# SUSITNA HYDROELECTRIC PROJECT

FEDERAL ENERGY REGULATORY COMMISSION
PROJECT No. 7114



# A FRAMEWORK FOR THE ASSESSMENT OF CHINOOK SALMON REARING IN THE MIDDLE SUSITNA RIVER UNDER ALTERED FLOW, TEMPERATURE AND SEDIMENT REGIMES

EWT&A
E. WOODY TRIHEY & ASSOCIATES



DRAFT REPORT

ONTRACT TO

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Mr. James B. Dischinger
Project Manager
Alaska Power Authority
334 West 5th Avenue
Anchorage, Alaska 99501

Subject: Susitna Hydroelectric Project
(#1) A Framework for the Assessment of Chinook Salmon Rearing in the Middle Susitna River Under Altered Flow, Temperature and Sediment Regimes and (#2) Response of Aquatic Habitat Surface Areas to Mainstem Discharge in the Talkeetna-to-Devil Canyon Reach of the Susitna River, Alaska

Dear Mr. Dischinger:

Enclosed for your review and comment is a draft copy of (#1) A Framework for the Assessment of Chinook Salmon Rearing in the Middle Susitna River Under Altered Flow, Temperature and Sediment Regimes and (#2) Response of Aquatic Habitat Surface Areas to Mainstem Discharge in the Talkeetna-to-Devil Canyon Reach of the Susitna River, Alaska.

There are also copies of the above mentioned reports enclosed for your transmittal for ADF&G SuHydro.

Please return your comments to me by May 31, 1985.

Very truly yours,

W.E. Larson
Project Director

klk

Enc: as noted

cc w/o Enc:
E. Marchegiani, Power Authority
L. Gilbertson, HE
J. Thrall, HE

425471/5

File No.

Resp.

Keywords

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# LETTER OF TRANSMITTAL

| DATE | JOB NO |
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| May 10, 1985 | |
| ATTENTION | |
| Dr. Dana Schmidt | |
| RE | |
| Draft Reports | |

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| | | | Response of Aquatic Habitat Surface Areas to Mainstem |
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# SUSITNA HYDROELECTRIC PROJECT

# A FRAMEWORK FOR THE ASSESSMENT OF CHINOOK SALMON REARING IN THE MIDDLE SUSITNA RIVER UNDER ALTERED FLOW, TEMPERATURE AND SEDIMENT REGIMES

Report by

E. Woody Trihey & Associates

Alexander M. Milner

Under Contract to

Harza-Ebasco Susitna Joint Venture

Prepared for

Alaska Power Authority

Draft Report
April 1984

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# 1. INTRODUCTION

The Alaska Power Authority (APA) has proposed the construction of two dams on the Susitna River over a period of 15 years; Devil Canyon Dam at river mile (RM) 152 upstream of the estuary and Watana Dam at RM 184. The Susitna River, an unregulated glacial river, flows approximately 318 miles from the terminus of the Susitna Glacier in the Alaska Mountain Range to its mouth in Cook Inlet, draining an area of 19,600 square miles (Figure 1). The setting, scope and technical specifications of the proposed Susitna hydroelectric project are given in the Instream Flow Relationships Report, Volume 1, prepared by E. Woody Trihey and Associates (EWT&A) and Woodward Clyde-Consultants (1985).

As part of the environmental assessment studies for the proposed project, investigations have been conducted since 1974 to quantify fish resources and evaluate utilization of aquatic habitats in the Susitna River drainage basin. In 1980 the Susitna Hydroelectric Aquatic Studies program was initiated, in which investigations were concentrated on the middle Susitna River from Talkeetna to Devil Canyon (RM 98.6 - 152). This section of the river is considered to be the most susceptible to with-project impacts. Anadromous salmon are usually prevented from moving upstream of Devil Canyon by high water velocity. Below Talkeetna (RM 98.6) project induced changes in streamflow, stream temperature and sediment concentration will be buffered by the input of a number of large tributaries, notably the Talkeetna, Chulitna and Yentna rivers, which will be unaffected by construction and operation of the project.

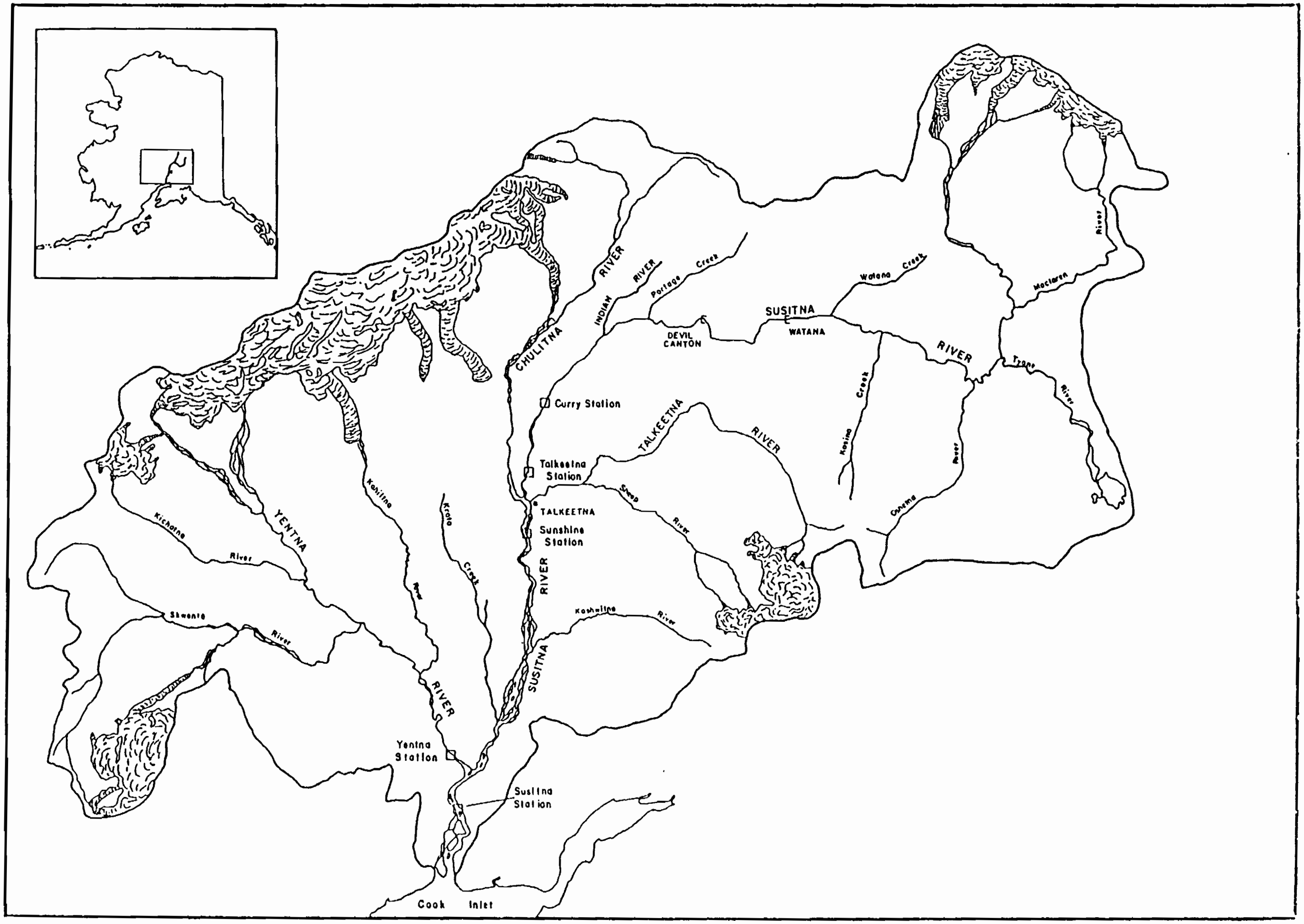
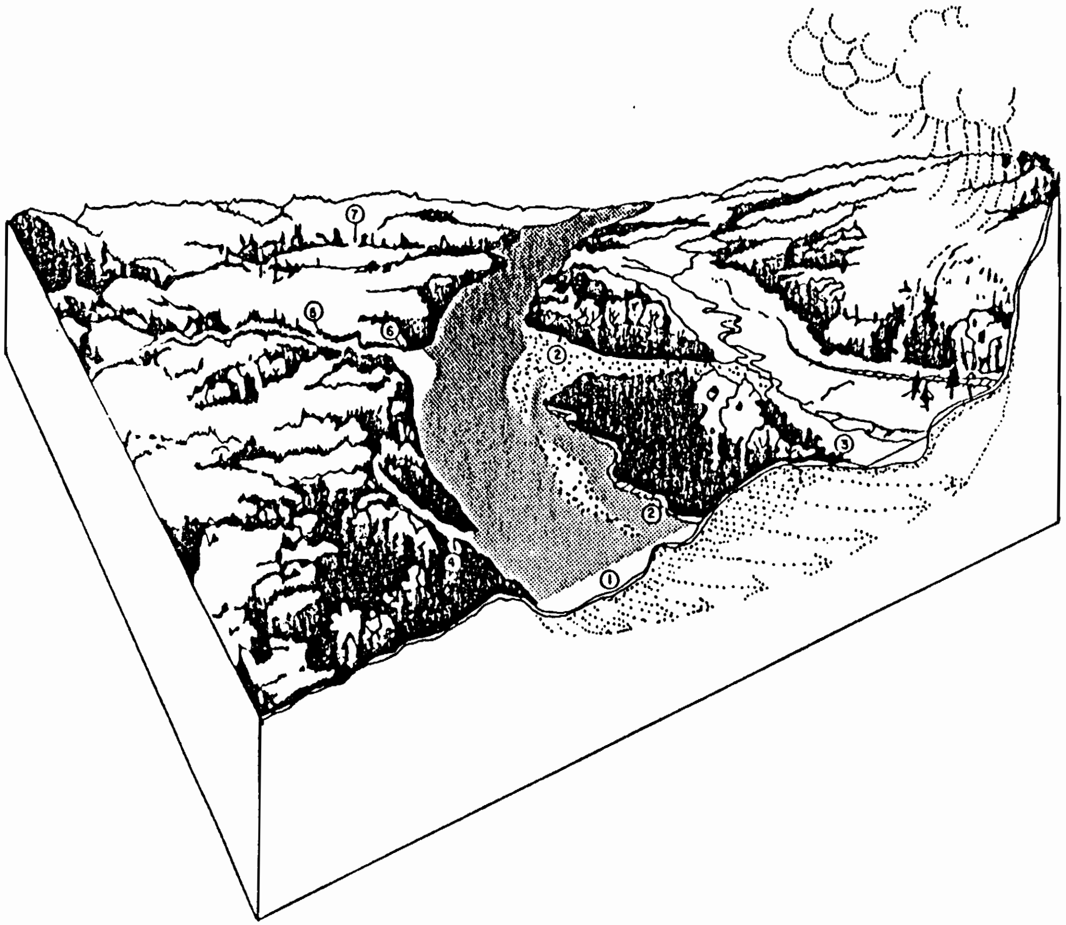



