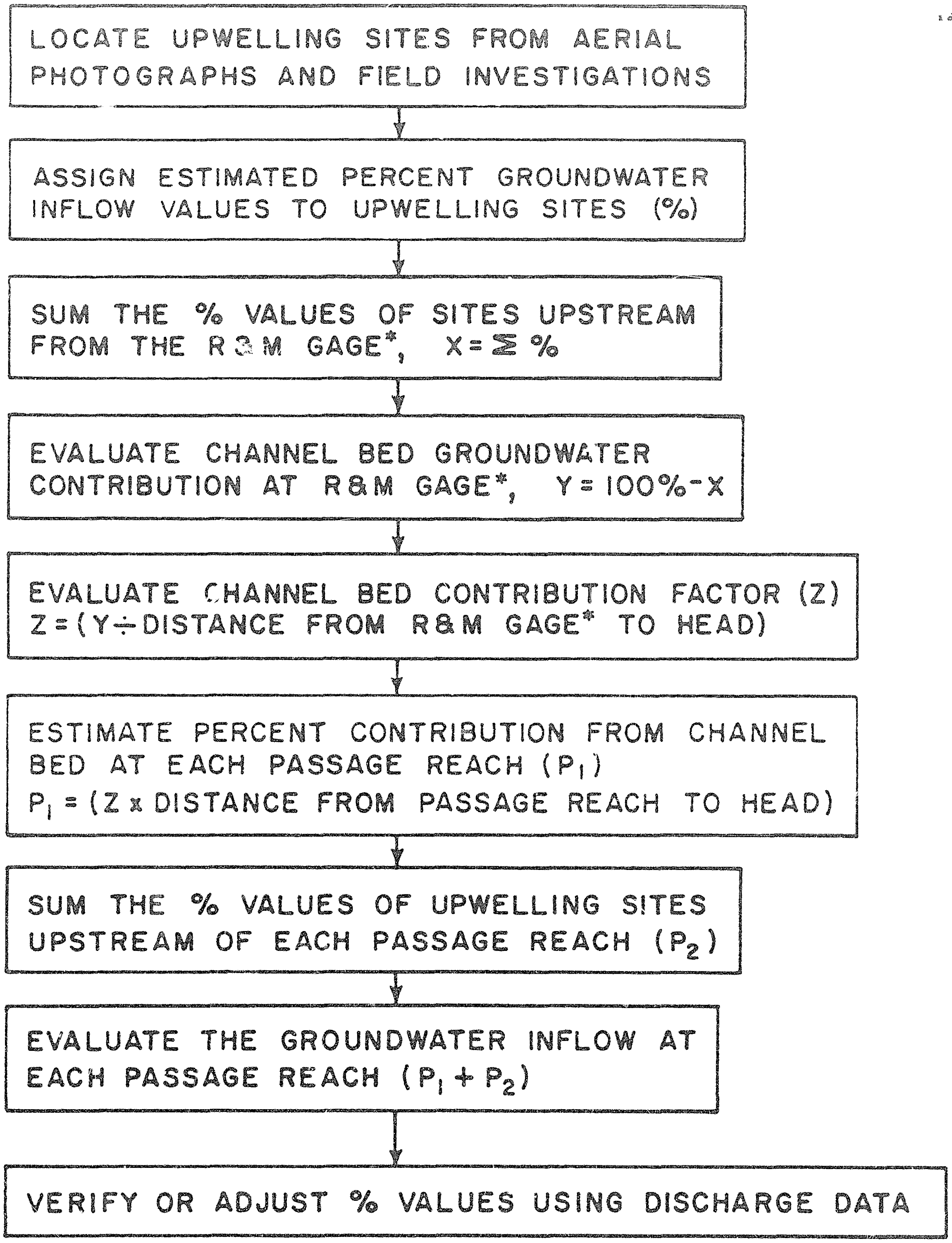
The general procedure for evaluating the required amount of local flow necessary for successful and unsuccessful passage and the frequency at which these required flows are expected to occur is described in Section 2.3.2.4. This appendix presents detailed methods for evaluating local flow distribution within a site, calibrating Manning's Equation, and evaluating the frequency of occurrence of local flows.

Local Flow Distribution Analysis

At passage reaches where discharge data were not collected, discharges were estimated from discharges measured elsewhere within the slough or side channel. The general procedure used to estimate the discharge at a passage reach involved assigning a percent groundwater flow value to each passage reach relative to total flow at an R&M discharge gage or other reference, such as another passage reach. These percent groundwater flow values were assumed to be constant at all slough and mainstem flows. The discharge at a specified passage reach may be estimated by multiplying the percent groundwater flow value at the passage reach by a discharge measured elsewhere in the slough or side channel and adjusting this discharge for tributary and surface water inflow.

The percent groundwater flow values at passage reaches are evaluated through the use of aerial photographs, on-site investigations and discharge data measured at slough gages and passage reaches. Groundwater flow at a site is considered to be composed of both inflow evenly distributed along the channel bed and inflow concentrated at upwelling sites visible in aerial photographs or located during site investigations (R&M 1982). Appendix Figure A-1 illustrates the general procedure used to estimate the percent groundwater flow values. The upwelling sites were assigned percent groundwater flow values from field experience. At Sloughs 8A, 9, 11 and 21, the R&M discharge gage location was designated the 100 percent groundwater flow value. At sloughs and side channels lacking an R&M gage, the most downstream passage reach (Passage Reach I) was designated to be the reference point for 100 percent groundwater flow. The percent groundwater flow value at each passage reach was estimated by summing the percent groundwater flow values from (1) upwelling sites upstream of the passage reach and (2) the channel bed groundwater contribution.

Discharge data available at various passage reaches on the same date or on a date with a similar mainstem flow and antecedent precipitation were utilized to verify or adjust the percent groundwater flow values. Local flow data collected during the 1984 open water field season are presented in Appendix E (Appendix Table E2). The R&M discharge gages provided an additional source of discharge data for comparison of the percent groundwater flow values. The evaluated percentage values at the passage reaches of the sloughs and side channels considered are presented in Appendix Table A-1.



* AT SLOUGHS AND SIDE CHANNELS WITHOUT R&M GAGES, PASSAGE REACH I WAS SUBSTITUTED FOR THE R&M GAGE.

Appendix Figure A-1. Illustration of the general procedure used in the local flow distribution analysis.

Appendix Table A-1. Percent groundwater flow values for sloughs and side channels.

Study Site	Passage Reach	Percent Groundwater Flow Values
Whiskers Creek Slough	I	100
	II	50
Mainstem 2 Side Channel	I	100
	II	90
	III	80
	IVL	40
	IVR	40
	VR	35
	VIR	30
	VIIR	25
	VIIIR	20
Slough 8A	I	228
	II	71[a]
	III	71[a]
	IV	70[a]
	V	64[a]
	VI	128
	VII	113
	VIII	104
	R&M Gage	100
	IX	50
	X	20
Slough 9	I	166
	II	152
	R&M Gage	100
	III	97
	IV	80
	V	30
Slough 9A	I	100
	II	79
	III	71
	IV	62
	V	59
	VI	54
	VII	44
	VIII	40
	IX	32
	X	30
	XI	24

Appendix Table A-1 (Continued).

Study Site	Passage Reach	Percent Groundwater Flow Values
Slough 11	I	120
	II	114
	III	102
	R&M Gage	100
	IV	78
	V	58
	VI	40
	VII	10
Slough 19	I	100
	II	90
	III	80
	IV	70
	V	55
	VI	50
	VII	20
	VIII	15
	IX	5
Slough 20	I	100
	II	80
	III	70
	IV	55
	V	45
	VI	15
Side Channel 21[b]	I	252
	II	249
	III	243
	IV	135[a]
	V	133[a]
	VI	214
	VII	179
	VIII	144
	IX	138
Slough 21	I	111
	R&M Gage	100
	II	93
	IIIR	36
	IIIL	26

Appendix Table A-1 (Continued).

Study Site	Passage Reach	Percent Groundwater Flow Values
Slough 22	I	100
	II	55
	III	35

[a] Passage reach is in one channel of a multi-channel reach of the study site.

[b] Percentages are referenced from the R&M gage located in Slough 21.

Calibration of Manning's Equation

The Manning Equation is assumed to be applicable to the low flow and shallow depth conditions in the passage reaches. The Manning Equation is an empirical relationship between channel discharge (Q) and channel geometry:

$$Q = 1/n\ AR^{2/3}S^{1/2}$$

The energy gradient (S) is assumed to be represented by the water surface slope at the cross section and the steeper of the upstream and downstream slopes is assumed to govern the passage reach flow characteristics. The channel wetted perimeter (R) and area (A) are calculated from the surveyed cross section. Manning's roughness coefficient (n) is assumed to be primarily a function of bed material size and channel uniformity. For application to the passage reaches, the roughness values are assumed to be uniformly greater at the shallow depths associated with the passage analysis in comparison to the flood flow roughness values found in the literature (Chow 1959). The steps used to calibrate the Manning Equation at each passage reach is summarized below:

1. Obtain a surveyed cross section at the passage reach.

2. Measure the water surface elevation and collect corresponding local flow data.

Appendix Table A-2. Ranges of Manning's roughness coefficients as a function of substrate size and channel uniformity.

	Manning's Roughness Coefficient	
Substrate Material	Uniform Channel (u)	Non-uniform Channel (nu)
Sand/Silt (A)	Au 0.03 - 0.07	Anu 0.05 - 0.09
Sand/Silt and Gravel/Rubble/Cobble (B)	Bu 0.05 - 0.10	Bnu 0.07 - 0.12
Rubble/Cobble/Boulder (C)	Cu 0.06 - 0.12	Cnu 0.08 - 0.14

3. Classify substrate and channel uniformity to evaluate the applicable range of roughness values (Appendix Table A-2).

4. Obtain the reach energy gradient from on-site water surface measurements or from thalweg water surface profiles (Quane et al. 1984).

5. Calibrate Manning's Equation by adjusting the roughness and gradient values.

The roughness and gradient values were adjusted during equation calibration to reflect site conditions, as represented by the measured water surface elevation and the local flow evaluated in the Local Flow Distribution analysis. The roughness value for a passage reach was varied within the appropriate range until the discharge calculated with the Manning Equation approximated the measured discharge. For passage reaches where the variations in roughness values did not yield an appropriate discharge, the gradient values were adjusted. The average of minimum water surface slope was selected to represent the energy gradient if slopes from adjacent passage reaches were similar to the modified value. Alternatively, the slope of the reach was calculated from the thalweg water surface profile (Quane et al. 1984) and used when calculated and measured discharges compared well.

At passage reaches lacking surveyed water surface elevations, Manning's Equation was calibrated by comparison with calibrated equations from adjacent and similar passage reaches. The passage reach energy gradient, substrate size and channel uniformity were used as indices of similarity.

At passage reaches with low flows during cross section and water surface elevation data collection, a potentially significant proportion of local flow at the passage reach may be excluded by the flow computations using the surveyed cross section data. Following the calibration of roughness and gradient values, the Manning Equation in such low flow cases calculated less discharge at a passage reach than the estimated discharge. The calculated discharge was then subtracted from the measured discharge to estimate the amount of passage reach flow that was excluded using the surveyed cross section. The excluded flow was assumed to be a constant amount that would be continuously underpredicted by the calibrated Manning Equation. To evaluate the total passage reach discharge using the Manning Equation, the excluded flow was added to the calculated discharge following each computation. Appendix Table A-3 lists the values selected for calibration and the excluded flow at affected passage reaches.

Frequency of Occurrence Analysis

The frequency of occurrence of local flows at passage reaches may be evaluated through the analysis of the flow contributions from groundwater and precipitation runoff. Appendix Table A-4 presents the local flows and their corresponding frequencies of occurrence. The general

Appendix Table A-3. Values of Manning's roughness coefficient, energy gradient, and excluded flow for calibration of Manning's equation.

Study Site	Passage Reach	Substrate and Channel Uniformity Category[a]	Manning's Roughness Coefficient	Energy Gradient	Excluded Flow (cfs)
Whiskers Creek Slough	I	Bnu	0.11	0.00893	5.0
	II	Cu	0.06	0.00937	0.5
Mainstem 2 Side Channel	I	Bnu	0.12	0.00395	0
	II	Bnu	0.11	0.00615	0
	III	Cnu	0.13	0.01342	0
	IVL	Cnu	0.13	0.00235	0
	IVR	Cnu	0.13	0.02445	0
	VR	Cnu	0.13	0.02350	0
	VIR	Cu	0.08	0.00167	0
	VIIR	Cnu	0.13	0.00574[b]	0
	VIIIR	Bnu	0.11	0.00574	0
Slough 8A	I	Bnu	0.11	0.0015[c]	0
	II	Bu	0.08	0.0331	0
	III	Bnu	0.09	0.0331[b]	0
	IV	Bu	0.08	0.00742	0
	V	Bu	0.08	0.00742[b]	0
	VI	Cnu	0.12	0.0725	0
	VII	Cu	0.10	0.01179	0
	VIII	Bnu	0.09	0.0106	0.4
	IX	Cnu	0.12	0.0075	0.4
	X	Cnu	0.13	0.01826	0
Slough 9	I	Anu	0.05	0.00123	3.6
	II	Bnu	0.08	0.0107	0.8
	III	Bnu	0.09	0.000595	0.6
	IV	Bnu	0.09	0.00053	0.5
	V	Bnu	0.08	0.00053[b,d]	0
Slough 9A	I	Cnu	0.11	0.00403[b]	3.0
	II	Bnu	0.08	0.00403	1.9
	III	Bu	0.07	0.0188	0
	IV	Bu	0.07	0.0089	0.9
	V	Cnu	0.11	0.01818	0
	VI	Bnu	0.08	0.02286	2.3
	VII	Bnu	0.08	0.0118	0
	VIII	Cnu	0.14	0.00956	0
	IX	Cnu	0.11	0.0153	0
	X	Cnu	0.13	0.0056[d]	1.1
	XI	Bnu	0.08	0.01071	0

Appendix Table A-3 (Continued).

Study Site	Passage Reach	Substrate and Channel Uniformity Category[a]	Manning's Roughness Coefficient	Energy Gradient	Excluded Flow (cfs)
Slough 11	I	Cnu	0.12	0.00783[e]	0.7
	II	Bu	0.07	0.0064	0.4
	III	Bnu	0.08	0.0080	0
	IV	Cnu	0.11	0.01	0
	V	Cnu	0.10	0.00171[e]	0
	VI	Cnu	0.12	0.00913[d]	0
	VII	Cnu	0.11	0.00073[d]	0.4
Upper Side Channel 11	I	Cnu	0.11	0.0099	0.4
	II	Cnu	0.11	0.0177	0
Slough 19	I	Bu	f	f	f
	II	Bu	f	f	f
	III	Bnu	f	f	f
	IV	Bnu	f	f	f
	V	Bnu	f	f	f
	VI	Au	0.05	0.00778[b]	0
	VII	Bu	0.06	0.00778	0
	VIII	Au	0.05	0.00380	0
	IX	Bu	0.06	0.02	0
Slough 20	I	Cnu	0.14	0.0741[c]	0
	II	Bnu	0.11	0.0026[c]	0
	III	Bnu	0.11	0.0026[c]	0
	IV	Bnu	f	f	f
	V	Bnu	f	f	f
	VI	Bnu	0.11	0.016[c]	0
Side Channel 21	I	Bnu	0.08	0.009	0
	II	Bnu	0.07	0.015[b]	0.8
	III	Bnu	0.07	0.015[b]	1.2
	IV	Cnu	0.13	0.01519	0
	V	Cnu	0.13	0.01519[b]	0
	VI	Bnu	0.08	0.015[b]	1.2
	VII	Bnu	0.08	0.015[b]	0.8
	VIII	Bnu	0.07	0.02	0.8
	IX	Bnu	0.07	0.00902	0.8

Appendix Table A-4. Frequency of occurrence of local flows for successful (S) and unsuccessful (US) passage for a baseflow correspoding to 15,000 cfs Susitna River discharge at Gold Creek and including precipitation values from August 20 to Septebmer 20.

