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A DATA SUMMARY OF SURFACE AND INTRAGRAVEL WATER TEMPERATURE AND SUBSTRATE COMPOSITION OF MIDDLE SUSITNA RIVER MAINSTEM, SIDE CHANNEL AND TRIBUTARY SALMON SPAWNING HABITATS

Report No. 12

by

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ABSTRACT

The habitat characteristics of mainstem and side channel habitats in the middle reach of the Susitna River are expected to be altered by construction and operation of the Susitna Hydroelectric Project. Areas where salmon spawning was previously limited by high water velocities are expected to become more suitable for salmon spawning under the new flow regime with only minor habitat modifications necessary. As a mitigation option, these areas may be used to replace salmon spawning habitat that is lost in other areas due to changes in mainstem discharge.

The open water portion of the study examined the general habitat characteristics of 62 side channel and 27 mainstem sites. The selection of open water study sites was based on areas of open leads determined from aerial photographs, and spawning ground surveys. Selected sites from the open water study were chosen to continuously monitor water temperatures and determine substrate composition. Tributary habitats are generally highly utilized by spawning salmon. Mainstem and side channel spawning and non-spawning areas that had upwelling were compared against tributary habitats to determine their potential as replacement salmon spawning habitats. Areas without upwelling appear unsuitable as spawning habitats.

A data summary of water temperatures and substrate composition is presented to assist in determining the feasibility of using replacement spawning habitats as a mitigation option. Substrate composition in all

areas is comparable, with present non-spawning upwelling areas having a greater percentage of fine sediments less than 1.0 mm. Intragravel water temperatures in all sites are comparable, with non-spawning upwelling areas having the warmest and tributaries the coldest. This preliminary water temperature and substrate data indicates that present mainstem and side channel areas that have open leads but no present spawning may have potential as replacement salmon spawning habitat. Under with-project conditions, these areas may also require minor habitat modifications such as providing passage or loosening cemented substrate to provide suitable salmon spawning habitat.

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1.0 INTRODUCTION

This report presents a summary of surface and intragravel water temperature and substrate composition data in selected tributary, side channel and mainstem salmon spawning habitats in the middle reach of the Susitna River (Talkeetna, RM 98.0, to Devil Canyon, RM 152.0, Figure 1). These data will provide information which can be used for planning potential mitigation measures, such as locating areas that may be suitable as replacement salmon spawning habitat, and to assist in determining possible effects of with-project water temperature regimes on salmon spawning habitat. Mainstem and side channel areas that exhibit upwelling related open leads without reported salmon spawning were considered the most promising sites for replacement salmon spawning habitat becoming available and were the primary focus of this study. Other areas were considered as replacement habitat sites but were more limited in regard to suitable habitat characteristics and are therefore only discussed briefly in this report. The report is based on a two-phase study conducted during the open water and ice covered sampling periods from July 1 to October 15, 1984 and November 1, 1984 to April 25, 1985, respectively.

1.1 Background

A goal of the Alaska Power Authority (APA) is to insure that there is no net loss of fisheries production as a result of the construction and operation of the Susitna Hydroelectric Project (APA 1982). To meet this

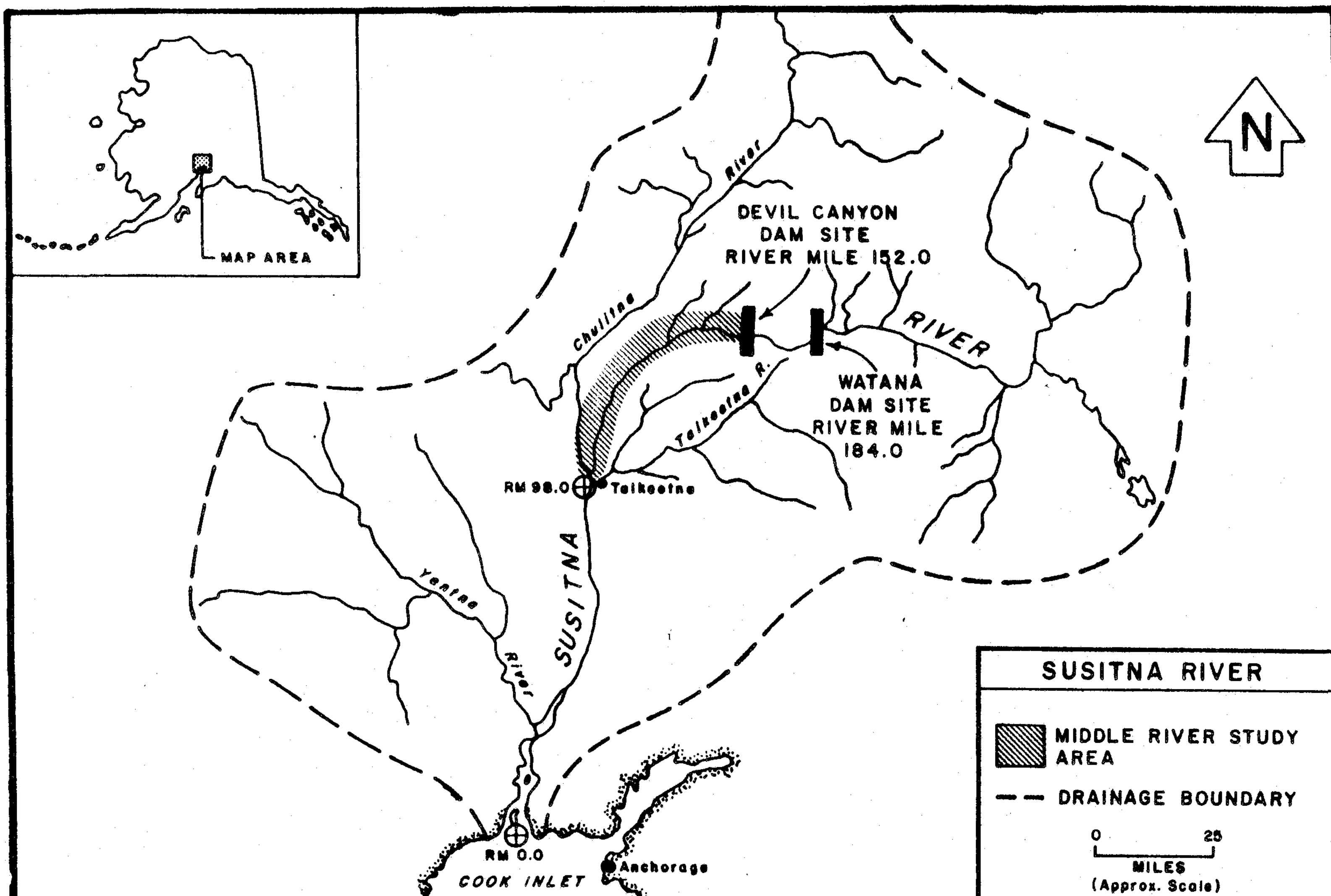

Figure 1. Drainage basin of the Susitna River, illustrating the middle reach study area from Talkeetna (RM 98.0) to the mouth of Devil Canyon (RM 150.0), 1984.

goal, the APA has supported maintaining the existing habitat or providing replacement habitat of sufficient quantity and quality to maintain the productivity of the present natural fish populations (APA 1983). This study evaluated the potential of replacement habitat, suitable for salmon spawning and incubation, becoming available under with-project flow conditions in the mainstem Susitna River to compensate for possible salmon spawning habitat losses in currently utilized peripheral habitats. This study examined two parameters, intragravel water temperature and substrate composition, which affect the incubation environment and therefore affect salmon spawning. The presence of upwelling, which affects water temperatures in the intragravel environment, was also considered when evaluating potential replacement salmon spawning habitat.

Development of the Susitna Hydroelectric Project is anticipated to result in a mean annual water temperature increase, and stabilize the natural annual discharge of the Susitna River (APA 1983). Lower than normal discharges are expected during the period of June through September with higher than normal discharges occurring during the rest of the year, resulting in a relatively constant annual discharge regime (Moulton et al. 1984). The change in the annual discharge regime of the Susitna River will likely result in changes in present habitat characteristics. Habitats presently classified as side channels may become sloughs and mainstem areas may become side channels (Klinger and Trihey 1984). The overall result will be that mainstem and side channel areas that were previously limited as salmon spawning habitats by high velocities, may become suitable for spawning, assuming other physical habitat requirements (temperature, substrate, upwelling, etc.) are acceptable.

The middle reach of the Susitna River was selected for this study because the most significant changes in the physical characteristics of aquatic habitats are expected to occur in this reach. Three habitat types, tributary, side channel and mainstem, were selected as the foci of this study. Tributary habitats are utilized by all five species of salmon spawning in the middle reach of the Susitna River (Figure 2). They were included in this study for comparison of water temperature and substrate characteristics with salmon spawning areas in mainstem and side channel habitats. Tributary habitats are not expected to be affected by changes in mainstem discharge (Trihey 1983). Mainstem and side channel habitats, which will be affected to a greater degree than tributary habitats, are the primary areas where replacement spawning habitats are likely to become available under with-project flow conditions. Chinook salmon are the only species that have not been observed spawning in mainstem or side channel habitats (Figure 2).

1.2 Objectives

To evaluate the feasibility of replacement salmon spawning habitat becoming available under with project flow conditions in mainstem and side channel sites in the middle Susitna River, a two phase study was initiated during the 1984 open water season. The initial phase

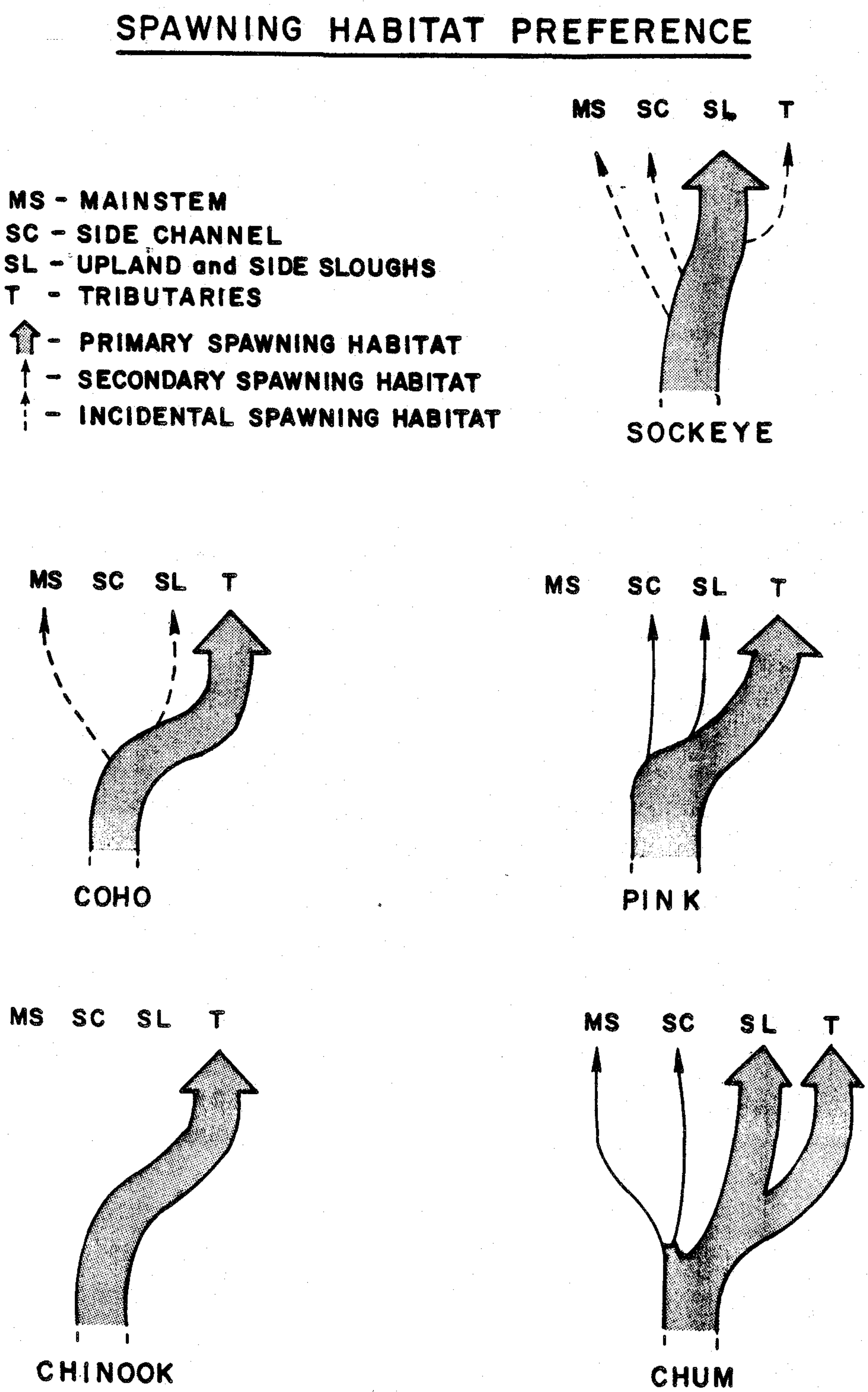

Figure 2. General spawning habitat preference of the five species of salmon utilizing the Susitna River basin. (derived from data from Barrett et al 1984).

consisted of a preliminary assessment of potential replacement salmon spawning habitat by locating areas of open leads in the ice cover using aerial photographs from March 1983. Open leads that were in areas of known or suspected upwelling were selected for reconnaissance surveys during the open water period. Open leads that are a result of upwelling, were selected as indicators of potential spawning sites due to chum salmons preference for spawning in areas of upwelling (Kogl 1965; Bakkala 1970; Vining et al. 1985). The surveys evaluated general habitat characteristics (habitat types, general substrate composition, instantaneous surface and intragravel water temperatures, and upwelling) in each of the sites. A preliminary assessment was made to determine if each open lead was upwelling or velocity related. Data from ADF&G spawning surveys (Barrett et al. 1984) were later included to indicate which sites were presently used by spawning salmon. Data from these surveys were also used to assist in identifying potential sites that could be used as replacement salmon spawning habitats as an alternative for maintaining naturally occurring salmon populations during construction and operation of the proposed hydroelectric project. The second phase of the study provides a preliminary evaluation of intragravel water temperature and substrate composition affecting the incubation environment of selected sites in each habitat type. These data were collected to provide additional information for determining the feasibility of replacement salmon spawning habitats becoming available in the middle Susitna River.

The present study was designed to provide additional data to be used to supplement previous fish mitigation plans (Moulton et al. 1984). This study's recommendations as to the feasibility of this alternative as a mitigation option are presented in this report by addressing the following objective:

1. Evaluate the feasibility of using replacement salmon spawning habitat as a mitigation option by comparing the incubation environment (substrate composition and intragravel water temperature) in selected tributary, side channel and mainstem habitats.

2.0 METHODS

2.1 Open Water Studies

2.1.1 Site Selection

Mainstem and side channel habitats in the middle reach of the Susitna River (Figures 3-9) were selected for study because these habitats will be greatly affected by changes in mainstem discharge and appear to provide the greatest potential for providing replacement salmon spawning habitats. Sixty-two side channel sites and 27 mainstem sites were selected for reconnaissance level surveys of general habitat characteristics during the 1984 open water studies.

The selection of reconnaissance sites to be evaluated in this study was initially determined by locating mainstem and side channel habitat areas that contained open leads during the ice covered period. Open leads in the mainstem Susitna River are considered to be indicators of either thermal influences resulting from the presence of upwelling, or high water velocities. Upwelling related open leads were used as indicators of possible salmon spawning areas based on the preference of chum salmon to select upwelling areas for spawning (Kogl 1965; Bakkala 1970; Vincent-lang et al. 1984; Vining et al. 1985). Open leads resulting from thermal influences were initially identified in the mainstem and side channels of the middle reach of the Susitna River by E. Woody Trihey and Associates (EWT&A) using aerial photographs from March, 1983

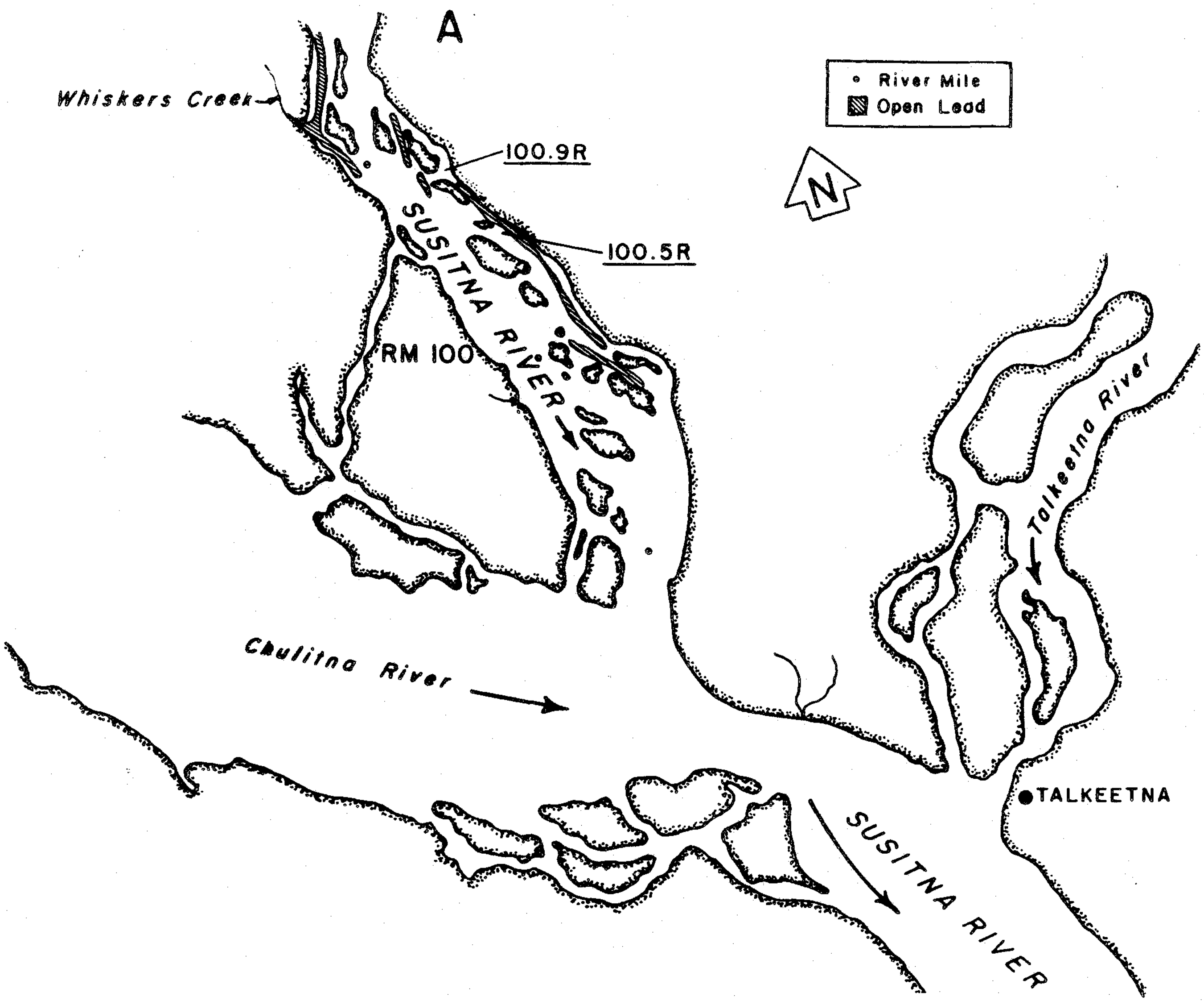

Figure 3. Map of the middle Susitna River from RM 98.0 to 101.5 showing study sites and open leads, 1984.

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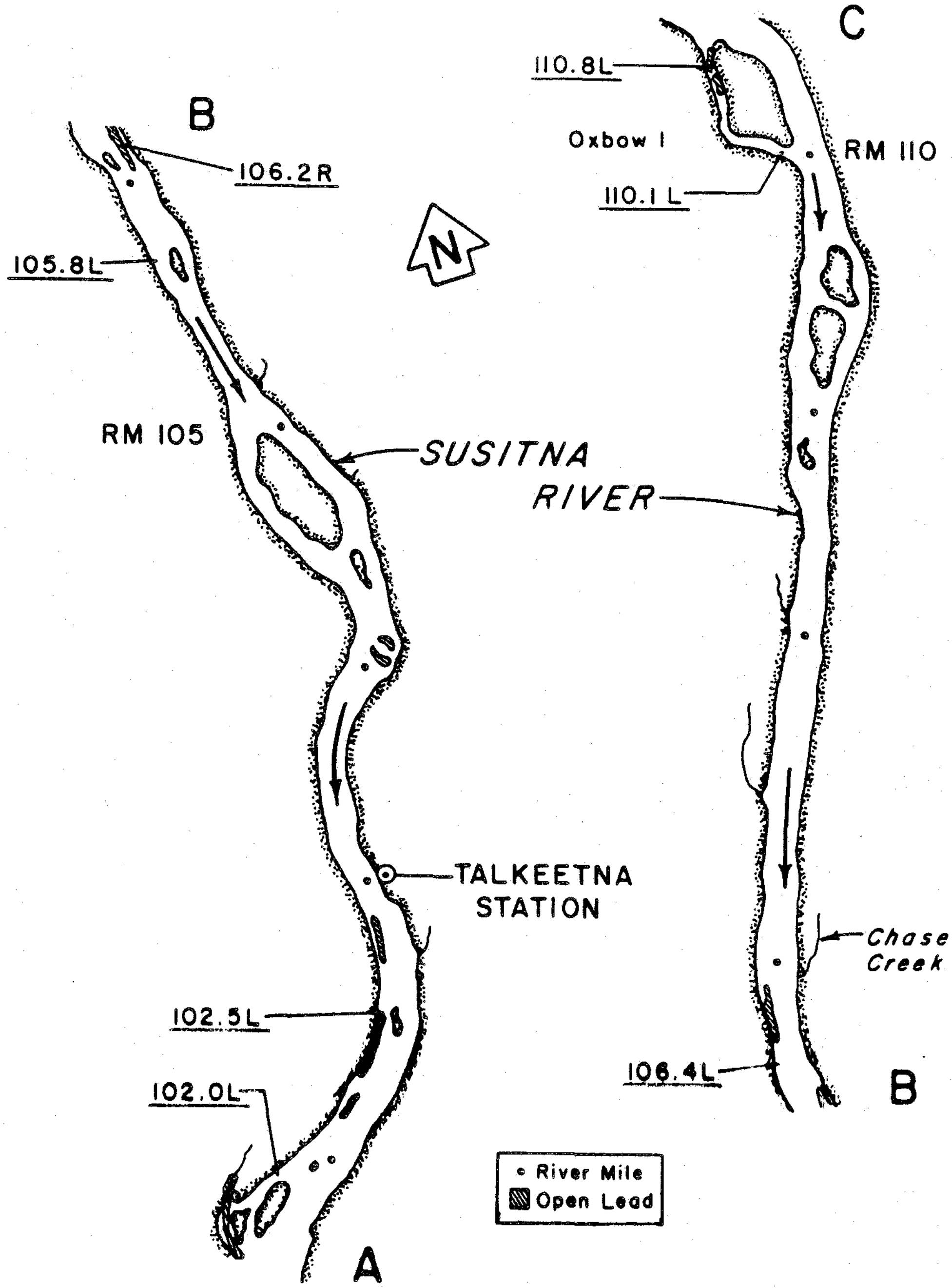

Figure 4. Map of the middle Susitna River from RM 101.5 to 110.5 showing study sites and open leads, 1984.

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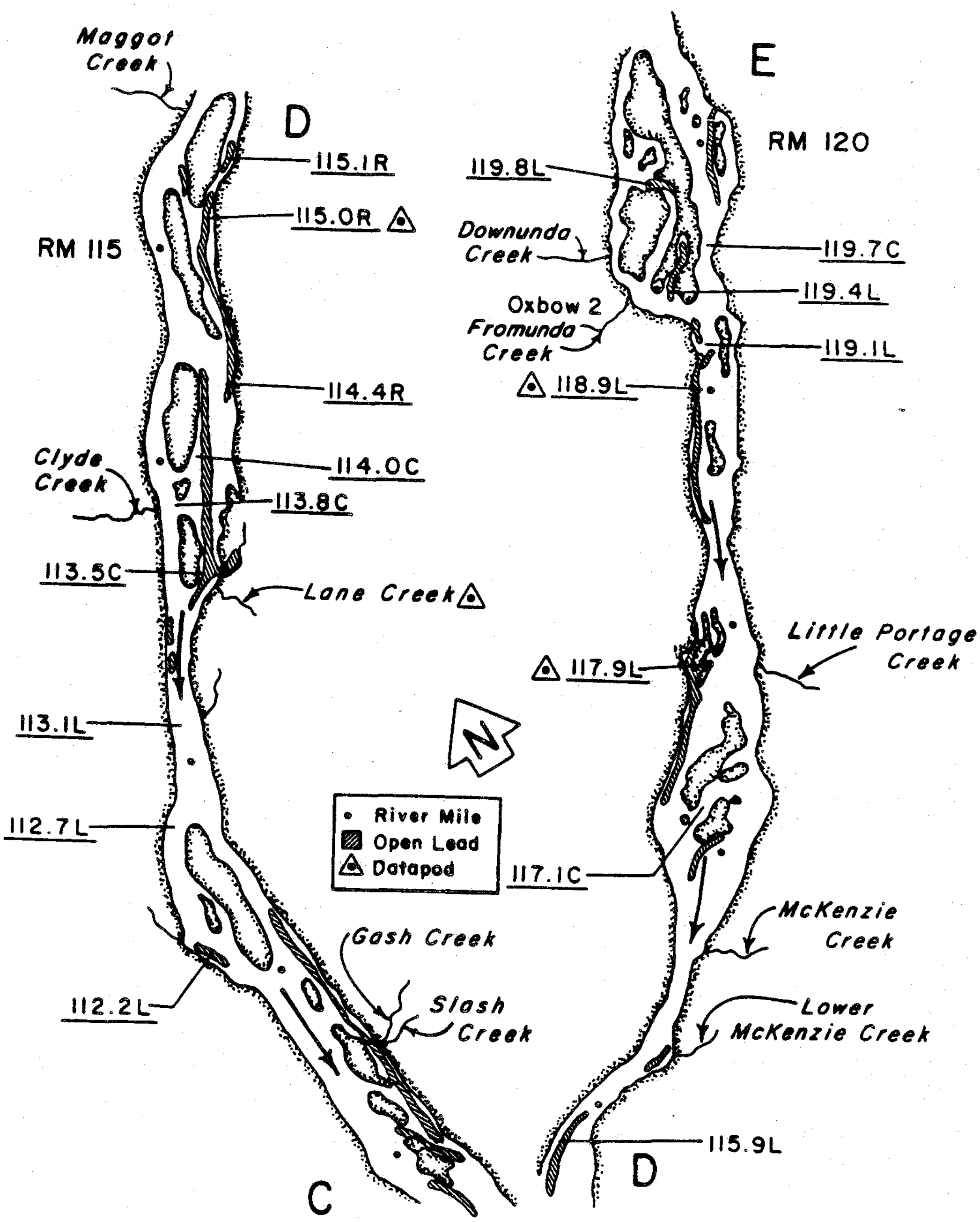


Figure 5. Map of the middle Susitna River from RM 110.5 to 120.5 showing study sites, open leads and datapod locations, 1984.

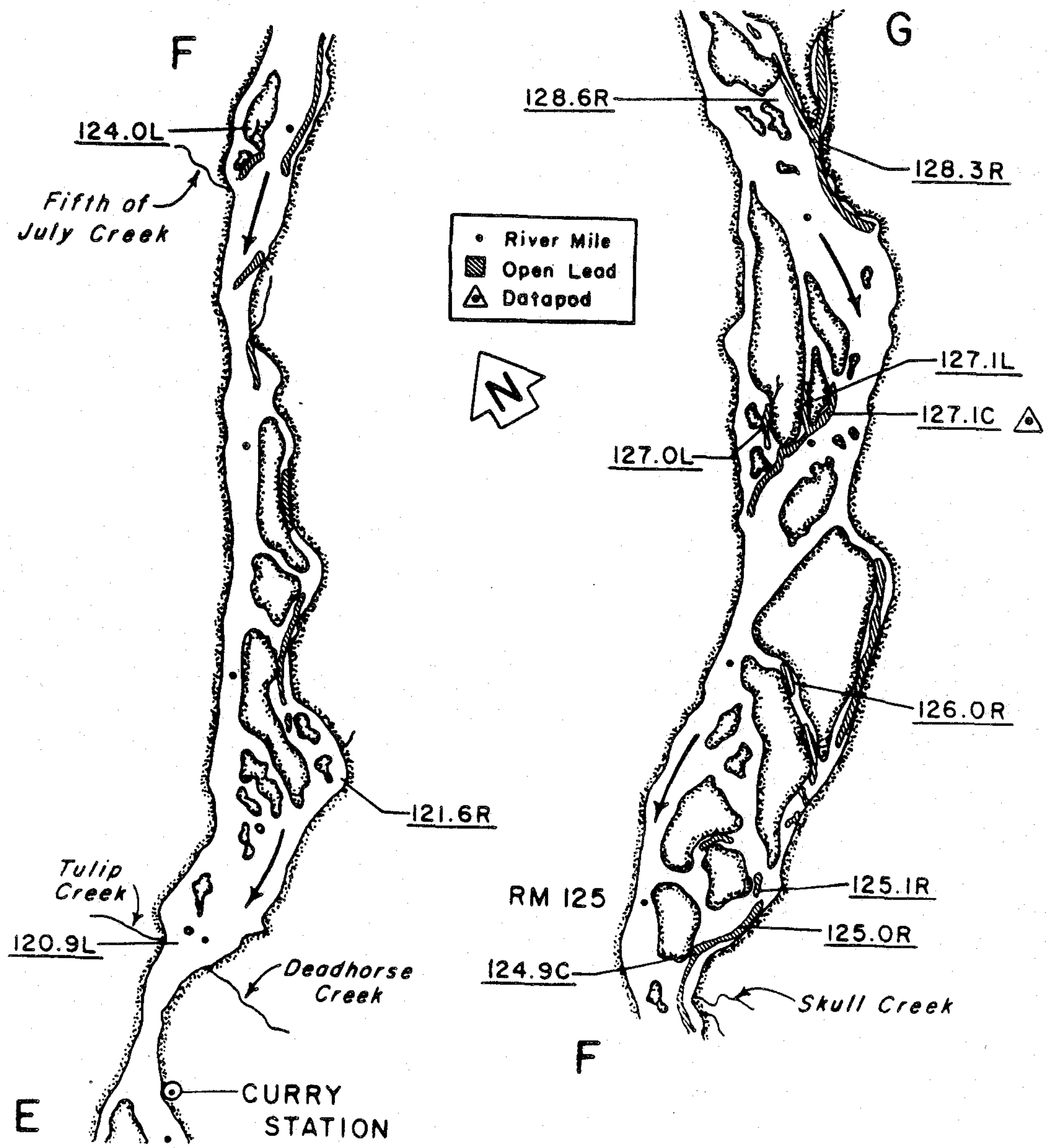


Figure 6. Map of the middle Susitna River from RM 120.0 to 128.5 showing study sites, open leads, and datapod locations, 1984.