Figure 1. Susitna River drainage basin with major tributaries and geographic featuers. (University of Alaska, Arctic Environmental Information and Data Center 1984b).

Within the middle Susitna River, evaluation species have been selected for study. This procedure is in accordance with Alaska Power Authority, Alaska Department of Fish and Game, and U.S. Fish and Wildlife Service guidelines for studying habitats of greatest concern, which are those utilized by commercially and recreationally important fish species that are most likely to be significantly influenced by the project. Six principal aquatic habitat types, based on morphologic, hydrologic and hydraulic characteristics, have been identified within the Talkeetna-to-Devil Canyon reach of the Susitna River, namely; mainstem, side channel, side slough, upland slough, tributary, and tributary mouth. Their characteristics are summarized in Figure 2.

The habitats that respond most markedly to variations in mainstem discharge are the side channels and side sloughs and thus are the most likely to be significantly altered in a with-project situation (Klinger and Trihey 1984). The primary species and life stages selected for evaluation were chum salmon (*Oncorhynchus keta*) spawning adults and their incubating embryos and chinook salmon (*O. tshawytscha*) rearing juveniles (E. Woody Trihey and Associates and Woodward-Clyde Consultants 1985), which typically utilize the side channel and side slough habitats to the greatest extent (Dugan, Sterritt, and Stratton 1984). Chinook salmon are important to both the commercial and sport fishery. Coho (*O. kisutch*) fry principally rear in the tributaries and upland sloughs while sockeye (*O. nerka*) make the most use of the side sloughs and upland sloughs (Figure 3). Juvenile chum salmon were selected as a secondary evaluation species for rearing habitat, as their freshwater residence period in side channels and side sloughs does not typically exceed three months (Jennings 1984).



### GENERAL HABITAT CATEGORIES OF THE SUSITNA RIVER

1) **Mainstem Habitat** consists of those portions of the Susitna River that normally convey streamflow throughout the year. Both single and multiple channel reaches are included in this habitat category. Groundwater and tributary inflow appear to be inconsequential contributors to the overall characteristics of mainstem habitat. Mainstem habitat is typically characterized by high water velocities and well-armored streambeds. Substrates generally consist of boulder and cobble size materials with interstitial spaces filled with a grout-like mixture of small gravels and glacial sands. Suspended sediment concentrations and turbidity are high during summer due to the influence of glacial melt-water. Streamflows recede in early fall and the mainstem clears appreciably in October. An ice cover forms on the river in late November or December.

2) **Side Channel Habitat** consists of those portions of the Susitna River that normally convey streamflow during the open water season but become appreciably dewatered during periods of low flow. Side channel habitat may exist either in well-defined overflow channels, or in poorly defined water courses flowing through partially submerged gravel bars and islands along the margins of the mainstem river. Side channel streambed elevations are typically lower than the mean monthly water surface elevations of the mainstem Susitna River observed during June, July, and August. Side channel habitats are characterized by shallower depths, lower velocities, and smaller streambed materials than the adjacent habitat of the mainstem river.

3) **Side Slough Habitat** is located in spring-fed overflow channels between the edge of the floodplain and the mainstem and side channels of the Susitna River and is usually separated from the mainstem and side channels by well-vegetated bars. An exposed alluvial berm often separates the head of the slough from mainstem or side channel flows. The controlling streambed/streambank elevations at the upstream end of the side sloughs are slightly less than the water surface elevations of the mean monthly flows of the mainstem Susitna River observed for June, July, and August. At the intermediate and low-flow periods, the side sloughs convey clear water from small tributaries and/or upwelling groundwater (ADF&G 1981c, 1982b). These clear water inflows are essential contributors to the existence of this habitat type. The water surface elevation of the Susitna River generally causes a backwater to extend well up into the slough from its lower end (ADF&G 1981c, 1982b). Even though this substantial backwater exists, the sloughs function hydraulically very much like small stream systems and several hundred feet of the slough channel often conveys water independent of mainstem backwater effects. At high flows the water surface elevation of the mainstem river is sufficient to overtop the upper end of the slough (ADF&G 1981c, 1982b). Surface water temperatures in the side sloughs during summer months are principally a function of air temperature, solar radiation, and the temperature of the local runoff.

4) **Upland Slough Habitat** differs from the side slough habitat in that the upstream end of the slough is not interconnected with the surface waters of the mainstem Susitna River or its side channels. These sloughs are characterized by the presence of beaver dams and an accumulation of silt covering the substrate resulting from the absence of mainstem scouring flows.

5) **Tributary Habitat** consists of the full complement of hydraulic and morphologic conditions that occur in the tributaries. Their seasonal streamflow, sediment, and thermal regimes reflect the integration of the hydrology, geology, and climate of the tributary drainage. The physical attributes of tributary habitat are not dependent on mainstem conditions.

6) **Tributary Mouth Habitat** extends from the uppermost point in the tributary influenced by mainsteam Susitna River or slough backwater effects to the downstream extent of the tributary plume which extends into the mainstem Susitna River or slough (ADF&G 1981c, 1982b).

7) **Lake Habitat** consists of various lentic environments that occur within the Susitna River drainage. These habitats range from small, shallow, isolated lakes perched on the tundra to larger, deeper lakes which connect to the mainstem Susitna River through well-defined tributary systems. The lakes receive their water from springs, surface runoff, and/or tributaries.

Figure 2. General habitat categories of the Susitna River. (Alaska Dept. of Fish and Game, Susitna Hydro Aquatic Studies 1983a).