Study Site	Passage Reach	Basin[a] Area	Percent Runoff	Base Flow (cfs) at 15,000 cfs	Required Local Flow (cfs) S	Required Local Flow (cfs) US	Required Surface Water (cfs) S	Required Surface Water (cfs) US	Required Site Precipitation (in) S	Required Site Precipitation (in) U	Precipitation Coefficient	Required Talkeetna Precipitation (in) S	Required Talkeetna Precipitation (in) US	Percent Exceedence S	Percent Exceedence US
Slough 8A	I	2.21	65	4.6	2.0	0.8	0.0	0.0	0	0	1.30	0	0	> 50	> 50
	II	1.91	65	1.4	5.0	2.0	3.6	0.6	0.205	0.034	1.30	0.157	0.026	22	38
	III	1.88	65	1.4	4.0	1.0	2.6	0.0	0.153	0	1.30	0.118	0	24	> 50
	IV	1.79	65	1.4	6.0	2.0	4.6	0.6	0.298	0.039	1.30	0.229	0.030	16	37
	V	1.74	65	1.3	6.0	2.0	4.7	0.7	0.322	0.048	1.30	0.248	0.037	15	35
	VI	1.45	65	2.6	3.0	0.6	0.4	0.0	0.042	0	1.30	0.032	0	36	> 50
	VII	1.31	65	2.3	7.0	3.0	4.7	0.7	0.665	0.099	1.30	0.511	0.076	7	28
	VIII	1.28	65	2.1	11.0	3.0	8.9	0.9	1.359	0.137	1.30	1.045	0.105	2	25
	IX	1.01	10	1.0	4.0	0.8	3.0	0.0	1.043	0	1.30	0.802	0	4	> 50
	X	0.81	10	0.8	2.0	0.4	1.6	0.4	0.735	0.183	1.30	0.565	0.141	6	22
Slough 9	I	2.89	65	4.0	5.0	4.0	1.0	0.0	0.036	0	1.20	0.030	0	37	> 50
	II	2.04	65	3.6	6.0	3.0	2.4	0.0	0.182	0	1.20	0.152	0	22	> 50
	III	1.83	65	1.3	5.0	2.0	2.7	0.0	0.284	0	1.20	0.237	0	16	> 50
	IV	1.62	65	1.9	3.0	1.0	1.1	0.0	0.189	0	1.20	0.157	0	27	> 50
	V	1.52	10	0.7	2.0	0.8	1.3	0.1	0.318	0.024	1.20	C.265	0.020	14	40
Slough 9A	I	2.27	40	5.7	9.0	4.0	3.3	0.0	0.135	0	1.10	0.123	0	24	> 50
	II	2.27	40	4.5	3.0	2.0	0.0	0.0	0.0	0	1.10	0	0	> 50	> 50
	III	2.27	40	4.0	4.0	2.0	0.0	0.0	0.0	0	1.10	0	0	> 50	> 50
	IV	.35	40	3.5	4.0	2.0	0.5	0.0	0.133	0	1.10	C.121	0	24	> 50
	V	.35	40	3.4	4.0	3.0	0.6	0.0	0.159	0	1.10	0.144	0	22	> 50
	VI	.35	40	3.1	6.0	3.0	2.9	0.0	0.770	0	1.10	0.700	0	< 4	> 50
	VII	.21	40	2.5	4.0	1.0	1.5	0.0	0.664	0	1.10	0.604	0	< 6	> 50
	VIII	.17	40	2.3	9.0	3.0	6.7	0.7	3.664	0.383	1.10	3.330	0.348	0	11
	IX	.10	40	1.8	3.0	0.8	1.2	0.0	1.116	0	1.10	1.014	0	< 2	> 50
	X	.08	40	1.7	2.0	0.6	0.3	0.0	0.349	0	1.10	C.317	0	13	> 50
	XI	.02	40	1.4	9.0	3.0	7.6	1.6	35.331	7.438	1.10	32.119	6.762	0	0
Slough 11	I	0	10	2.2	4.0	1.0	1.8	0.0	d	d	1.07	d	d	< 5	> 50
	II	0	10	2.1	1.4	1.4	0.0	b	d	d	1.07	d	d	> 50	> 50
	III	0	10	1.8	9.0	3.0	7.2	1.2	d	d	1.07	d	d	< 5	< 5
	IV	0	10	1.4	3.0	1.0	1.6	0.0	d	d	1.07	d	d	< 5	> 50
	V	0	10	1.0	3.0	1.0	2.0	0.0	d	d	1.07	d	d	< 5	> 50
	VI	0	10	0.7	2.0	0.6	1.3	0.0	d	d	1.07	d	d	< 5	> 50
	VII	0	10	0.2	0.5	0.4	0.3	0.2	d	d	1.07	d	d	< 5	< 5

Appendix Table A-3 (Continued).

Study Site	Passge Reach	Substrate and Channel Uniformity Category[a]	Manning's Roughness Coefficient	Energy Gradient	Excluded Flow (cfs)
Slough 21	I	Anu	0.07	0.00193	0
	II	Bu	0.06	0.00453	0
	IIIR	Cnu	0.10	0.00802	0
	IIIL	Cnu	0.10	0.00802	0
Slough 22	I	Cnu	0.13	0.02269	1.0
	II	Cnu	0.13	0.00833	0.5
	III	Cnu	0.13	0.01842	0.5

a Substrate and channel uniformity categories are taken from Table 3 in Section 2.3.2.4.

b Gradient from adjacent passage reach gradients.

c Gradient from entire thalweg reach.

d Average of upstream and downstream gradient.

e Minimum of upstream and downstream gradient.

f No cross section data available.

Appendix Table A-4. Frequency of occurrence of local flows for successful (S) and unsuccessful (US) passage for a baseflow correspoding to 15,000 cfs Susitna River discharge at Gold Creek and including precipitation values from August 20 to Septehmer 20.

Study Site	Passage Reach	Basin[a] Area	Percent Runoff	Base Flow (cfs) at 15,000 cfs	Required Local Flow (cfs)		Required Surface Water (cfs)		Required Site Precipitation (in)		Precipitation Coefficient	Required Talkeetna Precipitation (in)		Percent Exceedence	
					S	US	S	US	S	U		S	US	S	US
Slough 8A	I	2.21	65	4.6	2.0	0.8	0.0	0.0	0	0	1.30	0	0	> 50	> 50
	II	1.91	65	1.4	5.0	2.0	3.6	0.6	0.205	0.034	1.30	0.157	0.026	22	38
	III	1.88	65	1.4	4.0	1.0	2.6	0.0	0.153	0	1.30	0.118	0	24	> 50
	IV	1.79	65	1.4	6.0	2.0	4.6	0.6	0.298	0.039	1.30	0.229	0.030	16	37
	V	1.74	65	1.3	6.0	2.0	4.7	0.7	0.322	0.048	1.30	0.248	0.037	15	35
	VI	1.45	65	2.6	3.0	0.6	0.4	0.0	0.042	0	1.30	0.032	0	36	> 50
	VII	1.31	65	2.3	7.0	3.0	4.7	0.7	0.665	0.099	1.30	0.511	0.076	7	28
	VIII	1.28	65	2.1	11.0	3.0	8.9	0.9	1.359	0.137	1.30	1.045	0.105	2	25
	IX	1.01	10	1.0	4.0	0.8	3.0	0.0	1.043	0	1.30	0.802	0	4	> 50
	X	0.81	10	0.8	2.0	0.4	1.6	0.4	0.735	0.183	1.30	0.565	0.141	6	22
Slough 9	I	2.89	65	4.0	5.0	4.0	1.0	0.0	0.036	0	1.20	0.030	0	37	> 50
	II	2.04	65	3.6	6.0	3.0	2.4	0.0	0.182	0	1.20	0.152	0	22	> 50
	III	1.83	65	1.3	5.0	2.0	2.7	0.0	0.284	0	1.20	0.237	0	16	> 50
	IV	1.62	65	1.9	3.0	1.0	1.1	0.0	0.189	0	1.20	0.157	0	27	> 50
	V	1.52	10	0.7	2.0	0.8	1.3	0.1	0.318	0.024	1.20	0.265	0.020	14	40
Slough 9A	I	2.27	40	5.7	9.0	4.0	3.3	0.0	0.135	0	1.10	0.123	0	24	> 50
	II	2.27	40	4.5	3.0	2.0	0.0	0.0	0.0	0	1.10	0	0	> 50	> 50
	III	2.27	40	4.0	4.0	2.0	0.0	0.0	0.0	0	1.10	0	0	> 50	> 50
	IV	.35	40	3.5	4.0	2.0	0.5	0.0	0.133	0	1.10	0.121	0	24	> 50
	V	.35	40	3.4	4.0	3.0	0.6	0.0	0.159	0	1.10	0.144	0	22	> 50
	VI	.35	40	3.1	6.0	3.0	2.9	0.0	0.770	0	1.10	0.700	0	< 4	> 50
	VII	.21	40	2.5	4.0	1.0	1.5	0.0	0.664	0	1.10	0.604	0	< 6	> 50
	VIII	.17	40	2.3	9.0	3.0	6.7	0.7	3.664	0.383	1.10	3.330	0.348	0	11
	IX	.10	40	1.8	3.0	0.8	1.2	0.0	1.116	0	1.10	1.014	0	< 2	> 50
	X	.08	40	1.7	2.0	0.6	0.3	0.0	0.349	0	1.10	0.317	0	13	> 50
	XI	.02	40	1.4	9.0	3.0	7.6	1.6	35.331	7.438	1.10	32.119	6.762	0	0
Slough 11	I	0	10	2.2	4.0	1.0	1.8	0.0	d	d	1.07	d	d	< 5	> 50
	II	0	10	2.1	1.4	1.4	0.0	b	d	d	1.07	d	d	> 50	> 50
	III	0	10	1.8	9.0	3.0	7.2	1.2	d	d	1.07	d	d	< 5	< 5
	IV	0	10	1.4	3.0	1.0	1.6	0.0	d	d	1.07	d	d	< 5	> 50
	V	0	10	1.0	3.0	1.0	2.0	0.0	d	d	1.07	d	d	< 5	> 50
	VI	0	10	0.7	2.0	0.6	1.3	0.0	d	d	1.07	d	d	< 5	> 50
	VII	0	10	0.2	0.5	0.4	0.3	0.2	d	d	1.07	d	d	< 5	< 5

Appendix Table A-4 (Continued).

Study Site	Passage Reach	Basin[a] Area	Percent Runoff	Base Flow (cfs) at 15,000 cfs	Required Local Flow (cfs)		Required Surface Water (cfs)		Required Site Precipitation (in)		Precipitation Coefficient	Required Talkeetna Precipitation (in)		Percent Exceedence	
					S	US	S	US	S	U		S	US	S	US
Upper Side Channel 11	I	0	10	8.0[c]	8	2.0	0	0	d	d	1.07	d	d	> 50	> 50
	II	0	10	6.0[c]	b	b	b	b	d	d	1.07	d	d	e	e
Side Channel 21	I	5.03	65	7.6	5	2.0	0	0	0	0	1.07	0	0	> 50	> 50
	II	5.03	65	7.5	7	3.0	0	0	0	0	1.07	0	0	> 50	> 50
	III	5.03	65	7.3	7	3.0	0	0	0	0	1.07	0	0	> 50	> 50
	IV	0.84	40	3.3	4	1.0	0.7	0	0.122	0	1.07	0.122	0	24	> 50
	V	0.70	40	3.3	4	1.0	0.7	0	0.166	0	1.07	0.166	0	21	> 50
	VI	0.66	40	6.4	17	4.0	10.6	0	2.796	0	1.07	2.796	0	< 5	> 50
	VII	0.64	40	5.4	20	5.0	14.6	0	4.082	0	1.07	4.082	0	0	> 50
	VIII	0.61	40	4.3	7	2.0	3.7	0	0.830	0	1.07	0.830	0	0	> 50
	IX	0.53	40	4.1	5	2.0	0.9	0	0.376	0	1.07	0.376	0	3	> 50
Slough 21	I	0.41	10	3.3	4	1.0	0.7	0	0.635	0	1.07	0.635	0	< 5	> 50
	II	0.32	10	2.8	2	0.4	0	0	0	0	1.07	0	0	> 50	> 50
	IIIL	0.16	10	0.8	3	0.8	2.2	0	5.114	0	1.07	5.114	0	5	> 50
	IIIR	0.16	10	1.1	b	b	d	d	d	d	1.07	d	d	e	e

[a] Basin area evaluated from topographic maps from the United States Geological Survey (Scale 1:63,360), Talkeetna Mts C-6, D-1 and D-6.

[b] Cross section data not collected in field; required local flow cannot be evaluated.

[c] Local flow estimated from field observations.

[d] Precipitation does not yield a surface water contribution to local flow as no tributaries are located upstream of the passage reach and runoff infiltrates alluvium soil.

[e] Exceedence frequencies cannot be evaluated as local flow data are not available.

approach used to evaluate the frequency of occurrence corresponding to a specified local flow is described below:

1. Calculate the base flow for the period from August 20 to September 20 at the R&M gage using the mainstem versus slough discharge relationship. If a relationship has not been evaluated at the site, assume a base flow at Passage Reach I from the data collected for known mainstem flows.

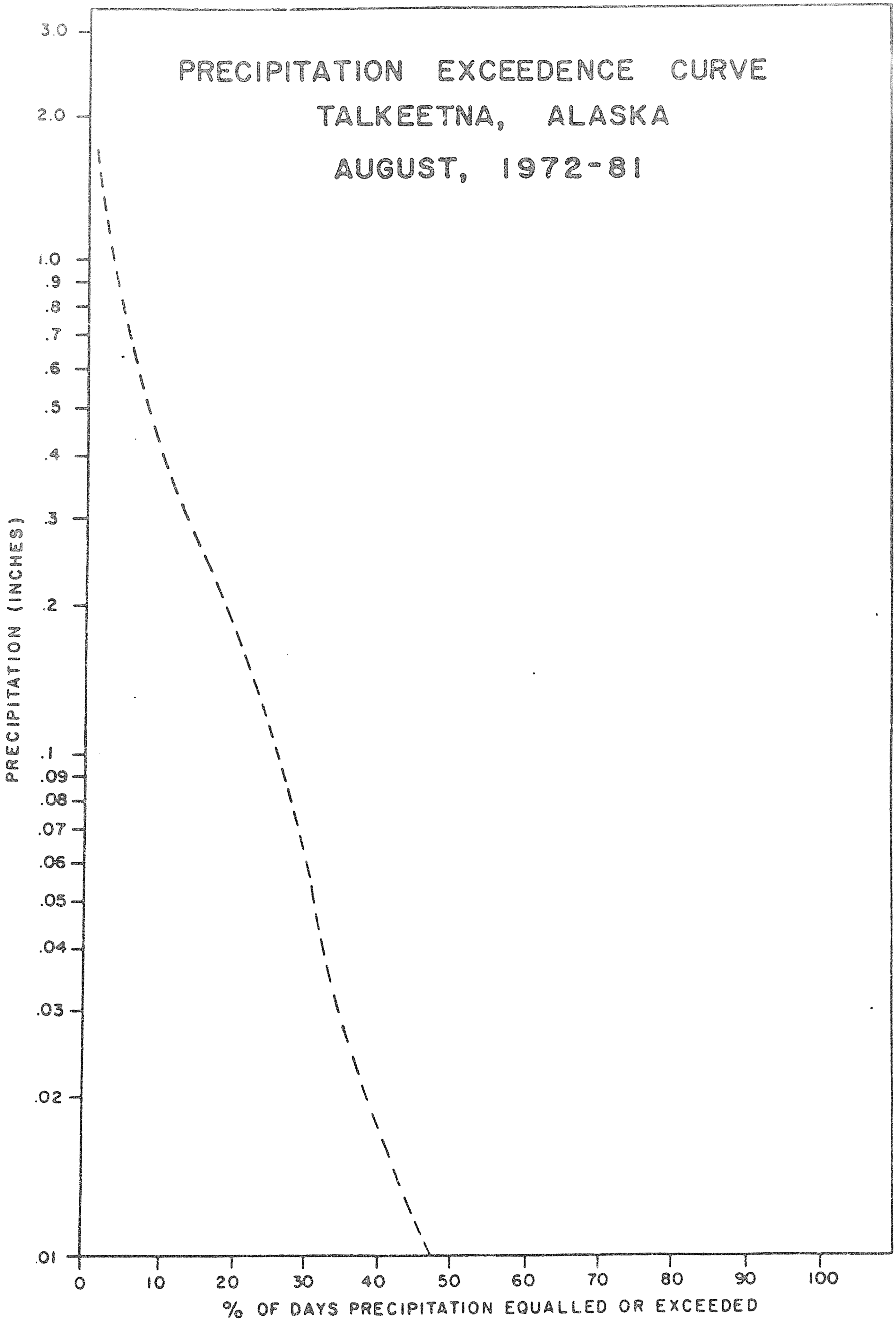
2. Evaluate the base flow at each passage reach by multiplying the base flow from Step 1 by the percent groundwater flow value obtained through the Local Flow Distribution analysis.

3. Evaluate the required surface water by subtracting the base flow from the local flow estimated for successful passage.

4. Calculate the basin area upstream of the passage reach contributing surface runoff.

5. Calculate the precipitation necessary to yield the required surface water.

6. Use the Precipitation Duration Curve at Talkeetna for August (Appendix Figure A-2) and adjust the daily precipitation by the coefficients listed in Appendix Table A-5 to obtain the frequency of occurrence.



Appendix Figure A-2. August Precipitation Duration Curve for the period 1972-1981 at the Talkeetna Weather Station (adapted from H-E 1984).

Appendix Table A-5. Precipitation coefficients for determining precipitation values at selected sloughs using precipitation values recorded at the Talkeetna weather station (derived from R&M 1984).

Study Site	River Mile	Precipiation[a] Coefficient
Slough 8A	125.3	1.3
Slough 9	128.3	1.2
Slough 9A	133.2	1.1
Slough 11	135.3	1.07
Slough 21	141.8	1.0

[a] To obtain precipitation estimates for above sloughs, multiply precipitation at Talkeetna by the appropriate coefficient.