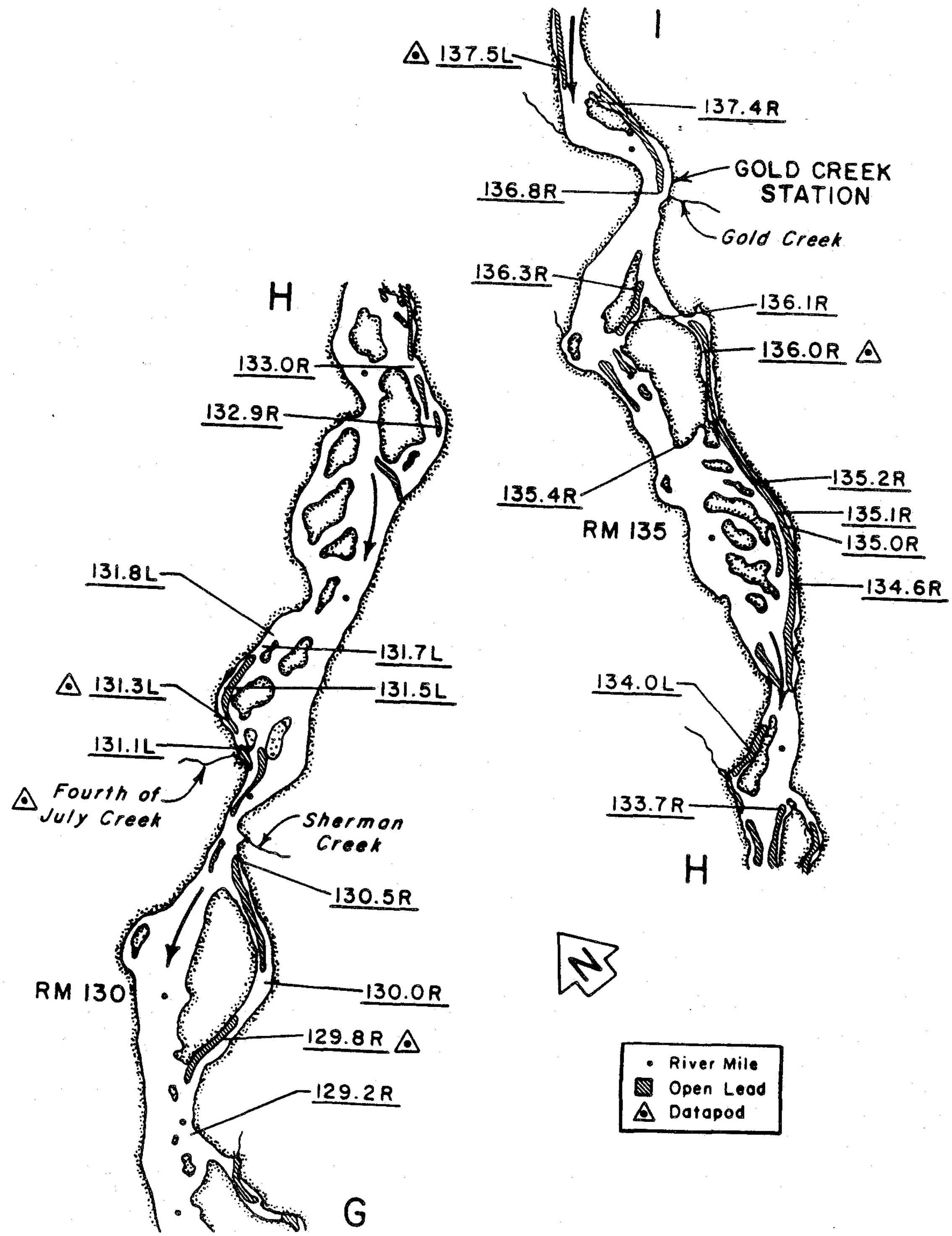


Figure 7. Map of the middle Susitna River from RM 128.5 to 137.5 showing study sites, open leads and datapod locations, 1984.

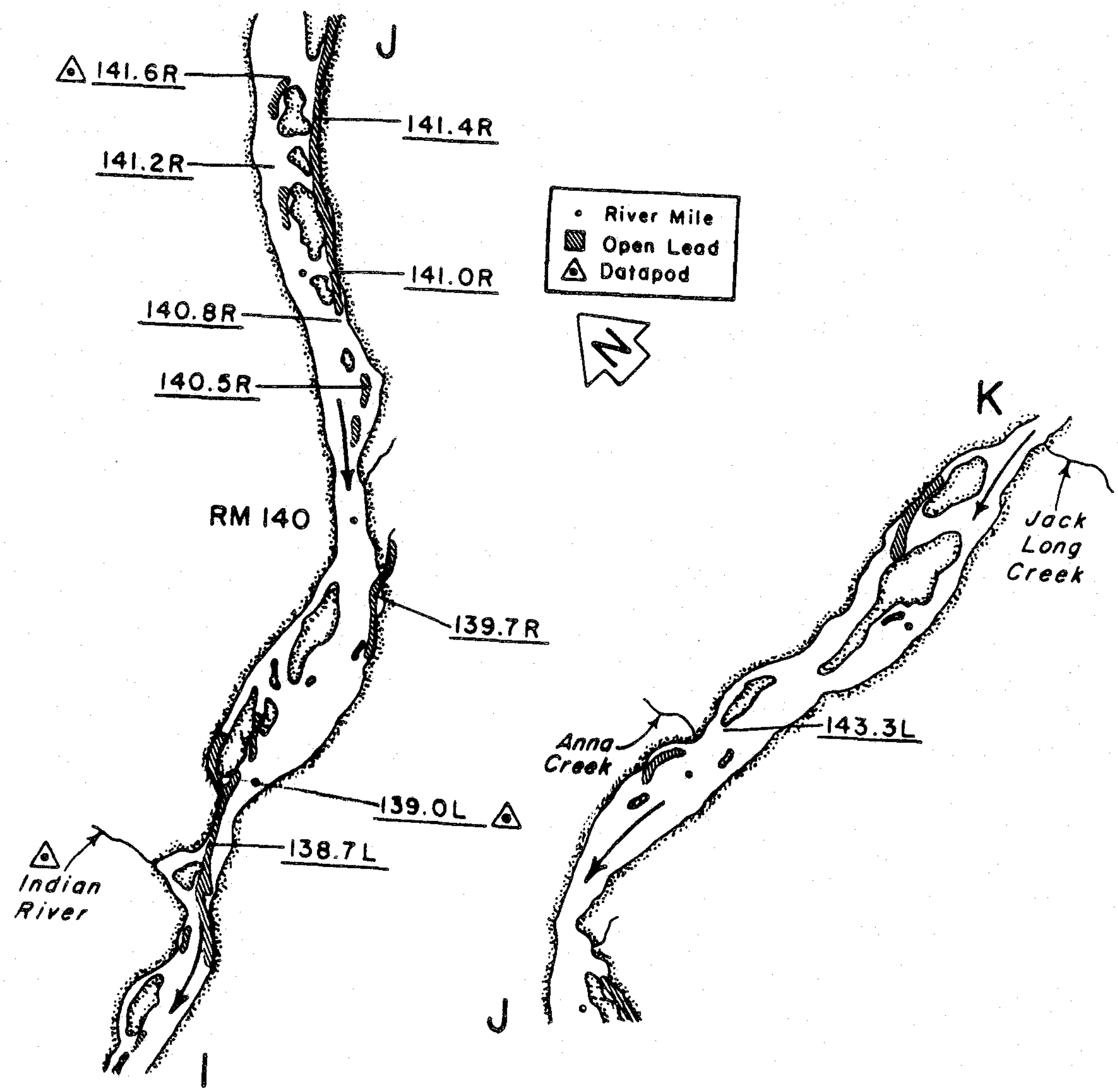


Figure 8. Map of the middle Susitna River from RM 137.5 to 144.5 showing study sites, open leads and datapod locations, 1984.

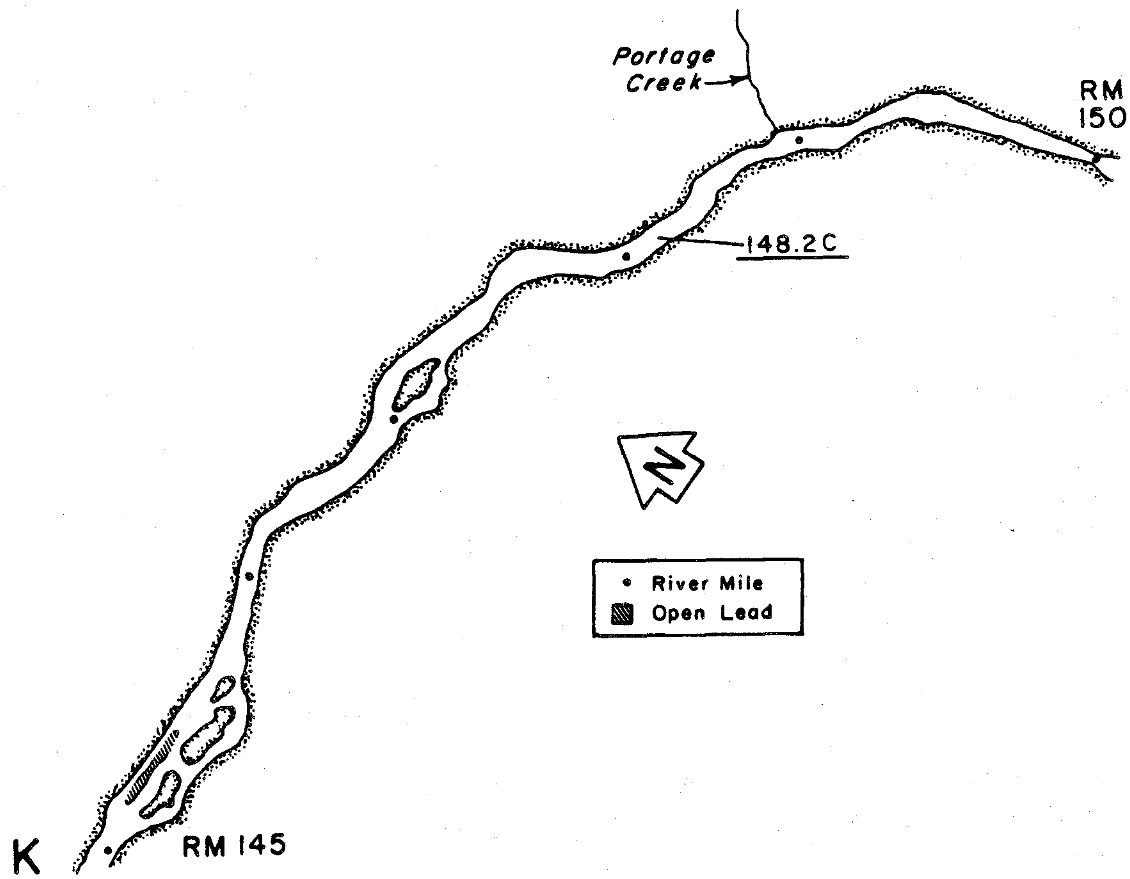


Figure 9. Map of the middle Susitna River from RM 144.5 to 150.0 showing study sites, and open leads, 1984.

(Trihey 1984). Based on this analysis, 50 study sites were initially selected for further evaluation.

The second step in consideration for study site selection involved the evaluation of salmon spawning utilization data at middle river mainstem and side channel sites. An evaluation was conducted to determine the extent of utilization of each of the initially selected sites by spawning salmon as well as locating any spawning sites not identified by open leads. The use of 1984 spawning survey data was useful in locating potential sites due to the high escapement and relatively clear water conditions. The combination of the two data bases (i.e., open leads and spawning surveys) resulted in the number of reconnaissance sites increasing from 50 to 89.

The following classification of mainstem and side channel sites was developed:

1. Open leads that have been utilized for salmon spawning;

2. Open leads that have not been used for salmon spawning; and

3. No open leads but salmon spawning had occurred.

Sites in each classification were evaluated for the purposes of the initial reconnaissance surveys. The results of the open water and ice covered studies combined determined the recommendations as to the suitability of each classification as potential replacement habitat sites.

2.1.2 Surface and Intragravel Water Temperature

A single series of instantaneous surface and intragravel water temperature measurements were made at five locations in each study site for general comparison purposes between sites. The measurements were made using a Digisense Model 8522-10, digital thermistor thermometer, and a Yellow Springs Instrument (YSI) Model 419 stainless steel probe. Intragravel water temperatures were taken at a depth of approximately 10 inches, the approximate egg deposition depth for chum salmon (Vining et al. 1985). These data were used as a measure of suitability of the incubation habitat in each site. In locations where it was difficult or impossible to push the probe in to a depth of 10 inches due to large substrate or cementation of substrate, the probe was inserted only as deep as possible. Surface water temperatures were taken as near as possible to the middle of the water column. These data were used for general comparisons between sites. All data were summarized and compared with accepted tolerance ranges for spawning and incubation of salmonid embryos as reported in Reiser and Bjornn (1979), Hale (1981) and Vining et al. (1985).

2.1.3 General Substrate Evaluations

General substrate evaluations were conducted by visual assessment of the dominant substrate types present throughout each study site. Substrate evaluations were conducted when the mainstem discharge, as measured at Gold Creek, approximated the anticipated summer project discharges of 9,000 to 12,000 cfs. This resulted in a better assessment of the wetted area of substrate under anticipated project conditions and also provided better visibility conditions due to clearer water at these lower discharges. The substrate evaluation was based on a size classification scheme (Table 1).

Table 1. Substrate classification scheme utilized to evaluate general substrate composition at mainstem and side channel study sites.

Substrate Code	Substrate Description	Size
SI	silt	very fine
SA	sand	fines
SG	small gravel	1/4"-1"
LG	large gravel	1"-3"
RU	rubble	3"-5"
CO	cobble	5"-10"
BO	boulder	greater than 10"

Substrate data are presented to provide a general comparison of all the sites surveyed. Data from these general substrate evaluations were compared to accepted substrate size ranges for spawning salmonids as reported in Reiser and Bjornn (1979), Lotspeich and Everest (1981), and Vincent-Lang et al. (1985) to provide an index as to the suitability of the substrate at each site for spawning salmon.

2.1.4 Upwelling and Bank Seepage

Both upwelling and bank seepage contribute to make suitable spawning and incubating habitat for salmonids (Kogl 1965; Bakkala 1970; Vincent-Lang et al. 1984; Vining et al. 1985). Upwelling and bank seepage are important in 1) preventing dewatering and freezing of redds, 2) stabilizing the incubation environment, and 3) increasing rate of exchange of water to replenish dissolved oxygen and remove metabolic wastes (Vining et al. 1985). For these reasons, locating areas of upwelling was important for identifying potential mitigation sites.

Areas of upwelling and bank seepage were visually observed during foot surveys of each study site. Upwelling was usually apparent as water percolating through the substrate of a site. It is most readily apparent in areas of silt or sand where the flow of water could be easily observed as a bubbling action. In areas of substrate with little silt or sand, upwelling was observed as a current circulating through the water column if the water was calm enough and/or the upwelling strong enough. Bank seepage appeared as a lateral movement of water from the banks of a site.

Observing upwelling in mainstem sites was difficult, therefore, several approaches were used to discern its presence at a study site. The first approach consisted of a visual assessment of the presence or absence of upwelling or bank seepage at a study site. This visual assessment proved difficult at several sites due to the presence of larger substrates, turbid water, and/or high water velocities. For this reason, a second approach was used to assess the presence of upwelling at those sites where it was not easily discernible. During winter, open leads in the ice cover due to thermal influences are known to be associated with the presence of upwelling (Vincent-Lang et al. 1984). Thus, study sites that exhibited open leads as determined from March, 1983 aerial photographs and also have historically had salmon spawning activity, were assumed to be affected by thermal influences resulting from upwelling.

In some areas, open leads may be a result of high water velocity rather than upwelling. If water velocities appeared to be a controlling factor, and there was no apparent upwelling and no historical chum salmon spawning was reported, then the open lead was tentatively assumed to be a result of water velocity and was not considered further for study purposes.

2.2 Ice Covered Studies

2.2.1 Site Selection

The ice covered study used the 89 sites surveyed during the open water period as a basis for site selection. One habitat type not included in the open water study due to logistical constraints, but included in the ice covered study was tributary habitats. Tributary habitats are least affected by changes in mainstem discharges and are used by all species of salmon (Barrett et al. 1985). They were included for comparison purposes with mainstem and side channel salmon spawning habitats as well as possible replacement spawning habitat sites. Based on the results of the open water studies nine primary and four secondary sites were selected for this study in order to be better able to assess their potential as possible mitigation sites.

The site selection process for the ice covered studies involved two steps. The first step divided the middle reach of the Susitna River into the following three subreaches: Talkeetna (RM 97.0) to Curry (RM 120.5); Curry (RM 120.5) to Gold Creek (RM 136.6); and Gold Creek (RM 136.6) to the mouth of Devil Canyon (RM 150.0). These subreaches were established so that selected sites would be equally distributed throughout the middle reach of the Susitna River. The second step included dividing the initial sites into primary and secondary sites. Primary sites included tributary spawning habitats as well as side channel and mainstem spawning habitats that exhibited both upwelling and salmon spawning activity. Secondary sites were limited to side channel and mainstem habitats and included: 1) sites that exhibited upwelling but had no salmon spawning activity; and 2) sites that had spawning activity but exhibited no upwelling. Within each subreach, a primary site, representing each habitat type (tributary, side channel and mainstem), as well as a secondary site, representing each classification, was selected for monitoring of surface and intragravel water temperatures and substrate composition (Table 2).

The number of winter study sites was limited by the number of datapods available for continuous monitoring of surface and intragravel water

Table 2. Location of ice covered study sites for continuous water temperature monitoring and substrate sampling in the middle reach of the Susitna River, 1984.

		Site Name	River Mile[a]	Geographic Code
Sub Reach I (Talkeetna to Curry)				
Primary:	Tributary spawning area	Lane Creek	113.6 R/TRM 0.1	S 28N 05W 12 DAA
	Side Channel spawning area with open leads	Mainstem 2	115.0 R	S 23N 04W 06 BAB
	Mainstem spawning area with open leads	Susitna River at 118.9L	118.9 L	S 29N 04W 16 CDD
Secondary:	Open lead Without Spawning	Side Channel at 117.9L	117.9 L	S 29N 04W 29 AAA
Sub Reach II (Curry to Gold Creek)				
Primary:	Tributary spawning area	4th of July Creek	131.1 L/TRM 0.2	S 30N 03W 03 DBA
	Side Channel spawning area with open lead	Side Channel at 4th of July Creek	131.3 L	S 30N 03W 03 ADD
	Mainstem spawning area with open lead	Susitna River at 132.9R	132.9 R	S 30N 03W 01 BAD
Secondary:	Open lead Without Spawning	Susitna River at 127.1C	127.1 C	S 30N 03W 09 ACB
	Spawning Without Open lead	Side Channel at 129.8R	129.8 R	S 30N 03W 20 ADC
Sub Reach III (Gold Creek to Devil's Canyon)				
Primary:	Tributary spawning area	Indian River[b]	138.6 L/TRM 0.2	S 31N 11W 09 CAB
	Side Channel spawning area with open lead	Side Channel 21	141.6 R	S 31N 02W 02 AAB
	Mainstem spawning area with open lead	Susitna River at 139.0L	139.0 L	S 31N 02W 09 DAC
Secondary:	Open lead Without Spawning	Susitna River at 137.5L	137.5 L	S 31N 02W 17 ACB

[a] L = Left Bank
R = Right Bank
C = Center Channel
TRM = Tributary River Mile

[b] Indian River contained two study sites. Site 3 along the left bank was a chinook spawning area. Site 4 along the right was a spawning area utilized by all species of salmon found in Indian River.

temperatures. Study sites without upwelling where spawning had been recorded were the most difficult sites at which to collect data as there were only a very limited number of these types of sites in the middle reach of the Susitna River. Sampling conditions in these sites, during the winter, were extremely severe, limiting the amount and types of data that could be collected. Dewatering and freezing of these sites and overtopping with thick ice build up frequently occurred.

2.2.2 Surface and Intragravel Water Temperatures

Surface and intragravel water temperature data were collected to compare against tolerance ranges for incubating salmon embryos. This comparison provides an indication of the suitability of a site for effective spawning and incubation. The intragravel water temperatures of a spawning area during the winter are important to the incubation of salmon eggs and development of embryos and alevins (Vining et al. 1985). Water temperature, along with dissolved oxygen, most directly affect the rate of development, survival rate, and timing of emergence of incubating salmon embryos. Surface water temperature is important only to the extent that surface water influences intragravel water temperatures and as an indicator of upwelling.

A continuous record of surface and intragravel water temperatures was obtained using Omnidata Model 2321 two channel temperature recorders (datapod). These temperature recorders were installed and continuously operated in each winter study site following procedures in ADF&G (1983), Keklak and Quane (1985), and Keklak and Withrow (1985).

2.2.3 Freeze-Core Substrate Evaluations

Two types of substrate core sampling methods, the McNeil (McNeil and Ahnell 1960) and the freeze-core (Walkotten 1976; Everest et al. 1980) were considered for use in this study. The freeze-core technique was selected for this study for the following reasons:

1) it allows sub-sampling of the freeze-core at varying increments of depth;

2) allows sampling over a wide range of environmental conditions;

3) the metal probe of the freeze-core technique provides easier penetration of the large and cemented substrates present at many sites; and

4) allows more accurate sampling of sediments less than 0.062 mm (Walkotten 1976).

The only change made in the freeze core system described by Walkotten was the use of steel probes instead of copper. This modification was made because steel probes were found to be more durable.

Substrate samples were collected at three representative locations in each winter study site. Difficult sampling conditions such as frozen substrate or cores stripping off the probe at three sites limited sample collection to one or two locations at each site. In addition, due to adverse sampling conditions, no freeze core substrate samples were obtained at secondary sites that had spawning but exhibited no upwelling. These sites dewatered and froze late in the fall. Freeze core samples were collected to a depth of 16 inches at each of the three locations using a single probe freeze-core apparatus as described in Walkotten (1976) (Figure 10). A depth of 16 inches was selected because a review of literature indicated this is an average redd depth for all salmon.

Substrate cores were obtained by using a complete 20 lb. tank of CO_2 (approximately 10 minutes) for each freeze core sample. Frozen substrate samples were then extracted from the streambed using a tripod and hand operated winch. Cores were thawed using portable propane heaters and split into two samples, the top 8 inches and the bottom 8 inches, to observe differences in composition with depth (Everest et al. 1980, 1981; Scrivener and Brownlee 1981).

Freeze core samples were taken to the Alaska Department of Transportation (ADOT) Central Materials Testing Laboratory for analysis. Sieve analysis of the samples followed procedures of American Association of State Highway and Transportation Officials (AASHTO): procedures T27-82 and AASHTO T11-82 (AASHTO 1982). The analysis was performed using a series of seven sieves of the following mesh sizes: 127, 76.2, 25.4, 2.0, 0.84, 0.50, and 0.062 mm. The sieve size selection was based on the previous ADF&G (Vining et al. 1985) studies as well as recommendations from Wendling (1976), Shirazi et al. (1980),

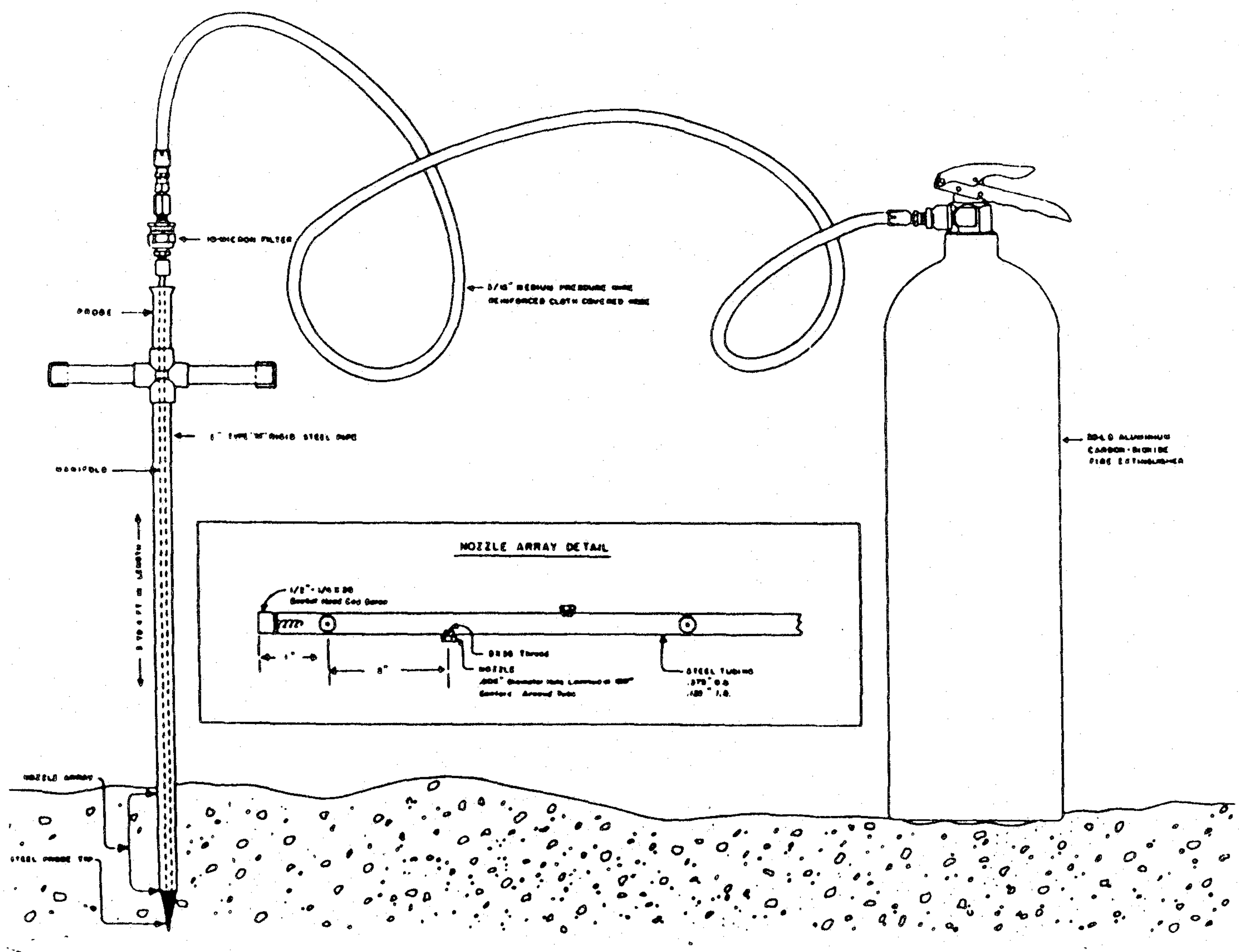


Figure 10. Single probe freeze core apparatus used to sample streambed substrates in the middle reach of the Susitna River, 1985.

Lotspeich and Everest (1981), Everest et al. (1981), and Platts et al. (1983). After sieving, the dry weight of each size class of substrate was measured to the nearest gram and expressed as a percentage of the total weight.

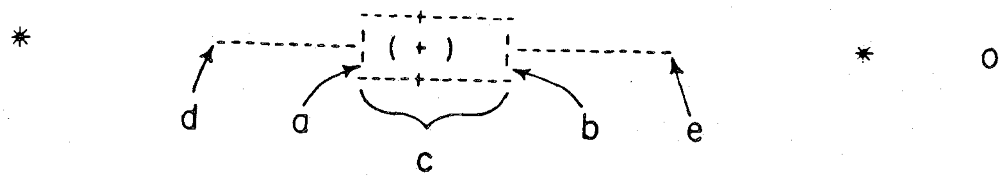
The quality of spawning gravels has traditionally been estimated by determining the percentage of fine grains less than some specified diameter. An inverse relationship between percent fines and survival exists. While percent fines provides an index of gravel quality for incubation purposes, it is limited because it ignores the textural composition of the remainder of the sample. Other methods, such as the use of geometric mean diameter of particles, have been proposed to improve on the percent fines method. Used alone, each method has its drawbacks. Further research and development has resulted in a quality index that appears to overcome the limitations of other methods. This index to the quality of gravels can be obtained by dividing geometric mean particle size by the sorting coefficient (a measure of the distribution of grain sizes) in a sample. The resulting number, called the "fredle index," is currently being used for evaluating the reproductive potential of spawning gravel (Lotspeich and Everest 1981; Everest et al. 1981; and Platts et al. 1983). The fredle index, used for this study, incorporates the influence of texture on two fundamental properties of spawning gravels - pore size and permeability - that influence survival. Pore size and permeability regulate intragravel water velocity and oxygen transport to incubating salmonid embryos and control intragravel movement of alevins. Pore size, rather than porosity, was chosen as a component of the quality index because pore size (and permeability) is directly proportional to mean grain size while porosity has been shown to be independent of grain size. To evaluate a fredle index, the raw data from textural analysis was entered into a computer program developed by Porter and Rogers (1984). This program provides a concise summary of the indices which describe the textural composition of spawning gravels.

2.3 Interpretation of Figures

Results in this report are shown in several types of figures of which two warrant a description of symbols used. These are referred to as box-and-whiskers plots (or boxplots) and scatter number plots.

Boxplots are used in this report to summarize water temperature, dissolved oxygen, pH, and conductivity data. The format basically follows that used by Velleman and Hoaglin (1981). The boxplots, as presented here, were computer generated by the microcomputer program MINITAB (Ryan et al. 1982). Measured values (i.e., dissolved oxygen, water temperature, etc.) from each study site comprise a data batch, which is ordered from lowest value to highest. Specific symbols used in the boxplot figures of this report are explained in Figure 12.

Scatter number plots are used in a number of figures in this report to summarize water temperature, dissolved oxygen, pH, and conductivity data. Each number in a figure represents the number of occurrences in single integers (1-9) at that point.



Symbol	Representative Term
a, b	lower and upper hinges (about 25 percent of the way in from each end of an ordered batch)
c	H-spread (the difference between the hinges; middle half of the data batch)
d	minimum adjacent value [lower hinge - (1.5 x H-spread)]
e	maximum adjacent value [upper hinge + (1.5 x H-spread)]
+	median (middle value of the batch)
*	outside value (outside of the adjacent values)
0	far outside value-outside of the following range: lower hinge - (3 x H-spread) upper hinge + (3 x H-spread)
( )	notches (represent approximately a 95 percent confidence limit about the median): median ± 1.58 x (H-spread)/ n

Figure 11. Definitions of symbols used in boxplots which summarize water temperature data.

3.0 RESULTS

3.1 Open Water Studies

The results of open water studies conducted at 89 potential mitigation sites in the middle reach of the Susitna River from July 1 to October 15, 1984 are presented in the following section. Of the 89 sites surveyed, 62 were side channel habitats and 27 were mainstem habitats. A total of 18 of the 62 side channel sites were typified as having observed spawning activity and upwelling present (Table 3), while nine of the 27 mainstem sites were classified as such. Ten of the side channel and eight of the mainstem sites had neither observed spawning activity nor upwelling present. A total of nine side channel and two mainstem sites had upwelling present with no observed spawning. Open lead areas, as an indicator of spawning sites, have not been delineated in tributaries. As a result, tributary habitats were not included in the general open water surveys.

3.1.1 Instantaneous Surface and Intragravel Water Temperature

Five instantaneous surface and intragravel water temperature measurements recorded at each site during the open water sampling period indicate that the sites have acceptable water temperatures for utilization of these habitats by spawning salmon (Table 3).

In both side channel and mainstem habitats, surface water was warmer than intragravel water early in the season with the difference between

Table 3. Habitat characteristics of selected side channel and mainstem sites in the middle reach of the Susitna River, 1984, including all observed side channel and mainstem salmon spawning sites 1981-1984.

River[a] Mile	Habitat[b] Type	Sample Date	Up-welling (Yes/No)	Open Lead (Yes/No)	Substrate[c]	Spawning Observed	Water Temperature Range Limits (°C)[d] Surface	Intragravel
100.5 R	SC	10-8-84	Y	Y	CO-RU-BO	1981	4.2 - 4.9	4.7 - 5.1
100.9 R	SC	10-8-84	N	N	RU-CO-BO	1984	3.5 - 5.0	4.0 - 6.4
101.2 R	SC	10-8-84	N	N	RU-CO-BO	1984	3.9 - 4.6	4.4 - 5.2
102.0 L	SC	10-8-84	Y	N	CO-BO-RU	e	3.9 - 4.3	3.3 - 3.9
102.5 L	SC	10-8-84	N	Y	CO-BO	e	f	f
105.8 L	MS	10-8-84	N	N	BO-CO	e	2.9 - 3.0	3.0 - 3.2
106.2 R	MS	10-8-84	N	Y	BO-CO	e	3.1 - 3.2	3.4 - 3.5
110.1 L	SC	10-8-84	N	N	SI-RU-CO	1984	3.2 - 4.0	5.2 - 5.7
110.8 L	SC	10-8-84	Y	Y	RU-CO-BO	e	3.9 - 4.5	5.0 - 5.4
112.2 L	MS	9-14-84	N	Y	RU-CO-BO-LG	e	6.8 - 6.9	6.9 - 7.0
112.7 L	MS	9-14-84	N	N	RU-CO-BO	e	7.2 - 7.4	6.2 - 6.9
113.1 L	MS	9-14-84	N	N	RU-CO-BO	e	f	f
113.5 C	SC	9-14-84	N	Y	LG-RU-CO	e	6.7 - 6.8	6.3 - 7.0
113.8 C	MS	9-14-84	N	N	RU-CO-BO	e	f	f
114.0 C	SC	9-14-84	Y	Y	SG-LG-RU	1984	7.1 - 7.3	4.1 - 7.1
114.4 R	SC	g	f	Y	f	1984	f	f
114.5 R	SC	g	f	Y	f	1984	f	f
114.6 R	SC	9-14-84	N	Y	SA-RU-CO-BO	1982, 1983, 1984	6.8 - 7.5	4.5 - 7.4
115.0 R	SC	9-14-84	Y	Y	RU-CO-BO	1982, 1983, 1984	f	f
115.1 R	SC	9-14-84	Y	Y	BO-CO-RU	1983, 1984	6.9 - 8.9	5.5 - 8.6
115.4 R	SC	g	f	Y	f	1984	f	f

Table 3 (Continued).