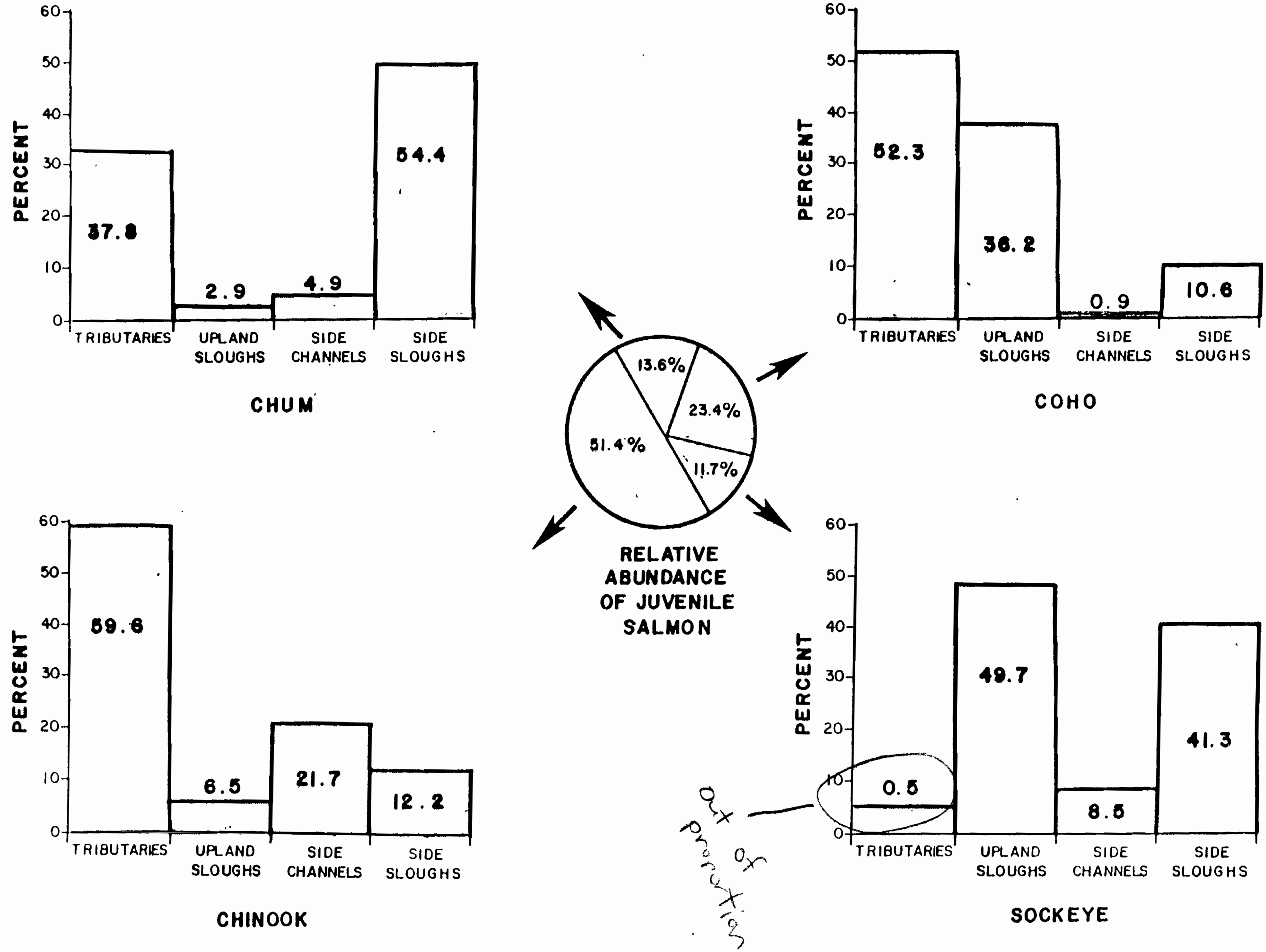



Figure 3. Relative abundance and distribution of juvenile salmon within different habitat types of the middle Susitna River. (Schmidt et al. 1984).

The purpose of this preliminary draft report is to provide a framework for evaluating chinook rearing in the middle Susitna River under with-project conditions when further data become available and appropriate analyses are completed. At present, this report contains an overview of juvenile chinook Susitna River studies to date, a comparative evaluation of the significance of the principal environmental factors influencing the rearing of juvenile chinook, and an extensive literature review. A subjective assessment has been made of how these factors may be altered under with-project conditions, and the likely consequences for juvenile chinook. A future draft of this report will include the following analyses presently underway by EWT&A.

(a) Modeling of streamflow variability under with-project conditions and the potential effect on the quantity of suitable rearing habitat.

(b) Weighted Usable Area (WUA) forecasts for specific size(?) for juvenile chinook rearing habitat as related to mainstem discharge.

(c) An euphotic zone model assessing the effects of reduced turbidity on light penetration and the implication for primary and secondary productivity levels.

(d) Extrapolation of WUA forecasts for juvenile chinook to the entire middle Susitna River.

A number of reports prepared by the Alaska Department of Fish and Game (ADF&G) are important to this analysis, including the 1984 resident juvenile anadromous fish study, the 1984 food availability study, and the 1984/85 overwintering study.

## 2. OVERVIEW OF CHINOOK SALMON ESCAPEMENT AND SPAWNING OF THE SUSITNA RIVER DRAINAGE

The Susitna River affords a migrational corridor and spawning and juvenile rearing areas for chinook, coho, chum, sockeye, and pink (O. gorbuscha) salmon from its mouth on Cook Inlet (RM 0) to Devil Canyon (RM 152). From 1981 to 1984, 95 percent of the commercial monetary value in the Upper Cook Inlet fishery was derived from sockeye, chum, and coho catches. Chinook salmon contribution in 1984 was 1.65 percent.

Approximately 10 percent of the total commercial chinook catch in Upper Cook Inlet is Susitna River drainage stock, representing an average annual contribution of 1,160 fish from 1964 to 1984. Catches have decreased markedly since 1964, due to the adoption of later opening dates by the commercial fishery, thereby allowing the majority of spawning chinook salmon to reach their natal streams. The river basin supports a comparatively larger annual chinook salmon sport catch, which averaged 7,950 fish from 1978 to 1983. The sport catch has increased from 2,830 fish in 1978 to 12,420 fish in 1983 (Barrett, Thompson, and Wick 1984).

Chinook salmon enter the Susitna River in late May to early June. In 1983, the minimum total escapement was 125,600 fish. Subdrainage escapement and timing for 1983 are given in Table 1, in which estimate methods and their associated limitations were summarized by Jennings (1984). Approximately 80 percent of the chinook salmon were estimated to have returned to the River or Susitna side - RM 80 Yentna ~~sub-basin~~. Spawners in the middle river (Talkeetna-to-Devil Canyon reach) account for a small percentage of the remaining escapement. In 1983 this percentage was 3.5, or 3,800 fish. The majority of the spawning above

was poor

of Su exp

1/3 is not a "small percentage"

| Sub-Basin | Numbers | Timing |
| --- | --- | --- |
| Lower Susitna River (RM 0 to 80), excluding Yentna River (RM 28) | 56,300 | Mid June to mid July |
| Yentna River (RM 28) | 44,700 | --- |
| Talkeetna (RM 97.1) and Chulitna (RM 98.6) rivers, including Susitna River from RM 80 to 98.6 | 16,100 (62,000) | --- |
| Talkeetna Station to Devil Canyon (RM 98.6 to 152) | 8,500 (9,500) | third week in June to third week in July |
| Total Susitna basin | 125,600 | |

Minimum estimates of escapement from ADF&G 1983 survey counts and conversion factor of 52 percent (Nielson and Geen 1981); numbers in parenthesis are 1982-83 average of ADF&G escapement estimates.

Table 1. Susitna River annual chinook salmon escapement and timing for 1983 by sub-basin. (Adapted from Jennings 1984).

RM 80 occurs in the larger tributaries, notably the Talkeetna and Chulitna rivers. In the past three years, an average of 34 chinook salmon have overcome the high velocities and spawned in tributaries above the Devil Canyon.

In the middle Susitna River, chinook salmon spawn only in tributary stream habitat. Portage Creek and Indian River account for over 90 percent of the spawners (Barrett, Thompson, and Wick 1984). Trihey (1983) examined the hydraulic conditions in the mouths of these two tributaries and concluded that passage of spawning fish is not likely to be impaired at low mainstem discharges. Peak spawner survey counts in the tributary streams indicate an average annual increase of 87 percent between 1981 and 1984 (Table 2). Spawning peaks ~~fell~~ between July 24 and August 8 in each year (Alaska ~~Dept.~~ of Fish and ~~Game,~~ Susitna Hydro ~~Aquatic Studies~~ 1981a, 1982; Barrett, Thompson, ~~and Wick~~ 1984).