7. Repeat steps 3 through 6 using the local flow estimated for unsuccessful passage.

Base flows from groundwater contributions in the sloughs and side channels were evaluated at the average mainstem discharge during the period from August 20 to September 20. The average Susitna River discharge at Gold Creek for this period was estimated to be 15,000 cfs determined from the flow duration curve developed in Sautner et al. (1984). The slough versus mainstem discharge relationships used to evaluate the base flows at Sloughs 8A, 9, and 11 (Gemperline pers. comm. 1984) are listed below:

$$Q8A = -368.211 + 0.6356\ W_{sel} \text{ at RM } 127.1$$

$$Q9 = -171.8788 + 0.28892\ W_{sel} \text{ at RM } 129.3$$

$$Q11 = -335.39272 + 0.49209\ W_{sel} \text{ at RM } 136.68.$$

At sloughs and side channels where local flow versus mainstem discharge relationships have not been evaluated, base flows corresponding to a 15,000 cfs mainstem discharge at Gold Creek were estimated from local flow data. Slough flows, measured on dates when the mainstem discharge was 15,000 cfs, provided an estimate of base flows. Alternatively, local flows measured at the same site on different days were plotted and extrapolated to yield a base flow for a mainstem discharge of 15,000 cfs. Data collected during periods of high precipitation were excluded. Appendix Table A-6 lists the base flows evaluated at specific sites.

Appendix Table A-6. Base flows for a mainstem discharge at Gold Creek of 15,000 cfs.

Study Site	Local Flow (cfs)	Location of Local Flow Evaluation
Slough 8A	2.0	R&M Gage
Slough 9	2.4	R&M Gage
Slough 9A	5.7	PRI
Slough 11	1.8	R&M Gage
Side Channel and Slough 21	3.5	R&M Gage

Precipitation events were assumed to contribute rainfall for 24 hours to permit comparison with the August Precipitation Duration Curve (R&M 1984a). The Precipitation Duration Curve (Appendix Figure A-2) was developed from daily precipitation records from 1972 to 1981. The August Precipitation Duration Curve was assumed to be applicable to the August 20 to September 20 period as the rainfall records for August and September appeared similar when compared. Talkeetna records were adjusted using precipitation coefficients for transfer of recorded data (R&M 1984b).

Antecedent moisture conditions were assumed invariable and a constant surface water runoff to precipitation percentage was selected for each passage reach. Variations in soil moisture prior to rainfall events may affect the amount of precipitation which becomes surface water runoff; in the precipitation frequency analysis, these variations were assumed negligible. For Sloughs 8A, 9, 11 and 21, the runoff to precipitation percentages reflected known topographic and soil conditions and were selected from runoff coefficients presented in the R&M Consultants Water Balance report (R&M 1984b). Sloughs and side channels with primarily alluvial soil watersheds were assigned a runoff coefficient of 10 percent. Steep slopes in the watershed would increase runoff; a runoff coefficient of 65 percent would be used in the precipitation analysis. For sloughs and side channels with watersheds encompassing both steep side slopes and alluvial materials, a runoff coefficient of 40 percent was selected. Appendix Table A-3 lists the runoff coefficients used at each site.

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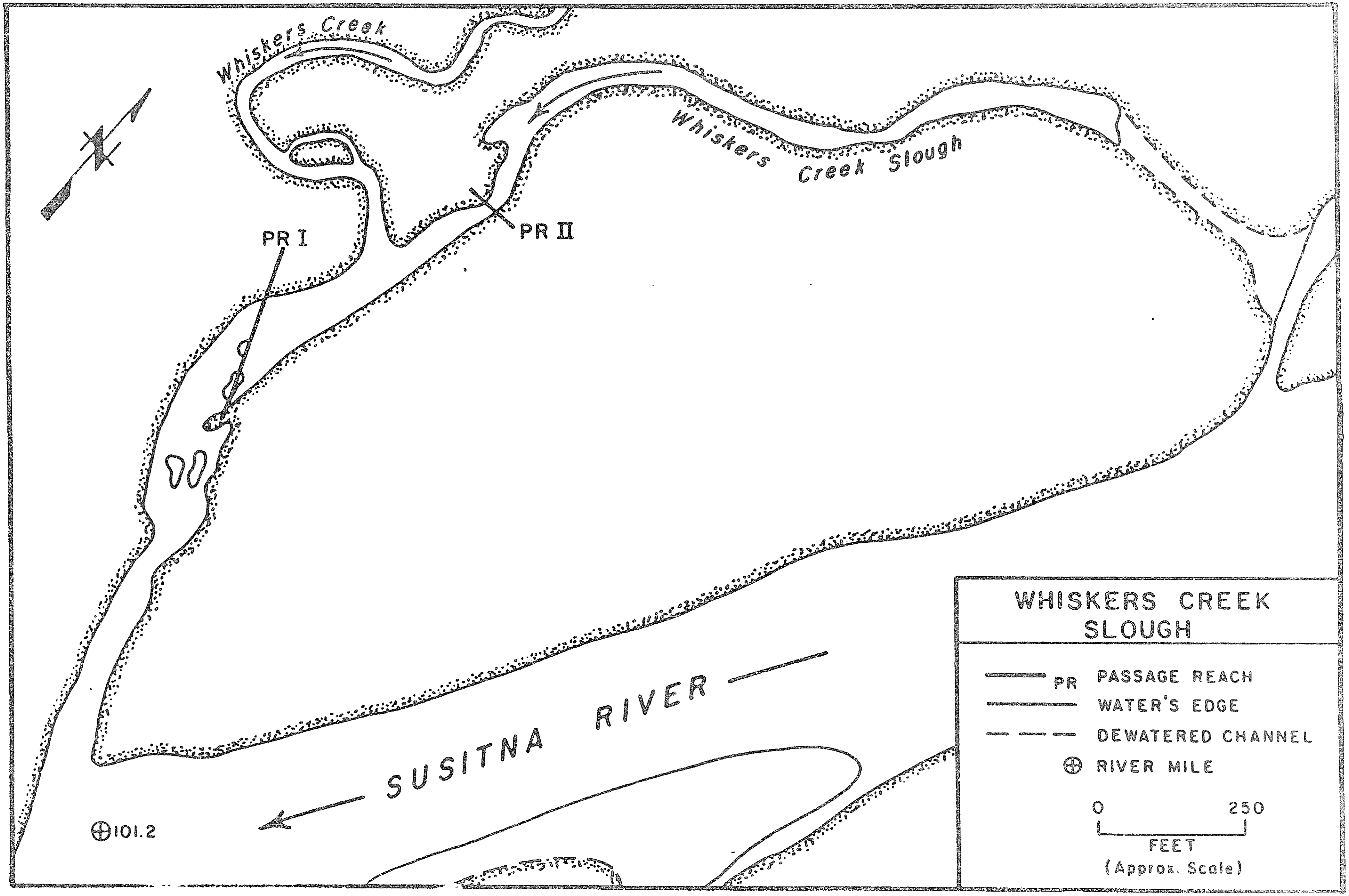
APPENDIX B

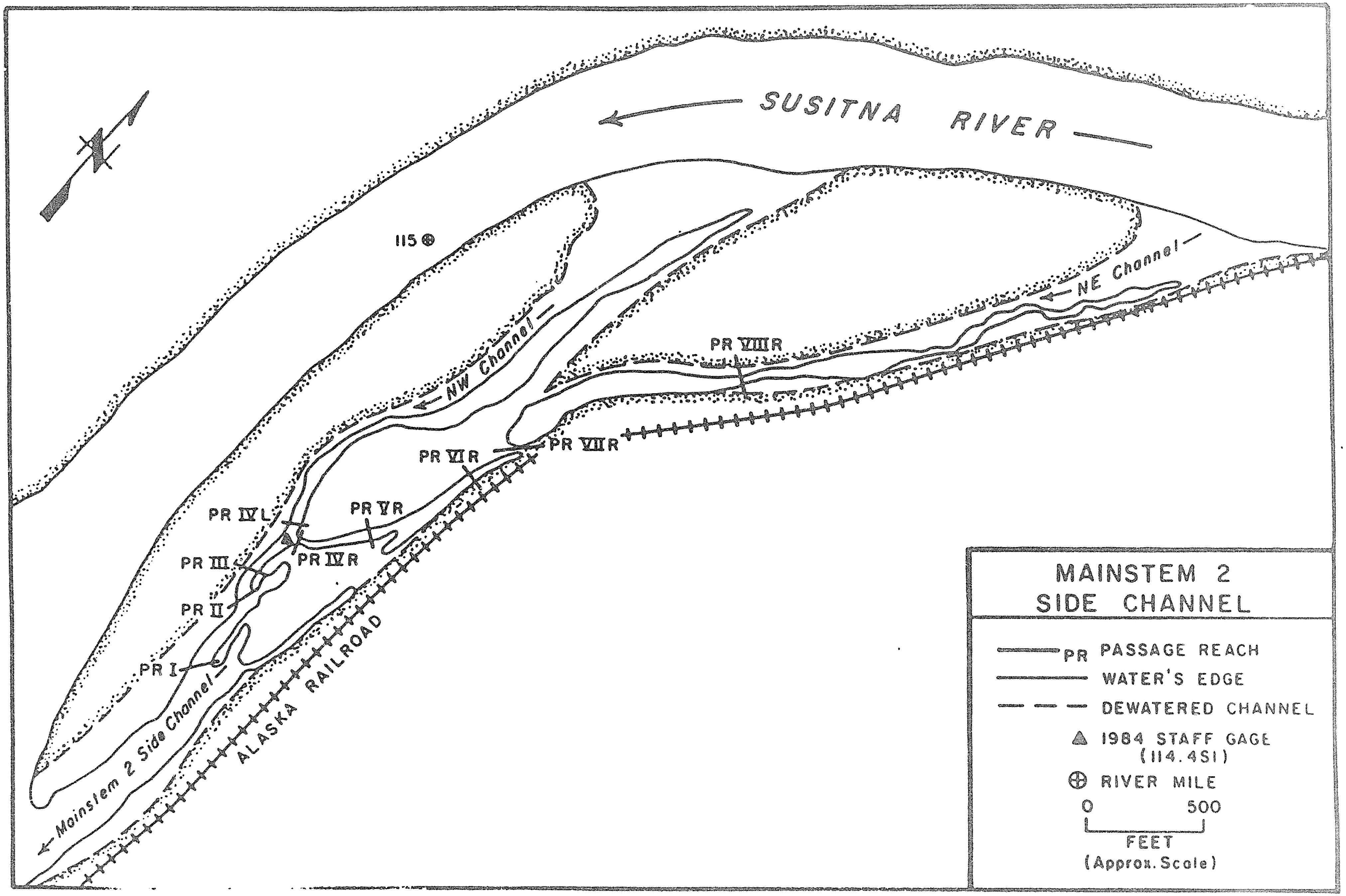
Passage Reach Distribution Maps

APPENDIX B: PASSAGE REACH DISTRIBUTION MAPS

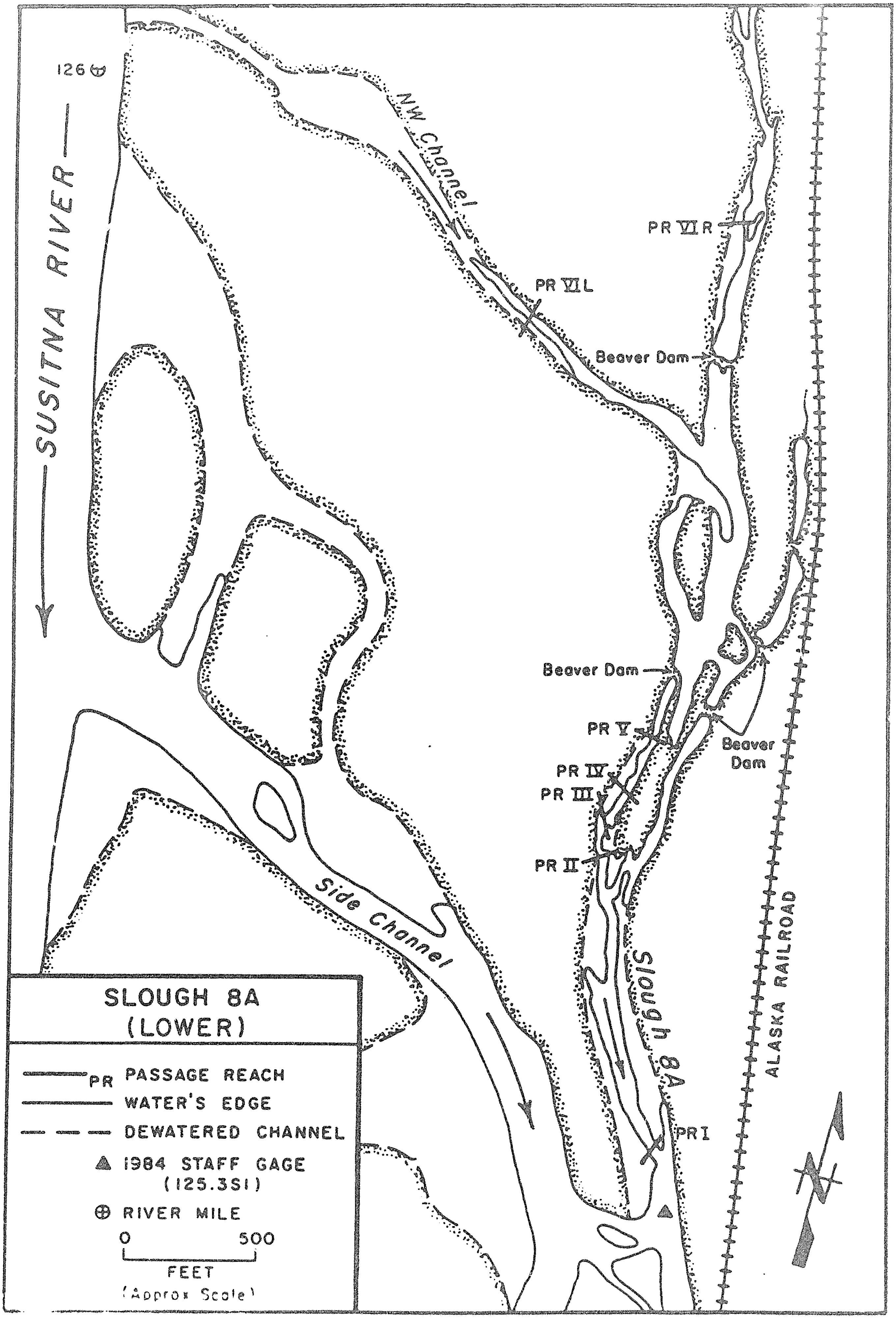
The maps compiled in this appendix show the locations of passage reaches at selected slough and side channel study sites of the middle Susitna River identified during the 1984 open water season (Appendix Figures B-1 to B-13). These maps have been revised from those appearing in Sautner et al. (1984) to show the wetted area of each site at unbreached flows. Locations of staff gages established in 1984 are designated on the appropriate site maps. These maps were derived from aerial photos of the middle Susitna River.



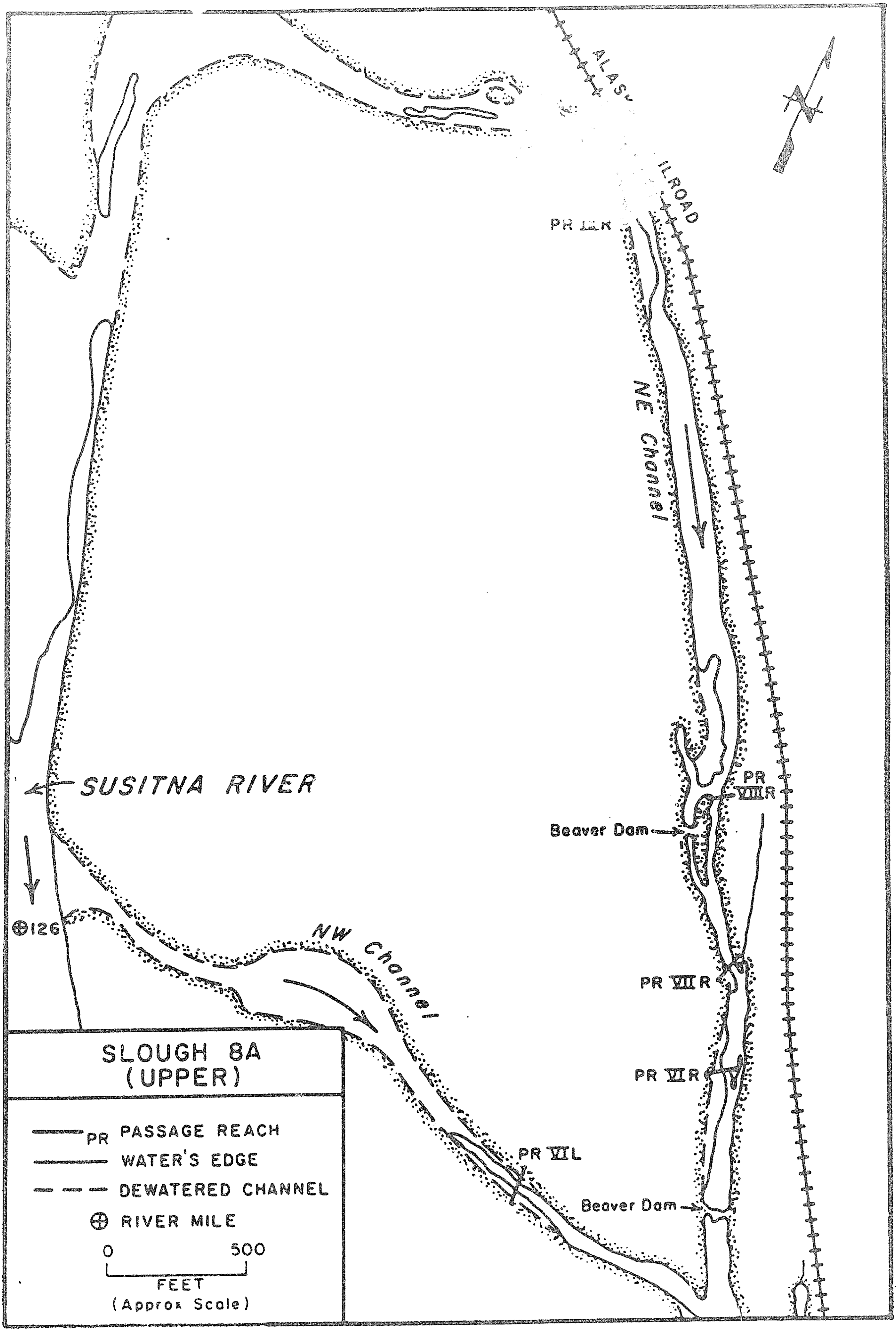
Appendix Figure B-1. Locations of passage reaches at Whiskers Creek Slough during the 1984 open water season.