River[a] Mile	Habitat[b] Type	Sample Date	Up-welling (Yes/No)	Open Lead (Yes/No)	Substrate[c]	Spawning Observed	Water Temperature Range Limits (°C)[d]	
							Surface	Intragravel
115.9 L	MS	9-14-84	N	Y	CO-BO-RU	e	6.3 - 7.7	4.6 - 5.1
117.1 C	SC	9-14-84	N	N	SA-RU-CO	e	f	f
117.9 L	SC	9-14-84	Y	Y	RU-CO-BO	e	7.2 - 7.8	5.7 - 7.3
117.9 R	MS	9-14-84	Y	N	CO-BO	1984	f	f
118.9 L	MS	9-14-84	Y	Y	CO-BO-RU	1983, 1984	7.1 - 7.2	5.2 - 7.1
119.1 L	MS	9-18-84	N	Y	LG-RU-CO	1984	7.8 - 8.0	7.6 - 7.9
119.4 L	SC	9-18-84	Y	Y	SA-LG-RU-CO	1984	7.0 - 8.2	5.3 - 7.6
119.7 C	SC	9-18-84	Y	N	SA-LG-RU-CO	---	8.0 - 8.5	5.3 - 7.4
119.8 L	SC	9-18-84	N	Y	LG-RU-CO	1984	8.0 - 8.2	6.9 - 8.2
120.9 L	MS	9-18-84	N	N	f	1984	f	f
121.6 R	SC	g	f	N	f	1984	f	f
123.1 R	MS	9-13-84	N	Y	RU-CO-BO	e	7.5 - 7.6	7.5 - 7.6
124.0 L	SC	9-12-84	Y	N	SI-RU-CO	1984	7.2 - 8.7	4.4 - 8.4
124.9 C	SC	9-12-84	Y	Y	LG-RU-CO	1984	7.5 - 10.9	4.5 - 5.5
125.0 R	SC	9-18-84	Y	Y	RU-CO-BO	e	7.5	7.1 - 7.5
125.1 R	SC	9-18-84	N	Y	LG-RU-CO	e	7.4 - 7.6	7.6 - 8.4
127.0 L	SC	9-18-84	Y	Y	LG-RU-CO	e	5.7 - 7.4	5.9 - 7.4
127.1 L	SC	9-18-84	N	Y	LG-RU-CO	e	7.2 - 7.3	7.3 - 7.7
127.1 C	SC	9-18-84	Y	Y	LG-RU-CO	e	6.4 - 7.1	3.7 - 7.6
127.8 R	SC	g	f	Y	f	1984	f	f

Table 3 (Continued).

River Mile[a]	Habitat Type[b]	Sample Date	Up-welling (Yes/No)	Open Lead (Yes/No)	Substrate[c]	Spawning Observed	Water Temperature Range Limits (°C)[d] Surface	Intragravel
128.3 R	MS	9-18-84	N	Y	f	1984	f	f
128.6 R	SC	9-17-84	Y	Y	RU-CO-BO	1982, 1984	5.7 - 8.4	4.7 - 5.9
128.7 R	SC	g	Y	Y	f	1984	f	f
129.2 R	SC	9-17-84	N	N	RU-CO-BO	1981	7.6 - 7.7	7.7 - 7.8
129.8 R	SC	9-17-84	N	Y	SA-RU-CO-LG	1981, 1982, 1984	7.2 - 9.5	4.8 - 7.5
130.0 R	SC	9-17-84	Y	Y	f	1981, 1984	f	f
130.5 R	SC	9-17-84	Y	Y	CO-BO-RU	1984	7.8 - 8.5	5.6 - 7.8
131.0 R	MS	g	N	N	f	1984	f	f
131.0 L	SC	9-17-84	Y	Y	SA-RU-CO	1981, 1982, 1983, 1984	6.7 - 7.1	4.3 - 6.0
131.1 L	SC	9-17-84	Y	N	SA-LG-RU	1981, 1982, 1984	6.4 - 7.3	4.3 - 5.3
131.2 L	SC	g	f	Y	f	1984	f	f
131.3 L	SC	9-17-84	Y	Y	RU-LG-CO	1982, 1983, 1984	4.6 - 7.1	4.6 - 7.0
131.5 L	SC	9-17-84	Y	Y	RU-LG-CO	1984	f	f
131.6 L	SC	g	f	Y	f	1981, 1982, 1983, 1984	f	f
131.7 L	SC	9-17-84	N	N	RU-CO	1984	6.5 - 6.6	6.9 - 7.0
131.8 L	SC	9-12-84	N	N	RU-CO	1984	6.5 - 6.6	7.0
132.9 R	MS	9-17-84	Y	Y	RU-CO-BO	1984	f	f
133.7 R	SC	9-17-84	N	Y	RU-CO-BO	e	7.1	6.5 - 7.2
134.0 L	SC	9-17-84	Y	Y	LG-RU-CO	e	7.1 - 8.5	5.1 - 5.8
134.6 R	SC	9-17-84	N	Y	RU-CO-BO	e	6.7 - 6.9	6.5 - 7.0
134.7 R	SC	g	N	Y	f	1984	f	f

Table 3 (Continued).

River[a] Mile	Habitat[b] Type	Sample Date	Up-welling (Yes/No)	Open Lead (Yes/No)	Substrate[c]	Spawning Observed	Water Temperature Range Limits (°C)[d] Surface	Intragravel
135.0 R	SC	9-17-84	N	Y	LG-RU-CO	1984	6.8 - 6.9	5.2 - 7.1
135.1 R	SC	9-17-84	N	Y	LG-RU-CO	e	f	f
135.2 R	SC	9-17-84	N	Y	RU-CO	e	f	f
135.4 R	SC	9-17-84	N	N	SI-LG-RU	e	6.6 - 6.8	6.3 - 7.1
136.1 R	SC	9-17-84	Y	Y	SA-LG-RU-CO	1981, 1982, 1983, 1984	4.9 - 5.4	4.0 - 6.1
136.3 R	SC	9-17-84	N	Y	f	1981, 1982, 1983, 1984	f	f
136.5 R	SC	g	N	Y	f	1981, 1982, 1983, 1984	f	f
136.8 R	MS	9-15-84	N	Y	RU-CO-BO	1983, 1984	8.7 - 10.1	6.3 - 7.3
137.4 R	SC	9-15-84	Y	Y	SA-RU-CO-BO	e	10.4 - 12.3	4.7 - 8.1
137.5 L	MS	9-15-84	Y	Y	SA-BO-CO	e	10.4 - 11.6	4.7 - 8.1
138.0 L	MS	9-15-84	Y	Y	LG-RU-CO	1982	f	f
138.3 L	MS	9-15-84	Y	Y	LG-RU-CO	1982, 1984	9.6 - 9.8	7.8 - 8.2
138.7 L	MS	9-15-84	Y	Y	CO-BO-RU	1982, 1983, 1984	8.8 - 9.0	7.9 - 8.1
138.8 L	MS	g	f	Y	f	1984	f	f
139.0 L	MS	9-11-84	Y	Y	RU-LG-CO	1982, 1983, 1984	7.7 - 8.6	5.3 - 6.6
139.4 L	SC	9-11-84	N	Y	RU-LG-CO	1984	8.5	7.6 - 8.1
139.7 R	SC	9-15-84	Y	Y	SA-RU-CO-BO	e	7.7 - 8.0	6.9 - 7.7
140.5 R	SC	9-15-84	N	Y	CO-BO-RU	1984	f	f
140.8 R	SC	9-15-84	N	N	CO-BO-RU	1981, 1982, 1983, 1984	f	f
141.0 R	SC	9-15-84	Y	Y	BO-CO-RU-LG	1981, 1982, 1983, 1984	7.4 - 7.5	7.4 - 7.5

Table 3 (Continued).

River[a] Mile	Habitat[b] Type	Sample Date	Up-welling (Yes/No)	Open Lead (Yes/No)	Substrate[c]	Spawning Observed	Water Temperature Range Limits (°C)[d]	
							Surface	Intragravel
141.2 R	MS	9-15-84	Y	Y	CO-BO-RU	e	7.4 - 7.5	7.4 - 7.5
141.4 R	SC	9-15-84	Y	Y	SI-CO-BO	1981, 1982, 1983, 1984	5.3 - 5.7	4.5 - 5.4
141.6 R	MS	9-15-84	N	Y	RU-CO-BO	1984	7.2 - 7.3	7.2 - 7.8
141.6 R	SC	9-15-84	Y	Y	SA-RU-CO-BO	1981, 1982, 1983, 1984	f	f
143.0 L	MS	9-11-84	Y	N	RU-CO	1984	9.3	7.4
143.3 L	MS	9-11-84	Y	N	CO-BO	1982, 1984	8.5 - 12.7	7.4 - 12.3
148.2 C	MS	9-11-84	N	N	CO-BO	1982	6.8 - 7.1	6.9 - 7.4

a L = Left Bank
R = Right Bank
C = Center Channel

b MS = Mainstem
SC = Side Channel

c Substrate size classification as described in Table 1, in the methods section.

d Sample size equals 5. A single reading indicates all recorded temperature values were identical.

e No spawning observed.

f No data available.

g These sites are the result of spawning surveys, no other data available.

the two becoming less as the ice covered period approached. Side channel habitats exhibited a range for the sampling period, of 3.2-12.3°C for surface water and 3.3-8.6°C for intragravel water (n=205). During the same time period, mainstem habitats exhibited a range of 2.9-12.7°C for surface water and 3.0-12.3°C for intragravel water (n=90). The highest recorded temperature for both surface and intragravel water in mainstem habitats was recorded at the site at RM 143.3L, an area of spawning but no open lead. Further studies indicated that this site was a peripheral habitat unsuitable for incubation due to dewatering and freezing. For this reason it was removed from further study.

3.1.2 General Substrate Evaluations

Both side channel and mainstem habitats exhibit similar substrate patterns (Figures 12 and 13). Rubble-cobble-boulder substrate predominate in both habitat types (Table 3). Side channel habitats have an approximately equal number of sites containing rubble and cobble substrate while mainstem habitats contain a greater number of sites with cobble substrate. In comparing spawning with non-spawning areas in both habitats, the same trends appeared. Mainstem habitats also appear to be more cemented with fine silts and sands than occurs in side channel habitats. Side channel and mainstem sites generally contain larger substrate (rubble-cobble-boulder) than is found in tributary spawning habitats (small gravel-large gravel-rubble). There are areas of suitable substrate in all sites that coincide with the recommended size

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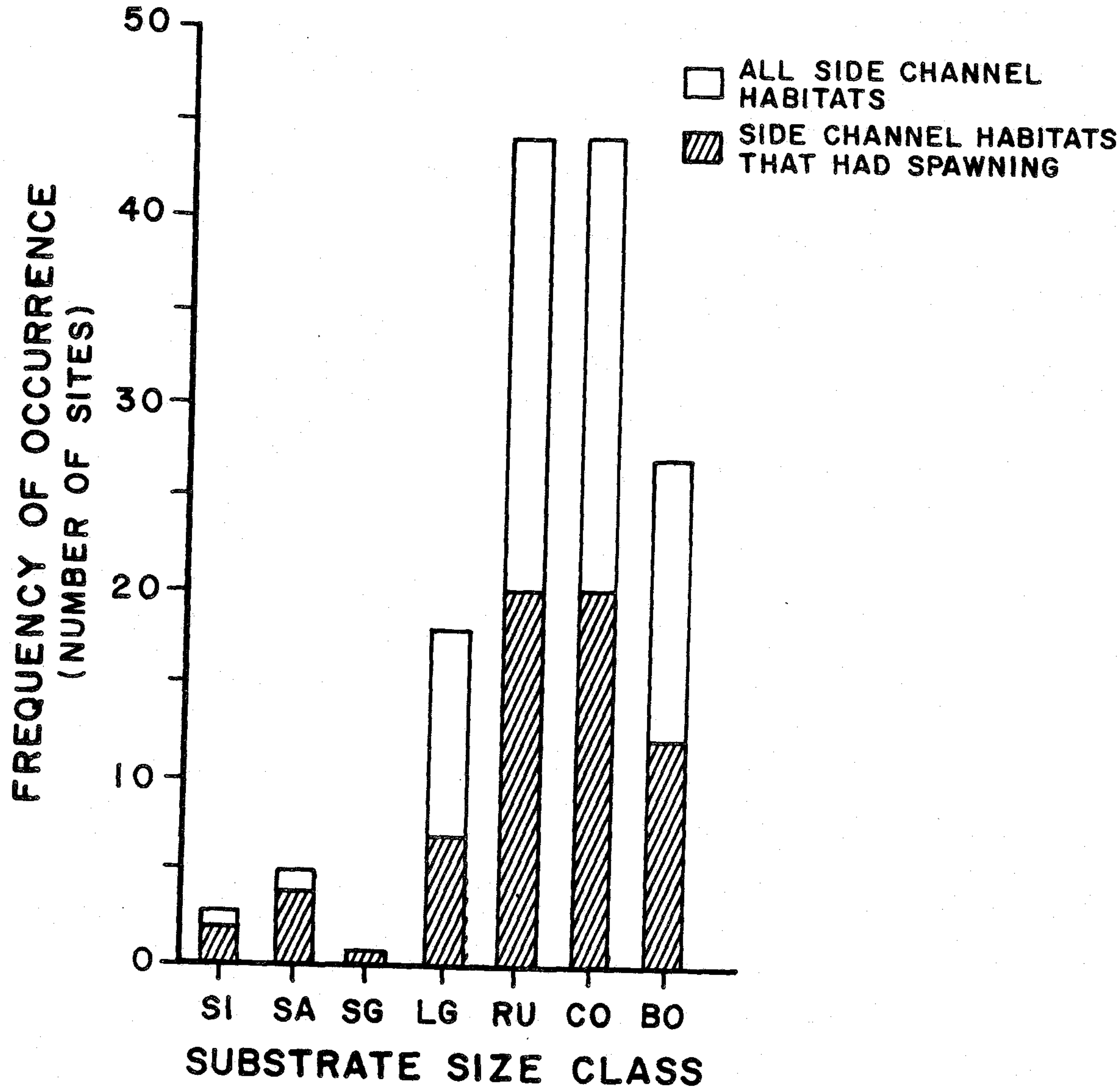

Figure 12. Frequency of occurrence of surface substrate size classes occuring inside channel habitats.

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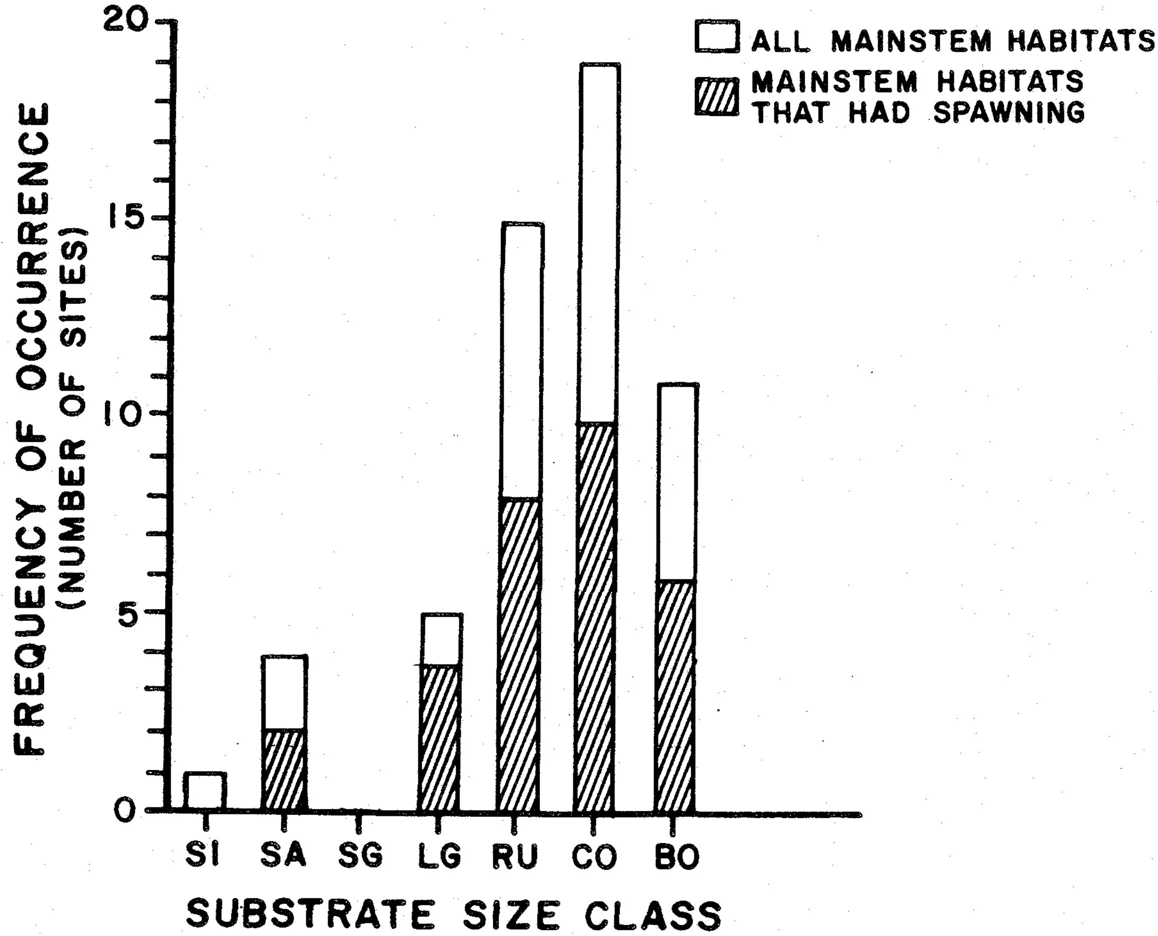

Figure 13. Frequency of occurrence of surface substrate size classes occurring in mainstem habitats.

range for salmon spawning (Reiser and Bjornn 1979; Lotspeich and Everest 1981; and Platts et al. 1983).

3.1.3 Upwelling and Bank Seepage

Visual observations of upwelling and bank seepage made during foot surveys were recorded at side channel and mainstem habitats after initially identifying potential areas of upwelling (open leads) from winter aerial photos (Table 3).

Ten of the 62 side channel sites were added after the open water season as a result of salmon spawning surveys and therefore only salmon spawning data are available at these sites. Of the remaining 52 side channel sites surveyed during the open water season to determine the presence of upwelling, 29 (54%) had observed upwelling or bank seepage while 39 (75%) exhibited open leads during the winter (Table 3). Four sites (14% of the sites with upwelling) exhibited upwelling but no open leads, which indicates that the upwelling was not very strong or was intermittent in nature. There were 15 sites (38% of the sites with open leads) that exhibited open leads in the winter but had no visible upwelling. Upwelling may be present in these sites but was not observed due to the difficult survey conditions. It appears that seven side channel sites have open leads that are all or partially controlled by water velocity.

Two of the 27 mainstem sites were added after the open water season as a result of salmon spawning surveys and only have spawning data. Of the remaining 25 sites, 11 (44%) had observed upwelling or bank seepage while 16 (64%) had open leads during the ice covered period (Table 3). These sites (27% of those with observed upwelling) had no open leads during the winter. This indicates that the upwelling observed in these sites is either weak or intermittent. Eight sites (50% of those with open leads) had open leads during the ice covered period but no observed upwelling. This indicates that either upwelling is present but not observed due to the difficult conditions present at mainstem sites, or that water velocity is the controlling factor. It appears that open leads in nine mainstem sites are controlled all, or in part, by water velocity.

3.1.4 Salmon Spawning Utilization

Side channel and mainstem salmon spawning sites located by ADF&G surveys from 1981-1984 are shown on individual site maps in Appendix A. Salmon spawning data at individual sites are summarized by year in Table 3.

The following summary, by species, is based on ADF&G spawning surveys conducted in side channel and mainstem habitats from 1981-1984. Chum salmon are the predominant species found spawning in both side channel and mainstem habitats. Sockeye salmon were observed spawning in eight side channel and three mainstem sites. Coho salmon have been found spawning in three side channel sites while pink salmon spawned in two. Spawning by coho or pink salmon was not observed in mainstem sites.

Chinook salmon have not been observed spawning in either side channel or mainstem sites.

A comparison of observed spawning activity in side channel and mainstem sites from 1981-1984 is presented in Table 4. While the number of sites varies between habitat type, the percentage in each category is similar between habitat types. The relatively high percentage of new spawning sites in each habitat type observed during 1984 can be attributed to a high escapement and excellent survey conditions.

Table 4. A comparison of observed salmon spawning activity between side channel and mainstem sites in the middle reach of the Susitna River, 1981-1984.

Spawning Utilization Category	Side Channel (62 Total Sites) (No. of Sites/ % of Total)	Mainstem (27 Total Sites) (No. of Sites/ % of Total)
Spawning during at least 1 year	42 (68%)	17 (63%)
Spawning during more than 1 year	17 (27%)	6 (22%)
No spawning	20 (32%)	10 (32%)
First spawning during 1984	23 (37%)	9 (33%)

3.2 Ice Covered Studies

Based on the results of the open water studies, nine primary and four secondary sites were selected for this study in order to be better able to assess their potential as possible mitigation sites (Table 2). The sites are distributed throughout the middle reach of the Susitna River and are generally categorized as either tributary, side channel, or mainstem. Mainstem and side channel sites were subdivided based on presence of open leads and spawning. Intragravel water temperature and substrate composition were monitored at each site to provide an index as to the suitability of salmon incubation conditions.

3.2.1 Continuous Surface and Intragravel Water Temperature

Continuous surface and intragravel water temperatures were measured at one location in each site with the exception of Indian River which had two sites. Indian River site #3 was initially installed in a chinook salmon spawning site for another ADF&G study. Monitoring of temperatures was continued for this study to obtain temperatures on a spawning site used only by chinook salmon. Indian River site #4 was installed in a coho, chum and pink salmon spawning area. A complete presentation of these data are included in Keklak and Withrow (1985). A boxplot diagram is presented to summarize the surface and intragravel water temperatures by site classification (Figure 14). Similar trends appear to exist in both intragravel and surface water temperatures. Mainstem and side channel sites that have open leads and no spawning have the warmest median temperatures, while tributary and mainstem spawning sites have the lowest.

In general, surface and intragravel water temperatures dropped in all sites from September until late October or early November. At this time

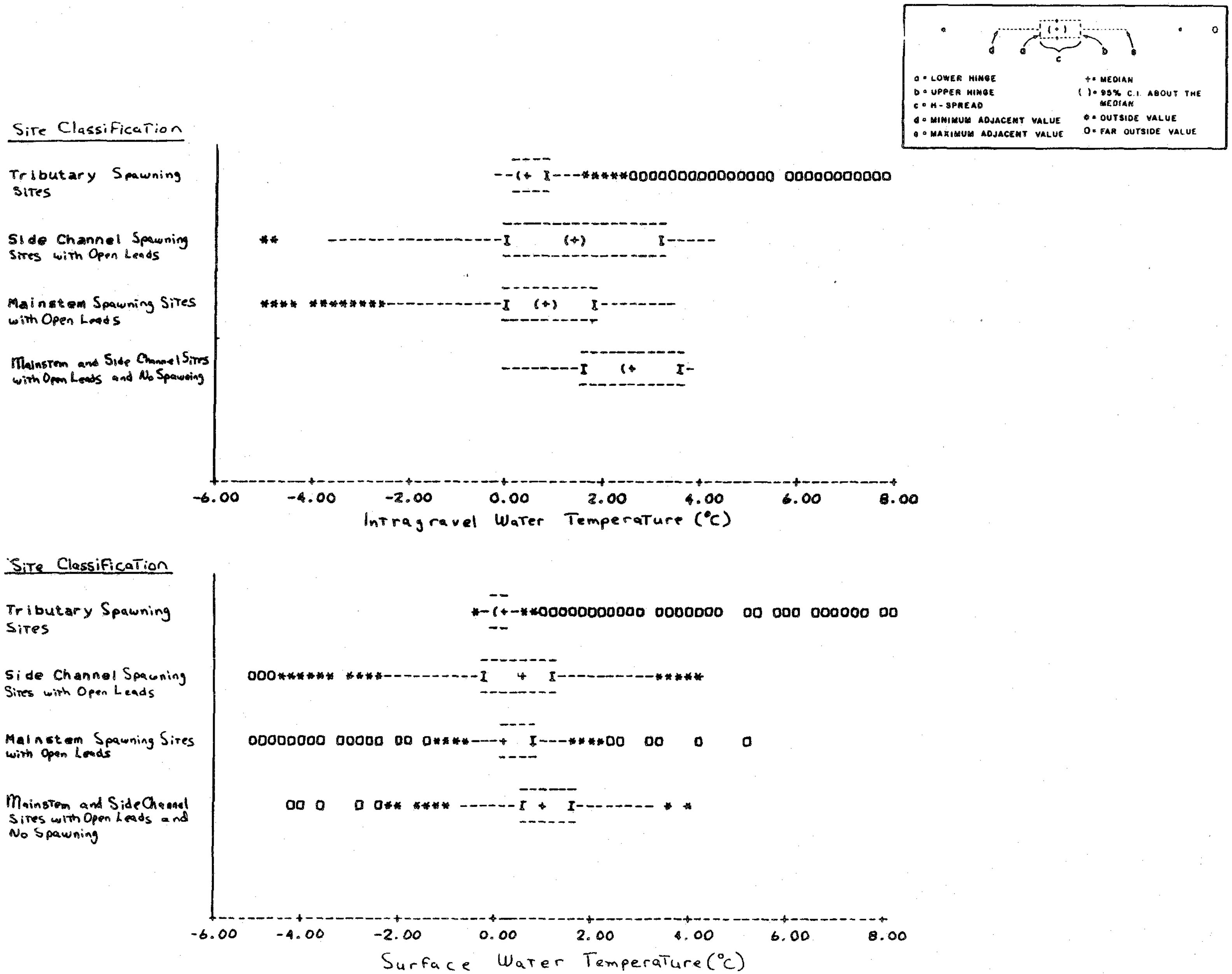

Figure 14. Summary by site classification of continuous surface and intragravel water temperature data (°C) measured during the 1984-1985 ice covered period in the middle Susitna River, Alaska. (refer to section 2.3 for detailed explanation of figure symbols).

the temperatures rose slightly and stabilized, with intragravel water temperatures generally warmer than surface water temperatures. Freezing of sites for part or all of the winter occurred in side channel, and mainstem spawning areas. The intragravel environment of tributary spawning habitats and areas of open leads with no spawning in mainstem and side channel habitats, generally remained above freezing.

3.2.2 Freeze Core Substrate Evaluations

Freeze-core substrate samples collected at all sites were analyzed to compute the fredle index as a measure of substrate quality. The fredle index is a measure of both pore size and relative permeability, both of which increase as the fredle index increases. This textural analysis verifies the general substrate evaluations made during the open water survey period. The composition of substrate samples collected at all sites are summarized in Appendix Table C-1.

The substrate composition presented in Appendix Table C-1 shows similar substrate composition for salmon spawning areas in tributary, side channel and mainstem habitats. The greatest percentage of substrates collected in all these habitat types are greater than 2.0 mm in size. Only a small percent of the substrates in all three habitats are less than 2.0 mm. One sample, collected at Lane Creek, in which 53% of the substrate was less than 0.062 mm, did not fit the general trend for these habitats.

Mainstem and side channel sites that exhibited open leads but had no reported salmon spawning, had slightly smaller substrates. The majority of substrates in these sites was between 2.0 mm and 127 mm. Only a small percentage of the substrates were either smaller than 2.0 mm or greater than 127 mm. It appears that there is a slight increase with depth, in the percent of fines found in the samples.

The results of the analysis to determine substrate quality (fredle index) are presented in Table 5. This analysis is based on the entire 16 inch freeze core sample at each site. No clear trends were obvious in substrate quality with depth, in any of the habitats.

In looking at the four indices (geometric mean particle size, sorting coefficient, fredle index and percent finer than 10 mm) general comparisons of substrate composition between site classifications can be determined.

The average geometric mean particle size is largest in tributary habitats and smallest in areas of open leads and no spawning. Mainstem spawning habitats have an average geometric mean similar to that of areas with open leads and no spawning.

The sorting coefficient, used to quantify the distribution of grain sizes in gravels, is a useful indicator of a gravel's reproductive potential for salmonids (Lotspeich et al. 1981). A sorting coefficient greater than one implies that pores between large grains are filled

Table 5. Summary of substrate quality analysis of freeze core samples obtained at selected sites in the middle reach of the Susitna River, 1984-85.[a]

Habitat Type	Site	Sample Size	Total Sample Weight (gm)	Geometric Mean Particle Size (mm)	Sorting Coefficient	Fredle Index	Percent Finer Than 1.0 mm
Tributary Spawning Areas	Lane Creek	3	2215.700	86.800	13.162	52.693	16.939
	4th of July Creek[b]	1	1546.000	64.598	1.827	35.349	3.094
	Indian River #3	3	3216.367	128.917	1.878	71.094	1.472
	Indian River #4	3	1611.900	47.315	2.396	20.863	4.879
Side Channel Spawning Areas with Open Leads	Mainstem 2	3	1233.300	27.888	2.353	14.003	10.825
	Side Channel at 4th of July Creek	3	2143.667	66.644	2.423	27.930	5.326
	Upper Side Channel 11 #1[b]	1	2152.000	55.838	2.211	25.252	6.671
	Upper Side Channel 11 #2[b]	1	1227.000	34.815	2.079	16.745	6.818
	Side Channel 21	3	3025.167	97.751	2.074	51.187	3.763
Mainstem Spawning Areas with Open Leads	Susitna River at 118.9L	3	1448.533	47.755	2.615	23.094	6.997
	Susitna River at 132.9R	3	2030.900	50.621	2.594	19.453	6.535
	Susitna River at 139.0L	3	1709.233	50.848	1.898	26.932	5.221
Side Channel and Mainstem Sites with Open Lead and No Spawning	Side Channel at 117.9L	3	1146.733	50.859	2.541	23.565	11.243
	Susitna River at 127.1C #1[b]	1	2022.000	90.860	2.514	36.146	5.411
	Susitna River at 127.1C #2[b]	1	542.000	4.404	5.198	0.847	28.193
	Susitna River at 137.5L	3	2745.633	34.211	2.634	13.341	11.386

[a] All results presented are means based on sample size.

[b] Sampling problems limited the number of freeze cores collected at these sites. Due to the small sample size, each freeze core was analyzed individually. The results are the mean of a sample size of one instead of three.

with smaller grains that restrict permeability. The sorting coefficient is inversely proportional to permeability. Side channel and mainstem spawning sites with open leads have the lowest and most closely related average sorting coefficients, indicating less fine particles filling the pore spaces between larger particles. Tributary spawning habitats have the largest average sorting coefficients.

Areas of open leads with no spawning have the largest average percentage of fines less than 1.0 mm. The other three site classifications, tributary, side channel and mainstem spawning areas, have almost identical average percentages of fines, less than half of that found in non-spawning areas.

Tributary spawning habitats have the largest average fredle index of all habitat types. The other three site classifications have almost identical average fredle index numbers. The average fredle index number in the other sites is roughly half of that found in tributary habitats.

4.0 DISCUSSION

This report provides a preliminary data summary of surface and intragravel water temperatures and substrate composition in tributary, side channel, and mainstem habitats in the middle Susitna River. These data provide information on salmon incubation conditions which can be used to evaluate potential replacement salmon spawning habitat in mainstem and side channel sites in the middle Susitna River. These potential salmon spawning areas appear to be presently limited by high water velocities and may have flows more suitable for salmon spawning under with-project flow regimes. The data in this report only provide baseline information on salmon incubation conditions to allow preliminary identification and comparison of potential replacement salmon spawning habitats.

The primary means used to locate potential replacement salmon spawning areas in mainstem and side channel habitats was to focus on areas of open leads identified in winter aerial photos. Open leads often indicate the presence of upwelling areas which are used as spawning habitats for chum salmon (Vincent-Lang et al. 1984). Upwelling areas in mainstem and side channel sites would therefore be likely locations for providing suitable replacement salmon spawning habitat under with-project flow conditions, assuming other salmon spawning requirements are favorable. Although salmon have been observed spawning in mainstem and side channel habitats in which open leads did not occur during winter, periodic freezing and dewatering of substrates in these areas make them unsuitable for salmon incubation. Upwelling areas would provide a more stable incubation environment (Vining et al. 1984) and therefore should be considered first when selecting potential salmon spawning replacement habitat.