The majority of chinook spawners aged 5 and 6 had migrated to sea in their second year of life. The number of eggs per female spawner has not been estimated for chinook salmon, but Beauchamp, Sneperd, and Pauley (1983) put the typical range as 3,000 to 6,000. No information is available on egg-to-fry survival, but Jennings (1984) summarized the factors affecting incubation and their application to the middle Susitna River.

| Stream | River Mile | 1981 Peak Count 1/ | 1981 % Distri-bution | 1982 Peak Count 1/ | 1982 % Distri-bution | 1983 Peak Count 1/ | 1983 % Distri-bution | 1984 Peak Count 1/ | 1984 % Distri-bution | Average % Distribution |
|---|---|---|---|---|---|---|---|---|---|---|
| Whiskers Creek | 101.4 | - | - | 0 | 0 | 3 | 0.1 | 67 | 0.9 | 0.6 |
| Chase Creek | 106.9 | - | - | 15 | 0.6 | 15 | 0.3 | 3 | * | 0.4 |
| Lane Creek | 113.6 | 40 | 3.6 | 47 | 1.9 | 12 | 0.3 | 23 | 0.3 | 0.8 |
| 5th of July Cr. | 123.7 | - | - | 3 | 0.1 | 0 | 0 | 17 | 0.2 | 0.2 |
| Sherman Creek | 130.8 | - | - | 3 | 0.1 | 0 | 0 | 0 | 0 | * |
| 4th of July Cr. | 131.1 | - | - | 56 | 2.3 | 6 | 0.1 | 92 | 1.3 | 1.3 |
| Gold Creek | 136.7 | - | - | 21 | 0.9 | 23 | 0.5 | 23 | 0.3 | 0.6 |
| Indian River | 138.6 | 422 | 37.6 | 1,053 | 42.6 | 1,193 | 26.9 | 1,456 | 20.3 | 26.8 |
| Jack Long Creek | 144.5 | - | - | 2 | 0.1 | 6 | 0.1 | 7 | 0.1 | 0.1 |
| Portage Creek | 148.9 | 659 | 58.8 | 1,253 | 50.7 | 3,140 | 70.9 | 5,446 | 75.9 | 68.3 |
| Cheechako Creek | 152.5 | - | - | 16 | 0.7 | 25 | 0.6 | 29 | 0.4 | 0.6 |
| Chinook Creek | 156.8 | - | - | 5 | 0.2 | 8 | 0.2 | 15 | 0.2 | 0.2 |
| Devil Creek | 161.0 | - | - | 0 | 0 | 1 | * | 0 | 0 | * |
| Fog Creek | 176.1 | - | - | 0 | 0 | 0 | 0 | 2 | * | * |
| | TOTALS 2/ | 1,121 | 100.0% | 2,474 | 100.2% | 4,432 | 100.0% | 7,180 | 99.9% | 99.9% |

1/ Peak count includes live plus dead fish.

2/ Percent distribution totals may not equal 100 due to rounding errors.

* Trace

Table 2. Peak survey counts and percent distribution of chinook salmon in streams above RM 98.6 in 1981-84. (Alaska Dept. of Fish and Game, Susitna Hydro Aquatic Studies 1985).

## 3. DISTRIBUTION OF REARING JUVENILE CHINOOK SALMON IN THE MIDDLE RIVER

As part of the Susitna Hydroelectric Aquatic Studies program, the juvenile anadromous habitat study was carried out by ADF&G. In 1981 and 1982 the focus was primarily on determining the relative abundance of each species and the types of habitat associated with rearing (Alaska Dept. of Fish and Game, Susitna Hydro Aquatic Studies 1983a). This general distribution data was then used in 1983 and 1984 to select specific sites for more detailed investigations regarding the suitability of selected habitat areas for juvenile chinook salmon, and for measuring rearing habitat response to changes in mainstem discharge.

Young chinook salmon generally go to sea during their first year, normally after a few months of feeding in the river (Ricker 1972; Lister and Walker 1966). However, studies of juvenile chinook in Alaska rivers indicate that migration mainly occurs after one winter in freshwater (Burger et al. 1983; Kissner 1976; Meehan and Sniff 1962; Waite 1979). This is principally the situation for juvenile chinook in the Talkeetna-to-Devil Canyon sub-basin of the Susitna River (Alaska Dept. of Fish and Game, Susitna Hydro Aquatic Studies 1981b; Dugan, Sterritt, and Stratton 1984).

Juvenile chinook salmon in the Susitna River emerge from the gravel in March or April (Alaska Dept. of Fish and Game, Susitna Hydro Aquatic Studies 1983). Chinook fry spend up to two months following emergence in the vicinity of their natal areas, after which they may redistribute and frequently display a downstream migration (Burger et al. 1983; Delaney, Hepler, and Roth 1981; Miller 1970; Waite 1979). Throughout their operation in 1983 from mid May to the end of August, outmigrant traps at RM

103 captured young of the year (0+) chinook, with a major peak in the middle of August. This peak may have been related to a discharge of 32,000 cubic feet per second (cfs) measured at Gold Creek on August 10 (Roth, Gray, and Schmidt 1984). Some chinook populations have been reported to slowly migrate downstream feeding, rather than living, in distinct reaches of the river for extended periods of time (Beauchamp, Sneperd, and Pauley 1983).

Redistribution of chinook fry in the middle Susitna River results in increased utilization of side channels, side sloughs, and upland sloughs from July onwards. Highest densities are typically found in the side channels (Dugan, Sterritt, and Stratton 1984). Side sloughs become more important as rearing areas in September and October. Tributaries become less significant after November as low winter flows and icing occur. The mainstem, side channels, side sloughs, and tributaries are used by juvenile chinook as overwintering areas (Alaska Dept. of Fish and Game, Susitna Hydro Aquatic Studies 1981b; Dugan, Sterritt, and Stratton 1984). Riis and Friese (1978) concluded that juvenile chinook overwinter mainly in side channels, as opposed to side sloughs, but their results were based on a small sample size and thus are probably inaccurate.

Population estimates of rearing juvenile chinook by conventional methods have not been undertaken in the middle Susitna River. Indices of fish density in four macrohabitat types (side channels, side sloughs, upland sloughs, and tributaries) were obtained in 1983 using backpack electrofishing units and beach seines to collect fish. Results, expressed as catch per unit effort (CPUE) and defined as the number of fish per 300 square foot cell (6 feet (ft) wide by 50 ft long), are summarized in Figure 4.

Highest densities of 0+ juvenile chinook salmon were recorded in the tributaries from May through early August, attaining 24 fish per cell, or 0.88 fish per square meter ($m^2$). Conversely, averages of less than one fish per cell were found in some side and upland sloughs in May. Chinook fry (0+) densities increased at mainstem associated macrohabitats in late July following redistribution from the tributaries. A comparison of side slough and side channel densities for 1983 is given in Figure 5. The highest values of juvenile chinook salmon mean catch occurred in the side channels during August, with close to six fish per cell (0.2 fish/$m^2$). Side slough densities in September and October may reach five times the values for earlier in the year. Typical chinook fry densities from a number of other studies are given in Table 3.

| Age | Fish/Area(no/$m^2$) | Region | Reference |
|---|---|---|---|
| 0+ | 0.59 - 1.35 | Idaho | Bjornn (1978) |
| 0+ | 0.44 - 1.60 | Idaho | Sekulich and Bjornn (1977) |
| 0+ | 1.90 | Idaho | Bjornn et al. (1974) |

Table 3. Typical juvenile chinook densities from other studies.