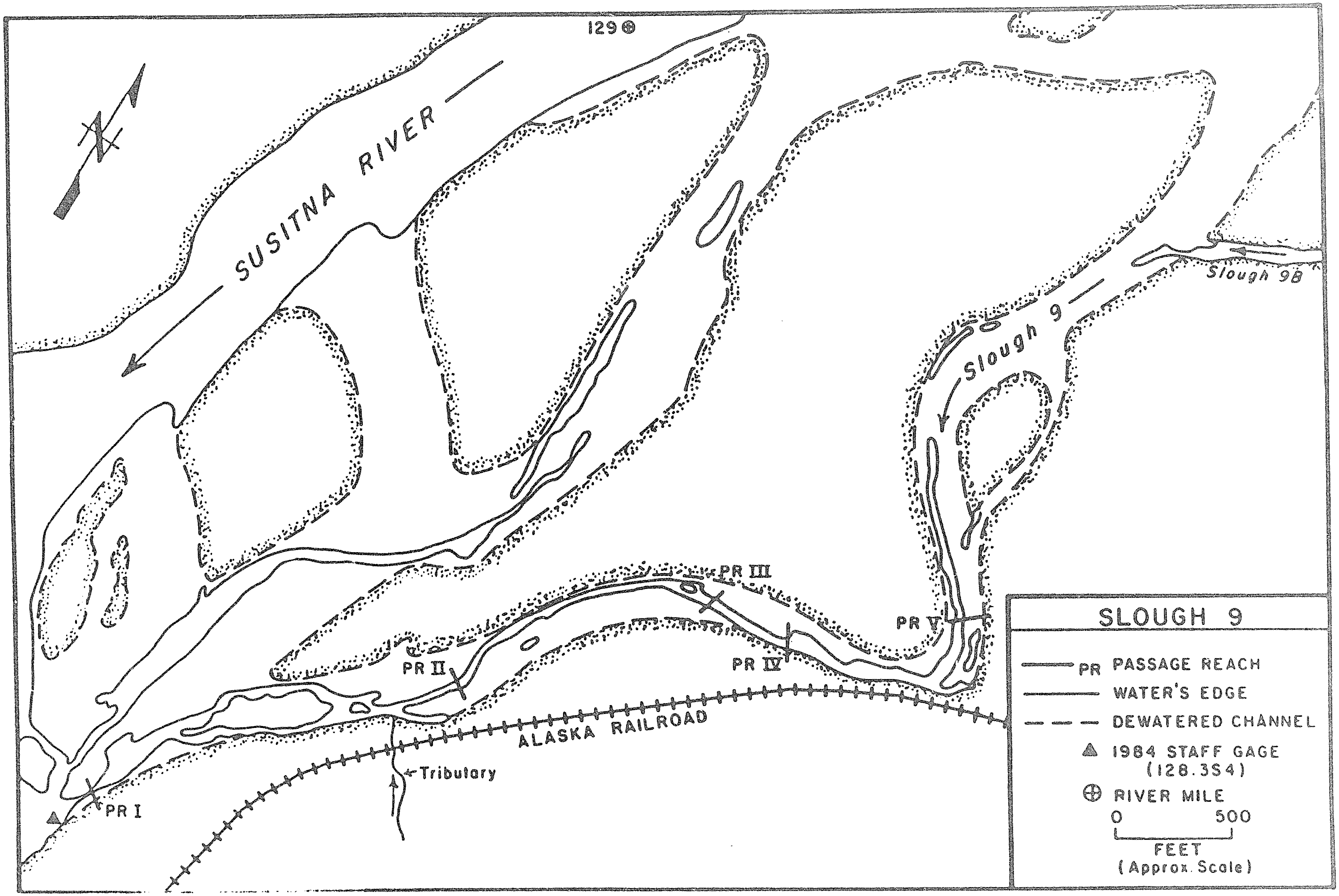
Appendix Figure B-2. Locations of passage reaches at Mainstem 2 Side Channel during the 1984 open water season.



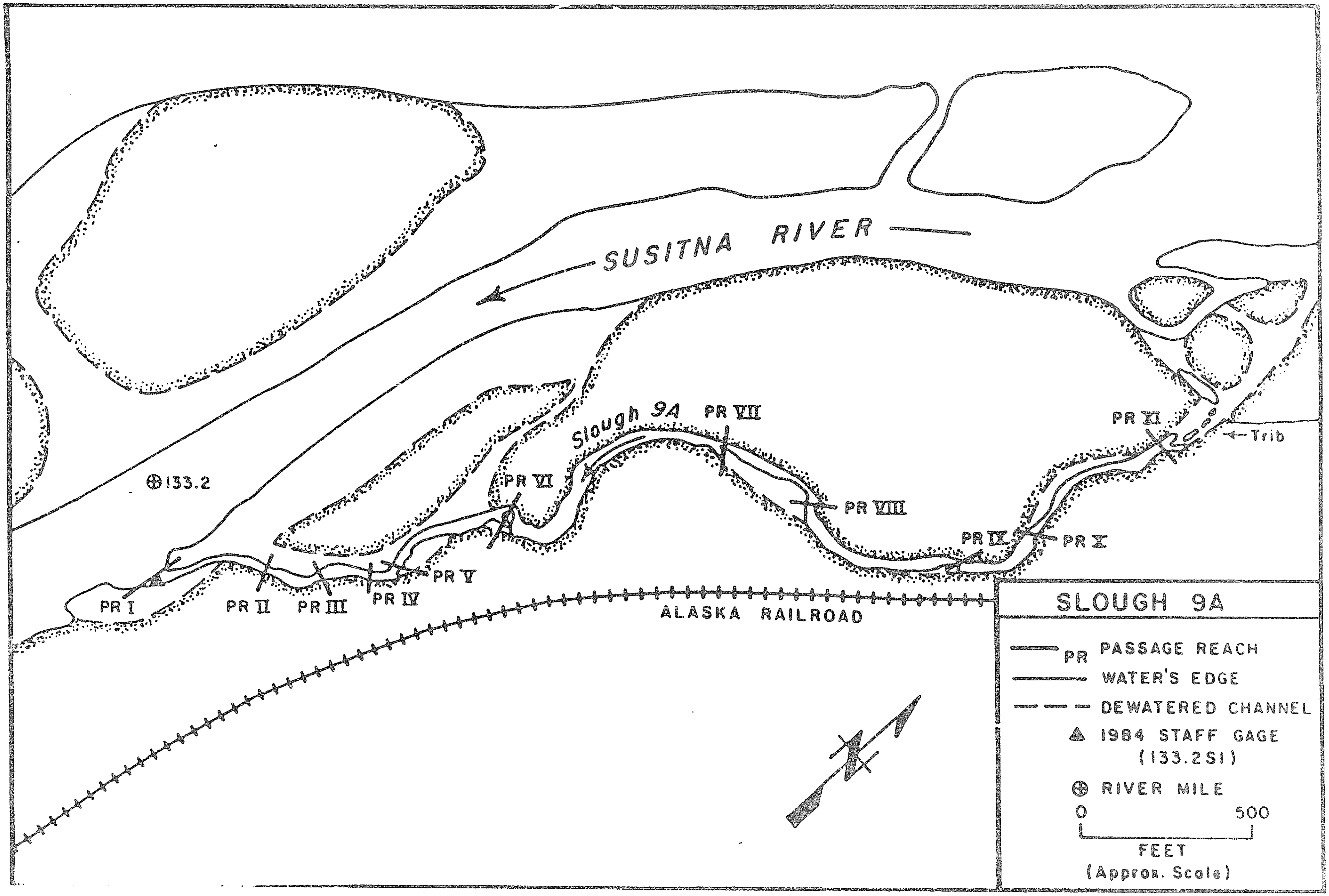
Appendix Figure B-3. Locations of passage reaches at Slough 8A (lower) during the 1984 open water season.



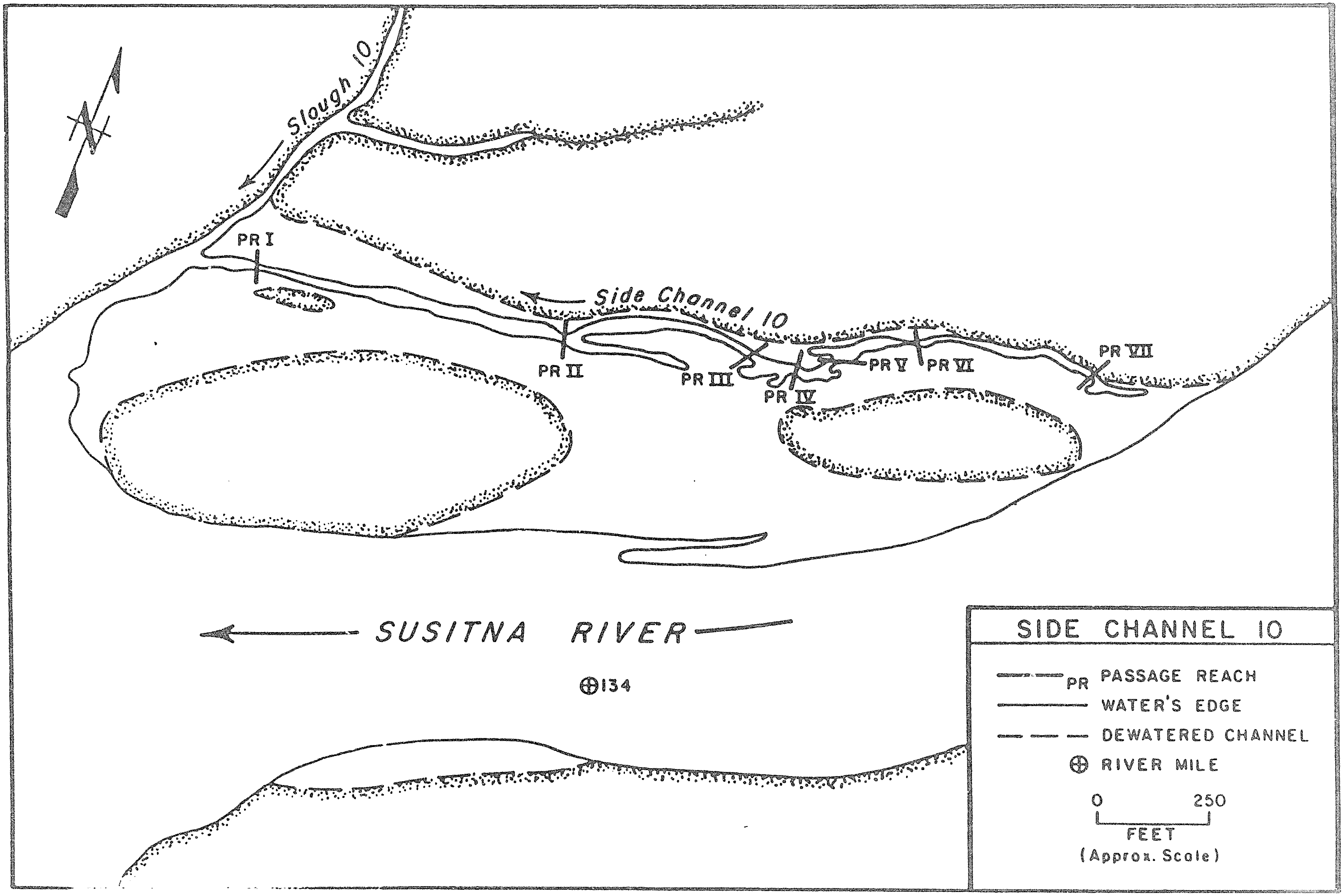
Appendix Figure B-4. Locations of passage reaches at Slough 8A (upper) during the 1984 open water season.



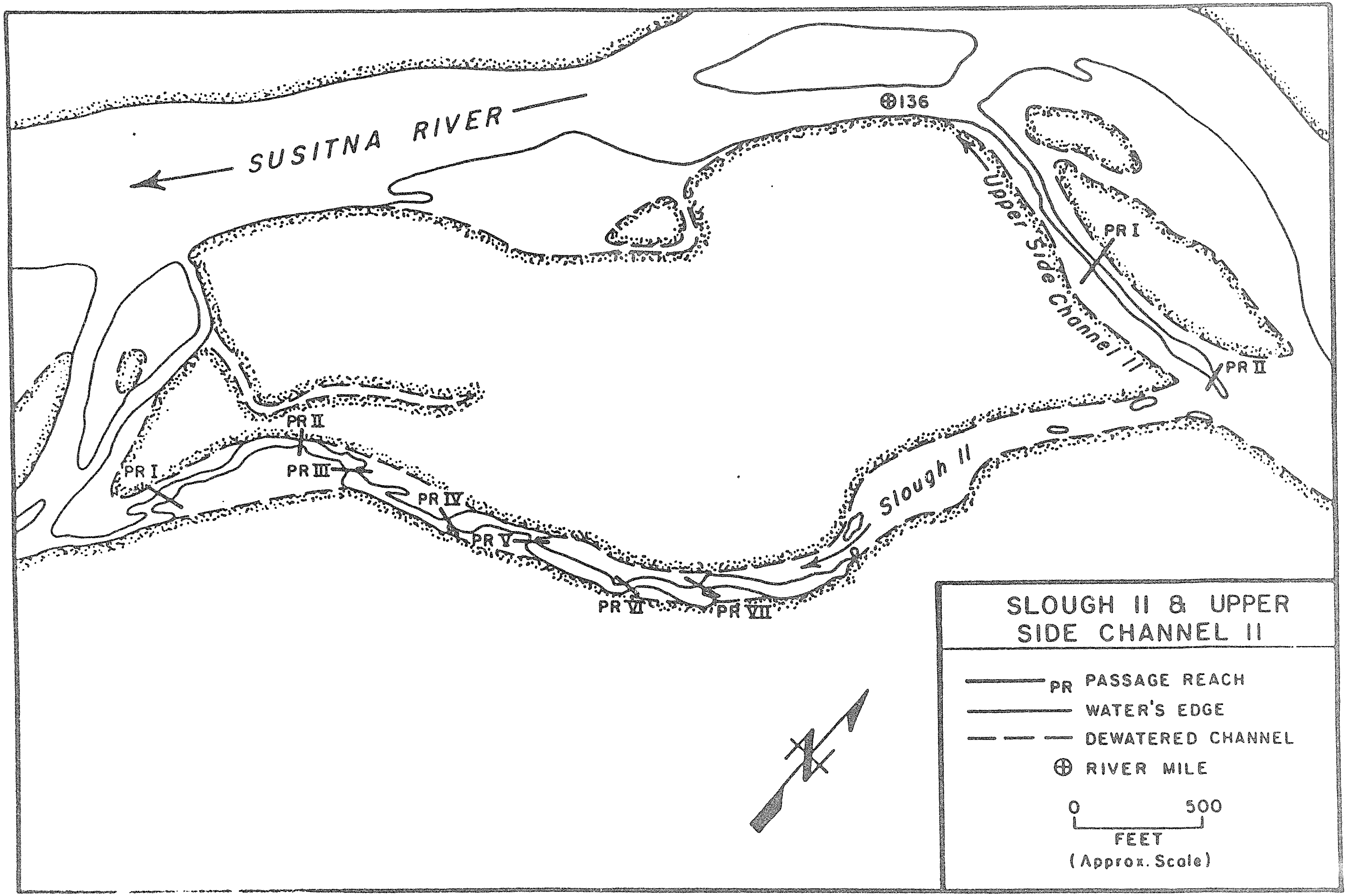
Appendix Figure B-5. Locations of passage reaches at Slough 9 during the 1984 open water season.