Comparison of intragravel water temperatures and substrate composition in tributary, side channel and mainstem salmon spawning habitats indicate that these parameters are similar in spawning areas among these three habitat types. These data also indicate that comparable intragravel water temperatures and substrate composition exist in areas of open leads in mainstem and side channel habitats where salmon spawning has not been recorded. The presence of suitable intragravel water temperatures and substrate composition indicates that these areas have good potential as replacement salmon spawning habitat under with project flow conditions. In general, tributary habitats appear to be better suited for salmon spawning and incubation than those mainstem and side channel sites which were surveyed. Although areas of open leads in mainstem and side channel sites, where salmon spawning had not been recorded, contained suitable spawning substrates, the substrates contained twice as much fines less than 1.0 mm than the other three habitats.

Based on these preliminary surveys, it appears that sites exist in side channel and mainstem habitats in the middle Susitna River that may provide suitable replacement salmon spawning habitat. Some of these areas may require additional habitat modifications such as improving passage conditions or loosening of cemented substrates to provide better spawning habitat. However, the information presented in this report is based on limited field observations and data. More detailed studies should be conducted in the future at selected replacement habitat sites to determine which sites would be most cost effective for mitigation purposes.

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-- S. Crumley, N.E. Bradley, and T. Jennings of Entrix, Inc. for their assistance in data collection and helpful insights into the use of the freeze core sampler.

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8.0 APPENDICES

APPENDIX A

Mainstem and Side Channel

Salmon Spawning Distribution Maps.

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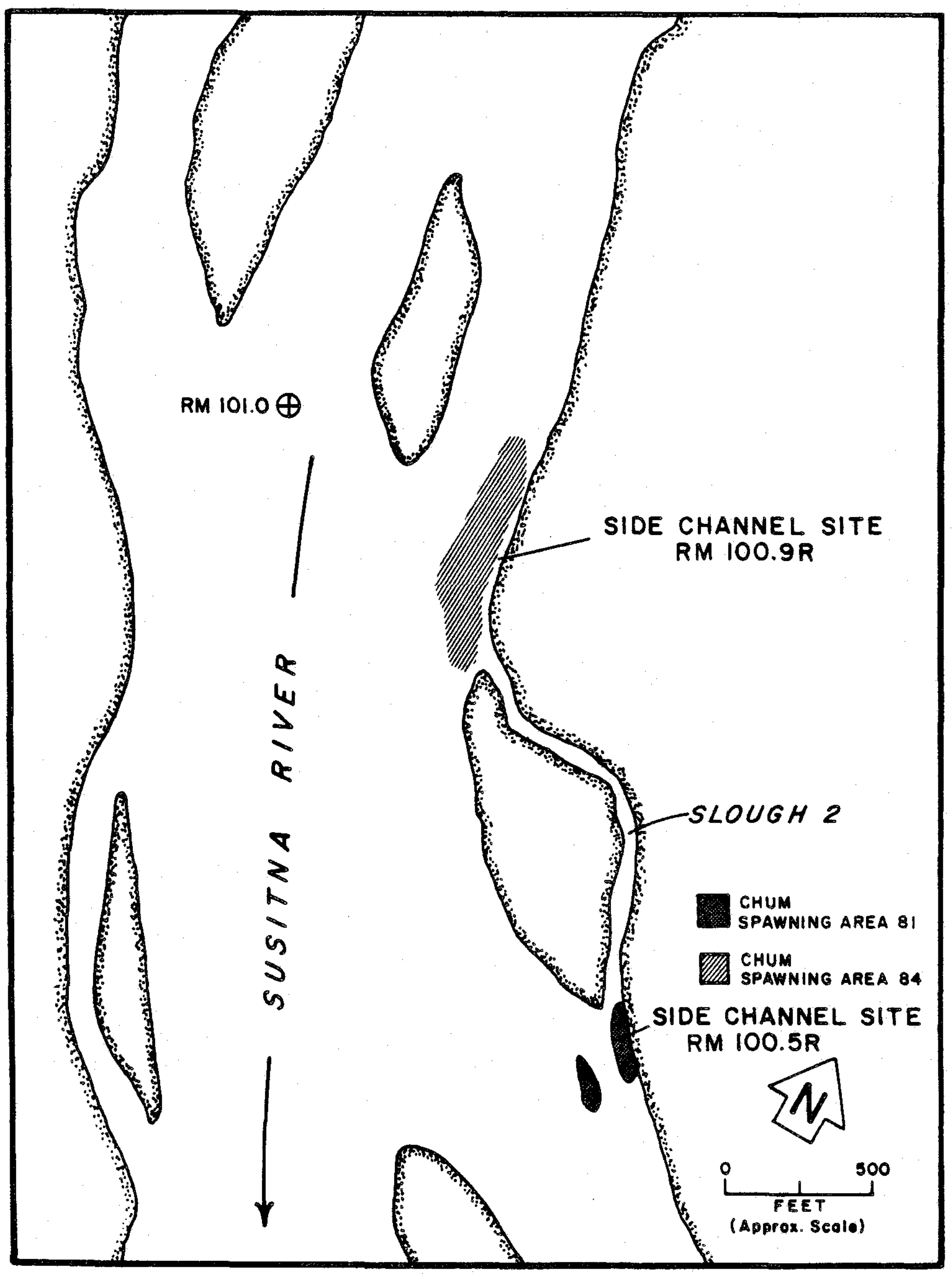

Appendix Figure A-1. Observed chum salmon side channel spawning sites between RM 100.0 and 101.0 in the middle Susitna River.

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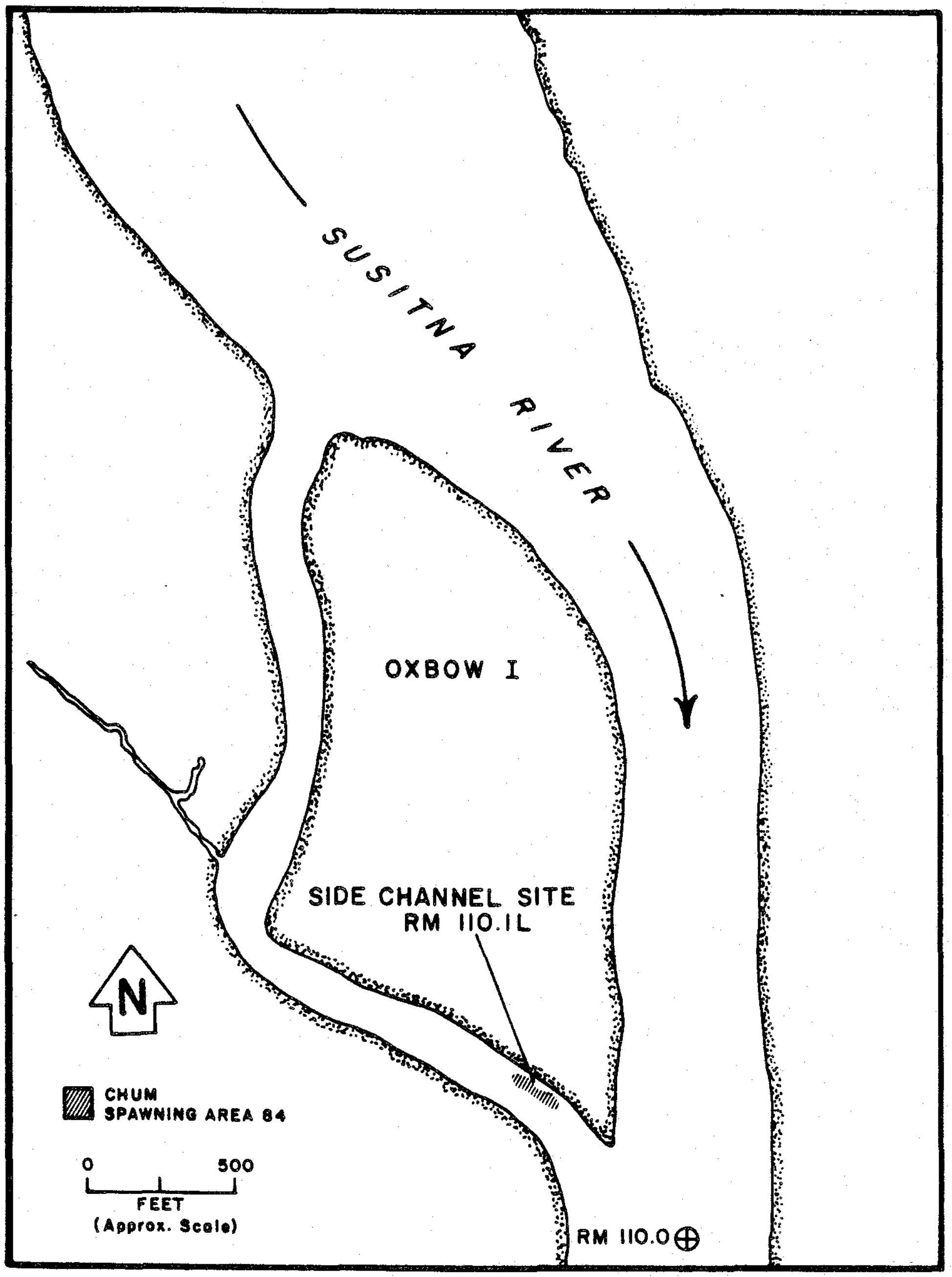

Appendix Figure A-2. Observed chum salmon side channel spawning site at RM 110.1 in the middle Susitna River.

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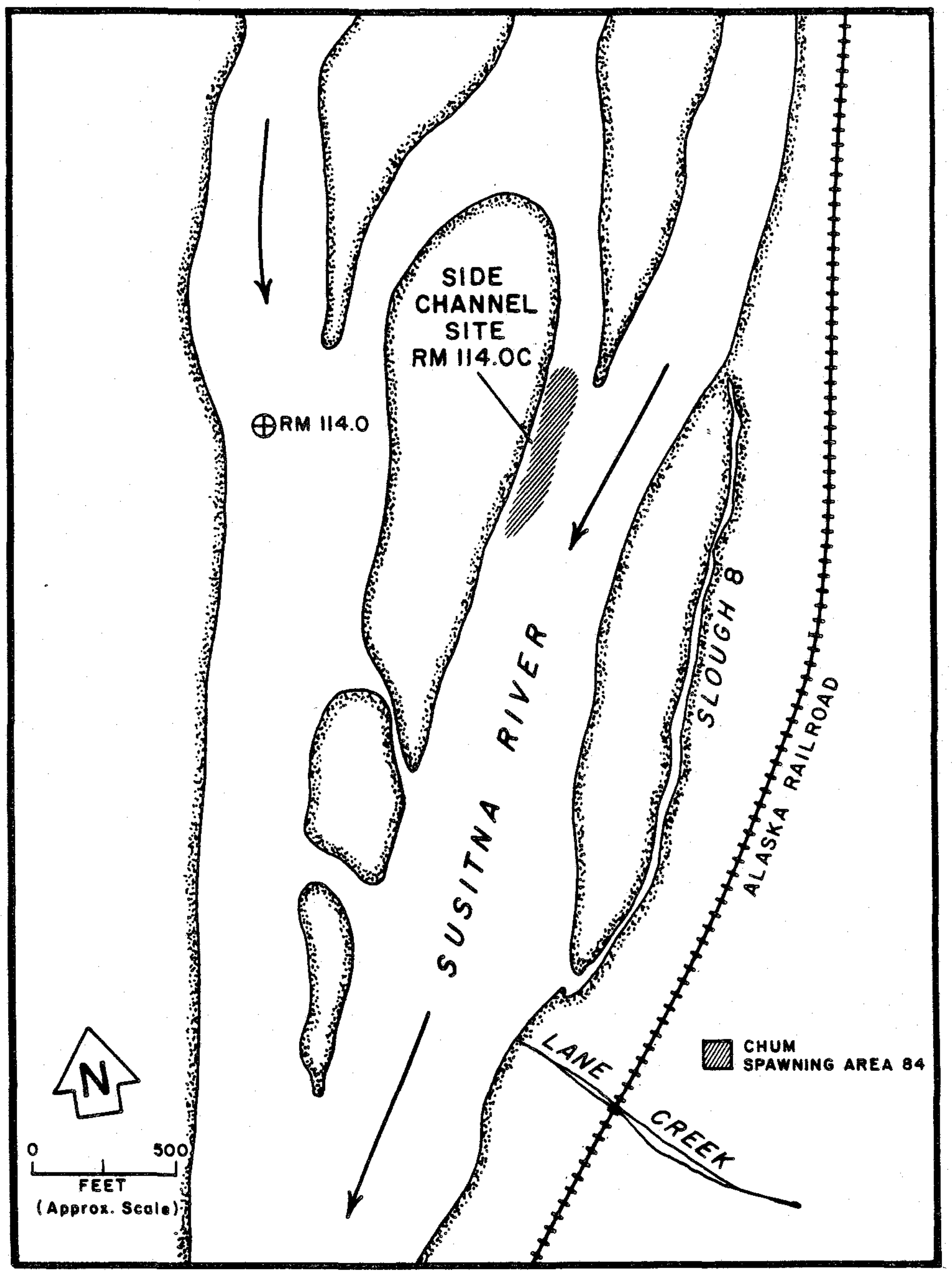
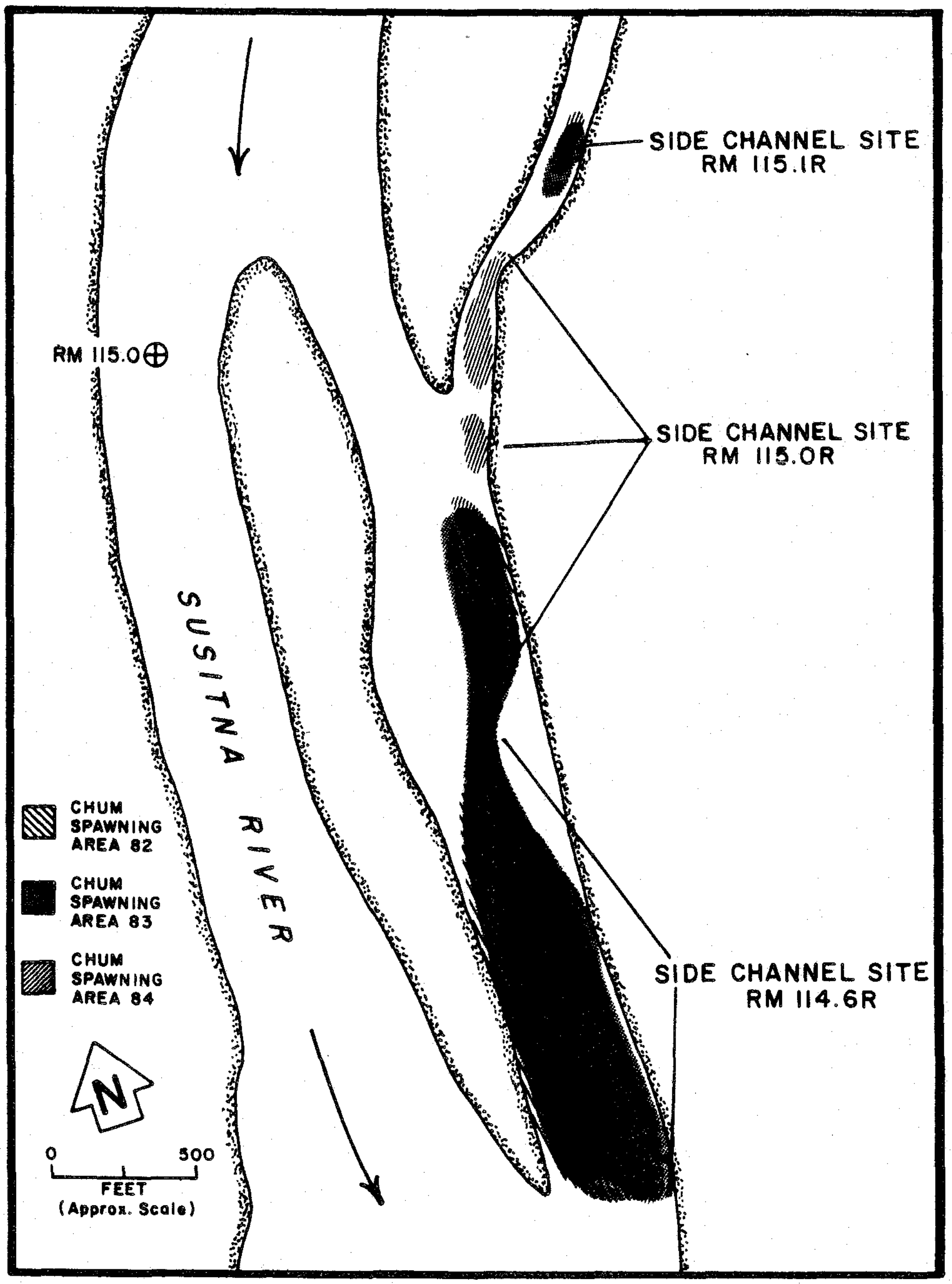
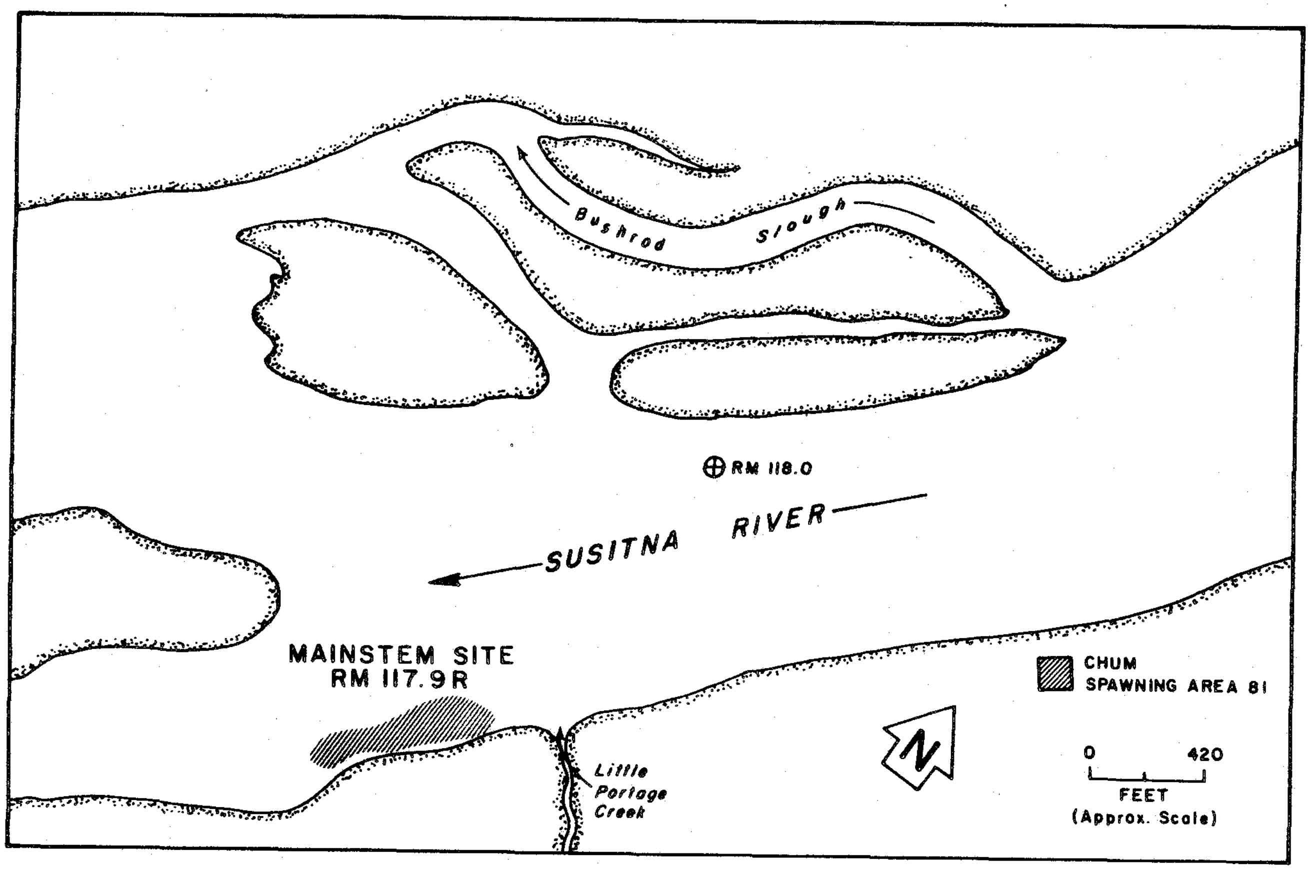


Appendix Figure A-3. Observed chum salmon side channel spawning site at RM 114.0 in the middle Susitna River.



Appendix Figure A-4. Observed chum salmon side channel spawning sites between RM 114.5 and 115.5 in the middle Susitna River.



Appendix Figure A-5. Observed chum salmon mainstem spawning site at RM 117.9 in the middle Susitna River.

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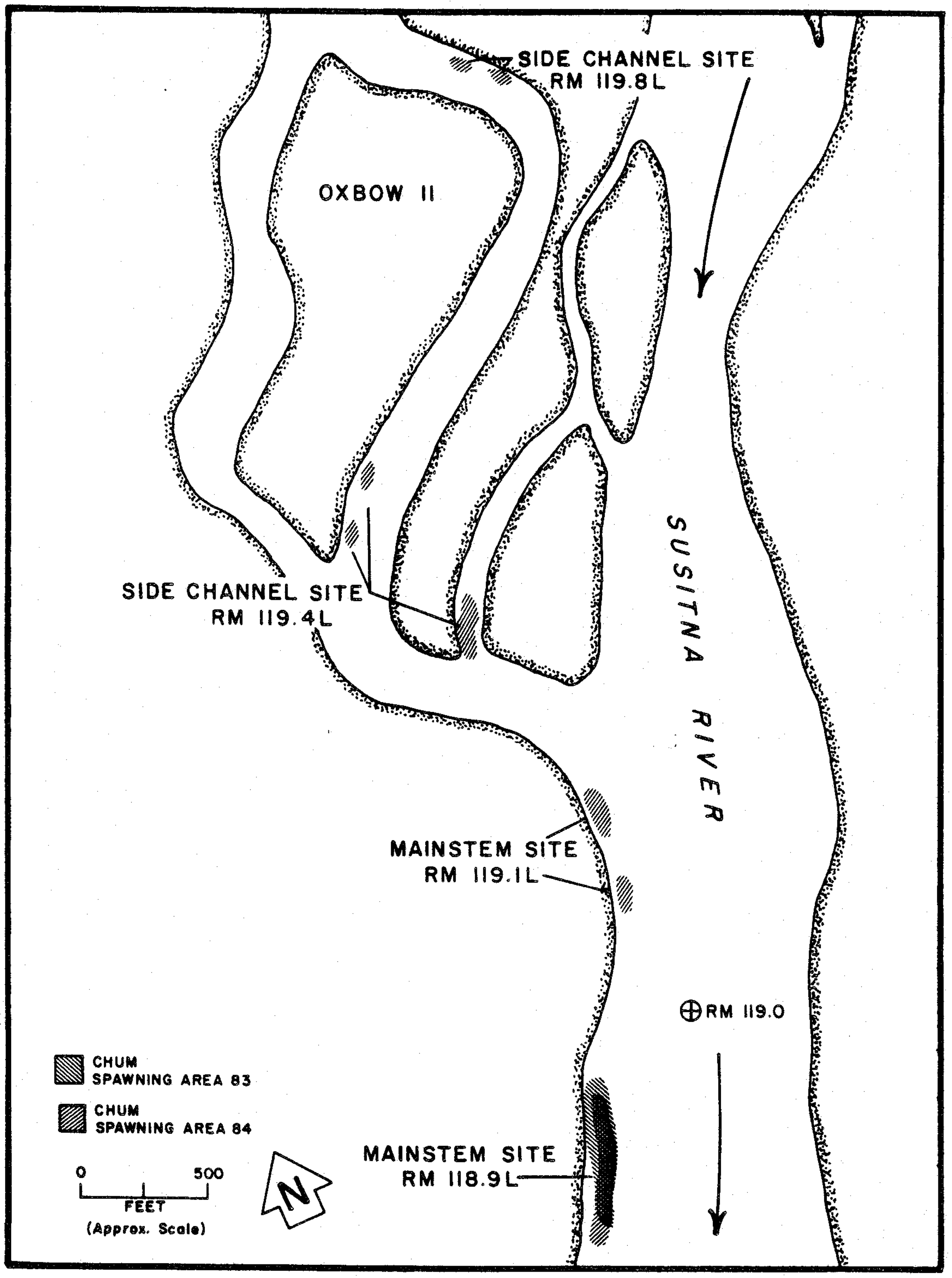

Appendix Figure A-6. Observed chum salmon side channel and mainstem spawning sites between RM 118.5 and 120.0 in the middle Susitna River.

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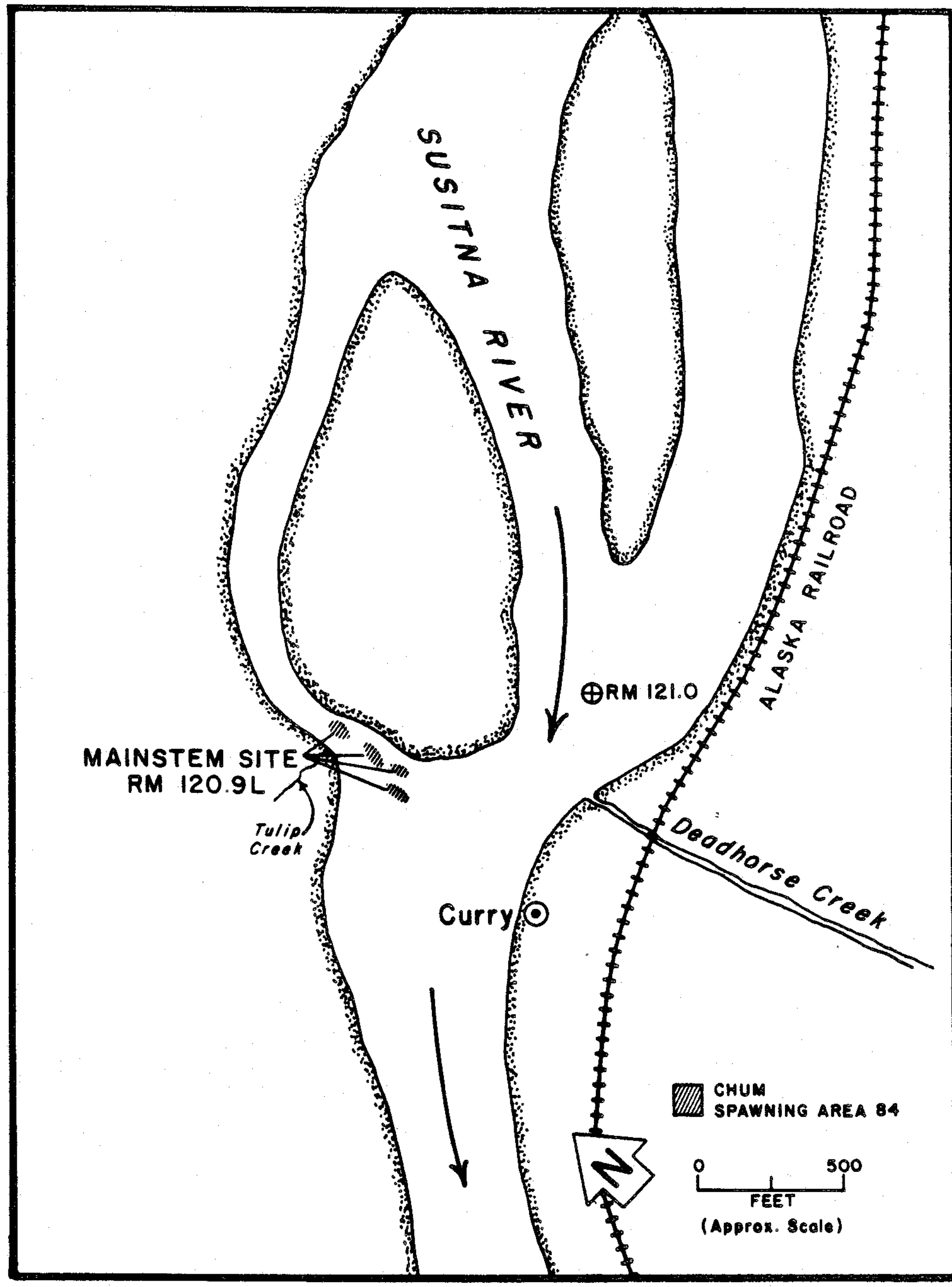

Appendix Figure A-7. Observed chum salmon mainstem spawning site at RM 120.9 in the middle Susitna River.

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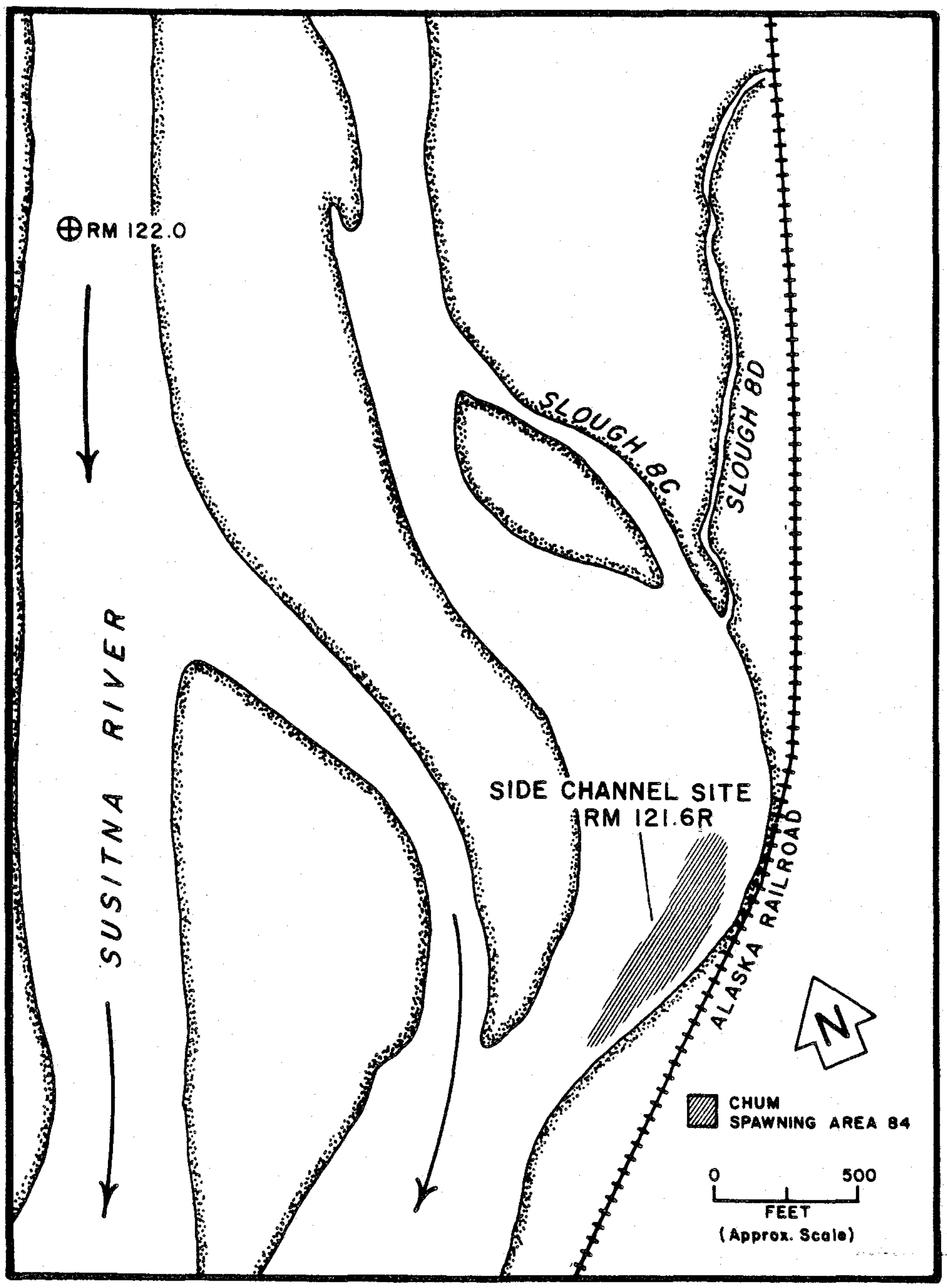

Appendix Figure A-8. Observed chum salmon side channel spawning site at RM 121.6 in the middle Susitna River.