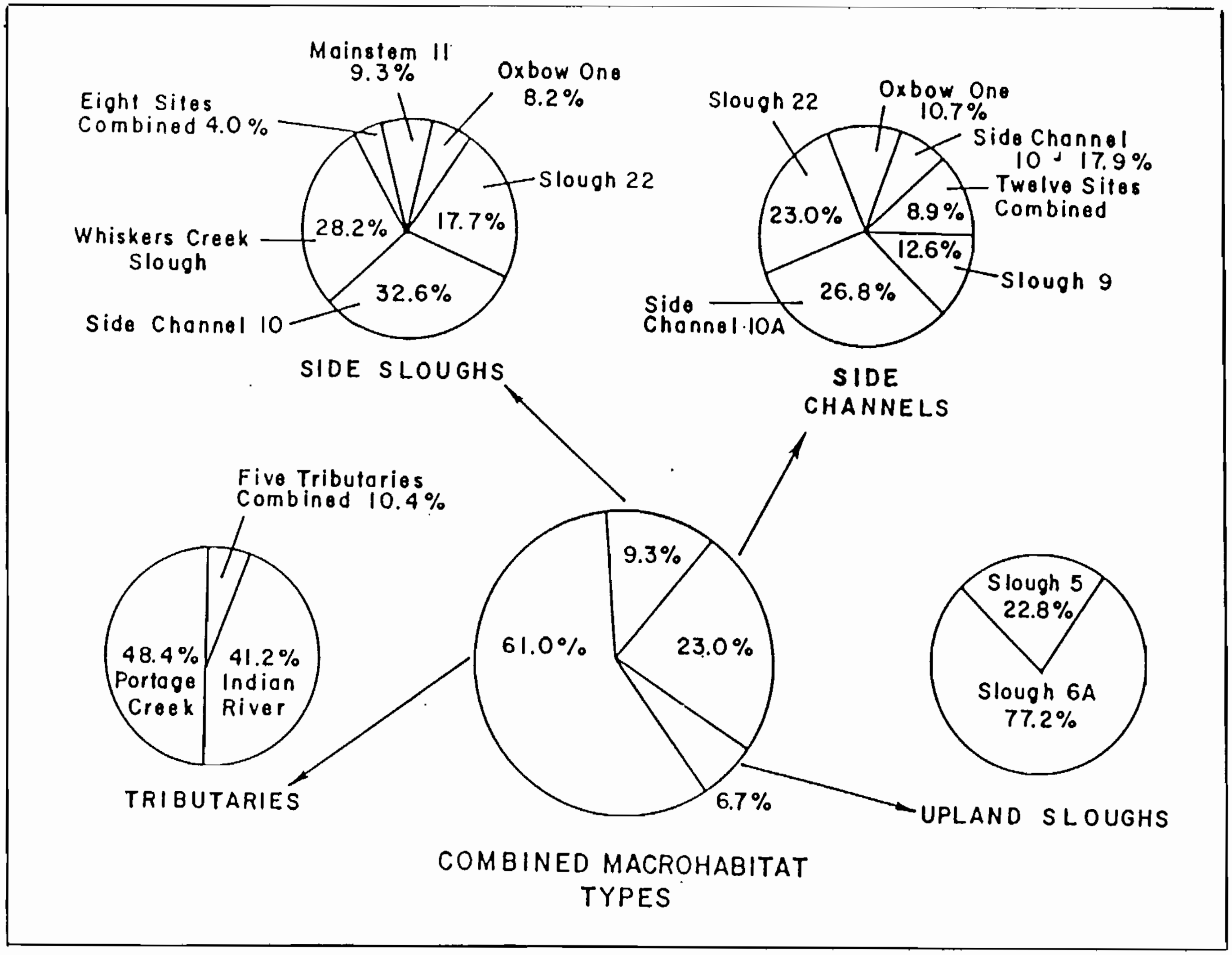



Figure 4. Density distribution of juvenile chinook salmon by macrohabitat type on the Susitna River between the Chulitna River confluence and Devil Canyon, May through November 1983. Percentages are based on mean catch per cell. (Dugan, Sterritt, and Stratton 1984).

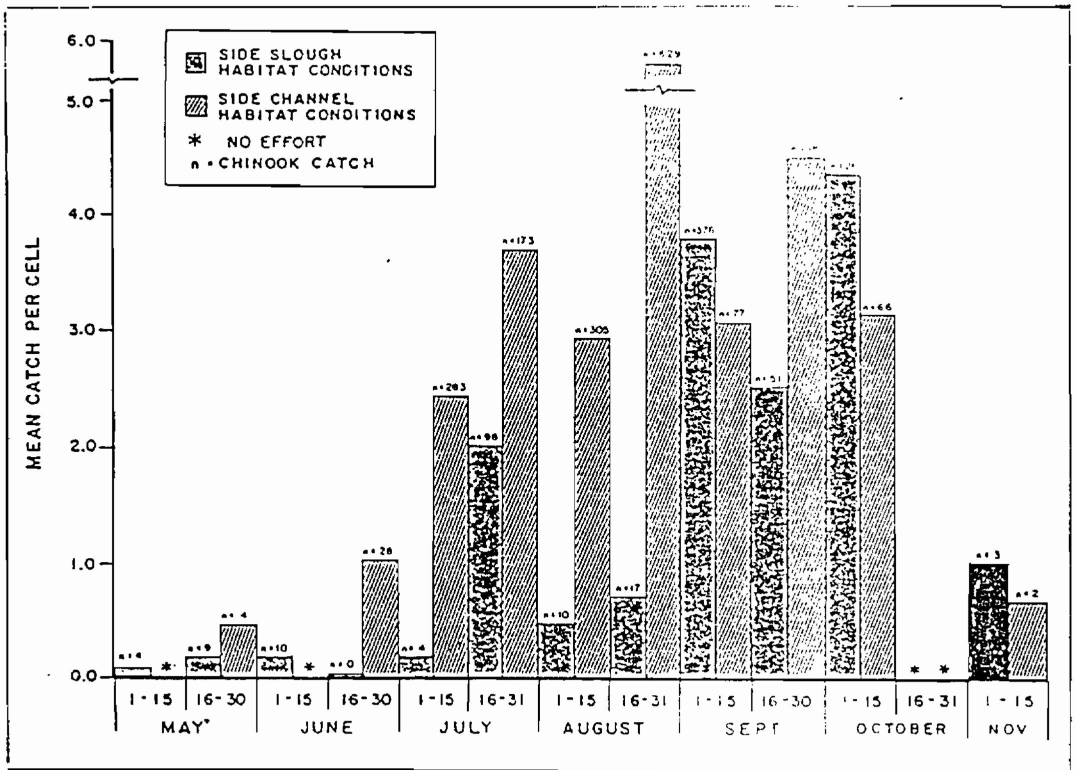



Figure 5. Juvenile chinook salmon mean catch per cell at side sloughs and side channels by sampling period, May through November 1983. (Dugan, Sterritt, and Stratton 1984).

Average total lengths of 0+ chinook for Indian River and mainstem associated habitats during 1984 are given in Table 4. No weight analyses are presently available to compare condition of juvenile chinook from different habitats.

| Time of Year | Indian River | Side Channels/ Side Sloughs |
|---|---|---|
| Late May | 38 mm | 41 mm |
| July 1st - 15th | 49 mm | 48 mm |
| July 16th - 31st | 55 mm | 52 mm |
| August 1st - 15th | 59 mm | 52 mm |
| August 16th - 31st | 61 mm | 56 mm |
| Early September | 64 mm | 58 mm |
| October 1st - 15th | 65.5 mm | 61 mm |

Table 4. Average total lengths of 0+ chinook salmon in millimeters (mm) during 1984 in the middle Susitna River. (Roth and Stratton in press).

Outmigration of the 1+ chinook smolts from the Talkeetna-to-Devil Canyon sub-basin occurs principally in May and June and is completed by September. Average smolt length for 1981 and 1982 was 90 mm (Roth, Gray, and Schmidt 1984). Rising water temperatures may stimulate smolt outmigration (Sano 1966). The critical temperature influencing this movement for chinook appears to be 7 degrees centigrade ($^{o}C$). When temperatures fall below this value, outmigration has been shown in other studies to slow or cease (Cederholm and Scarlet 1982; Raymond 1979). Photoperiod, discharge, magnetic fields, and lunar phases are also thought to influence smolt catch rate

migration (Godin 1980; Groot 1982). In 1983, num~~bers~~ of outmigrating chinook smolt from the middle Susitna River were ~~in~~significantly correlated with mainstem discharge~~s~~ ($r^2$ = 0.~~25~~) (Roth, Gray, and Schmidt 1984).

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# 4. FACTORS THAT INFLUENCE JUVENILE REARING CHINOOK SALMON IN THE MIDDLE SUSITNA RIVER

## 4.1 Introduction

Stream habitat parameters have a significant influence on all stages of the salmonid life cycle, including upstream migration of adults, spawning, incubation of eggs and the rearing of juvenile fish. Habitat requirements of juvenile anadromous fish in streams vary with species, age and time of year. For those species, like chinook, which spend an extended time rearing in freshwater, habitat quantity and quality determine the number of fish that survive to smoltification; and hence, the productive capacity of the system.

Figure 6 is a conceptual flow chart of the factors likely to influence the production of rearing juvenile chinook salmon in the middle Susitna River. Many of the factors are interrelated, but nine of them are highlighted for discussion. These factors and their interrelationships will be examined in regard to their effect on rearing chinook under preproject conditions. Section 5 examines how the with-project scenario may alter the significant factors and the possible implications for rearing chinook.

## 4.2 Flow Regime

Streamflow is a major determinant of juvenile rearing habitat for salmonids (Reiser and Bjornn 1979), and its effect is manifested through a number of factors (Figure 6). Streamflow and longitudinal channel profile determine the extent of riffles, runs and pools in a section of stream. Bjornn et