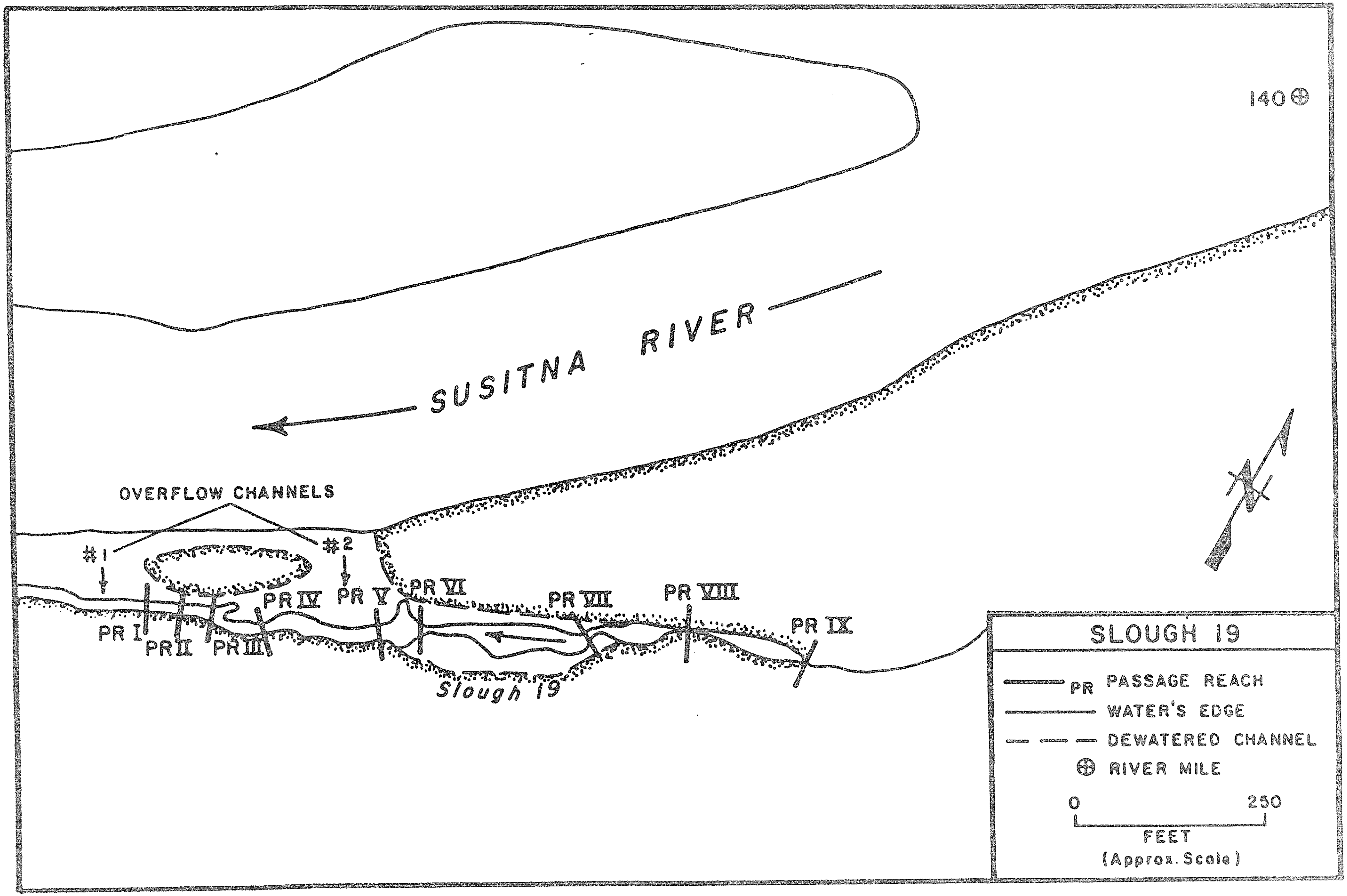
Appendix Figure B-6. Locations of passage reaches at Slough 9A during the 1984 open water season.



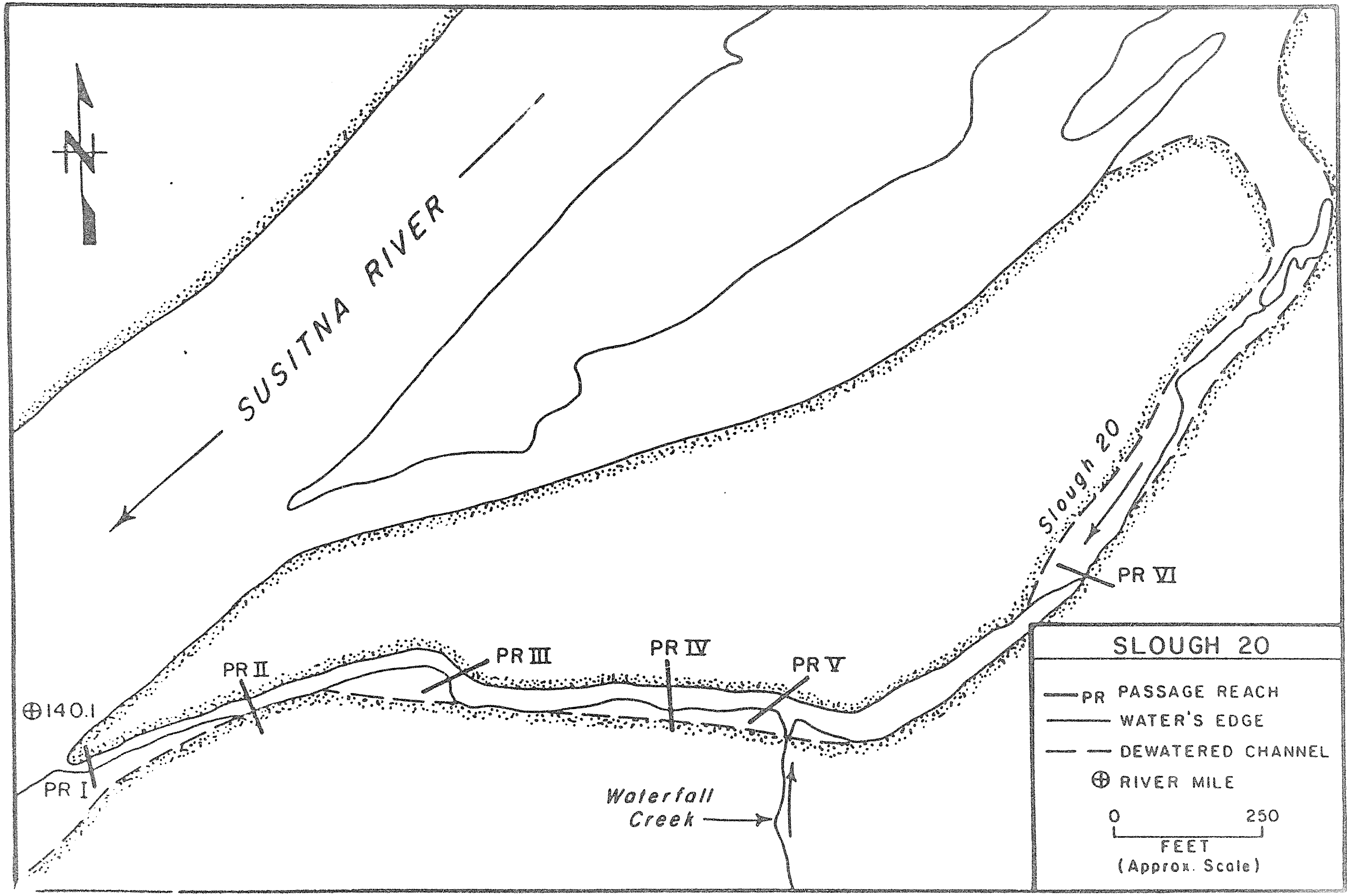
Appendix Figure B-7. Locations of passage reaches at Side Channel 10 as identified by the thalweg profile.



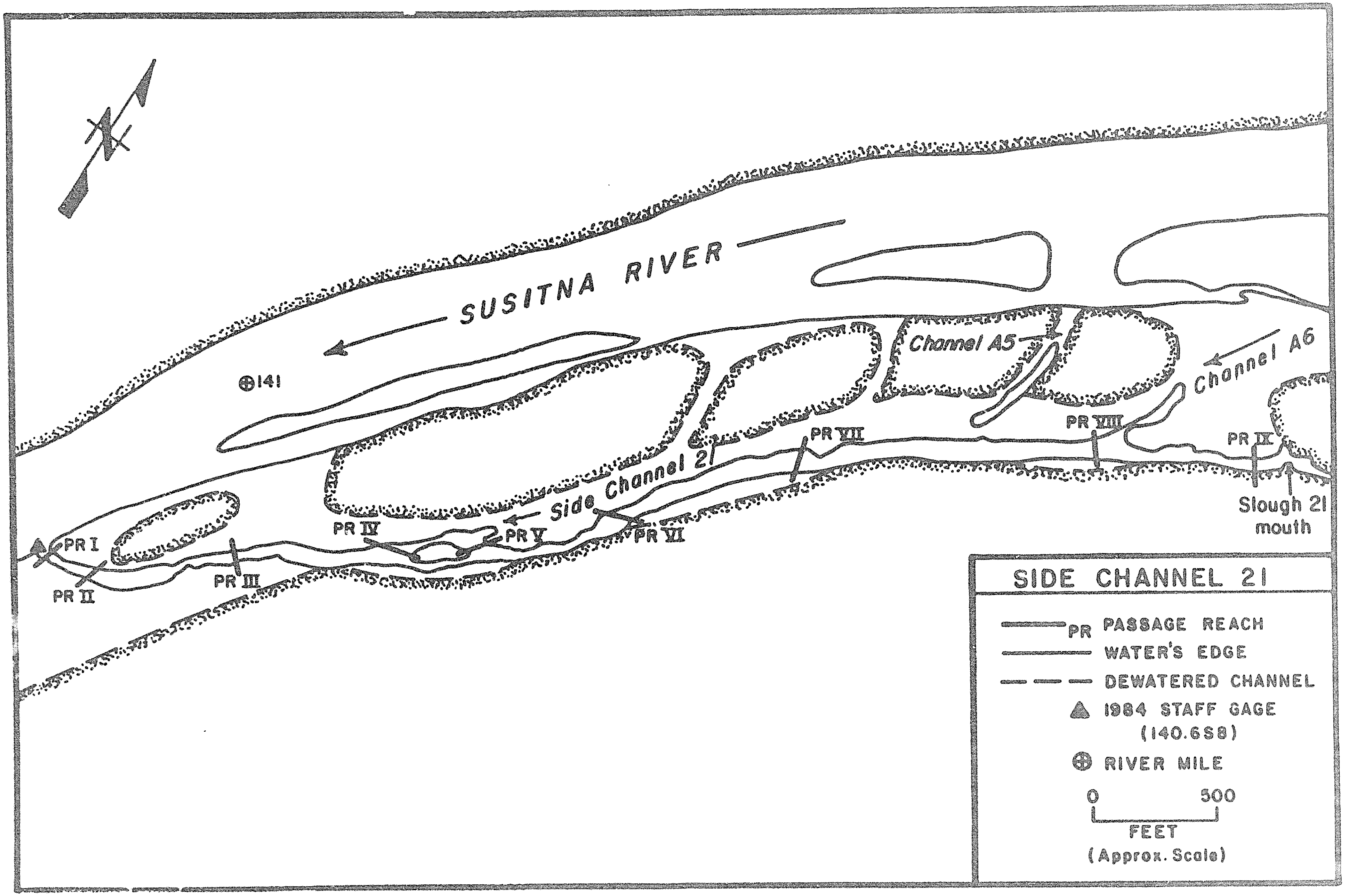
Appendix Figure B-8. Locations of passage reaches at Slough 11 and Upper Side Channel 11 during the 1984 open water season.



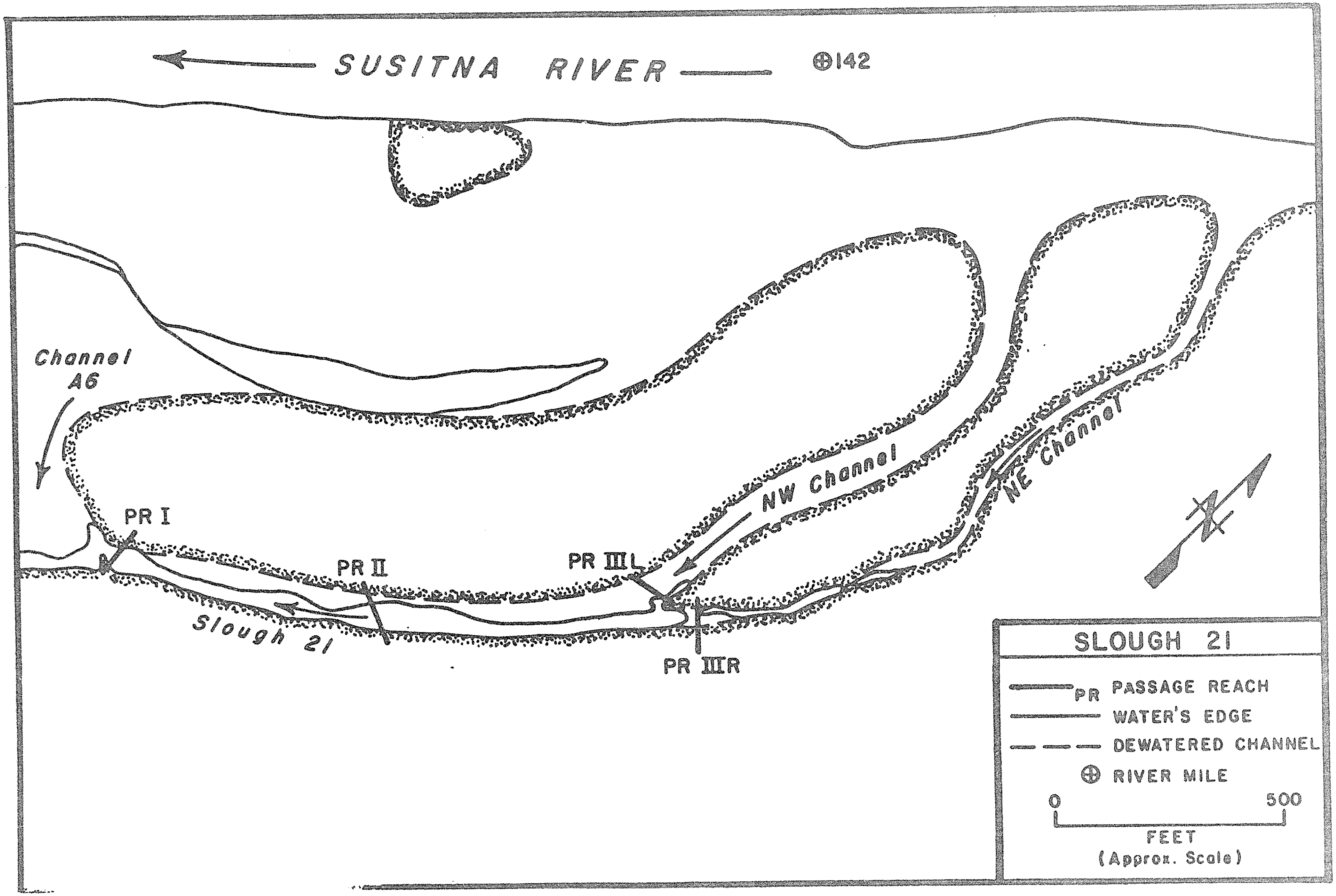
Appendix Figure B-9. Locations of passage reaches at Slough 19 during the 1984 open water season.