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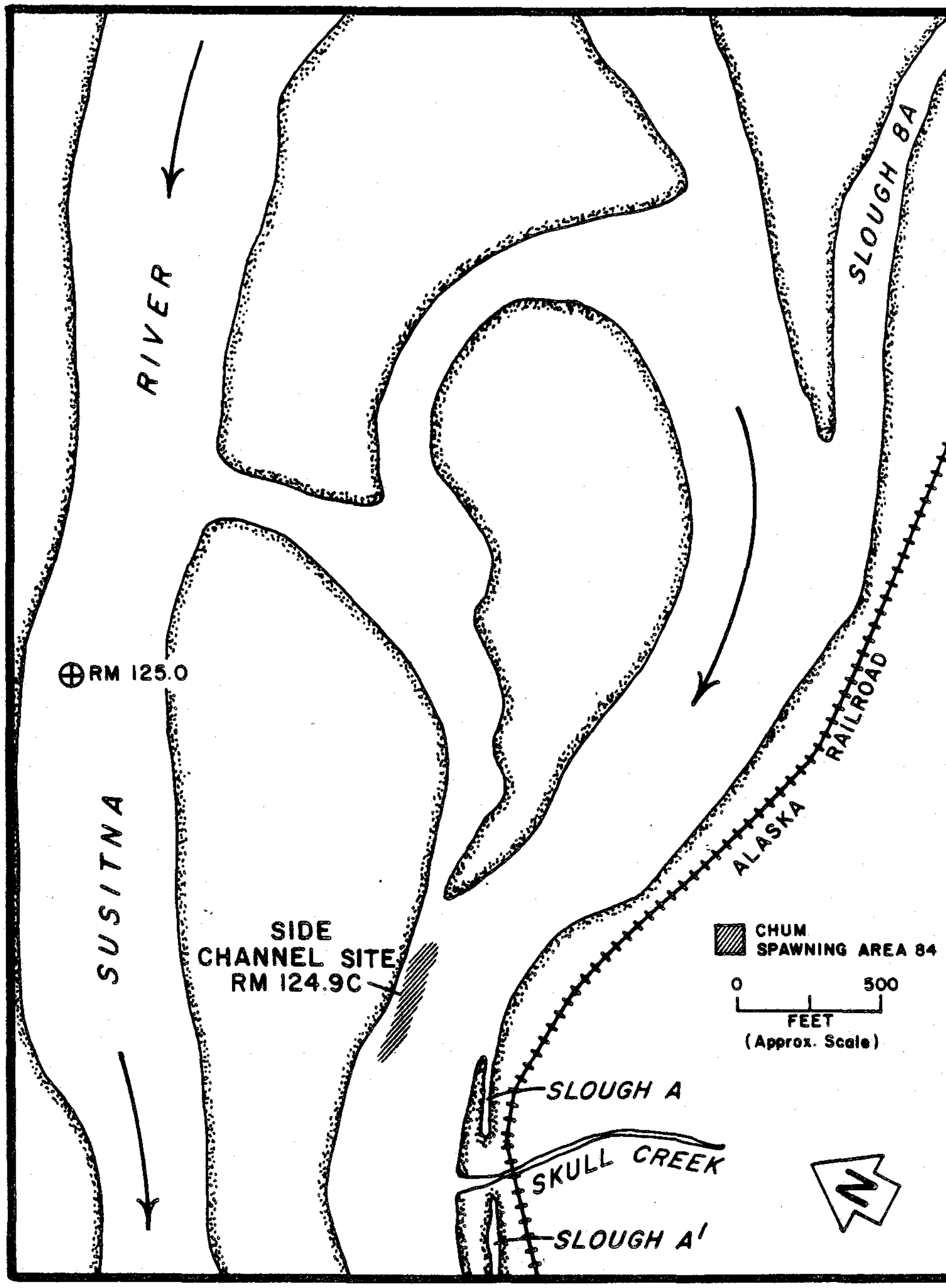
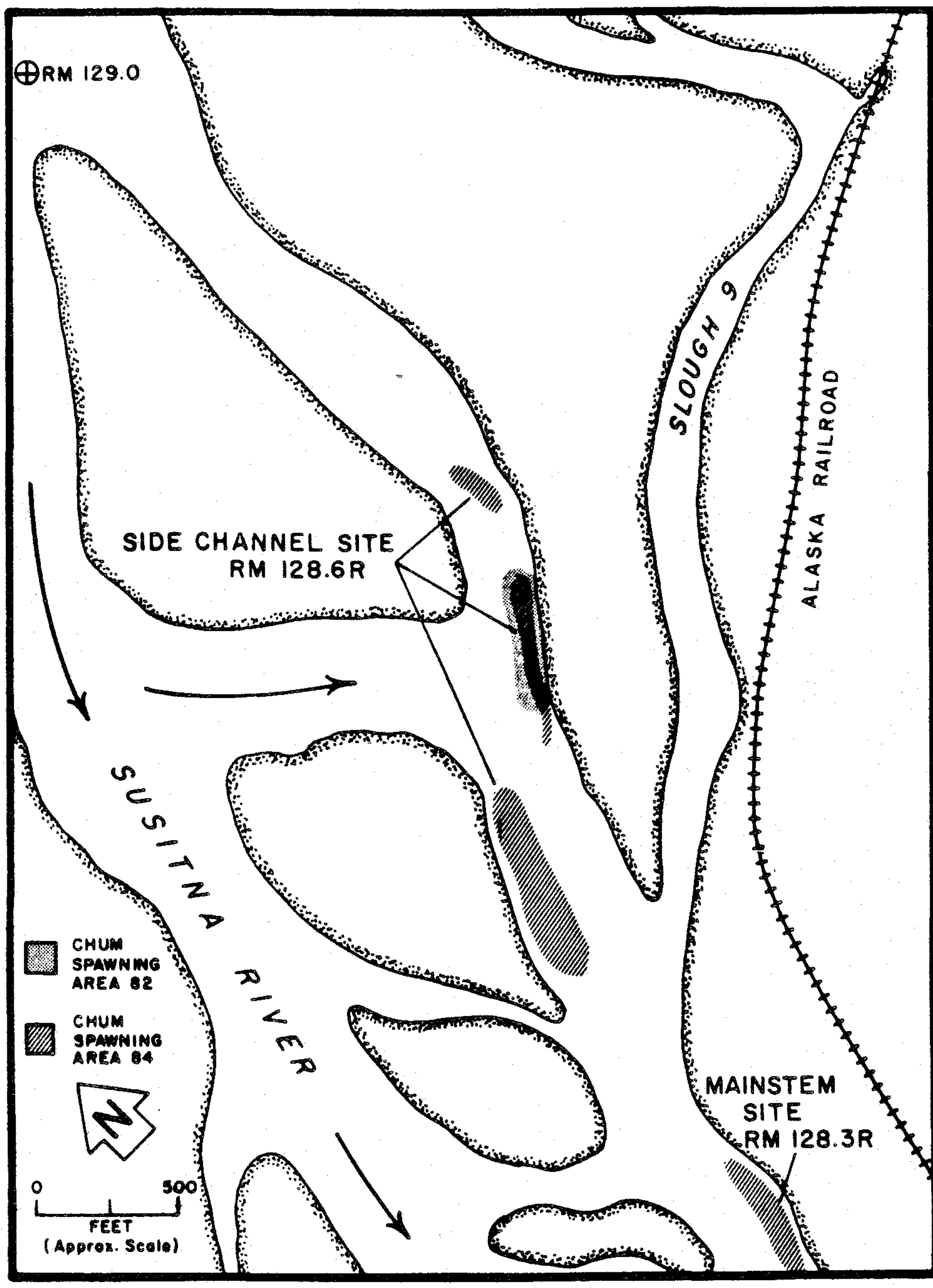
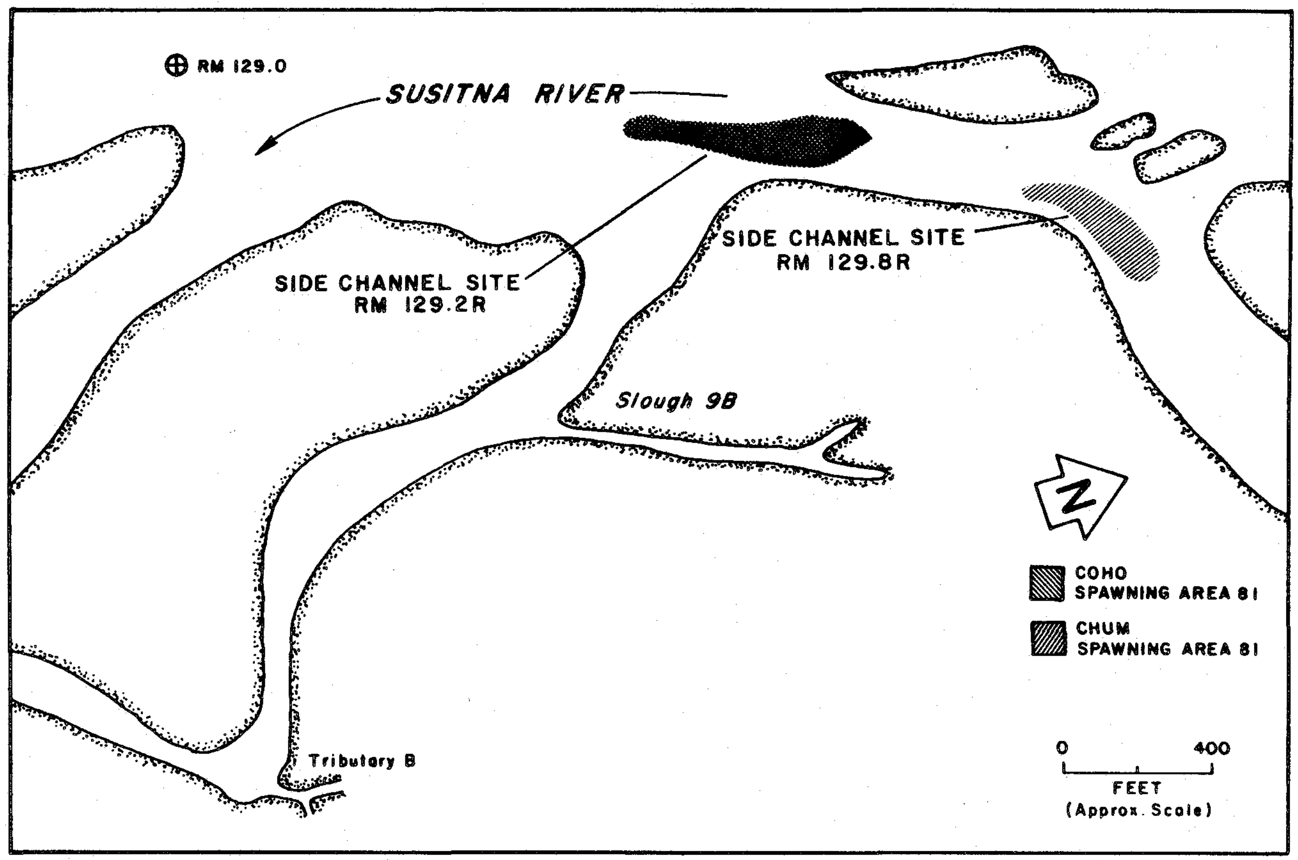


Appendix Figure A-9. Observed chum salmon side channel spawning site at RM 124.9 in the middle Susitna River.



Appendix Figure A-10. Observed chum salmon side channel and mainstem spawning sites between RM 128.0 and 129.0 in the middle Susitna River.



Appendix Figure A-11. Observed chum and coho salmon side channel spawning sites between RM 129.0 and 129.8 in the middle Susitna River.

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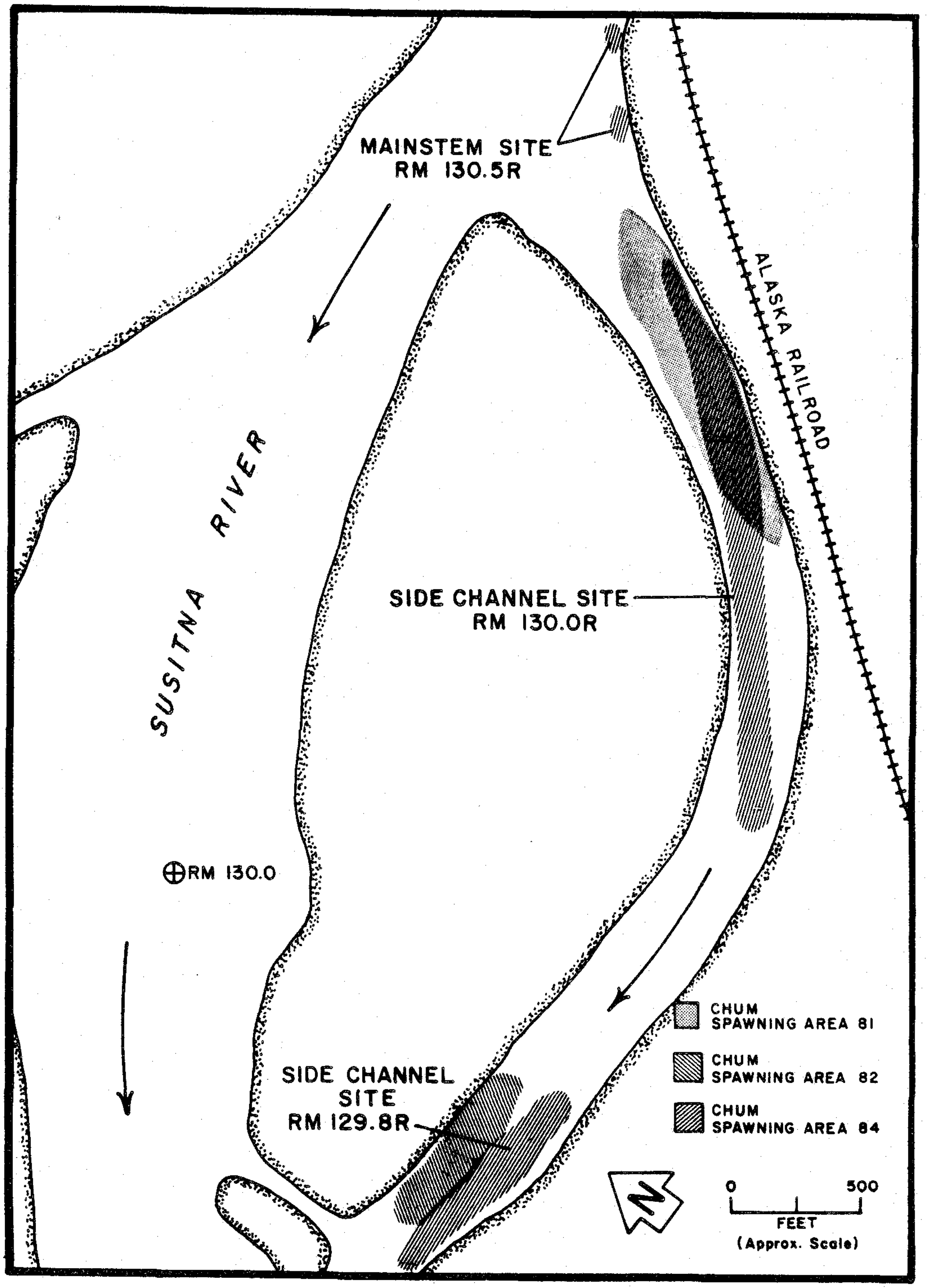

Appendix Figure A-12. Observed chum salmon side channel and mainstem spawning sites between RM 129.8 and 130.5 in the middle Susitna River.

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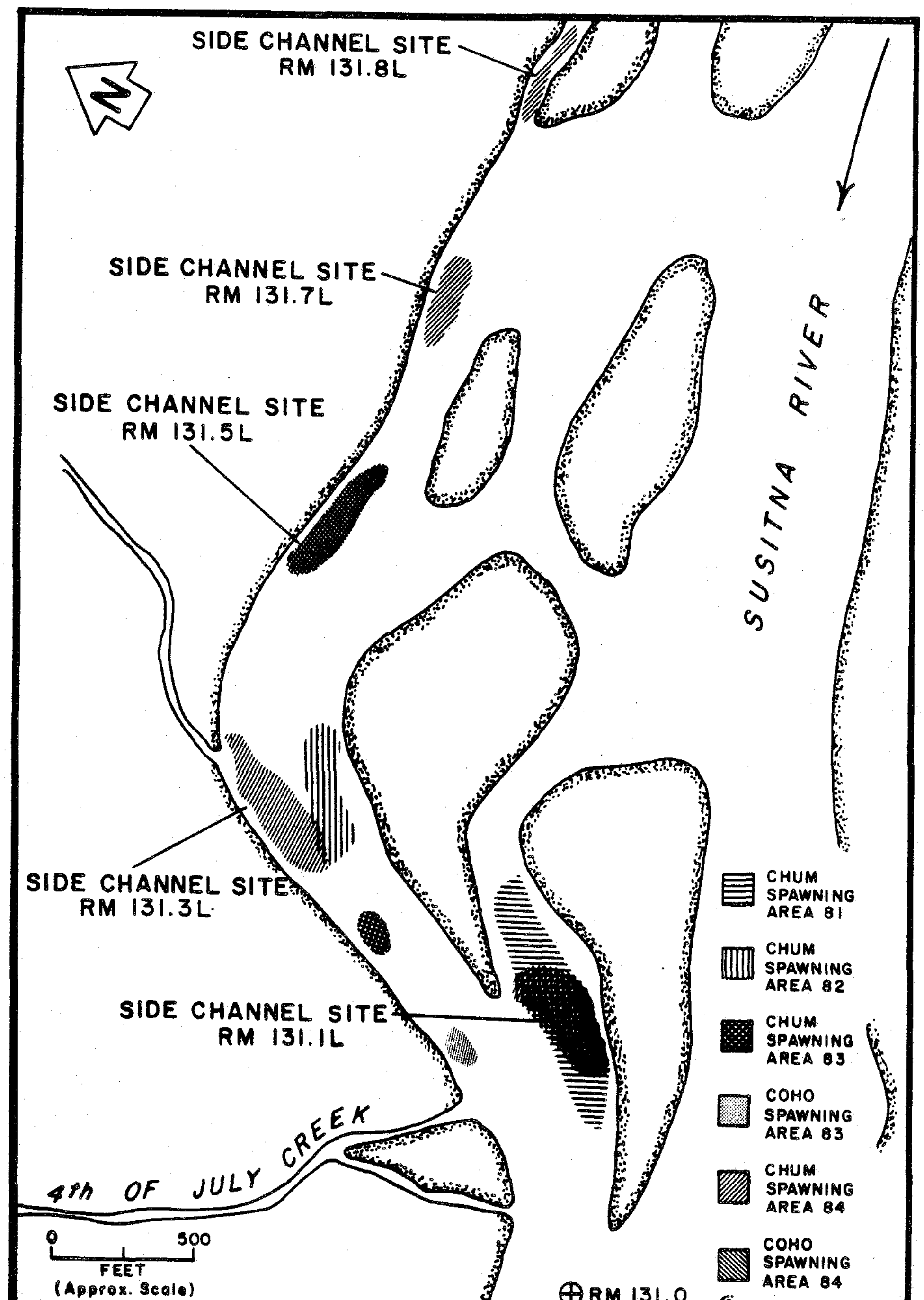

Appendix Figure A-13. Observed chum and coho salmon side channel spawning sites between RM 131.0 and 131.8 in the middle Susitna River.

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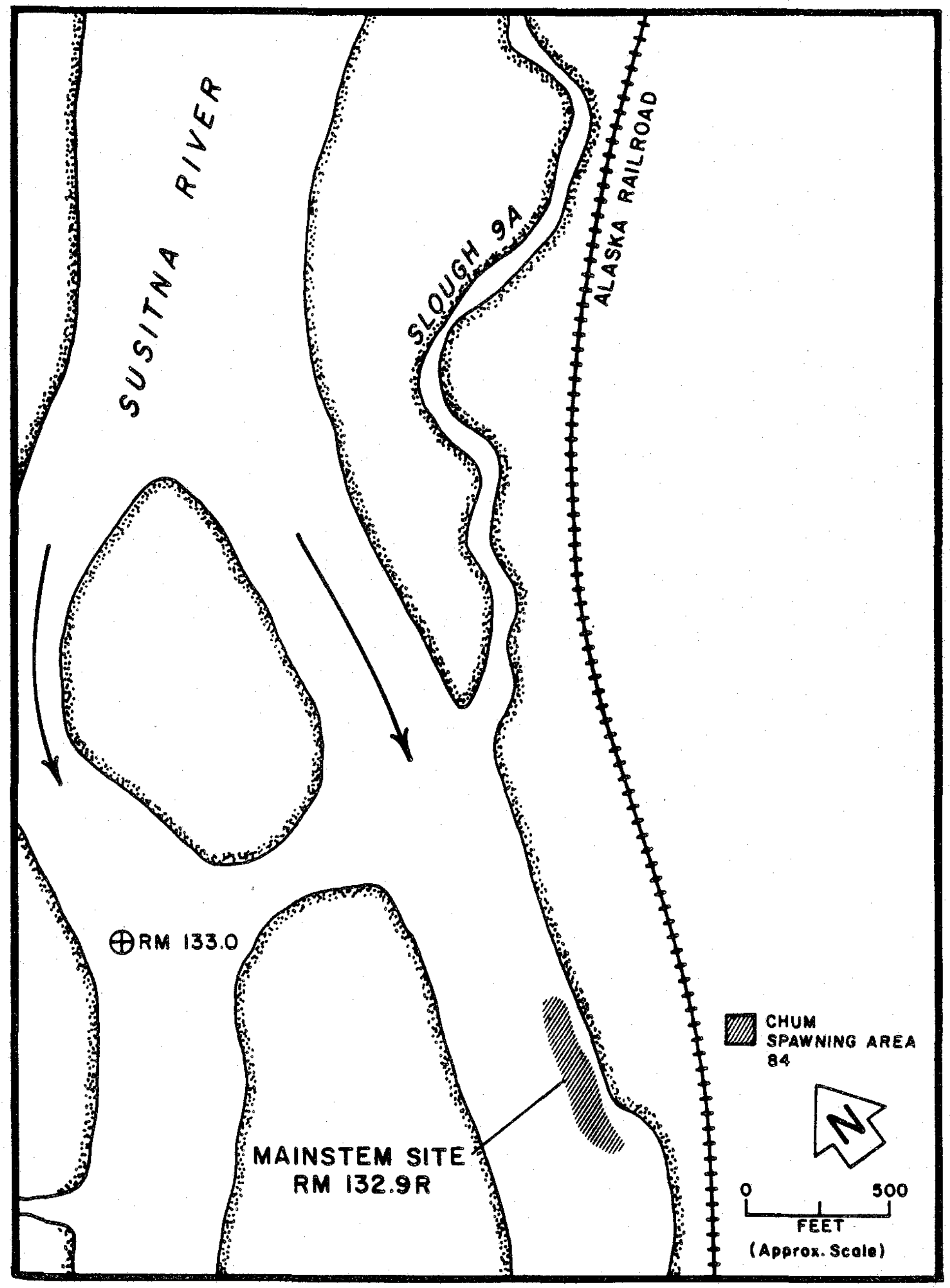
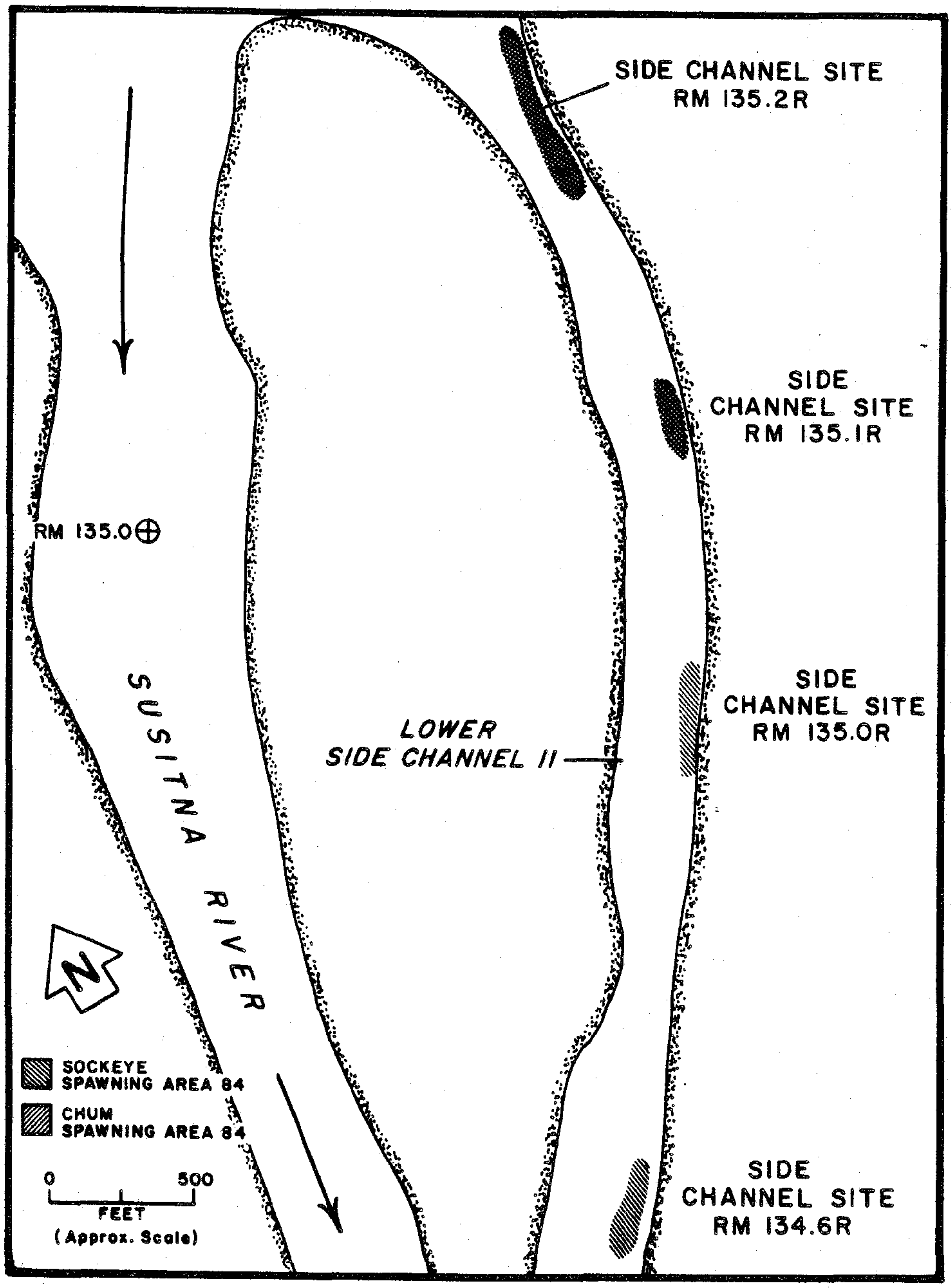


Appendix Figure A-14. Observed chum salmon mainstem spawning site at RM 132.9 in the middle Susitna River.



Appendix Figure A-15. Observed chum and sockeye salmon side channel spawning sites between RM 134.6 and 135.2 in the middle Susitna River.

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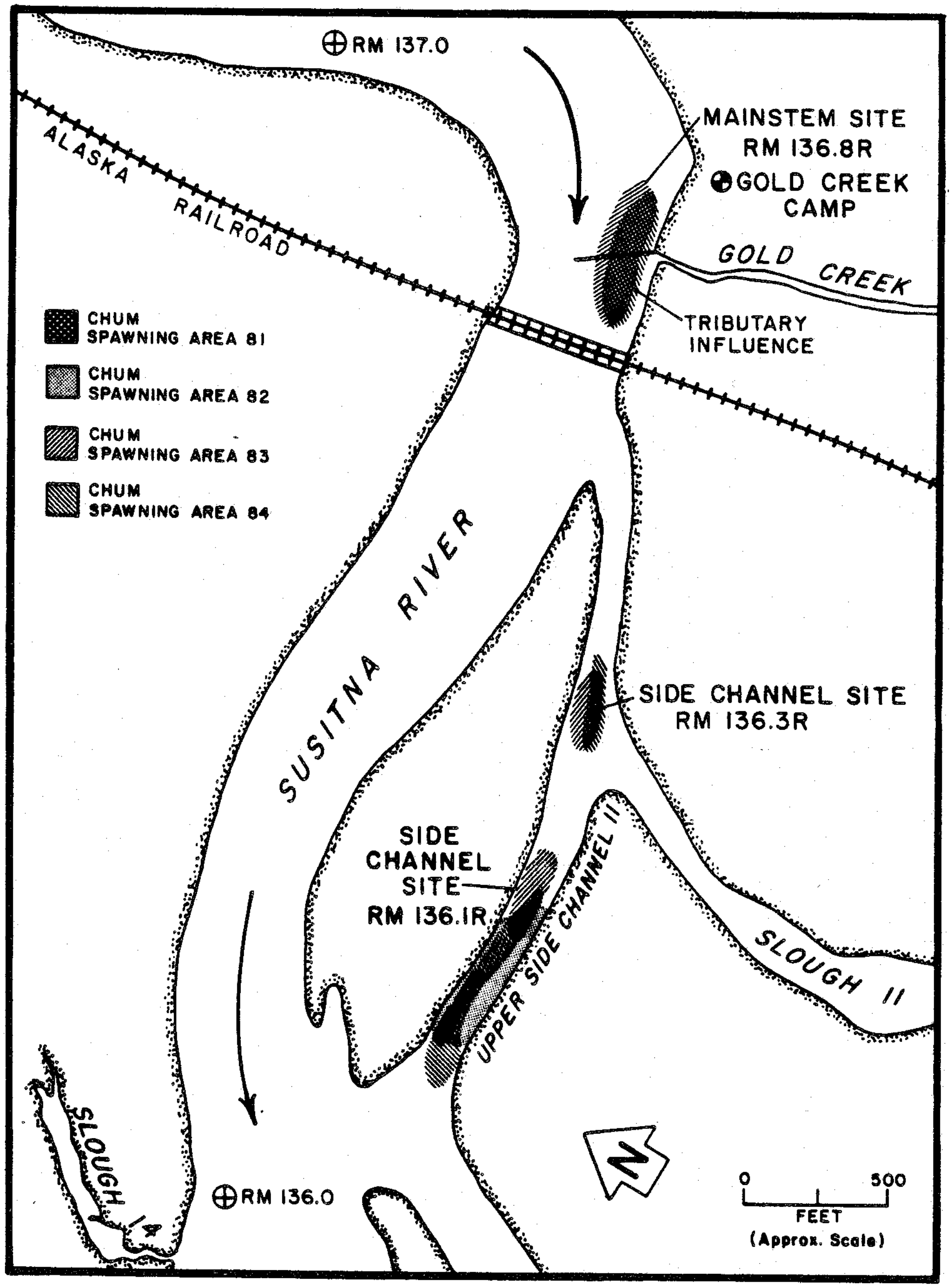
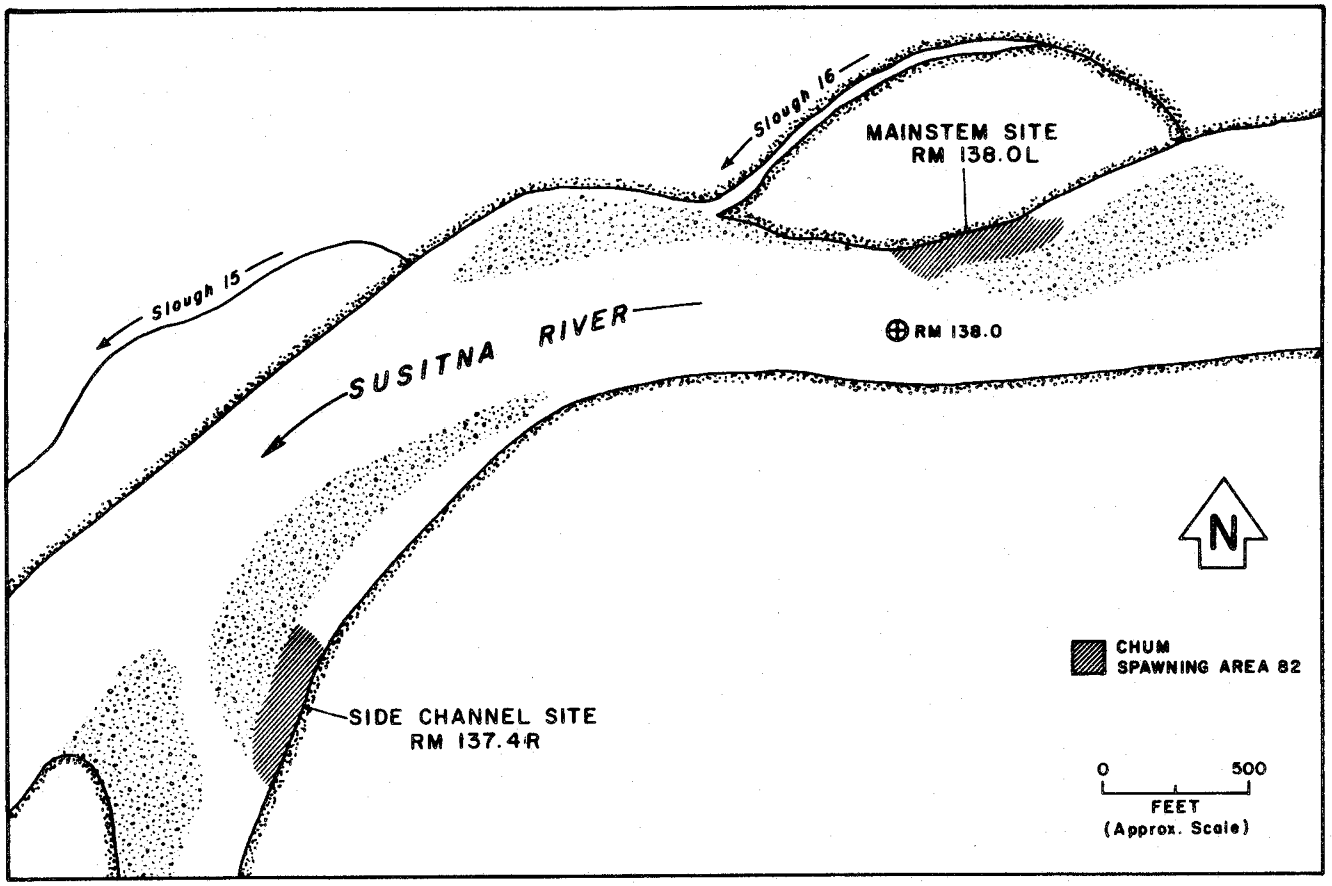


Appendix Figure A-16. Observed chum salmon side channel and mainstem spawning sites between RM 136.0 and 137.0 in the middle Susitna River.