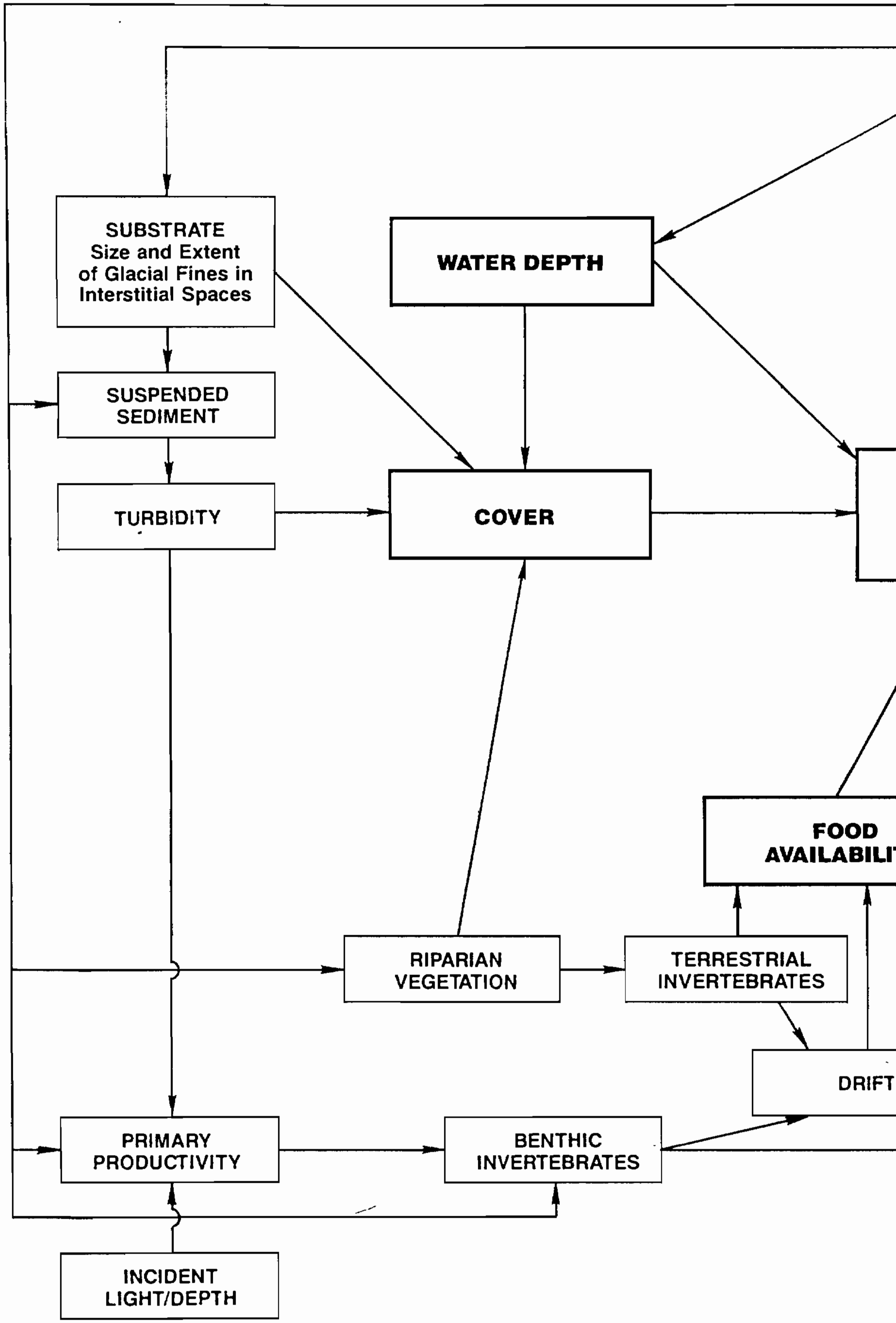
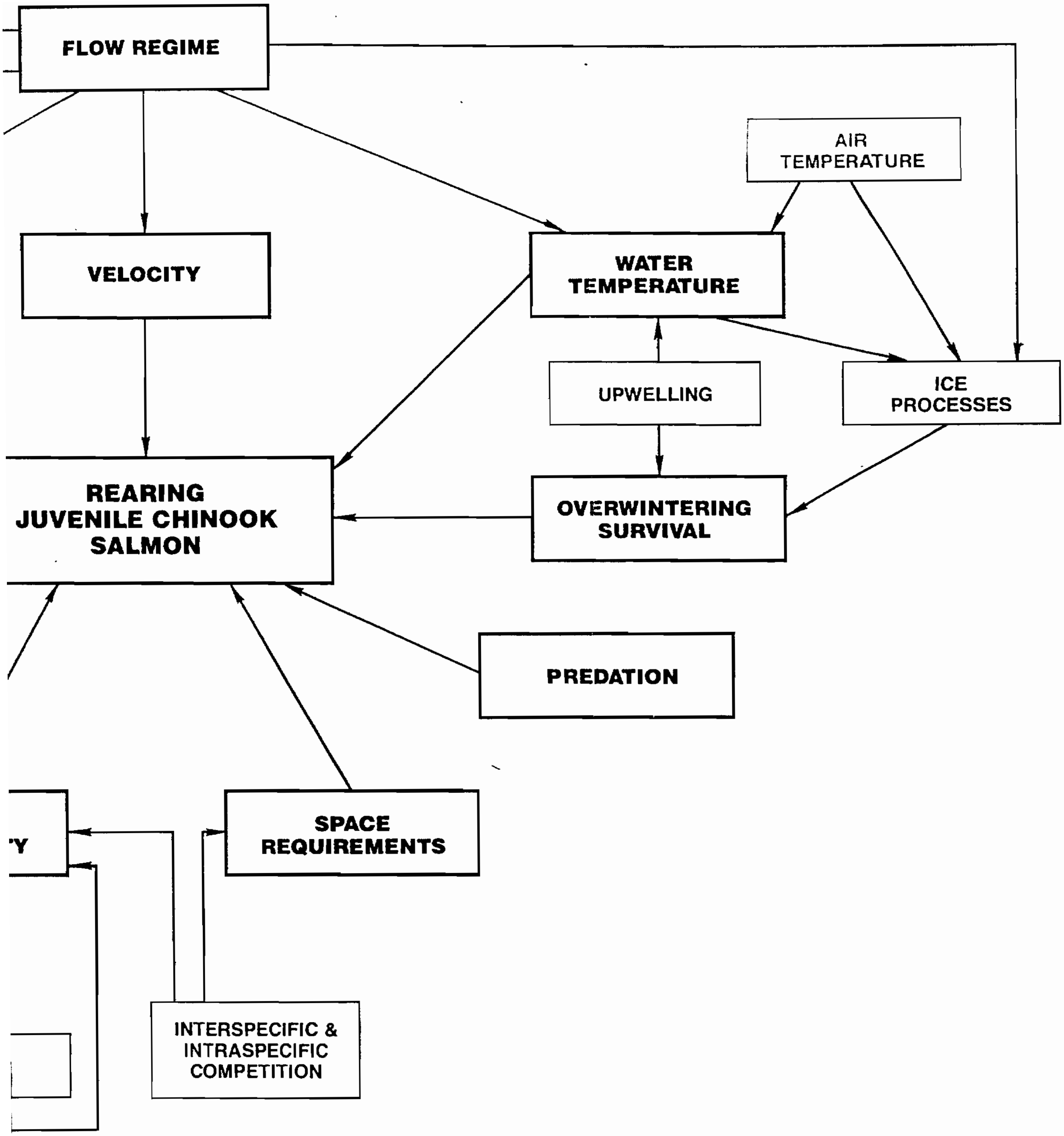



Figure 6. Conceptual flow diagram of the factors influencing chinook salmon rea
in the middle Susitna River.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WATER TEMPERATURE
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REARING JUVENILE CHINOOK SALMON
OVERWINTERING SURVIVAL
PREDATION
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INTERSPECIFIC & INTRASPECIFIC COMPETITION

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al. (1974) showed that a reduction in stream pool area resulted in a loss of juvenile salmonid rearing capacity, and Thompson (1972), in developing streamflow optima for rearing habitat, recommended a 1:1 pool to riffle ratio. D~~iversity and s~~treamflow is important to juvenile salmoni~~ds~~. Juvenile chinook salmon are typically associated with pools along the margins of riffles or current eddies (Kissner 1976; Platts and Partridge 1978). Streamflow is described and quantified by discharge and current velocity.

## 4.3 Discharge/Velocity

In a study of chinook salmon in the Kenai River, Alaska, young of the year (0+) fish under 50 mm were typically found in velocities below 0.6 feet per second (ft/sec) (Burger et al. 1983). Larger fish, in the range 50 to 100 mm, selected velocities under 1.1 ft/sec. Underwater observations showed that the optimum velocity was 0.3 ft/sec for the 55 to 95 mm length (Figure 7). Juvenile chinook were not observed in velocities exceeding 2.20 ft/sec. Velocity preferences of juvenile chinook from several studies are given in Table 5. The relationship between velocity and juvenile fish distribution depends on fish size, for as they become larger, they are able to move into faster deeper water.

| Age | Depth (ft) | Velocity (ft/sec) | Reference |
|---|---|---|---|
| 0+ | 0.5 - 1.0 | < 0.5 | Everest and Chapman (1972) |
| 0+ | < 2.0 | 0.3 | Stuehrenberg (1975) |
| 0+ | 1.0 - 4.0 | 0.2 - 0.75 | Thompson (1972) |

Table 5. Depth and velocity preferences for juvenile chinook from other studies.