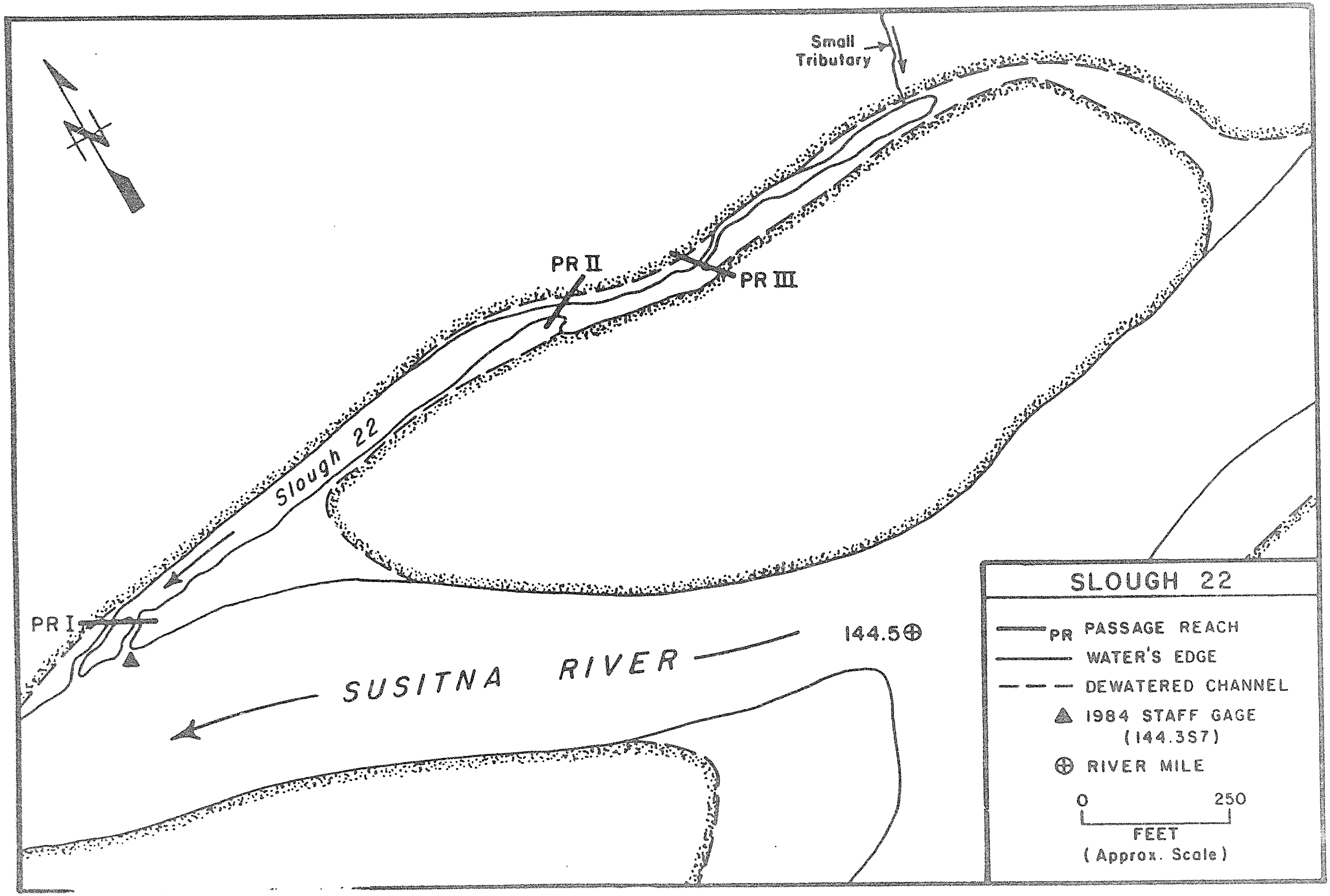
Appendix Figure B-10. Locations of passage reaches at Slough 20 during the 1984 open water season.



Appendix Figure B-11. Locations of passage reaches at Side Channel 21 during the 1984 open water season.



Appendix Figure B-12. Locations of passage reaches at Slough 21 during the 1984 open water season.



Appendix Figure B-13. Locations of passage reaches at Slough 22 during the 1984 open water season.

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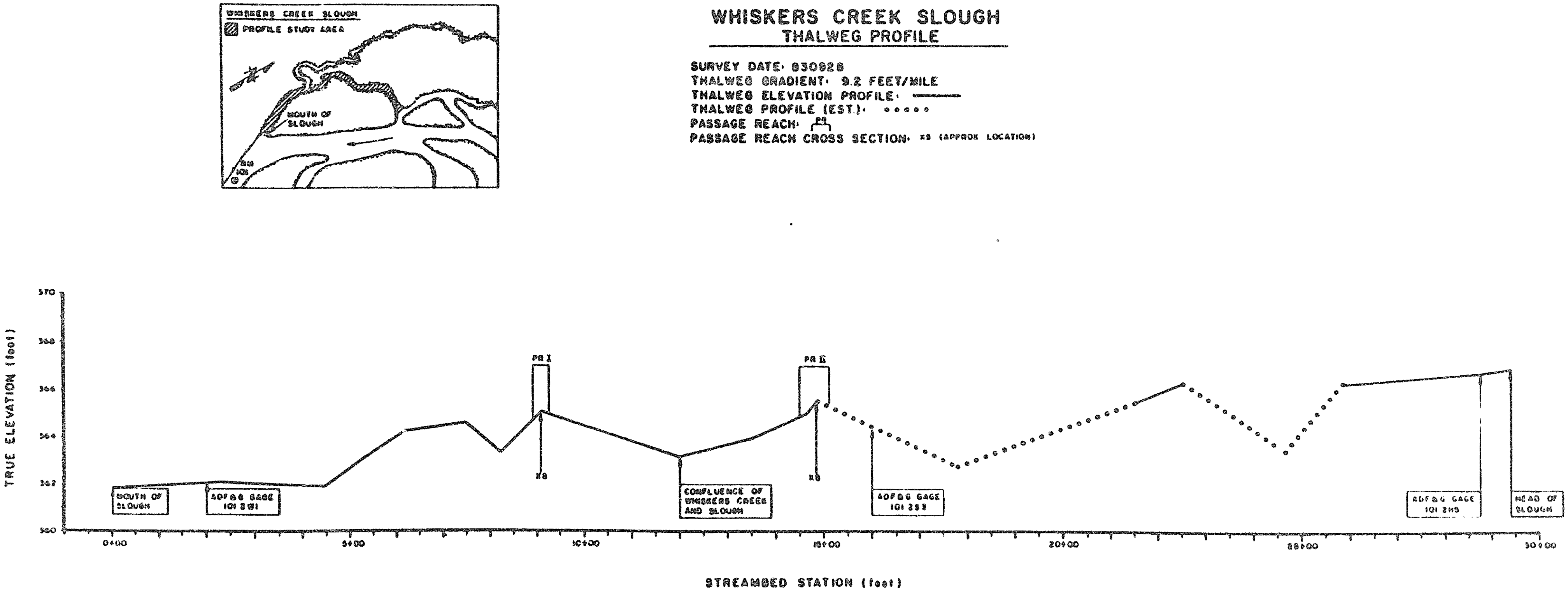
APPENDIX C

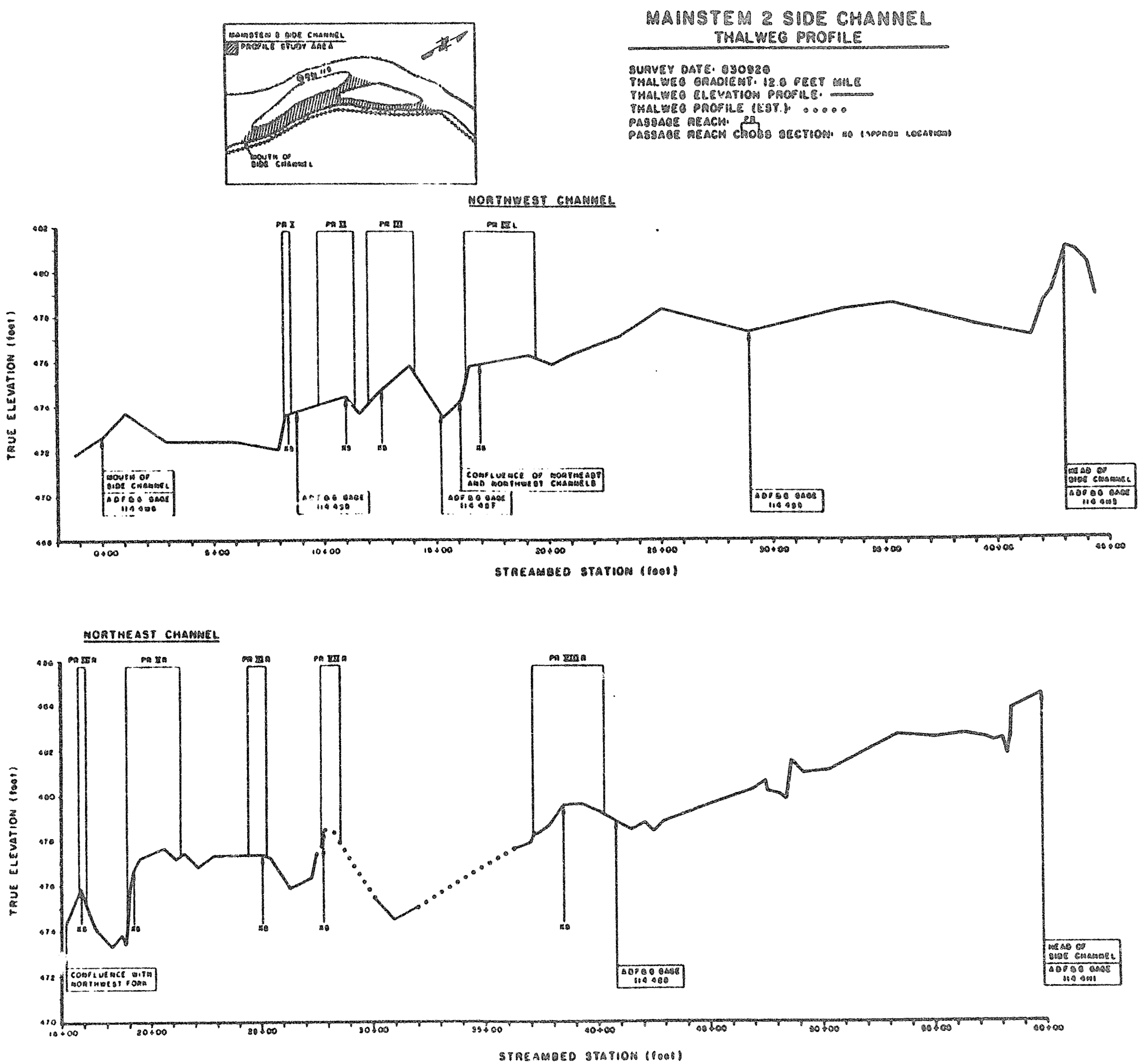
Thalweg Profiles of Passage Study Sites

APPENDIX C: THALWEG PROFILES OF PASSAGE STUDY SITES

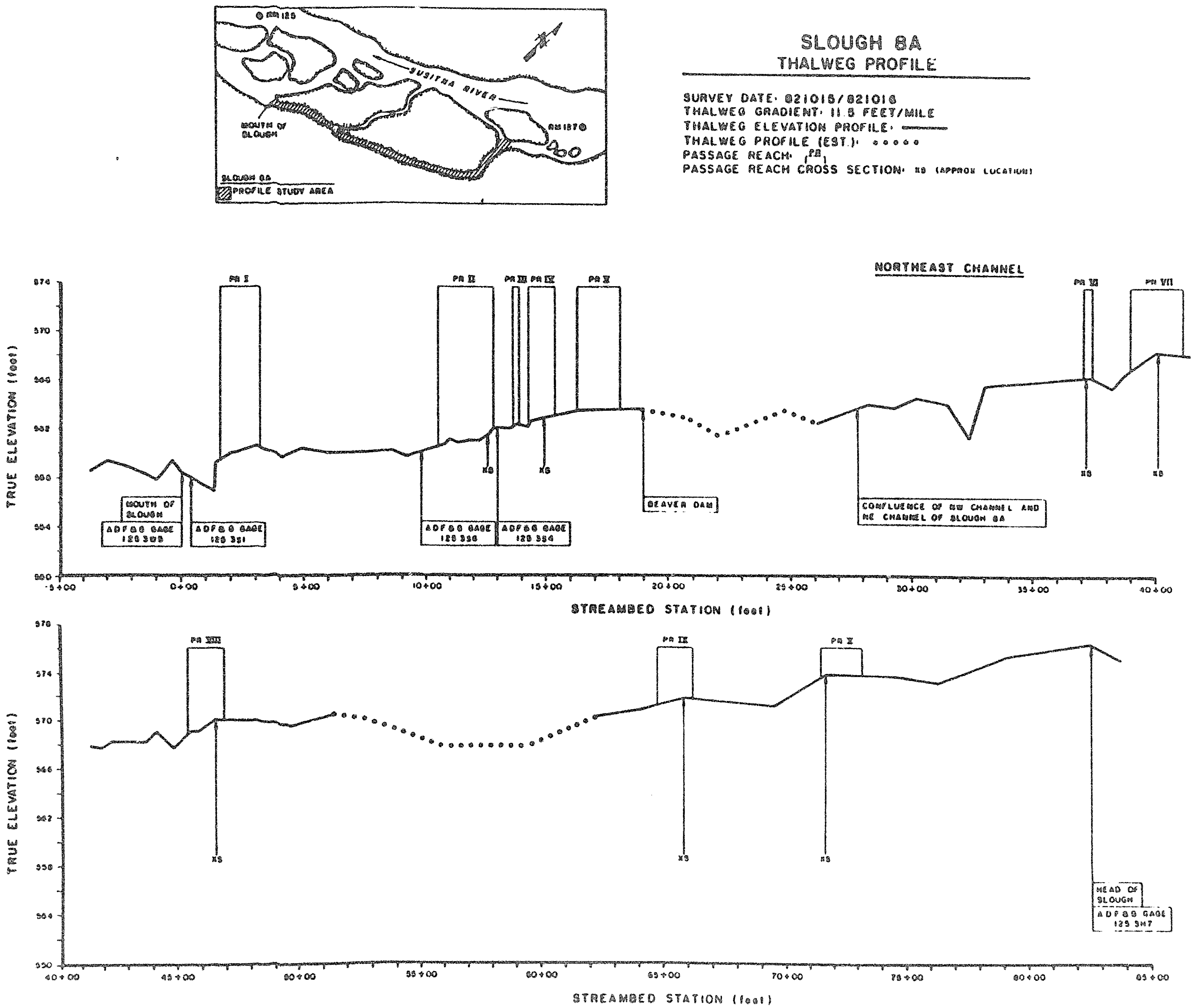
This appendix contains thalweg profiles of slough and side channel passage study sites illustrating passage reaches identified during the 1984 open water season (Appendix Figures C-1 to C-13). With the exception of Slough 19, these figures are revisions of thalweg profiles previously presented in Sautner et al. (1984). The Slough 19 thalweg, which was surveyed for the first time in 1984, is also presented here. Survey data used to complete the Slough 19 thalweg profile are summarized in Appendix Table C-1. Survey data for the other study sites are presented in Quane et al. (1984). These thalweg profiles are only intended to show approximate locations of passage reaches within each study site and due to their limited accuracy, should not be used for other, more detailed analyses.



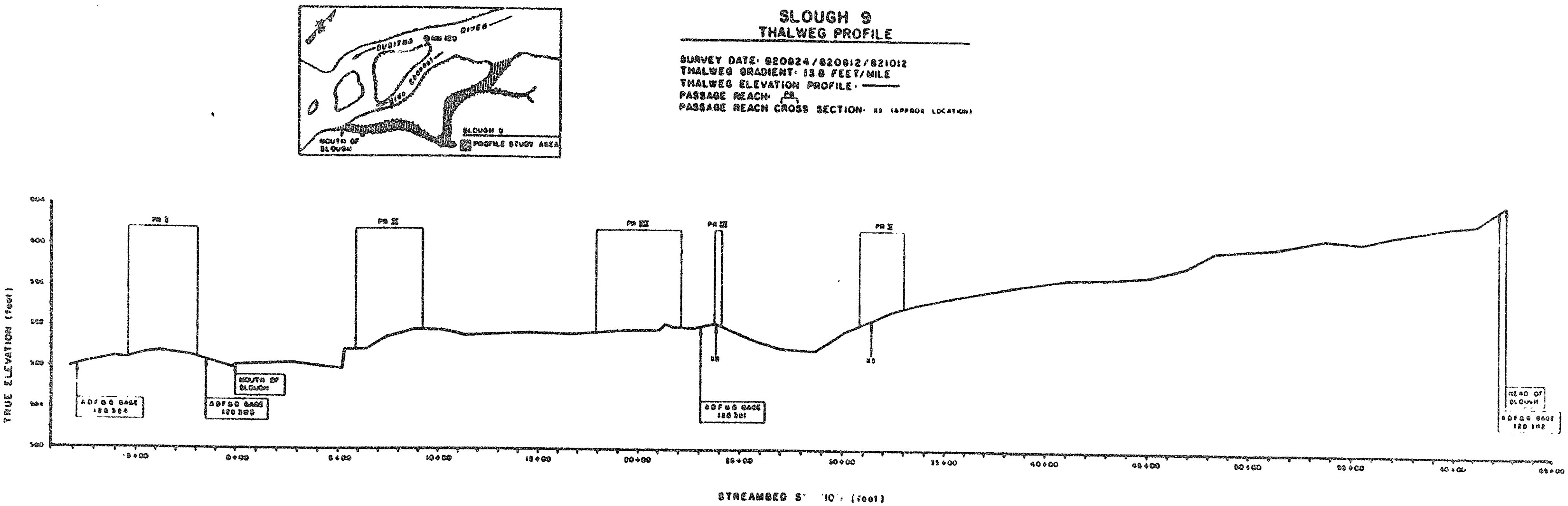
Appendix Figure C-1. Thalweg profile of Whiskers Creek Slough showing approximate locations of passage reaches.