Appendix Figure A-17. Observed chum salmon side channel and mainstem spawning sites between RM 137.0 and 138.0 in the middle Susitna River.

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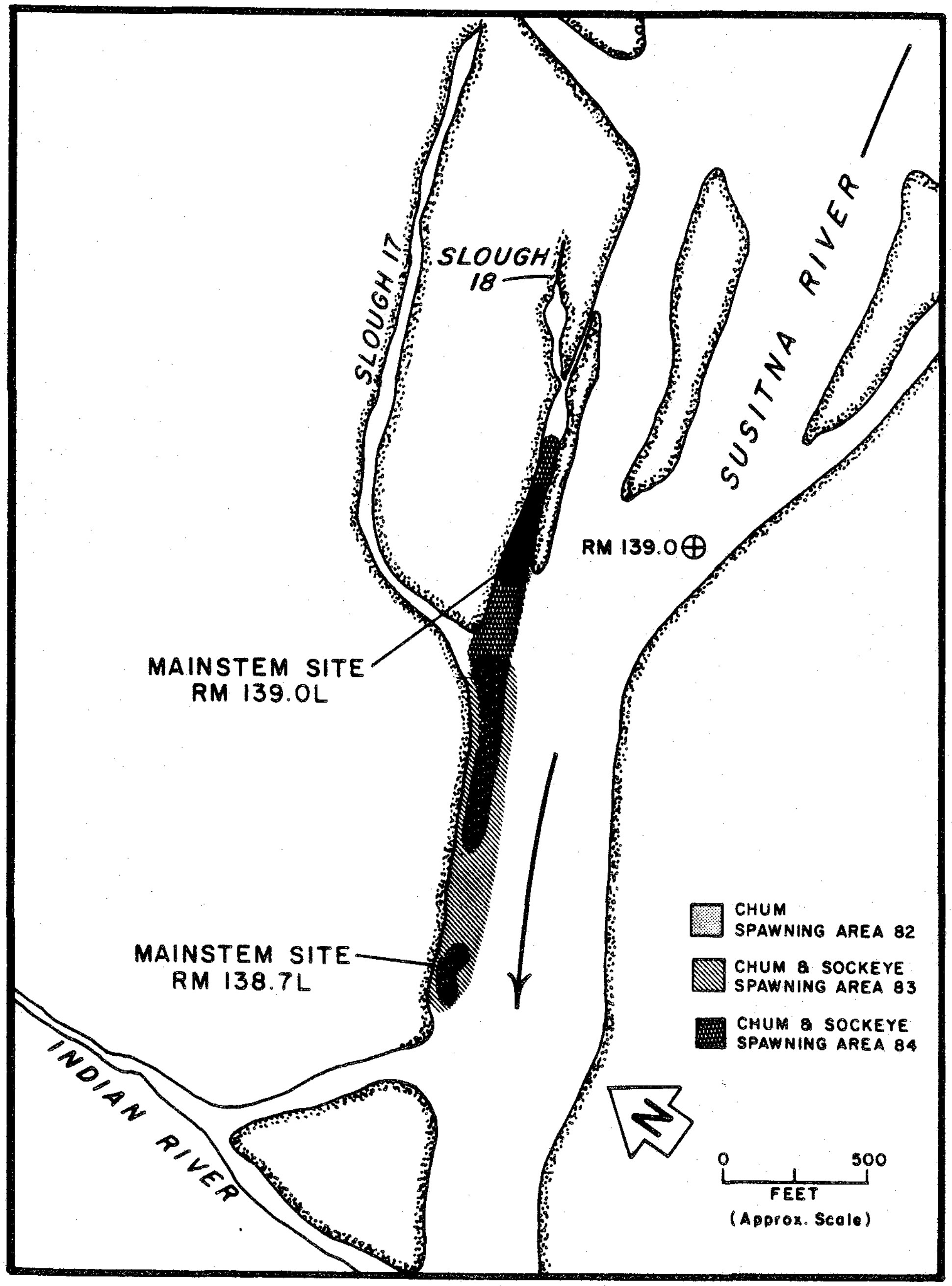
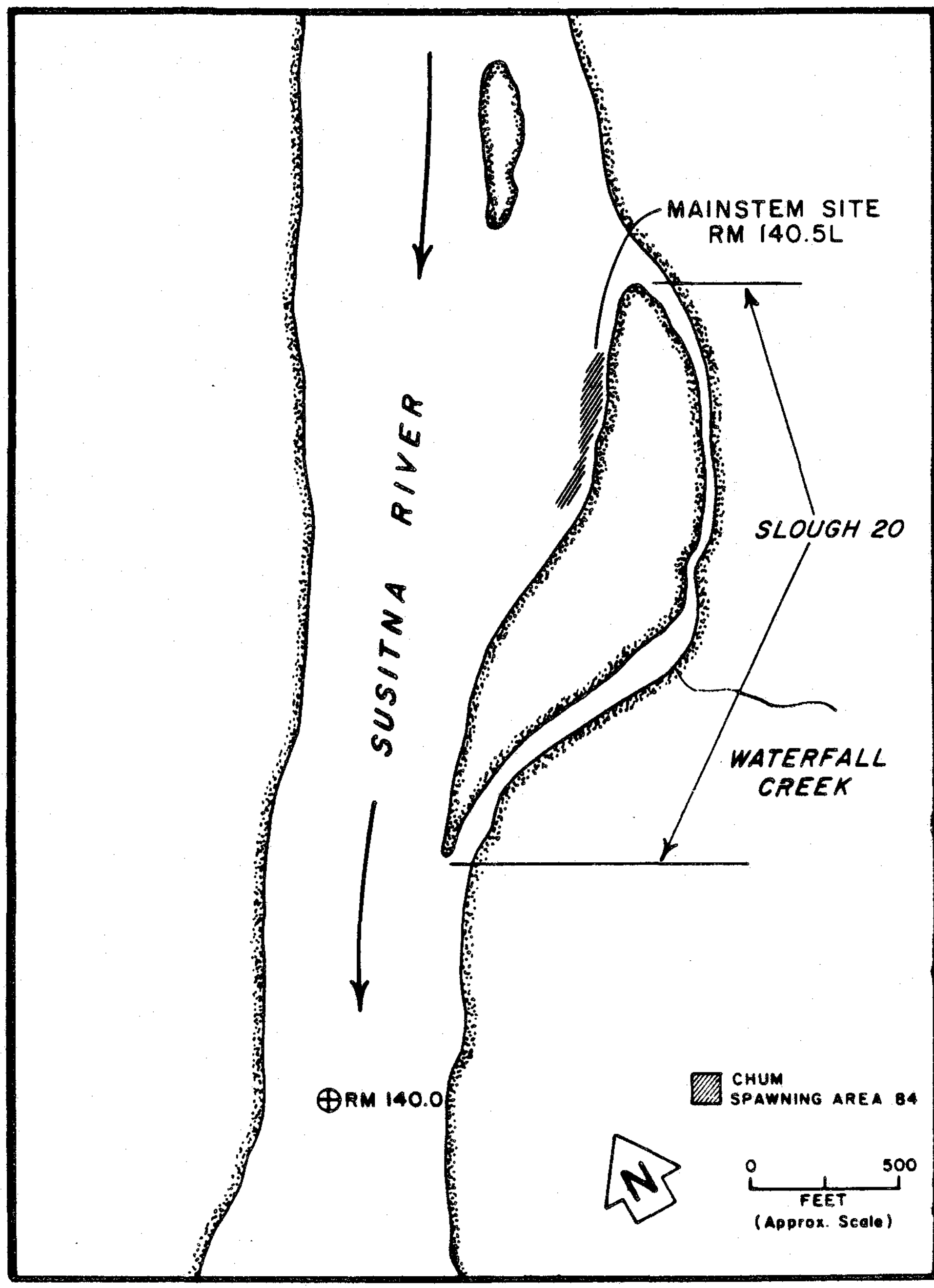
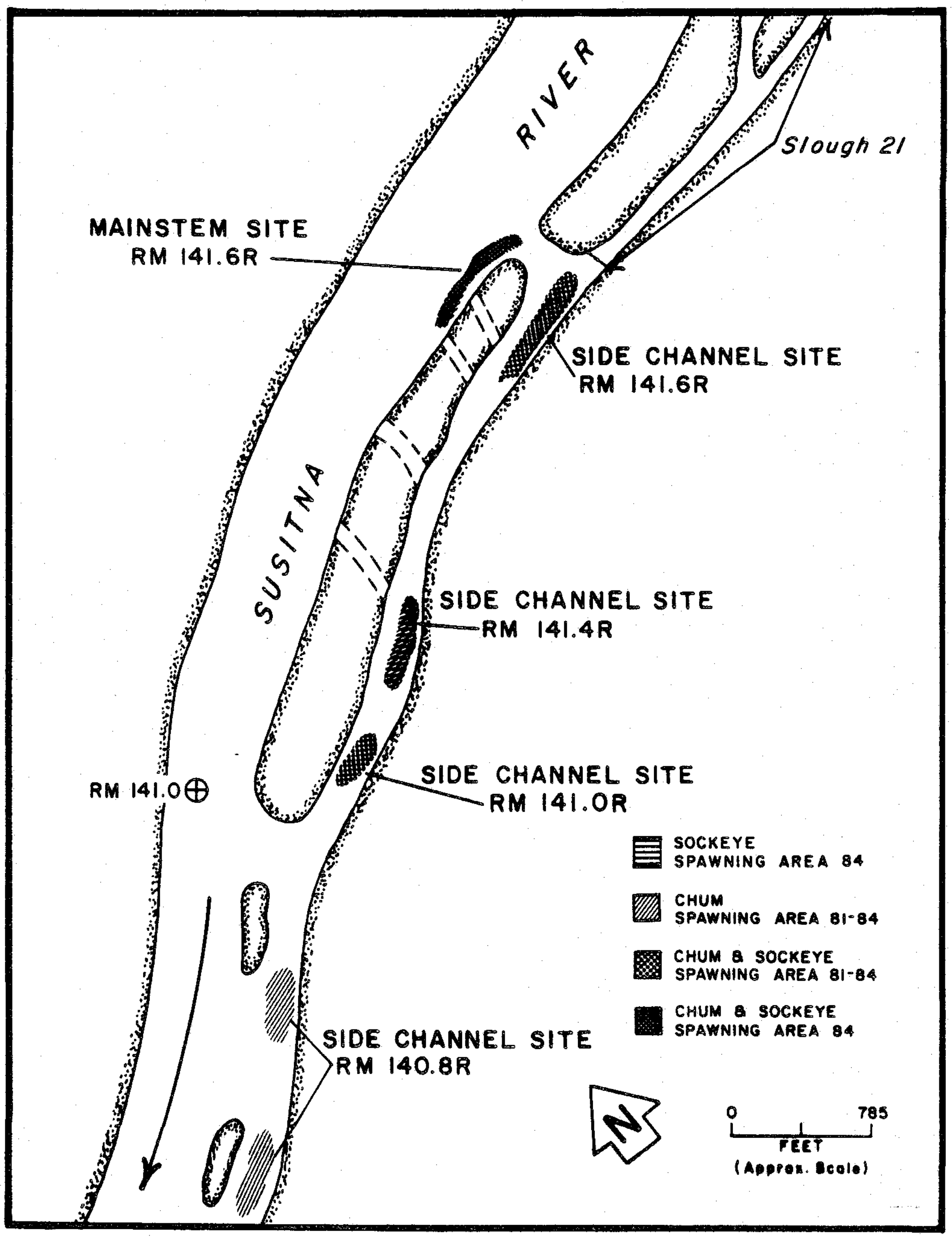


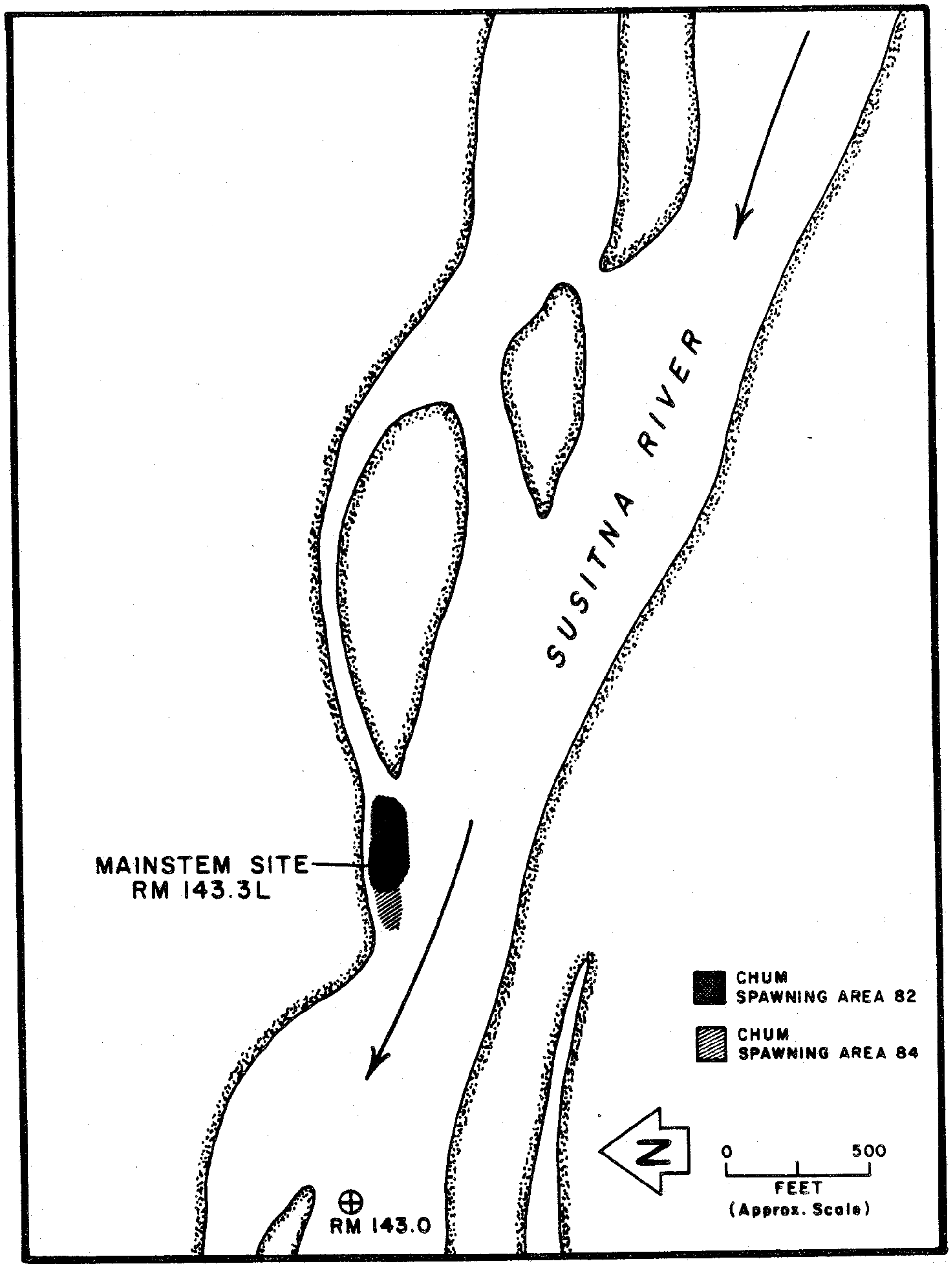
Appendix Figure A-18. Observed chum and sockeye salmon mainstem spawning sites between RM 138.5 and 139.5 in the middle Susitna River.



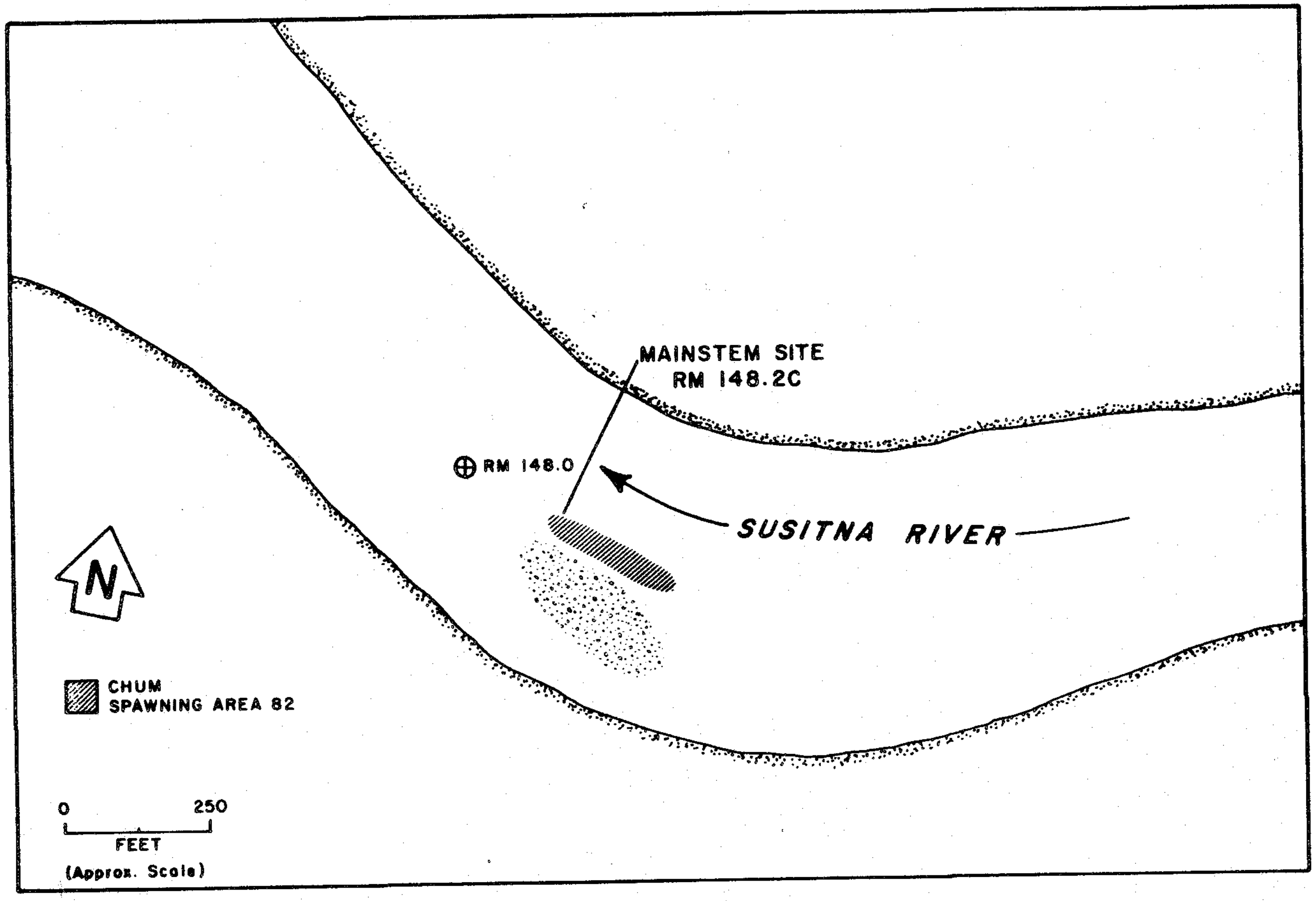
Appendix Figure A-19. Observed chum salmon side channel spawning site at RM 140.5 in the middle Susitna River.



Appendix Figure A-20. Observed chum and sockeye salmon side channel and mainstem spawning sites between RM 140.8 and 141.6 in the middle Susitna River.



Appendix Figure A-21. Observed chum salmon mainstem spawning site at RM 143.3 in the middle Susitna River.



Appendix Figure A-22. Observed chum salmon mainstem spawning site at RM 148.2 in the middle Susitna River.

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APPENDIX B

Site Descriptions at Continuous Water

Temperature Monitoring Locations

Used for Ice Covered Studies.

Tributary Habitats

Lane Creek (RM 113.6R/TRM 0.1)

Lane Creek is a clear water stream originating in the sloping terrain bordering the east bank of the Susitna River, entering the mainstem Susitna River at river mile 113.6. It consists of a series of pools, riffles and small falls flowing over boulder/cobble substrate. In the pools, there are areas of excellent large gravel/small gravel substrate. Overhanging vegetation grows along the banks, and algae flourishes on the rocks of the streambed.

Lane Creek is a traditional salmon spawning area for chinook, coho, chum and pink salmon. There doesn't appear to be any barriers to salmon passage except at the mouth during periods of low mainstem discharge. Additional information on chum salmon spawning in the tributary mouth habitat can be found in Sandone et al. 1984.

The datapod site is located in a 2-4 foot deep pool approximately 1,800 feet from the mouth on the left bank (Appendix Figure B-1). Substrate in the pool consists of small gravel/large gravel. During winter, an open lead is present through this area except during the coldest periods. The lead is possibly due to velocity and current effects, as no upwelling or bank seepage was observed. This area was utilized by all species of salmon spawning in the creek.

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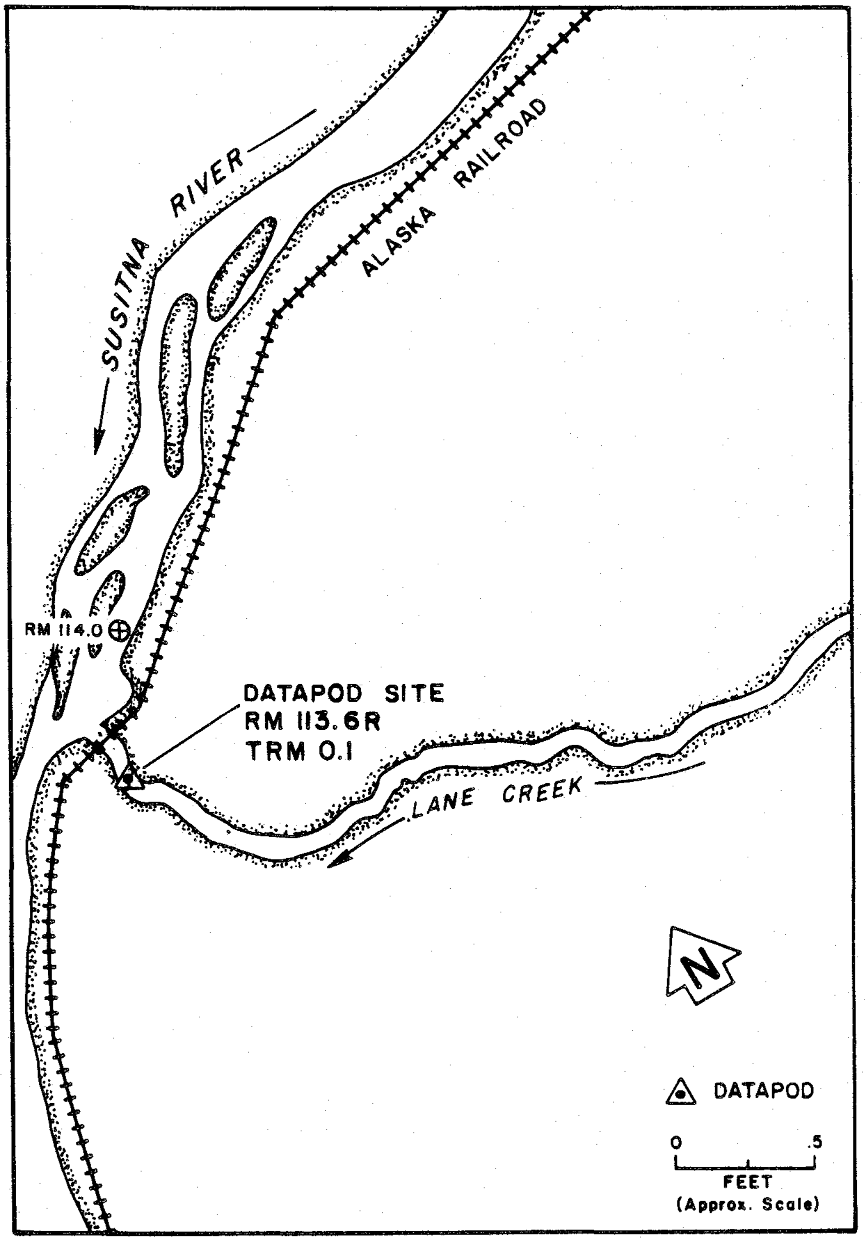


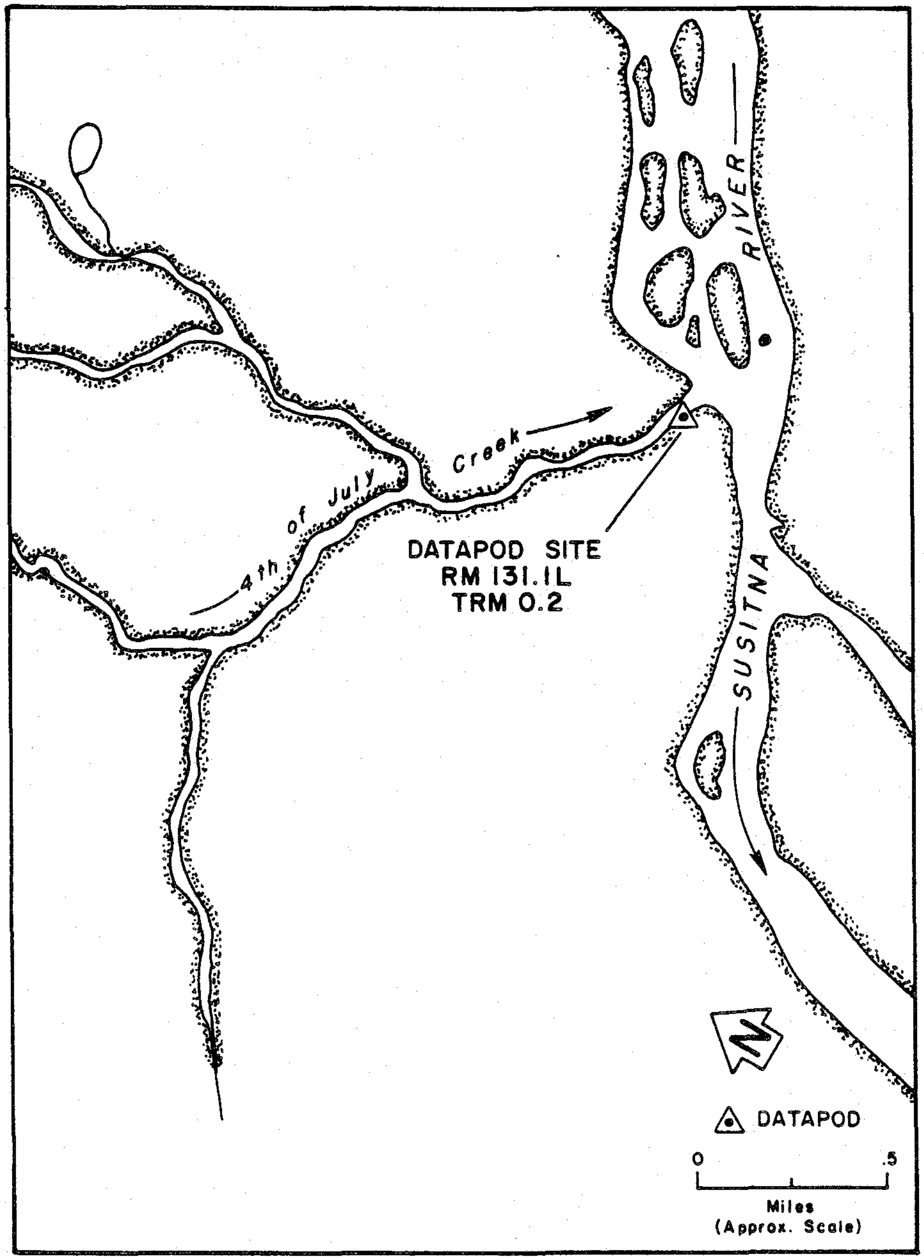
Appendix Figure B-1. Location of datapod in a tributary habitat, Lane Creek, RM 113.6R, TRM 0.1.

4th of July Creek (RM 131.0/TRM 0.2)

Fourth of July Creek enters the west side of the Susitna River at river mile 131.0. The habitat consists of a series of pools and riffles. Boulder/cobble substrate is present in the riffles, with pockets of large gravel and rubble in the slower velocity pool areas. Log jams are common in this reach. The mouth of 4th of July Creek is known for overflow events during the process of mainstem staging and freeze up which can result in a build up of ice several feet thick.

Chinook, coho, chum and pink salmon utilize 4th of July Creek for spawning. There is a large waterfall approximately 3.5 miles upstream from the mouth that constitutes a barrier to upstream fish migration. Suitable salmon spawning habitat exists above this waterfall that is inaccessable. Further information on chum salmon spawning in the tributary mouth habitat can be found in Sandone et al. 1984.

A datapod water temperature recorder was located near the first major log jam approximately 1,300 feet upstream of the mouth (Appendix Figure B-2). Immediately below this log jam is a deep pool with small gravel/large gravel substrate. The datapod probe was on the north side of this pool in about three and one-half feet of water. This area was utilized by all species of salmon spawning in the creek.



Appendix Figure B-2. Location of datapod in a tributary habitat, 4th of July Creek, RM 113.1L, TRM 0.2.

Indian River (RM 138.6L/TRM 0.2)

Indian River enters the Susitna River on the northwest side, at river mile 138.6. This is a clear water tributary flowing over cobble/boulder substrate in a pool-riffle pattern. There are areas of large gravel/rubble substrates associated with pool areas. The stream channel of Indian River is braided over the first mile due to a shallower gradient over this reach.