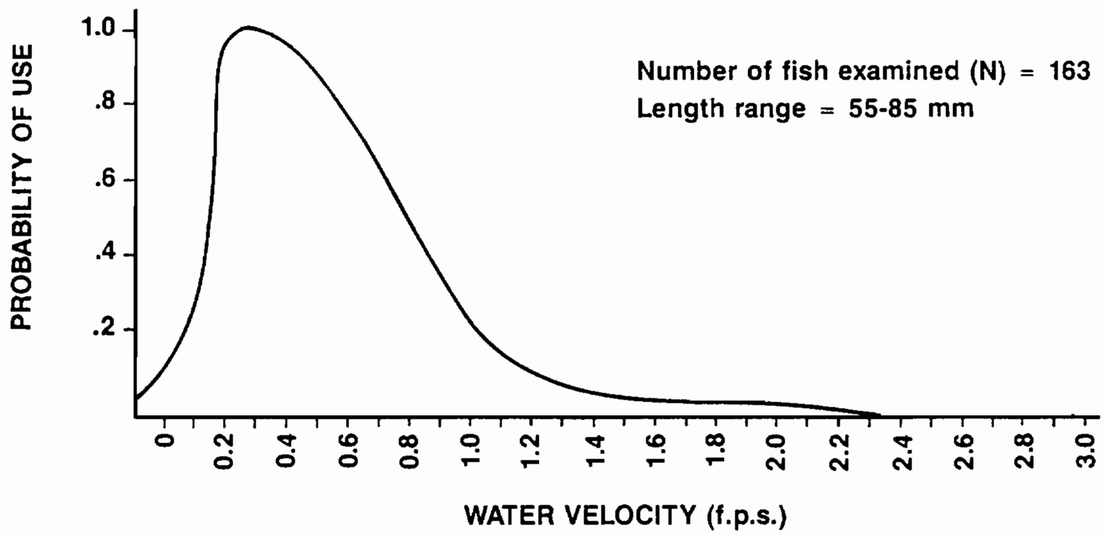



Figure 7. Facing-water velocity and probability of use for juvenile chinook compiled from underwater observations in the Kenai River, miles 18-36, during 1981. (Burger et al. 1983).

Suchanek et al. (1984) report that in the middle Susitna River, lower velocities and shallower depths are preferred by juvenile chinook under turbid conditions as compared to clear water. The greatest number of chinook per cell were captured at velocities between 0.1 and 0.3 ft/sec in turbid water greater than 30 Nephelometric Turbidity Units (NTU) and 0.4 to 0.6 ft/sec in low turbidity waters less than 30 NTU. No adjustments for gear efficiency differences were made in calculating the mean number of chinook per cell, as beach seines were used to capture fish in turbid water, while in clear water electrofishing was employed. Lorenz (1984) found that in small Alaskan streams, a hand held seine had a higher catch efficiency per unit effort than an electoshocker. The preference for lower velocities may be due to fewer velocity breaks from substrate being available in turbid side channels than are in clear water channels (Suchanek et al. 1984)

Discharge in the Susitna River varies markedly with the time of year. As is typical of unregulated northern glacier rivers, the Susitna River has high turbid water during the summer and low clearwater flow during the winter. Changes in surface area of the major habitat types occur in response to mainstem discharge variations (refer to Figure 9). A summary of mean, minimum and maximum monthly discharges for the Gold Creek gaging station show an annual mean of 9,650 cfs (Table 6). Average monthly discharges for June, July and August are approximately two and one half times the annual mean. Mid-channel velocities are frequently in the range of 7 to 9 ft/sec. Clearly the mainstem is unsuitable for chinook rearing during these months, although the fish use the margins for redistribution from the tributaries. Side channel flows typically mirror the mainstem, and the amount of suitable rearing habitat with acceptable velocities for juvenile chinook depends upon the channel geometry of the side channel and the proximal mainstem.

2

| Month | Monthly Flow (cfs) Maximum | Mean | Minimum |
|---|---|---|---|
| January | 2,452 | 1,542 | 724 |
| February | 2,028 | 1,320 | 723 |
| March | 1,900 | 1,177 | 713 |
| April | 2,650 | 1,436 | 745 |
| May | 21,890 | 13,420 | 3,745 |
| June | 50,580 | 27,520 | 15,500 |
| July | 34,400 | 24,310 | 16,100 |
| August | 37,870 | 21,905 | 8,879 |
| September | 21,240 | 13,340 | 5,093 |
| October | 8,212 | 5,907 | 3,124 |
| November | 4,192 | 2,605 | 1,215 |
| December | 3,264 | 1,844 | 866 |
| Average | 15,900 | 9,651 | 4,785 |

Table 6. Summary of monthly streamflow statistics for the Susitna River at Gold Creek. (Harza-Ebasco Susitna Joint Venture 1985b).

At most ranges of discharge, those side channels that have a broad relatively flat bottom and a gradually sloping shoreline profile possess a greater degree of marginal area with more suitable velocities than channels with a relatively narrow and incised cross section geometry. In addition, a reach of the mainstem that is constricted will have a steeper stage/discharge relationship than one less confined. In such areas there is an increase in responsiveness of site flows in adjacent s'de channels to incremental changes in mainstem discharge.

Mainstem discharges during late July and August, when the highest densities of juvenile chinook are in the side channels, average 23,100 cfs. Flows are relatively stable, with occasional sudden increases as the basin responds to the highly variable, and sometimes erratic, precipitation patterns. In August single day flood peaks have reached 60,000 cfs at the Gold Creek gage. Extremes of flow are recognized to limit juvenile fish production (Havey and Davis 1970; Smoker 1953). Spates may induce the downstream displacement of juvenile chinook or force them to seek refuge in pools, which may subsequently dewater on lowering discharges.

Side sloughs are principally dependent on local surface runoff and groundwater upwelling and possess velocities typically less than 1 ft/sec. reference They are characterized by a series of clearwater pools connected by short shallow riffles. Side slough velocities typically fall with mainstem discharge reduction as the rate of upwelling becomes reduced. Because there are differences in the elevation of the head berms relative to the mainstem, the flows at which sloughs become overtopped varies considerably, although generally it is between 20,000 to 30,000 cfs. Some sloughs are only overtopped at high discharge levels. At these overtopping flows, the side sloughs convey turbid mainstem water and velocities increase. Downstream displacement of rearing juvenile chinook may occur, but probably only to a small extent. Rearing fish may also obtain access to slough here

Tributary flows are independent of variations in mainstem discharges but may display significant fluctuations. Peaks typically occur in June following snowmelt and may be a factor in promoting redistribution of the juvenile chinook to other areas. Velocities in Indian River and Portage Creek can reach 3 to 4 ft/sec at these times. Velocities in tributary

At least

mouths are typically marginal for rearing juvenile chinook. Although the least favored by chinook of the possible rearing areas, upland sloughs have suitable velocites and are only slightly affected by increases in mainstem discharge.

From November through April, low air temperatures cause surface water in the basin to freeze and streamflow becomes markedly reduced. Groundwater inflow and baseflow from headwater lakes maintain mainstem streamflow. The significance of these low flows and the influence of upwelling on the overwintering survival of juvenile chinook will be discussed further in Section 4.10.

## 4.4 Water Depth

Water depth is determined by streamflow, channel form, and streambed materials. Providing other factors are suitable, rearing chinook salmon use a wide range of water depths. Burger et al. (1983) observed juvenile chinook at depths ranging from 0.2 to 9.5 ft in the Kenai River, Alaska, while Everest and Chapman (1972) reported preferences for depths of 0.5 to 1.0 ft in two Idaho streams. Depth preferences from several studies are summarized in Table 5. In the middle Susitna River, the greatest number of chinook per cell were found at depths of 0.1 to 0.5 ft in turbid water and 1.1 to 1.5 ft in low turbidity waters (Suchanek et al. 1984).

Temporal depth fluctuations are usually most variable within the side channels and tributaries, while the sloughs, when independent of the mainstem, are generally more uniform. Typical depths found in side channels, side sloughs or tributaries are not considered to be a limiting factor for juvenile chinook rearing in the middle Susitna River at the typical densities of fish presently found.

## 4.5 Cover

Cover is extremely important to rearing anadromous salmonids to avoid predation by other fish, birds, and terrestrial animals and to avoid unsuitable velocities. Predation can cause significant mortalities among rearing juveniles, particularly after emergence from the gravel (Allen 1969). Cover requirements may vary diurnally, seasonally or by species and fish size (Reiser and Bjornn 1979). Overhead cover can be in the form of overhanging riparian vegetation (Boussu 1954; Hartman 1965), turbulent or turbid water, large instream organic debris, or undercut banks (Bjornn 1971; Chapman and Bjornn 1969). Submerged cover is provided by cobbles and boulders with suitable interstitial spaces, logs and aquatic vegetation. Experiments have demonstrated that juvenile fish numbers increase when artificial cover is added to a stream (Bustard and Narver 1975). In the middle Susitna River, ice processes and flow variations are of such a nature that a well-developed riparian vegetation zone has generally not been able to become established along the edge of most side channels and side sloughs. Without the promotion of bank stabilization by the rooting of herbaceous and woody vegetation, undercut banks have been unable to form. Large organic debris is rare in side channels and is found only to a minor degree in side sloughs. Hence, riparian vegetation, undercut banks and large organic debris are not forms of cover typically available for juvenile chinook in these habitats. These types of cover are more prevalent in upland sloughs, although these areas contain relatively few juvenile chinook.