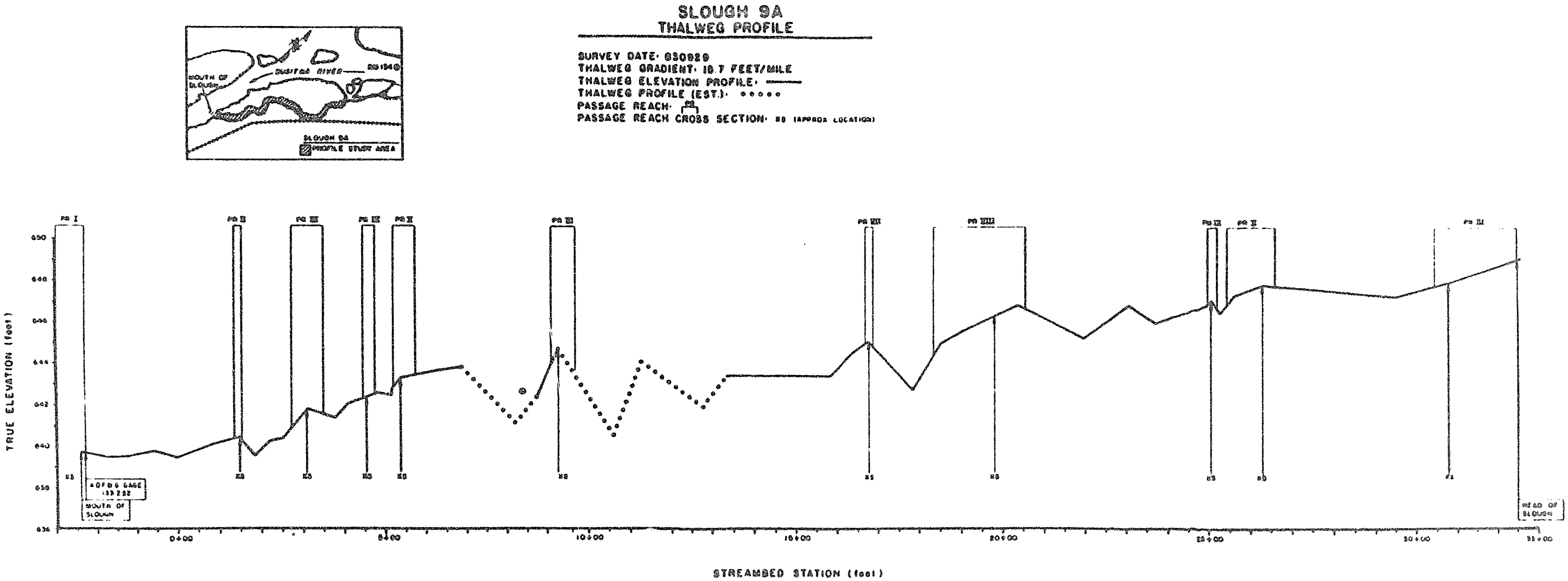
Appendix Figure C-2. Thalweg profile of Mainstem 2 Side Channel showing approximate locations of passage reaches.



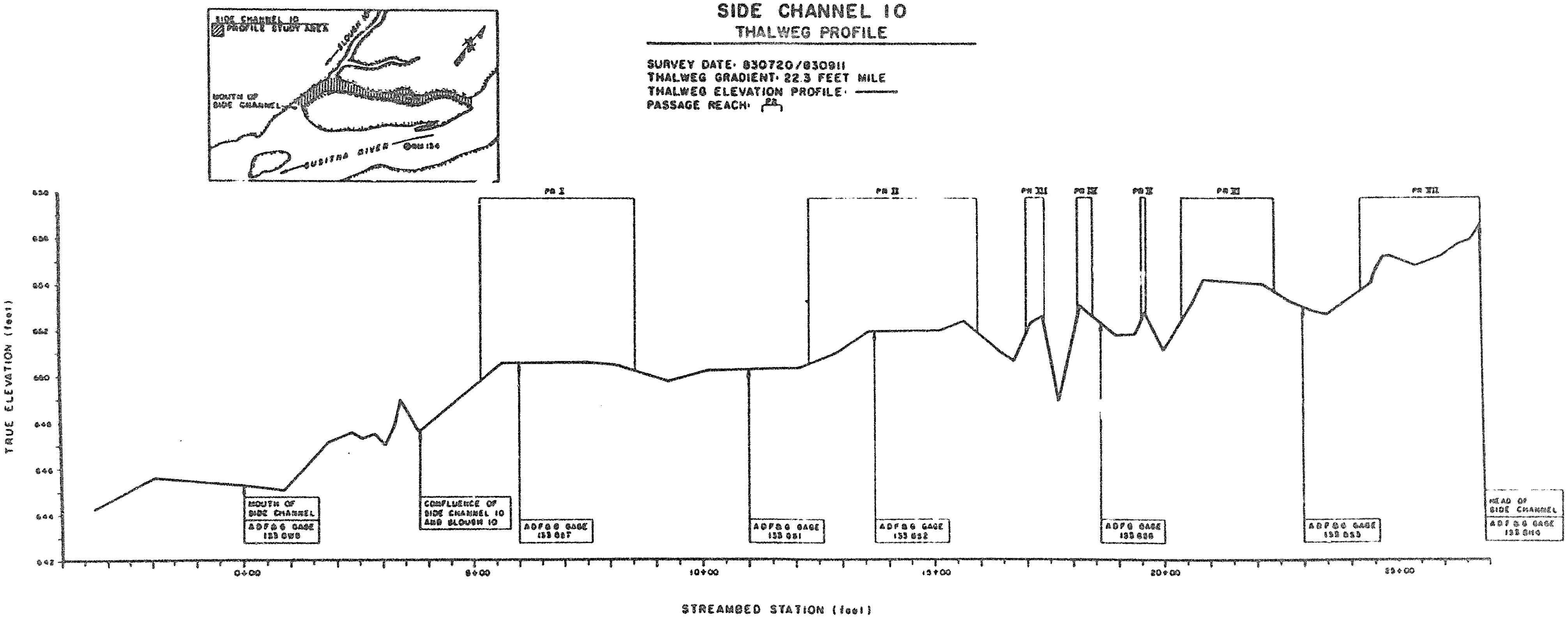
Appendix Figure C-3. Thalweg profile of Slough 8A showing approximate locations of passage reaches.



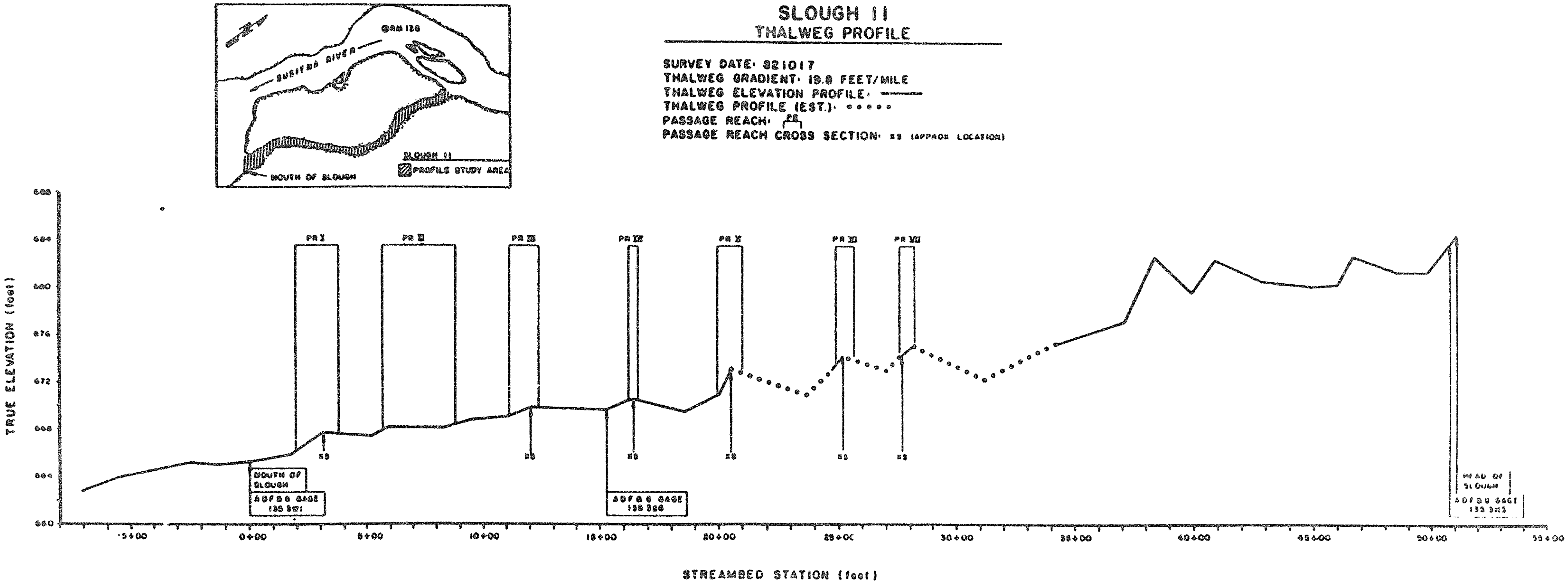
Appendix Figure C-4. Thalweg profile of Slough 9 showing approximate locations of passage reaches.



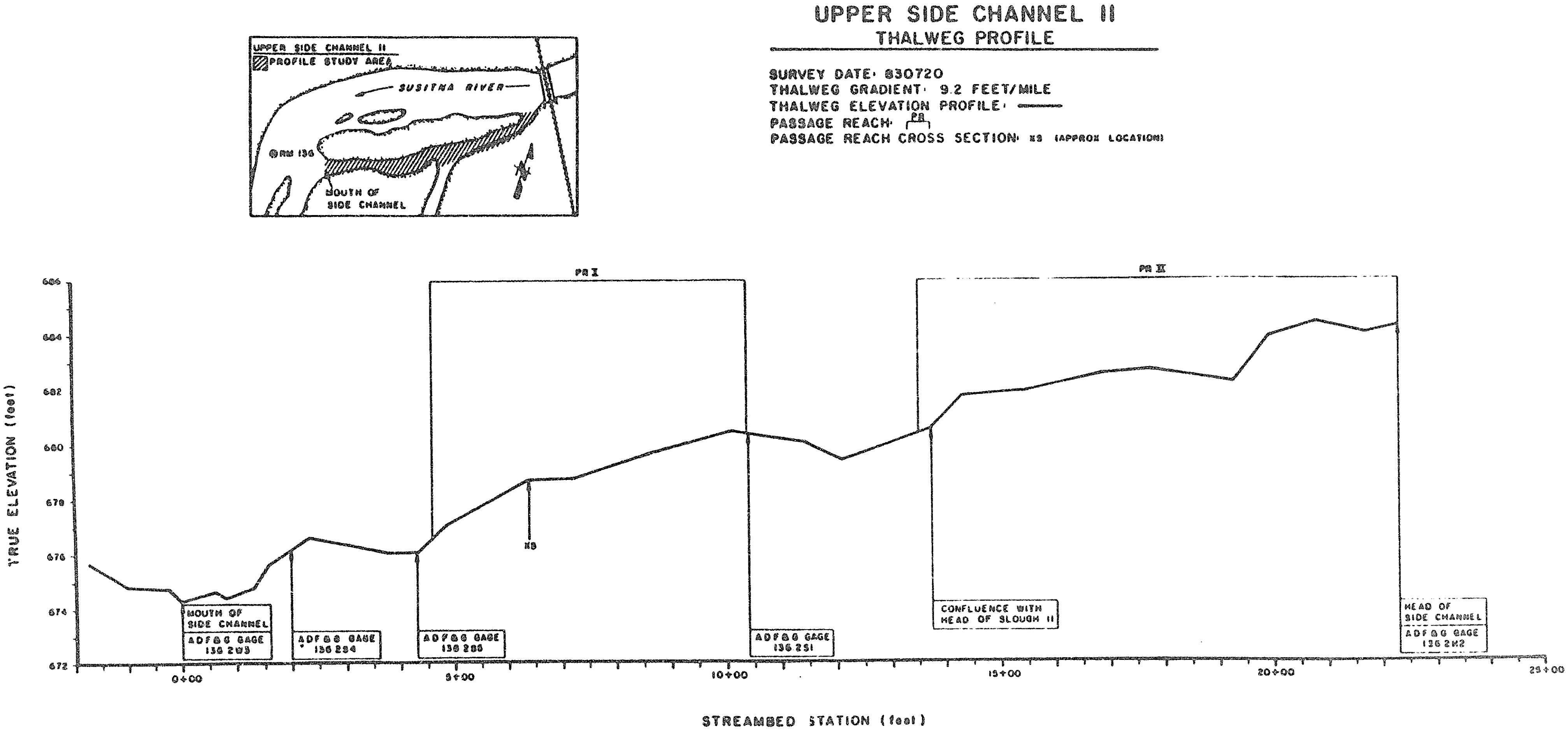
Appendix Figure C-5. Thalweg profile of Slough 9A showing approximate locations of passage reaches.



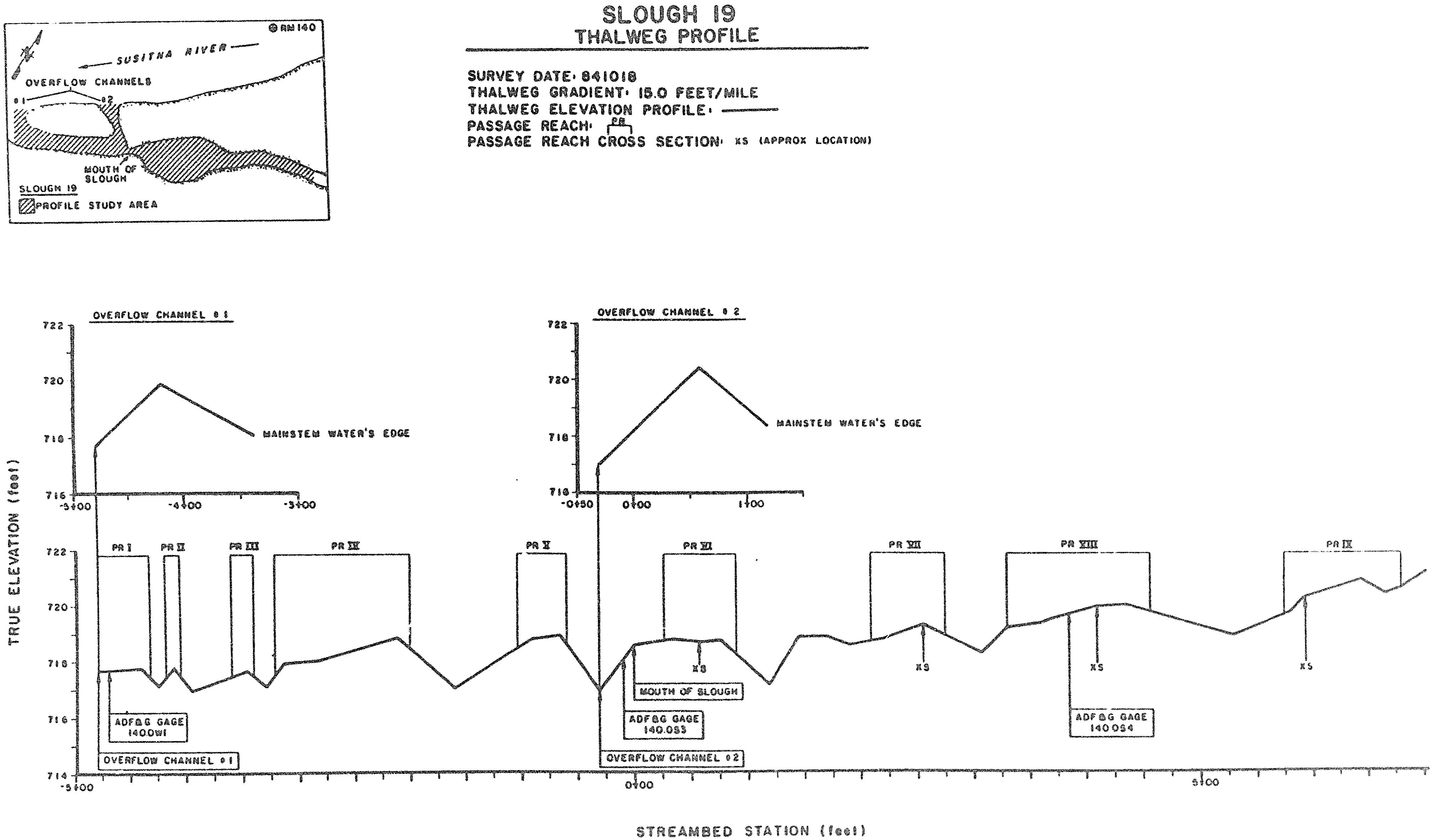
Appendix Figure C-6. Thalweg profile of Side Channel 10 showing approximate locations of passage reaches.