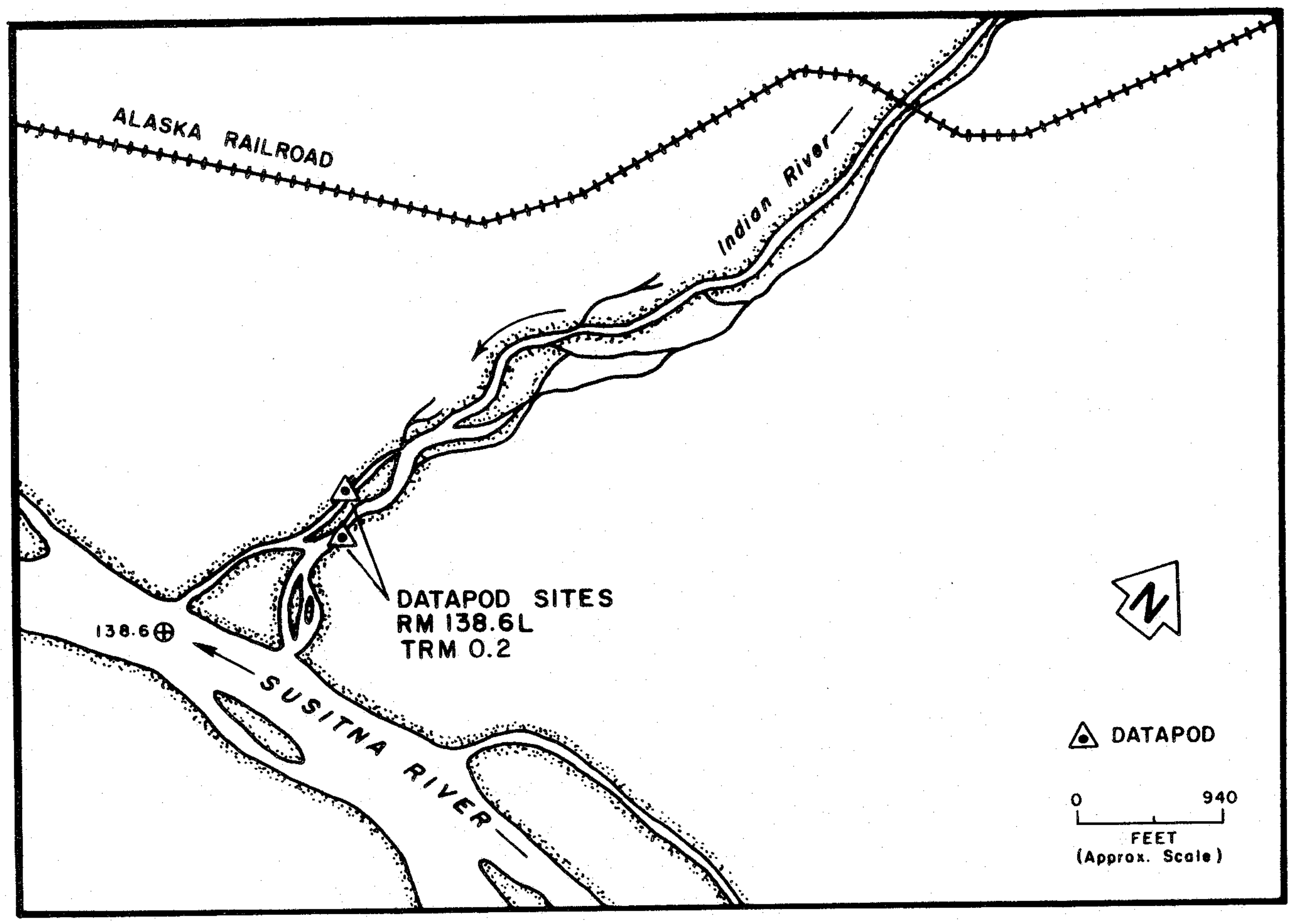
All five species of salmon spawn in Indian River. Chinook salmon use 13 miles of its reach. There appears to be little or no passage restrictions, as extensive areas are used for spawning.

There are two datapod water temperature recorders in Indian River (Appendix Figure B-3). One is on the right bank 3,000 feet upstream of the mouth. This spawning site was used by all species of salmon. The other datapod site is located on the left bank, 4,000 feet from the mouth. This site was only utilized by chinook salmon.

Side Channel Habitats

Mainstem Two Side Channel (RM 115.0R)

Mainstem Two is a Y-shaped side channel approximately one mile long located one mile upstream of Lane Creek. The side channel is separated from the mainstem Susitna by a large vegetated island.



Appendix Figure B-3. Location of datapod in a tributary habitat, Indian River, RM 138.6L, TRM 0.2.

The east and west forks are 4,400 and 2,800 feet long respectively. The confluence of the channels is approximately 1,600 feet upstream of the mouth. The east fork breaches at approximately 25,000 cubic feet/second (cfs) while the west fork breaches at 16,000 cfs.

The first 1,600 feet of the side channel is primarily a backwater area. Above this reach the habitat consists of pool and riffle sequences throughout both forks. Substrate in the backwater area is composed of a deep layer of silt/sand over cobble/boulder except in the extreme upper portions where there are pockets of rubble/large gravel. The riffles have well cemented cobble/boulder substrate, while the pools contain rubble/large gravel substrate.

There is moderate to heavy bank seepage and upwelling from both banks in the backwater area and in the east fork. In an unbreached condition, intragravel flow through the head of both forks may exist. According to winter aerial photos, an open lead extends from the lower one-quarter of the east fork down to the mouth (Figure 3). Due to low velocity and isolated pools during this time, this lead is likely the result of upwelling.

Chum salmon spawning in Mainstem Two has been documented for the past three years (1982-84) (Barrett et al. 1985). The preferred spawning areas appear to be the upper portions of the backwater and several pools of the east fork (Appendix Figure A-4). There is no record of any spawning activity in the west fork. ADF&G personnel have identified nine passage areas in Mainstem Two that may be restrictive to salmon passage (Blakely et al. 1984; Sautner et al. 1984).

A datapod was located in a chum salmon spawning area in the east fork on the right side of a pool (Appendix Figure B-4). Characteristically substrates are well armored cobble/boulder with some rubble.

Side Channel at Fourth of July Creek (RM 131.3L)

This site is located in a side channel 1,200 feet upstream of the mouth of 4th of July Creek (Appendix Figure B-5). The left bank is a 12 foot cut bank. A small bog fed creek drains into the channel immediately upstream of the site. Substrate is a loose conglomeration of rubble/large gravel/cobble. Upwelling and bank seepage are present throughout the northwest bank especially in the area of the bog drainage. The upwelling is probably responsible for the open lead present during the winter (Figure 3). Surface water temperatures ranged from 6.9° to 7.3°C while intragravel temperatures ranged from 4.4° to 5.3°C. Chum salmon and some coho salmon spawn in various areas of the side channel including the datapod site (Appendix Figure A-13).

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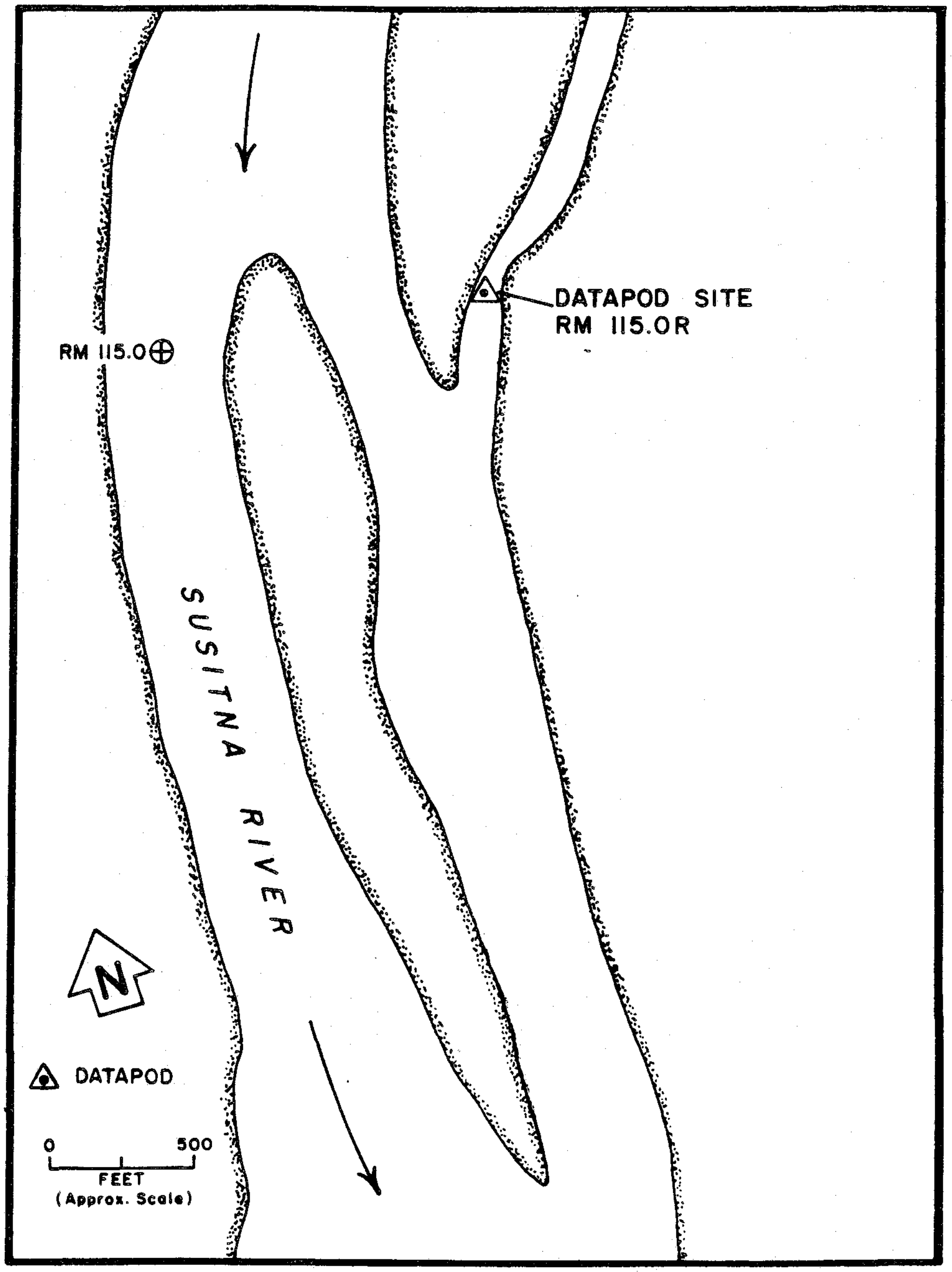

Appendix Figure B-4. Location of datapod in a side channel habitat, Mainstem 2, RM 115.0R.

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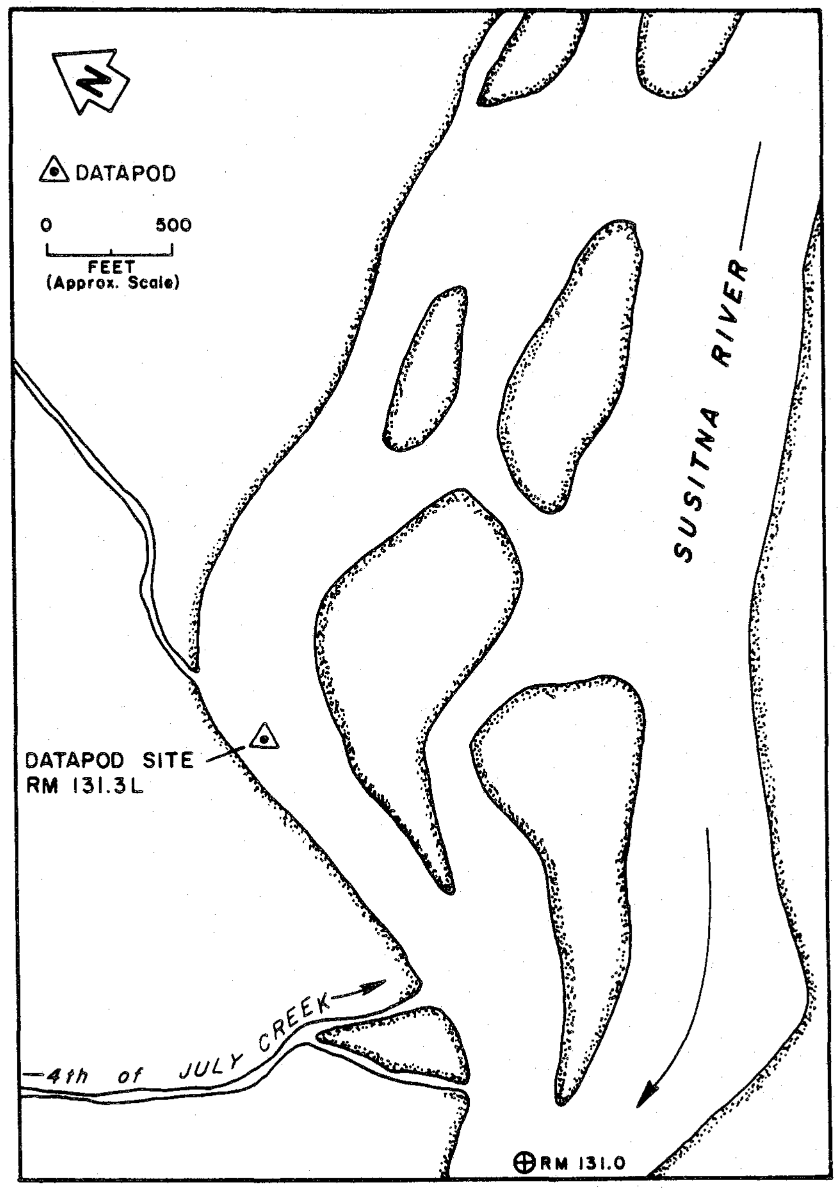

Appendix Figure B-5. Location of datapod in a side channel habitat, RM 131.3L.

Upper Side Channel 11 (RM 136.0R)

Upper Side Channel 11 is a straight broad channel on the right side of the Susitna River at river mile 136.0. The head of Slough 11 bisects the side channel on the right side. The first 500 feet of Upper Side Channel 11 consists of a wide backwater area with heavy silt accumulations over the substrate. The remaining area consists of a series of pools and long riffles flowing over boulder/cobble substrate. There is extensive bank seepage and upwelling along both banks of the backwater area but none discernible in the upper reaches. An open lead is usually present during the winter (Figure 3), although none was present during 1984/1985.

Chum spawning has been documented in two locations from 1981-84 (Appendix Figure A-16). The head of the backwater area and a pool across from the head of Slough 11 are the primary spawning areas. The datapod probe was located in the uppermost chum salmon spawning site (Appendix Figure B-6).

Side Channel 21 (RM 141.6R)

This site is 200 feet below the mouth of Slough 21 in Side Channel 21. Side Channel 21 is an approximately one mile long channel flowing over cemented cobble/boulder substrate with sand deposits occurring in pools. Intermittent channels connect the side channel with the mainstem. There is upwelling and bank seepage along both

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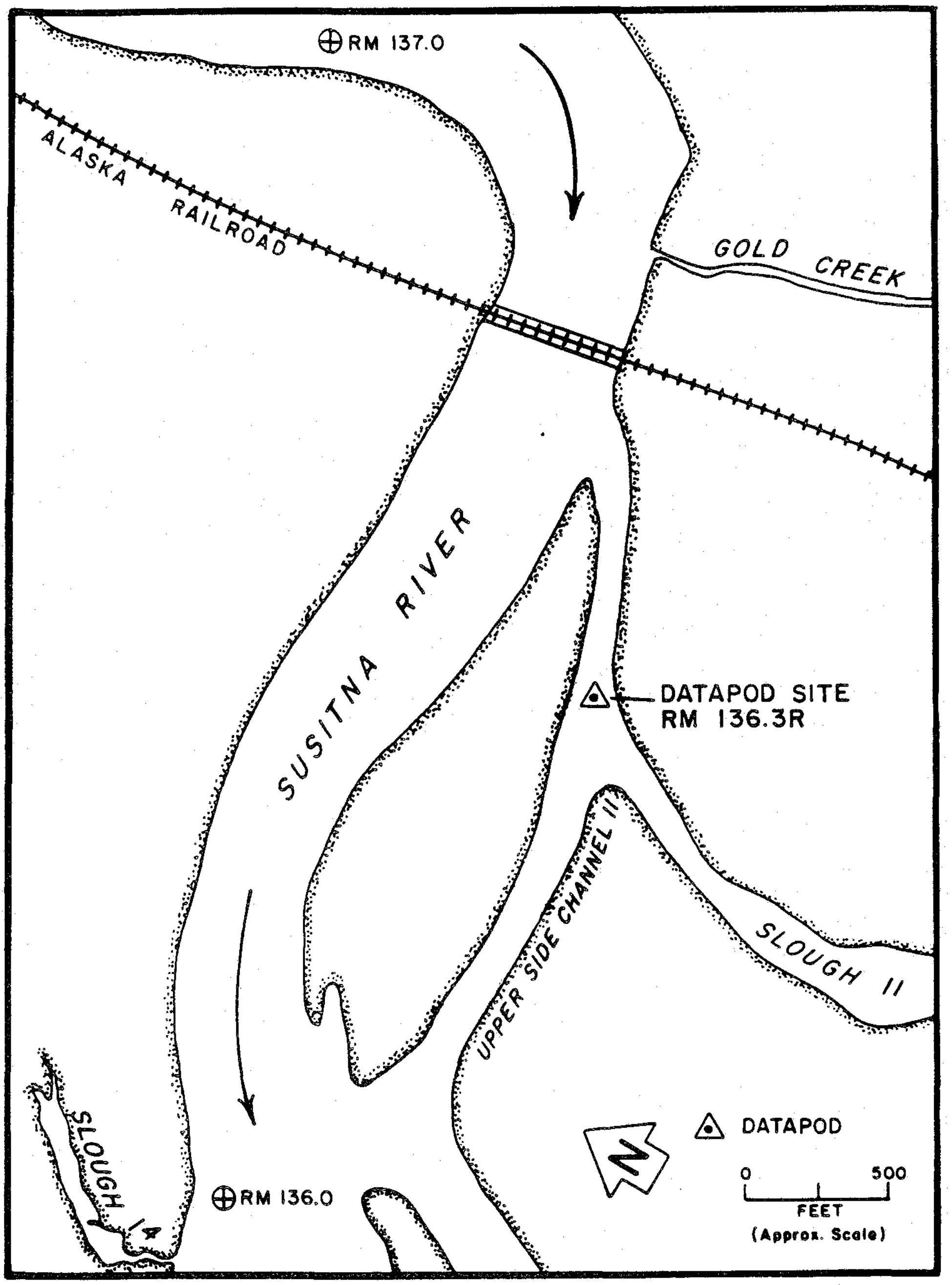

Appendix Figure B-6. Location of datapod in a side channel habitat, Upper Side Channel 11, RM 136.3R.

banks, especially in the upper reaches which, when combined with Slough 21 outflow results in an open lead originating in Slough 21 and extending beyond the mouth of the side channel (Figure 3). Surface water temperatures ranged from 5.3°C to 5.7°C, while intragravel temperatures ranged from 4.7°C to 5.4°C.

Chum and sockeye salmon have been observed spawning in the side channel from 1981-84 (Appendix Figure A-20). There are numerous reaches within this site that may be restrictive to upstream movements of salmon (Blakely et al. 1984 and Sautner et al. 1984).

A datapod probe was located in the middle of the channel approximately 250 feet downstream of the mouth of Slough 21 (Appendix Figure B-7). This area was heavily used by chum and sockeye salmon for spawning.

Mainstem Habitats

Susitna River at RM 118.9L

This site is located on along a straight, ten foot high cut bank section of the Susitna River approximately 3,000 feet below the mouth of Oxbow Two side channel (Appendix Figure B-8). A bog fed creek drains into the river 200 feet upstream of the site. Substrate is angular cobble/boulder through the lower 2/3 of the site with rubble/large gravel in the upper 1/3. The upper area has

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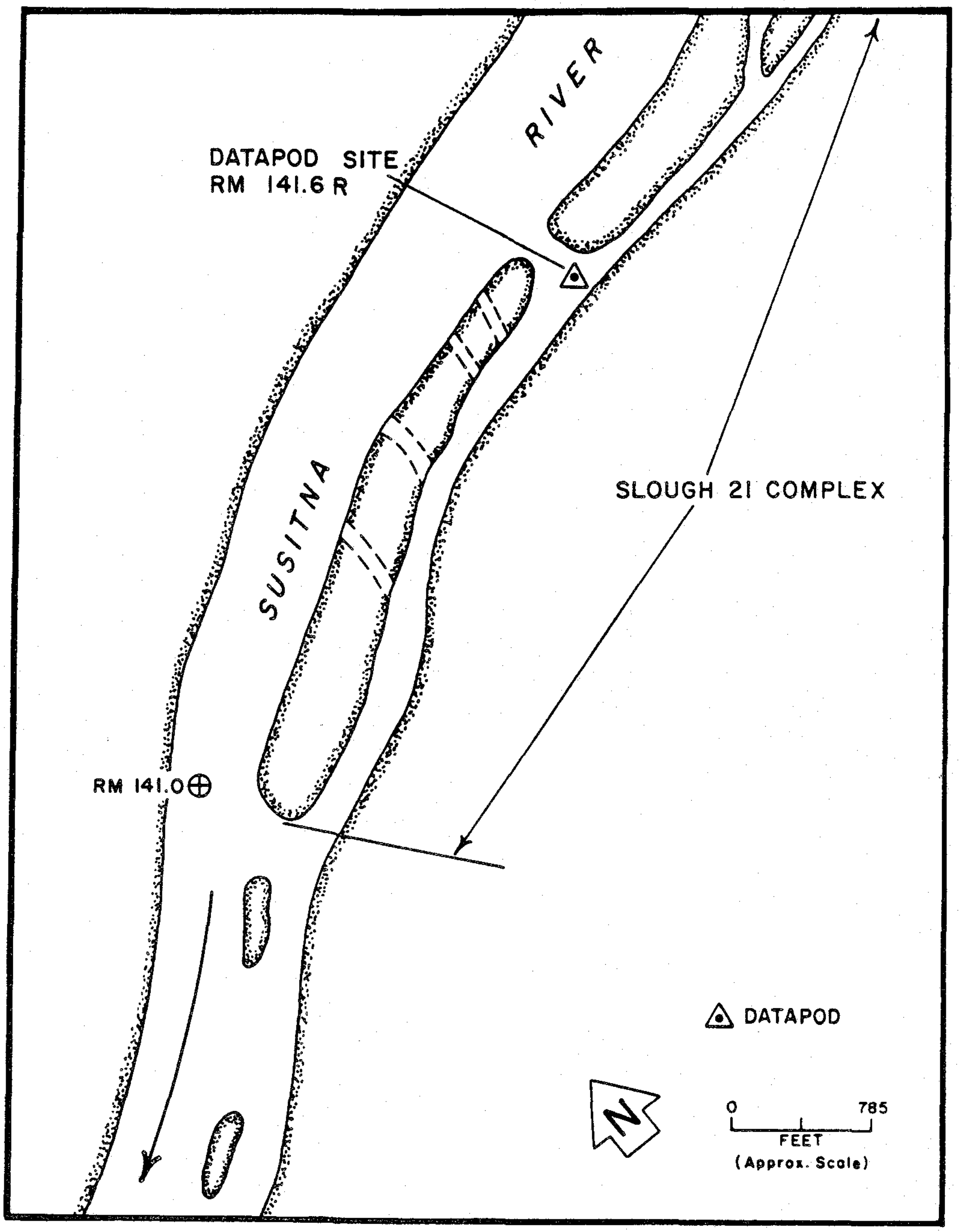

Appendix Figure B-7. Location of datapod in a side channel habitat, Side Channel 21, RM 141.6R.

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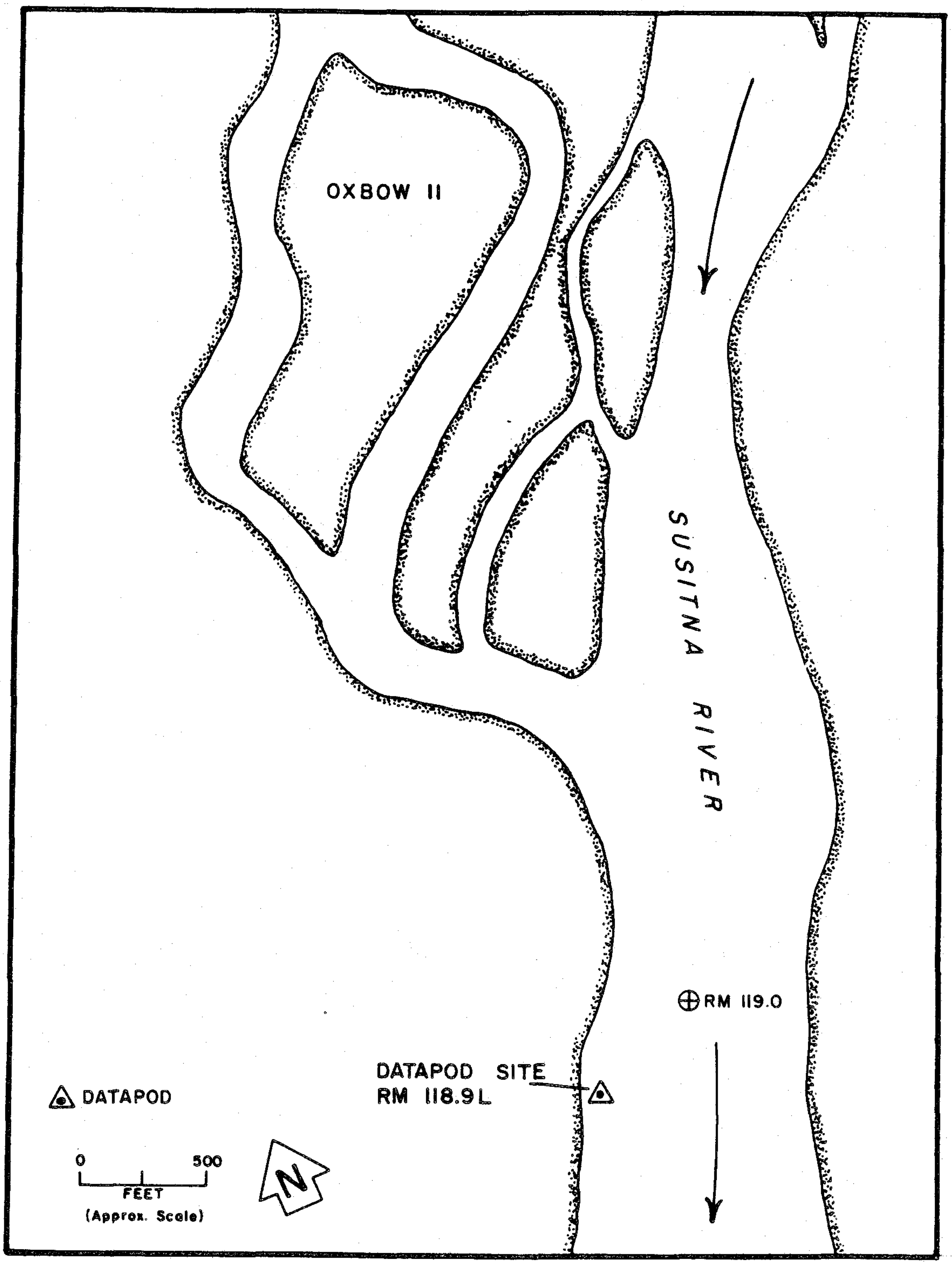

Appendix Figure B-8. Location of datapod in a mainstem habitat, RM 118.9L.

a good flow of bank seepage and upwelling, probably related to the bog drainage. There is an open lead throughout this area which is apparently the combination of velocity and upwelling/bank seepage (Figure 3). Surface water temperatures ranged from 7.1 to 7.2 while intragravel temperatures were 5.2 to 7.1.

Chum salmon spawning activity has been documented on this site for the past two years (1983-84) (Appendix Figure A-6). The majority of spawning occurs in the upper 1/3 where the good substrates and upwelling are located.

Susitna River at RM 132.9R

Mainstem site 132.9R is found 3,000 feet downstream of the mouth of Slough 9A on the east side of the river. The channel is broad and rectangular with gently sloping banks on both sides. Water velocity is fairly rapid and substrate consists of angular boulders and cobbles well cemented in. There is no upwelling visible and limited bank seepage. There is a small lead on the east bank apparently associated with this seepage (Figure 3).

In 1984 chum salmon were reported spawning at this site (Appendix Figure A-14). The datapod probe was located in the spawning area (Appendix Figure B-9).

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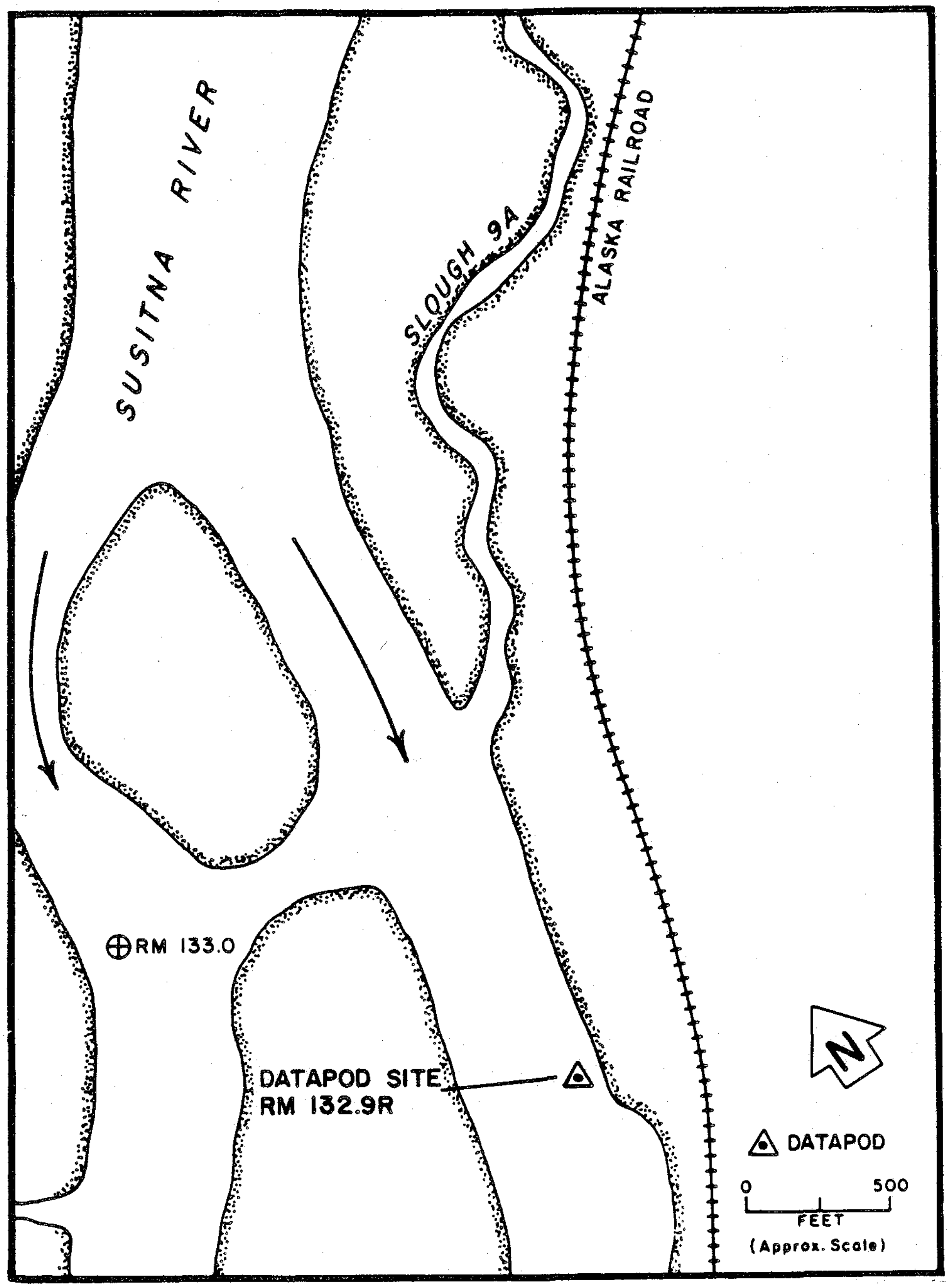

Appendix Figure B-9. Location of datapod in a mainstem habitat, RM 132.9R.

Susitna River at RM 139.0L

This mainstem site is approximately a 600 feet reach near the mouth of Slough 17 on the west side of the river. It has moderate to high velocities under most discharge ranges. Substrates are rubble/cobble with some areas of large gravel. Upwelling and bank seepage are present along the west bank, probably originating in Slough 17. Upwelling is likely responsible for the open lead which occurs here (Figure 3). Surface water temperatures ranged from 7.7°C to 8.6°C while intragravel temperatures range from 5.3°C to 6.5°C.

Chum spawning has been documented at this site for 1982, 1983 and 1984 and sockeye spawning was documented in 1984 (Appendix Figure A-18). The datapod probe was installed in the chum salmon spawning area approximately 500 upstream of the mouth of Slough 17 (Appendix Figure B-10).