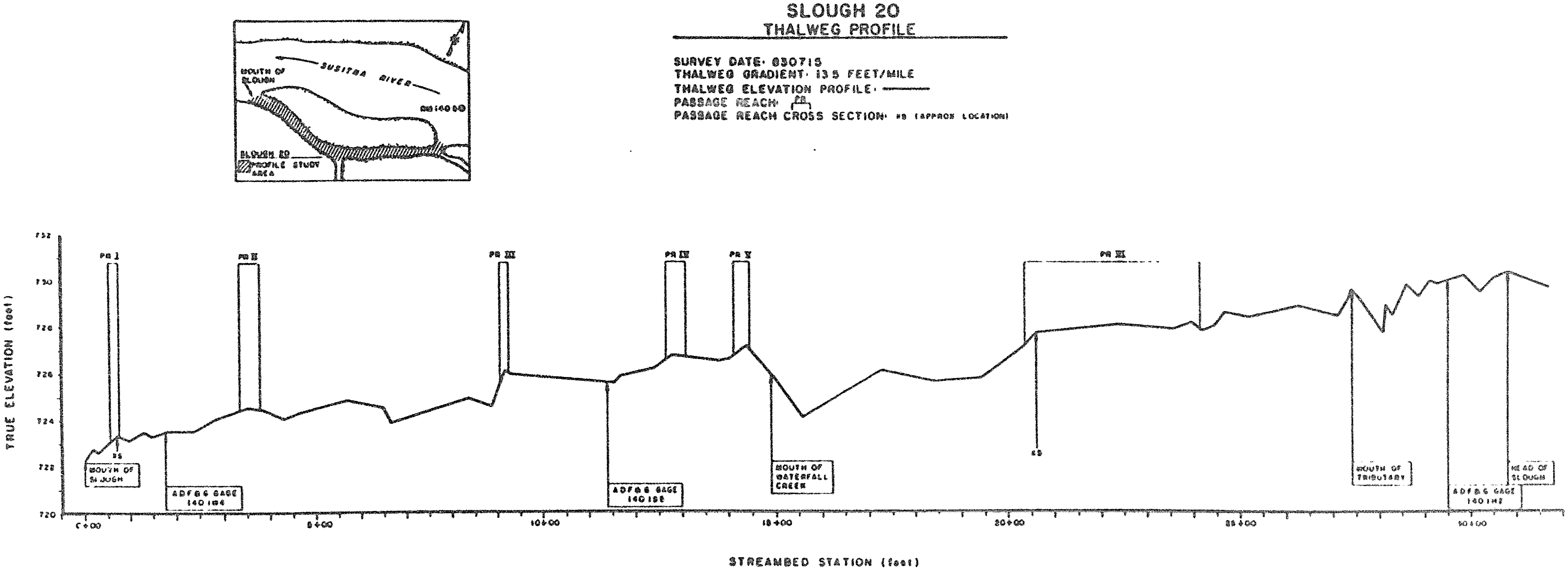
Appendix Figure C-7. Thalweg profile of Slough 11 showing approximate locations of passage reaches.



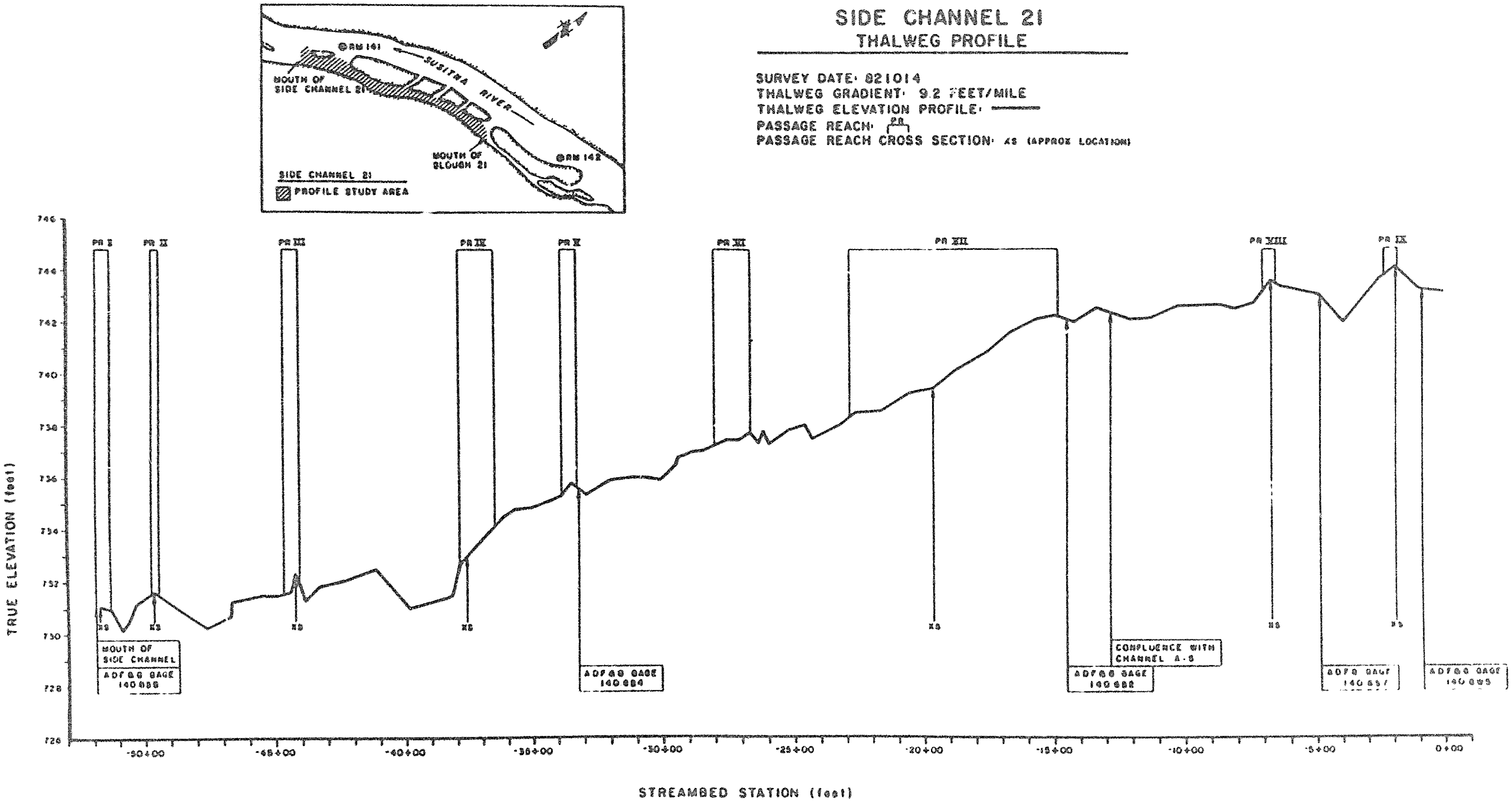
Appendix Figure C-8. Thalweg profile of Upper Side Channel 11 showing approximate locations of passage reaches.



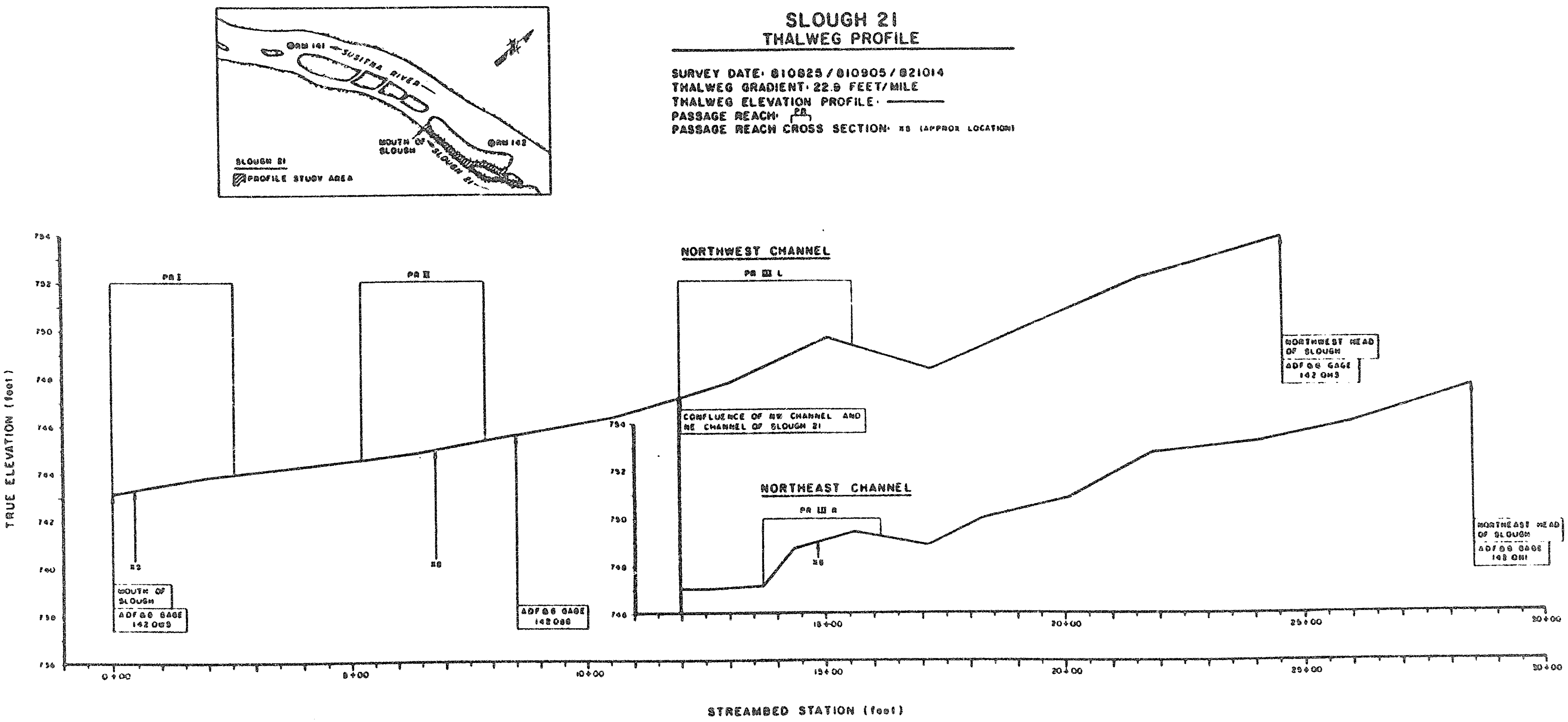
Appendix Figure C-9. Thalweg profile of Slough 19 showing approximate locations of passage reaches.



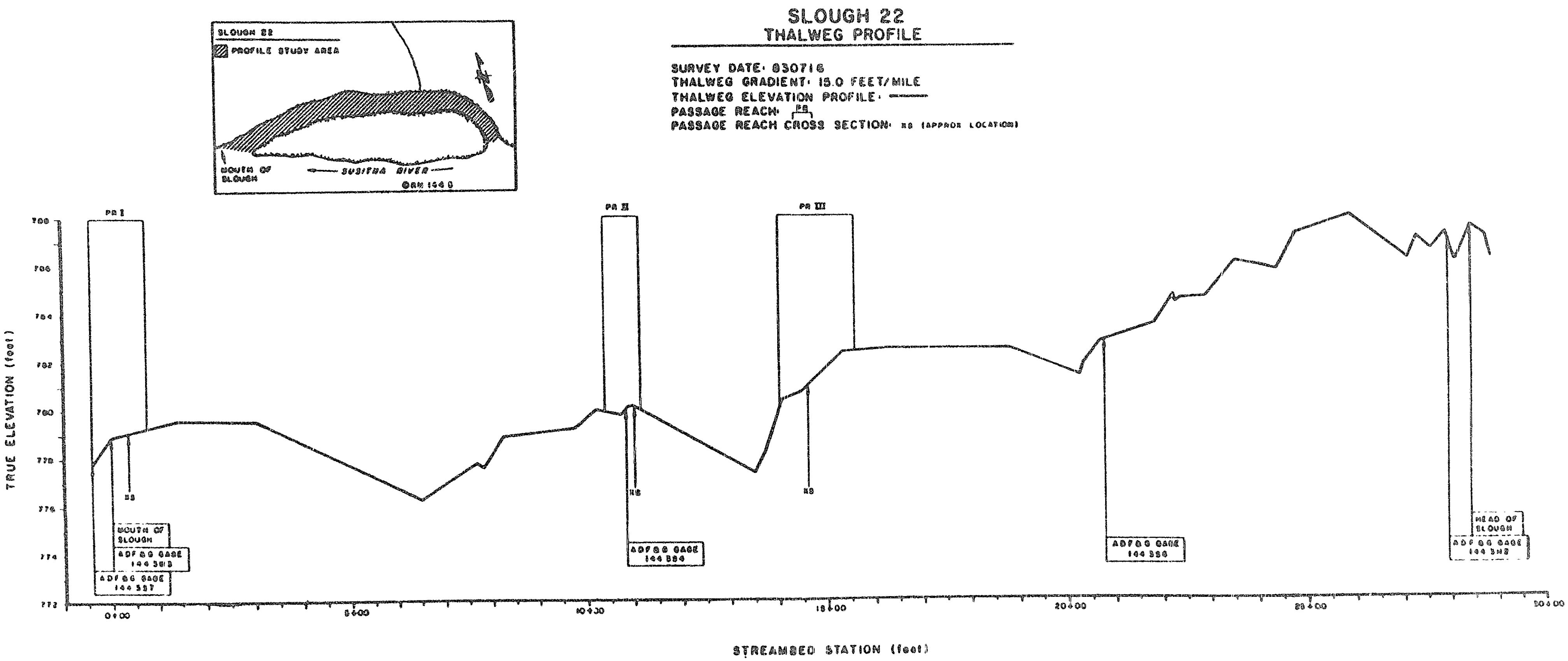
Appendix Figure C-10. Thalweg profile of Slough 20 showing approximate locations of passage reaches.



Appendix Figure C-11. Thalweg profile of Side Channel 21 showing approximate locations of passage reaches.



Appendix Figure C-12. Thalweg profile of Slough 21 showing approximate locations of passage reaches.



Appendix Figure C-13. Thalweg profile of Slough 22 showing approximate locations of passage reaches.

Appendix Table C-1. Summary of survey data collected for the thalweg profile of Slough 19 during the 1984 open water field season.

LOCATION OF THALWEG: Slough 19 (RM 140.0)
SITE FLOW: 0.1 cfs
USGS DISCHARGE: 5200 cfs

DATE: OCTOBER 18, 1984
TBM ID: ADF&G 140.0 RB 830914
Slough 19

Station (ft)	Thalweg Elevation (ft)	Water Depth (ft)	WSEL (ft)	Substrate Code[a]	Habitat Description
-4 + 79	717.70	0.20	717.90	SASI	Mid-Riffle
-4 + 40	717.79	0.17	717.96		Riffle/Pool
-4 + 24	717.16	0.80	717.96		Mid-Pool
-4 + 11	717.81	0.15	717.96	BOSI	Pool Constriction
-3 + 95	716.96	1.00	717.96	SISA	Mid-Pool
-3 + 46	717.64	0.33	717.97	SIBO	Pool Constriction
-3 + 29	717.09	0.89	717.98	SISA	Mid-Pool
-3 + 13	717.95	0.08	718.03	SISA	Pool/Riffle
-2 + 83	718.01	0.13	718.14	COSA	Mid-Riffle
-2 + 12	718.86	0.12	718.98	BOSA	Riffle/Pool
-1 + 60	717.06	1.90	718.96	SISA	Mid-Pool
-0 + 92	718.77	0.20	718.97		Pool/Riffle
-0 + 66	718.90	0.13	719.03	COSA	Riffle/Pool
-0 + 31	716.99	2.03	719.02	SISA	Mid-Pool
0 + 00	718.58	0.44	719.02	SISA	Mid-Pool, Mouth
0 + 36	718.80	0.22	719.02	SISA	Pool/Run
0 + 58	718.70	0.32	719.02	SISA	Mid-Run
0 + 76	718.77	0.27	719.04	SISA	Run/Pool
1 + 19	717.15	1.90	719.05	SISA	Mid-Pool
1 + 45	718.83	0.19	719.02	SISA	Pool/Run
1 + 70	718.84	0.21	719.05	SISA	Run/Pool
1 + 90	718.56	0.48	719.04	SISA	Mid-Pool
2 + 20	718.77	0.28	719.05	SISA	Pool/Riffle
2 + 56	719.28	0.09	719.37	BOCO	Riffle/Pool

Appendix Table C-1 (Continued).

Station (ft)	Thalweg Elevation (ft)	Water Depth (ft)	WSEL (ft)	Substrate[a] Code	Habitat Description
3 + 07	718.29	1.14	719.43	SISA	Mid-Pool
3 + 30	719.15	0.28	719.43	SISA	Pool/Riffle
3 + 60	719.31	0.13	719.44	SGSA	Mid-Riffle
3 + 69	719.47	0.01	719.48	LGSG	Mid-Riffle
4 + 11	719.89	DRY	719.89	LGSG	Mid-Riffle
4 + 35	719.95	ICE	719.95	SALG	Riffle/Pool
5 + 30	718.84	1.03	719.87	SISA	Mid-Pool
5 + 81	719.65	0.18	719.83	SA	Pool/Riffle
5 + 93	720.17	0.00	720.17	BOSI	Mid-Riffle
6 + 46	720.79	ICE	720.79	COBO	Riffle/Pool
6 + 67	720.30	0.35	720.65	CORU	Mid-Pool
6 + 81	720.48	ICE	720.65	CORU	Pool/Riffle
7 + 04	721.05	0.00	721.05	CORU	Riffle
Overflow Channel 1					
-4 + 79	717.70	0.20	717.90	SASI	Mid-Riffle
-4 + 20	719.89	DRY	719.89	CORU	High Point in Over-Flow Channel
-3 + 38	718.06	0.00	718.06	CORU	Mainstem Waters Edge
Overflow Channel 2					
-0 + 31	716.99	2.03	719.02	SISA	Mid-Pool
0 + 60	720.45	DRY	720.45	CORU	High Point in Overflow Channel
1 + 20	718.33	DRY	718.33	CORU	Mainstem Waters Edge

[a] Substrate code defined in Methods Section (see Table 2).

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