Open Lead No Spawning

Side Channel at RM 117.9L

Datapod site 117.9L is a small 1,500 foot side channel adjacent to Bushrod Slough on the west side of the Susitna River. It has a wide sloping channel of cobble/rubble substrate with riffles at both the head and mouth. The left bank slopes up to a small cut

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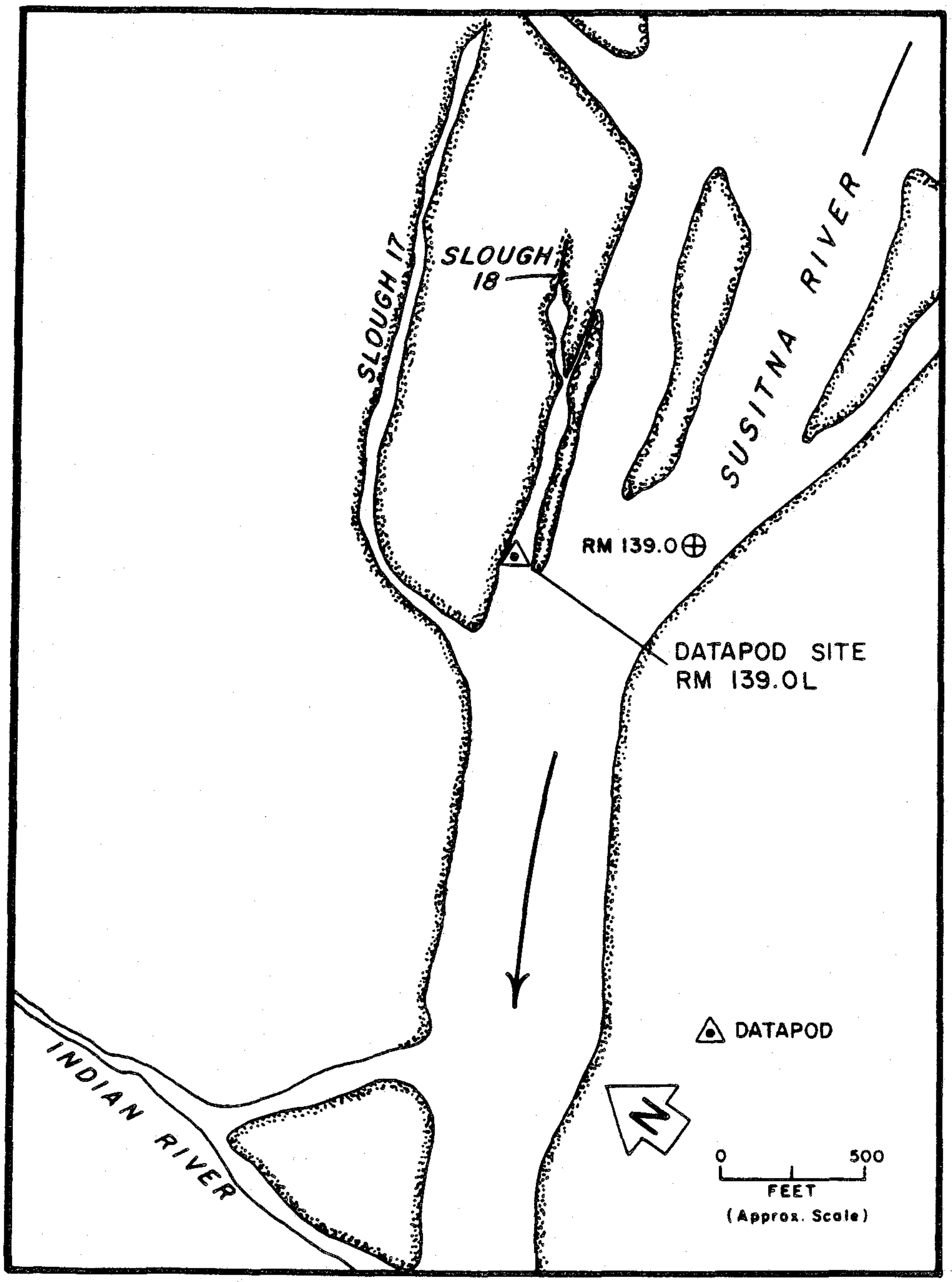

Appendix Figure B-10. Location of datapod in a mainstem habitat, RM 139.0L.

bank island which separates the side channel from Bushrod Slough. Along this bank there is heavy bank seepage and upwelling, especially at the upper end of the side channel. No upwelling is apparent along the right bank. Surface water temperatures ranged from 7.2 to 7.8°C, while intragravel temperatures were from 5.7 to 7.3°C. A dewatered channel extends upstream from the head of this side channel, connecting with the upper reach of Bushrod Slough. This channel is usually dry except during high water events at which time there is a backwater area at the lower end.

In winter, an open lead extends from just below the head down to and joining with the lead emerging from Bushrod Slough (Figure 3). This lead is likely the result of upwelling and bank seepage as there is little apparent flow during this time. There has never been any reported spawning in this side channel. The datapod probe was located in the open lead, approximately in the middle of the side channel along the northwest bank (Appendix Figure B-11).

Susitna River at RM 127.1C

This site is located in an island complex 1.2 miles downstream of the mouth of Slough 9. It is on the inside of a sweeping bend so that water velocities remain moderate. Substrate is predominately large gravel/rubble with numerous sand deposits. Upwelling and bank seepage are strong along the left bank, accounting for the open lead that exists during the winter (Figure 3). Surface water

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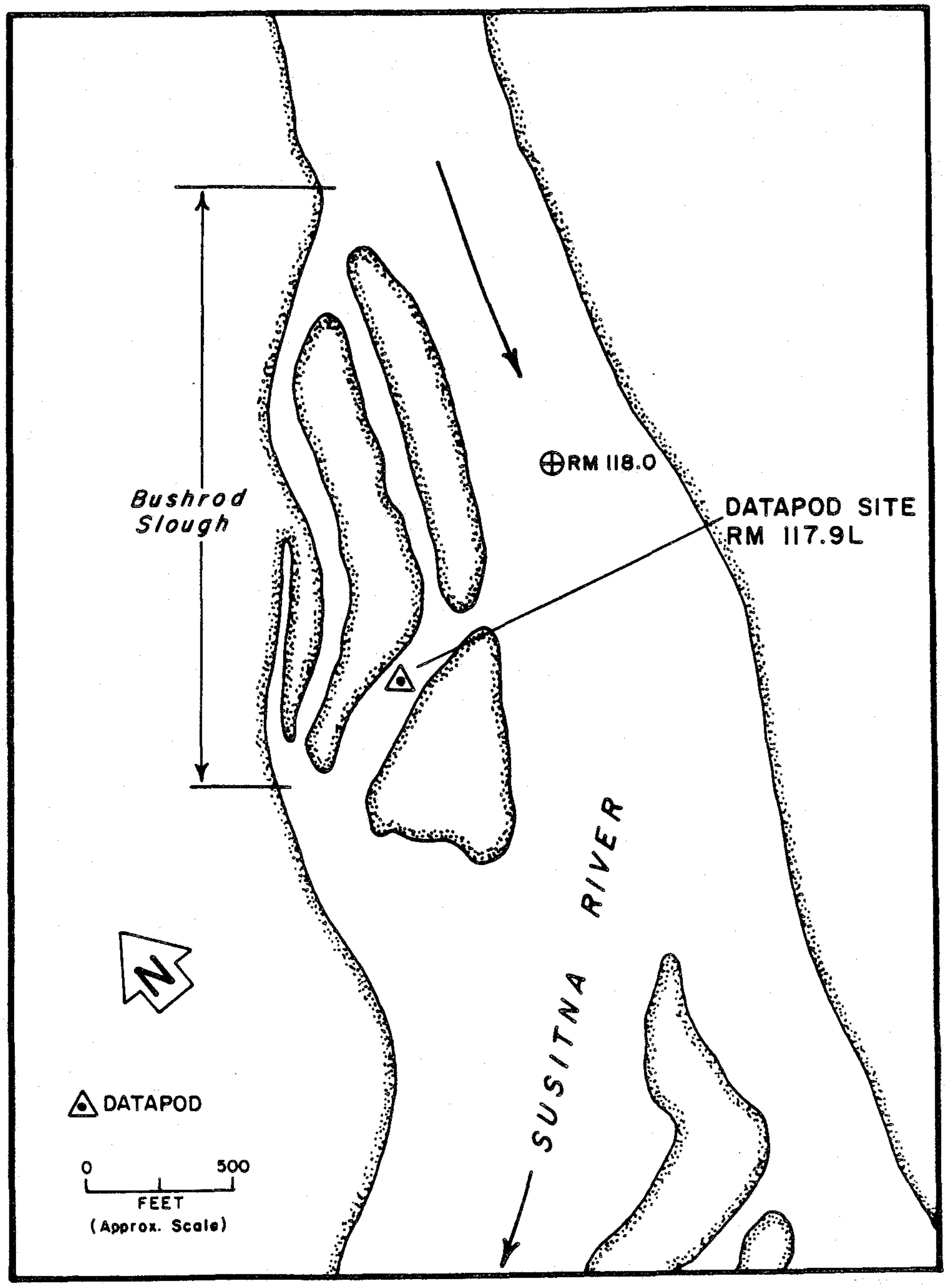

Appendix Figure B-11. Location of datapod in an area of an open lead with no spawning, RM 117.9L.

temperatures range from 6.4° to 7.1°C with intragravel temperatures ranging from 3.7° to 7.6°C. No spawning has been recorded for this site although it appears to contain excellent substrate. The datapod probe was located in the middle of the 200 foot reach about 15 feet from the left bank (Appendix Figure B-12).

Susitna River at RM 137.5L

This datapod site is located on the outside edge of a bend in the Susitna River, 100 feet downstream from the mouth of Slough 16 (Appendix Figure B-13). Water velocity in this reach is generally high. Accordingly, substrates tend to be well cemented boulder/cobble. The northwest bank slopes up to a 10 foot cut bank.

Open water surveys found surface water temperatures ranging from 10.4°C to 12.3°C, while intragravel temperatures range from 4.7°C to 8.1°C. There is no apparent upwelling or bank seepage. The open lead that exists here during the winter is most likely a velocity lead (Figure 3). Salmon spawning has not been documented on this site.

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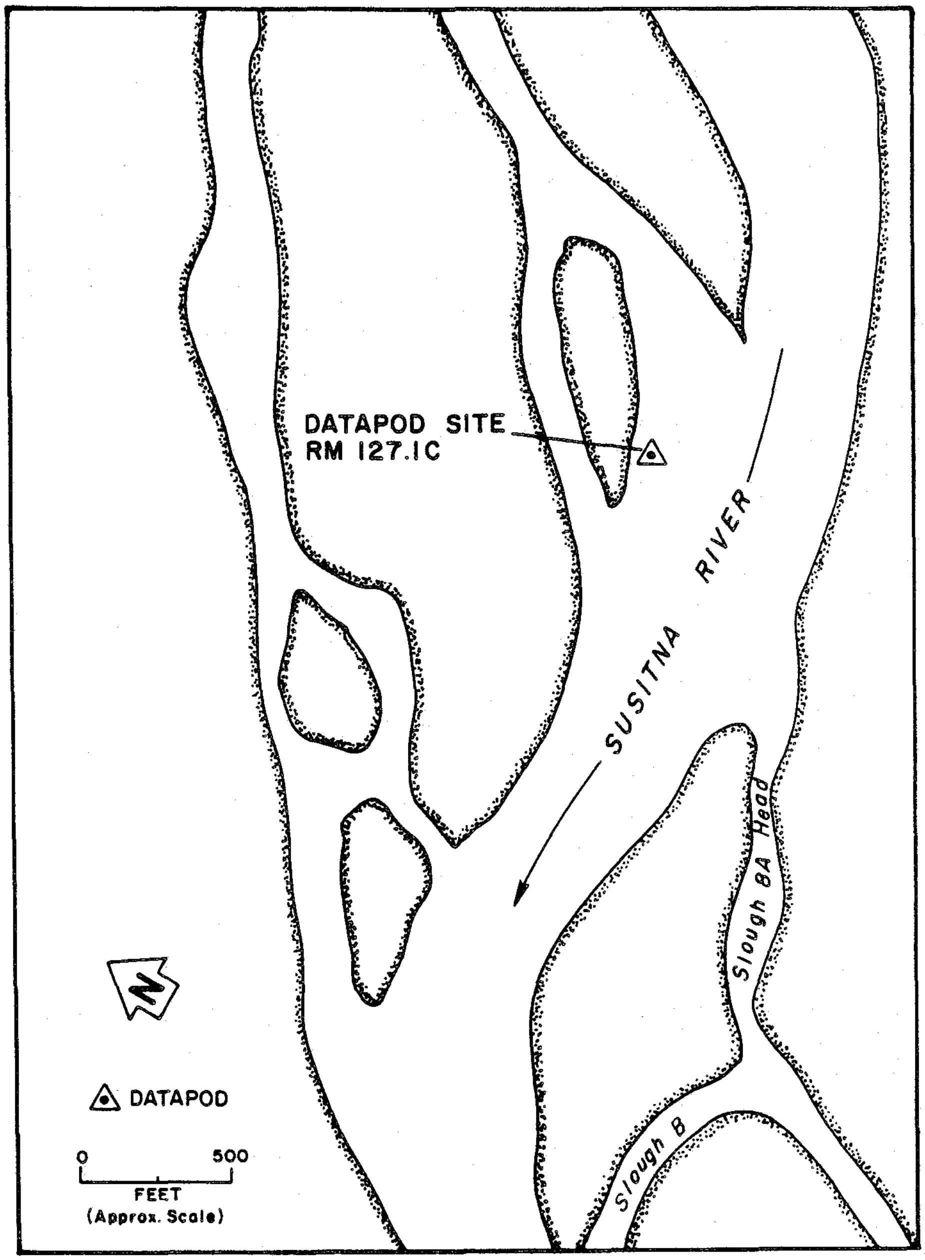

Appendix Figure B-12. Location of datapod in an area of an open lead with no spawning, RM 127.1C.

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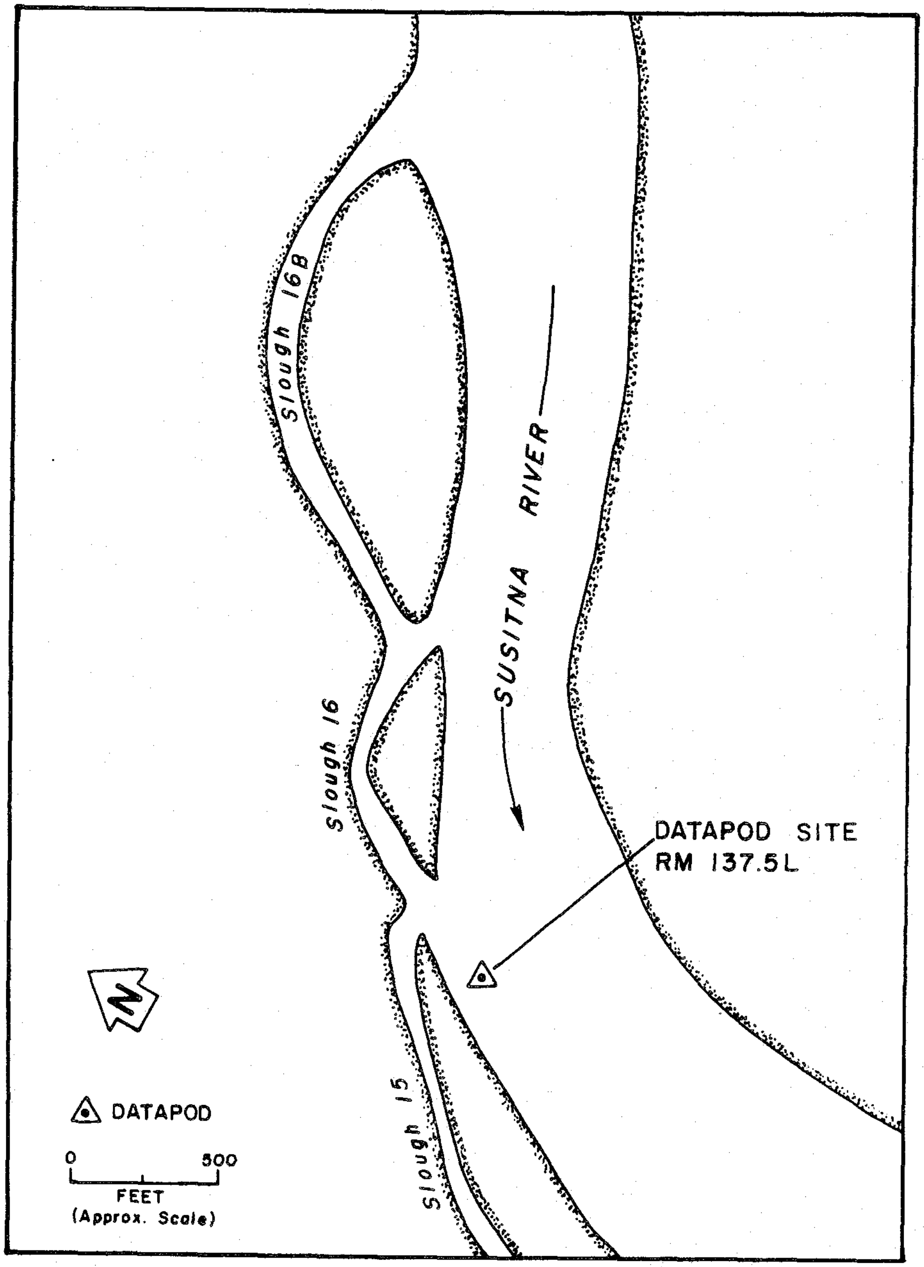


Appendix Figure B-13. Location of datapod in an area of an open lead with no spawning, RM 137.5L.

Spawning with No Open Lead

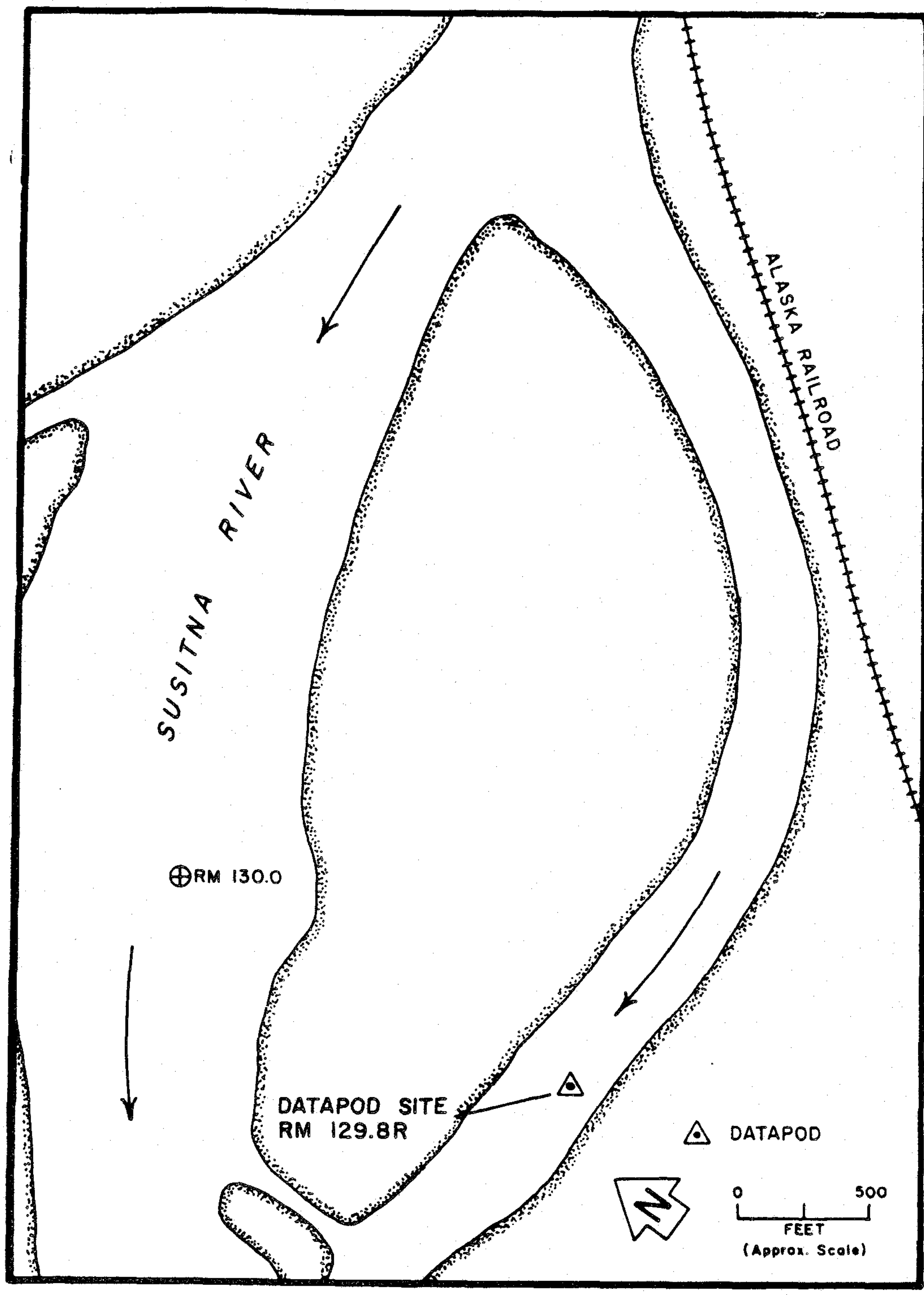
Side Channel at 129.8R

This is a broad side channel that extends from the head of Slough 9 to Sherman Creek along the south bank of the Susitna River. The site usually contains turbid mainstem water due to a low breaching discharge.

Open leads are generally present near the head of the side channel and along the left bank in the lower reach (Figure 3). Upwelling and bank seepage were observed near the head, probably due to the influence of Sherman Creek. While none was observed in the lower portion, chum salmon have previously spawned along the left bank (Appendix Figure A-12), indicating possible intermittent upwelling or bank seepage.

Substrates are generally well cemented rubble, cobble, boulder with limited areas of suitable substrate for spawning. Chum salmon have used this side channel for spawning during 1981, 1982 and 1984 (Appendix Figures A-11 and A-12).

The datapod was located in the lower portion of the site along the right bank (Appendix Figure B-14). This was an area of chum salmon spawning during 1984 but with no open lead usually present. This site dewatered and froze early in the winter, preventing an accurate assessment of temperatures and substrate.



Appendix Figure B-14. Location of datapod in an area of spawning with no open lead, RM 129.8R.

APPENDIX C

Freeze Core Substrate Data.

Appendix table C-1. Substrate composition of samples collected using a freeze core sampler at datapod sites; April 1985 to May 1985, Susitna River, Alaska.

			Substrate size classes (mm)																	
			Total	>127		127-76.2		76.2-25.4		25.4-2.0		2.0-0.84		0.84-0.5		0.5-0.062		<0.062		
Site (River mile)	Area	Sampling Date (y/m/d)	Dry wt. (g)	Dry wt. (g)	% Tot.	Dry wt. (g)	% Tot.	Dry wt. (g)	% Tot.	Dry wt. (g)	% Tot.	Dry wt. (g)	% Tot.	Dry wt. (g)	% Tot.	Dry wt. (g)	% Tot.	Dry wt. (g)	% Tot.	
Lane Creek (113.6R) TRM 0.1	1A	850411	22325	19374	87	0	0	1289	6	809	4	233	1	112	1	141	1	367	2	
	2A	850411	5446	0	0	2397	44	1594	29	1117	21	149	3	54	1	108	2	27	0	
	3A	850411	9979	0	0	1976	20	956	10	1301	13	257	3	61	1	93	1	5335	53	
	1B	850411	2907	0	0	0	0	1887	65	596	21	145	5	95	3	142	5	42	1	
	2B	850411	22777	17281	76	3383	15	879	4	872	4	179	1	70	0	84	0	29	0	
	3B	850411	3037	0	0	0	0	1390	46	1079	36	187	6	105	3	164	5	112	4	
Fourth of July Creek (131.1L) TRM 0.2	2A	850424	9366	3969	42	0	0	4177	45	903	10	153	2	60	1	85	1	19	0	
	2B	850424	6090	0	0	4023	66	902	15	709	12	189	3	78	1	139	2	50	1	
Indian River Site 4 (138.6L) TRM 0.2	1A	850417	3817	0	0	0	0	2240	59	1242	33	157	4	75	2	93	2	10	0	
	2A	850417	6540	2987	46	0	0	1335	20	1393	21	354	5	267	4	193	3	11	0	
	3A	850417	6250	0	0	0	0	2899	46	2320	37	424	7	212	3	253	4	142	2	
	1B	850417	4227	0	0	1612	38	1548	37	773	18	135	3	67	2	79	2	13	0	
	2B	850417	12823	0	0	9443	74	1326	10	1496	12	236	2	112	1	197	2	13	0	
	3B	850417	14700	9436	64	0	0	2633	18	2012	14	170	1	168	1	260	2	21	0	
Indian River Site 3 (138.6L) TRM 0.2	1A	850417	12845	8694	68	774	6	1767	14	1024	8	158	1	55	0	49	0	324	3	
	2A	850417	15311	11188	73	0	0	2461	16	1290	8	199	1	83	1	79	1	11	0	
	3A	850417	14348	10868	76	1079	8	1864	13	505	4	10	0	5	0	10	0	7	0	
	1B	850417	30563	24435	80	0	0	3440	11	1962	6	390	1	160	1	141	0	35	0	
	2B	850417	17148	12077	70	1281	7	1510	9	1690	10	342	2	116	1	110	1	22	0	
	3B	850417	6276	0	0	1301	21	3746	60	944	15	129	2	73	1	71	1	12	0	
Mainstem 2 Side Channel (115.0R)	1A	850403	7861	0	0	3090	39	2928	37	1033	13	100	1	30	0	544	7	136	2	
	2A	850403	8884	0	0	1477	17	3252	37	2352	26	307	3	124	1	947	11	425	5	
	3A	850403	1603	0	0	0	0	1010	63	406	25	25	2	8	0	114	7	40	2	
	1B	850403	2795	0	0	0	0	1269	45	1210	43	95	3	27	1	165	6	29	1	
	2B	850403	7132	0	0	0	0	3299	46	2353	33	182	3	205	3	960	13	133	2	
	3B	850403	8724	0	0	5677	65	1527	18	999	11	123	1	40	0	302	3	56	1	

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Appendix table C-1. continued

Site (River mile)	Area	Sampling Date (y/m/d)	Total Dry wt. (g)	>127 Dry wt. (g)	>127 % Tot.	127-76.2 Dry wt. (g)	127-76.2 % Tot.	76.2-25.4 Dry wt. (g)	76.2-25.4 % Tot.	25.4-2.0 Dry wt. (g)	25.4-2.0 % Tot.	2.0-0.84 Dry wt. (g)	2.0-0.84 % Tot.	0.84-0.5 Dry wt. (g)	0.84-0.5 % Tot.	0.5-0.062 Dry wt. (g)	0.5-0.062 % Tot.	<0.062 Dry wt. (g)	<0.062 % Tot.
				Substrate size classes (mm)															
Side Channel at Fourth of July Creek (131.3L)	1A	840429	7517	0	0	0	0	5015	67	2154	29	96	1	38	1	160	2	54	1
	2A	840429	5233	0	0	1993	38	887	17	1357	26	470	9	200	4	272	5	54	1
	3A	840429	18058	12157	67	685	4	3350	19	1005	6	84	0	35	0	543	3	199	1
	1B	840429	20428	14817	73	2207	11	2133	10	821	4	129	1	52	0	193	1	76	0
	2B	840429	6333	0	0	1500	24	2861	45	1391	22	266	4	121	2	167	3	27	0
	3B	840429	6741	0	0	2720	40	1912	28	1269	19	259	4	109	2	375	6	97	1
Side Channel 21 (141.6R)	1A	840424	13962	6151	44	919	7	4218	30	1668	12	286	2	215	2	477	3	28	0
	2A	840424	15822	9988	63	0	0	3532	22	1682	11	218	1	84	1	285	2	33	0
	3A	840424	25450	20250	80	1532	6	2123	8	1211	5	161	1	57	0	94	0	22	0
	1B	840424	10431	0	0	6200	59	1901	18	1324	13	243	2	118	1	552	5	93	1
	2B	840424	5293	1709	32	0	0	2273	43	840	16	112	2	60	1	243	5	56	1
	3B	840424	19797	11250	57	5928	30	999	5	1146	6	204	1	88	0	160	1	22	0
Susitna River at 118.9L (118.9L)	1A	850411	11053	4189	38	1082	10	3905	35	1161	11	107	1	51	0	396	4	162	1
	2A	850411	4241	0	0	0	0	2176	51	1489	35	99	2	40	1	389	9	48	1
	3A	850411	14203	0	0	11864	84	797	6	840	6	114	1	58	0	410	3	120	1
	1B	850411	2890	0	0	0	0	1218	42	1250	43	127	4	35	1	180	6	80	3
	2B	850411	4322	3110	72	0	0	142	3	708	16	102	2	28	1	185	4	47	1
	3B	850411	6747	2780	41	0	0	2149	32	1176	17	146	2	56	1	396	6	44	1
Susitna River at 132.9R (132.9R)	1A	850424	7398	0	0	0	0	4754	64	1643	22	256	3	137	2	496	7	112	2
	2A	850424	12689	3467	27	1668	13	3799	30	2235	18	338	3	269	2	781	6	132	1
	3A	850424	6519	0	0	2372	36	2215	34	1517	23	75	1	40	1	269	4	31	0
	1B	850424	15561	11018	71	0	0	2952	19	1095	7	0	0	148	1	291	2	57	0
	2B	850424	12034	5107	42	2118	18	1803	15	1955	16	277	2	185	2	430	4	159	1
	3B	850424	6726	0	0	2403	36	2508	37	1312	20	100	1	44	1	284	4	75	1
Susitna River at 139.0L (139.0L)	1A	850417	2233	0	0	0	0	1058	47	915	41	123	6	44	2	82	4	11	0
	2A	850417	11017	0	0	5603	51	3298	30	1333	12	163	1	66	1	478	4	76	1
	3A	850417	15997	9982	62	2212	14	2307	14	1223	8	102	1	49	0	101	1	21	0
	1B	850417	2987	0	0	0	0	1973	66	766	26	97	3	40	1	91	3	20	1
	2B	850417	9836	0	0	6508	66	1286	13	1132	12	222	2	152	2	529	5	7	0
	3B	850417	9207	0	0	5143	56	2177	24	1127	12	208	2	138	1	355	4	59	1

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Appendix table C-1. continued

Site (River mile)	Area	Sampling Date (y/m/d)	Total Dry wt. (g)	>127 Dry wt. (g)	>127 % Tot.	127-76.2 Dry wt. (g)	127-76.2 % Tot.	76.2-25.4 Dry wt. (g)	76.2-25.4 % Tot.	25.4-2.0 Dry wt. (g)	25.4-2.0 % Tot.	2.0-0.84 Dry wt. (g)	2.0-0.84 % Tot.	0.84-0.5 Dry wt. (g)	0.84-0.5 % Tot.	0.5-0.062 Dry wt. (g)	0.5-0.062 % Tot.	<0.062 Dry wt. (g)	<0.062 % Tot.
				Substrate size classes (mm)															
Side Channel	1A	850410	7281	0	0	1900	26	3774	52	953	13	91	1	52	1	416	6	95	1
at 117.9L	2A	850410	1309	0	0	0	0	588	45	405	31	53	4	26	2	218	17	19	1
(117.9L)	3A	850410	14793	12236	83	0	0	1391	9	719	5	37	0	14	0	318	2	78	1
	1B	850410	7375	0	0	2953	40	1837	25	1526	21	190	3	99	1	583	8	187	3
	2B	850410	1780	0	0	0	0	763	43	651	37	47	3	26	1	243	14	50	3
	3B	850410	1864	0	0	0	0	504	27	937	50	121	6	48	3	215	12	39	2
Susitna River	1A	850425	4411	0	0	0	0	1869	42	1909	43	77	2	34	1	486	11	36	1
at 127.1C	2A	850425	3273	0	0	0	0	216	7	2143	65	246	8	105	3	443	14	120	4
(127.1C)	1B	850425	15813	12556	79	0	0	2511	16	158	1	70	0	61	0	413	3	44	0
	2B	850425	2151	0	0	0	0	157	7	1065	50	118	5	148	7	651	30	12	1
Upper Side	1A	850501	16581	6427	39	6409	39	1453	9	1152	7	240	1	133	1	599	4	168	1
Channel 11	2A	850501	2624	0	0	0	0	821	31	887	34	472	18	179	7	240	9	25	1
at 136.0R	1B	850501	4942	0	0	0	0	2630	53	1537	31	316	6	94	2	257	5	108	2
(136.0R)	2B	850501	9645	0	0	5737	59	2464	26	939	10	206	2	79	1	174	2	46	0
Susitna River	1A	850501	30925	19344	63	2500	8	213	1	3423	11	792	3	654	2	1199	4	2800	9
at 137.5L	2A	850501	11641	0	0	5305	46	2664	23	2277	20	289	2	296	3	673	6	137	1
(137.5L)	3A	850501	6613	0	0	827	13	2060	31	2428	37	267	4	182	3	709	11	140	2
	1B	850501	15674	0	0	11893	76	1396	9	1549	10	272	2	169	1	277	2	118	1
	2B	850501	7780	0	0	4777	61	599	8	1340	17	201	3	132	2	622	8	109	1
	3B	850501	9736	0	0	5870	60	832	9	1837	19	321	3	279	3	483	5	114	1

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