Cover for juvenile chinook in the middle Susitna River is more typically provided by suitably sized substrate and turbid water. Field observations and catch data from ADF&G indicate that juvenile chinook salmon abundance differs in turbid water compared to clear water. Catch rates at turbidities greater than 30 NTU were significantly higher ($p = < 0.001$) than at turbidities less than 30 NTU in cells without any type of object cover. Thus, in the absence of object cover, turbid water is used for cover by rearing chinook salmon (Suchanek et al. 1984). The utilization of turbidity as cover appears to be most prevalent during July and August, following redistribution from the tributaries. When a turbid side channel becomes non-breached and transforms to a clearwater slough, the number of juvenile chinook per cell typically decreases (Suchanek et al. 1984). Some juvenile chinook in turbid pool habitat will school if the water clears and move up to riffles near the upstream end of the site where they seek out object cover. Middle Susitna River turbidity levels at Gold Creek range from 1 to 1,000 NTU, with an average summer turbidty of 200 NTU (E. Woody Trihey and Associates and Woodward-Clyde Consultants 1985).

The newly emergent fry in the tributaries are probably the most susceptible to predation. Indian River and Portage Creek afford little cover in the form of riparian vegetation, undercut banks, large organic debris, or turbid water. In Indian River and Portage Creek, substrate composition and the percentage of fine materials present affect the amount of cover available to juvenile chinook. Large quantities of silt and sand deposited in a channel may fill interstitial spaces, preventing access between and under the gravel and stones. The amount of fine sediments tends to be greatest in the side sloughs and is related to their velocities and breaching flows. Overtopping of side sloughs during early summer may flush fine sediments from the side sloughs, but in some instances large amounts of sand are transported into the slough, particularly the lower section. In addition, the backwater effects at the downstream juncture of the mainstem and side sloughs may increase the amount of sediment present. Consequently, object cover from substrate may be extremely variable within and between side sloughs. However, the turbidity associated with the overtopping flows increases the amount of cover available. Increases in numbers of juvenile chinook in these cases may not be attributable solely to juvenile chinook seeking out turbid water for cover. It may also be a function of access to fish migrating downstream. However, juvenile chinook freely move upstream into these sites, in response to salmon eggs from spawners, and seek overwintering habitat, so access may not be a problem if a suitable stimulus is present. Due to their higher velocities, side channels usually possess less fine sediment than side sloughs. Filamentous algae, where it is able to develop, may act as cover and is discussed in the next section on food availability.

## 4.6 Food Availability

Fish food production is probably the most important of the biotic factors affecting juvenile chinook. Chapman (1966) suggests that the density of juvenile anadromous salmonids may be regulated by food availability. Young salmon can feed both off the bottom and on drifting foods (Keenleyside

1962), but in streams, browsing on benthos may be rare and organisms are essentially derived from drift (Elliott 1973; Mundie 1971).

Published data on the food habits and feeding of young chinooks are fragmentary. Everest and Chapman (1972) observed a strong positive correlation between the size of juvenile chinook and water velocity at a given feeding station, and they postulated that the movement of the fish into faster water as they grew was related to the availability of insect drift food. Burger et al. (1981) reported that juvenile chinook fed predominantly on chironomids in the Kenai River, Alaska, but they did not differentiate which life stage. Becker (1970) and Dauble, Gray, and Page (1980), in studies of juvenile chinook feeding in the Hanford reach of the Columbia River, found that over 95 percent of the diet was aquatic insects, of which chironomids were the principal component. Fifty-five to 65 percent of these chironomids were sub-adults and few pupae were taken (Becker 1970). Terrestrial insects comprised only 4 percent numerically of the total food organisms. The majority of insects ingested were drifting or swimming when captured. Loftus and Lenon (1977) obtained similar results in their study of chinook salmon in the Salcha River, southeast of Fairbanks, Alaska.

Riis and Friese (1978), in a preliminary study of salmonid food habits in the Susitna River, concluded that adult terrestrial insects made the greatest contribution volumetrically to the stomach contents of chinook. However, their classification of adult terrestrial insects included those with immature aquatic stages and they did not separate out chironomids. In 1982 ADF&G conducted investigations of food habits of juvenile chinook at five side sloughs and two clear water tributaries of the middle Susitna

River during August and September. At all sites, chironomids were numerically most important with a variable ratio of larvae compared to adults. Terrestrial insects numerically averaged less than 15 percent of the total stomach contents. Electivity indices comparing abundance of prey items in juvenile chinook diets to drift samples indicated a preference for chironomid larvae over chironomid adults. Location of drift nets were not always proximal to areas where fish were caught, so drift samples may have been different from that to which the fish were exposed. No juvenile chinook were examined from side channels (Alaska Dept. of Fish and Game, Susitna Hydro Aquatic Studies 1983a).

Terrestrial insects usually enter the drift by falling or being blown off riparian vegetation or washed in from channel side areas inundated by rapid flow fluctuations (Mundie 1969; Fisher and LaVoy 1972). The relatively low importance of terrestrial insects in the diet of juvenile chinook in the middle Susitna River is probably related to low numbers in the drift, as the mainstem, side channels and side sloughs, in most instances, lack a close border of riparian vegetation.

Chironomids are the most ubiquitous of freshwater macroinvertebrates and are successful in a wide range of environmental conditions. Brundin (1967) suggests that pleisiomorph Chironomidae were initially cold adapted, thereby accounting for their success in the arctic at temperatures often close to the limit of life. The availability of food items for macroinvertebrates has been recognized as one of the major factors regulating their abundance and distribution in streams (Cummins 1975; Egglishaw 1969; Hynes 1970). Filamentous algae or moss on a streambed provides food sources for chironomids, if not directly, then in the microfauna and flora they support. Algal filaments are also important to chironomids in providing support and protection from the current and abrasive sediments. Whitton (1970) and Milner (1983) reported on the strong association of chironomids and filamentous algae in flowing streams.

It has been widely documented that suspended sediment reduces primary production (Cordone and Kelly 1961; Phillips 1971; Phinney 1959) It plays a dominant role in the levels of primary productivity of the middle Susitna River. Primary productivity rates or quantitative assessments of algal growth have not been measured, but EWT&A and the University of Alaska's Arctic Environmental Information and Data Center (AEIDC) are presently addressing this question. The information available to date is from field observations. A winter-spring transition algal bloom may occur at open leads along the margins of the mainstem and side channels and in side sloughs (E. Woody Trihey and Associates and Woodward-Clyde Consultants 1985). Observations by EWT&A in late winter/early spring of 1985 in open lead areas indicated that active algal growth was most evident where upwelling or bank seepage occurred. The most typical growth was diatomacous in nature and chironomids were observed in association with the algae present. Some of the benthic production that occurs during the winter-spring transition may be dislodged and swept downstream during spring breakup, with the rapid increase in streamflow (E. Woody Trihey and Associates and Woodward-Clyde Consultants 1985). At prevailing springtime turbidities (50 to 100 NTU), the mainstem margin and side channels apparently continue to support a low to moderate level of primary production wherever velocity is not limiting. Ward et al. (1980) report upon the scouring of algae from stone surfaces by suspended sediment and unfavorable velocities, and Cummins (1974) reported that Vannote and co-workers had shown in experimental stream channels that flow perturbations limited the growth of filamentous algae. The euphotic zone at this time is estimated to extend to an average depth of between 1.2 and 3.5 feet (Van Nieuwenhuyse 1984). when?

In summer, mainstem flows are at their highest levels. The total surface area available for primary production is limited by high turbidities that reduce the depth of useful light penetration to less than 0.5 feet (Van Nieuwenhuyse 1984). Conditions are more favorable in the side sloughs for algal growth (stabler flows and greater light penetration), unless they are breached. However, the amount of sediment on the channel bed is also an important factor influencing the degree of algal growth and is extremely variable within and between side sloughs. Sediment deposition on the streambed may bury suitable sites for algal colonization and reduce the ability of filamentous forms to obtain firm attachment.

Field observations by EWT&A suggest that some of the sediment carried through sloughs becomes part of an organic matrix of unknown composition (probably bacteria, fungi and other microbes), which is colonized by a layer of pennate diatoms and filamentous algae, and covers streambed material greater than two-three inches. This type of growth was also observed in a number of mainstem and side channel habitats. Phosphorus associated with the sediment may enhance this growth (E. Woody Trihey and Associates and Woodward-Clyde Consultants 1985).

During late September and early October, 1984, extensive algal blooms were observed in the mainstem, side channels and side sloughs dominated by mats of green filamentous algae. This bloom was induced partly by moderating streamflows but principally by a notable reduction in turbidity levels to less than 20 NTU. The depth of the euphotic zone at turbidities of 20 NTU approximates five feet (Van Nieuwenhuyse 1984). Some of this production is dislodged and swept downstream or frozen in situ at freeze-up. This type of bloom may be a characteristic annual feature of the system (E. Woody Trihey and Associates and Woodward-Clyde Consultants 1985).

Macroinvertebrate populations are also dependent on other factors in addition to their requirement for food. High flows can directly dislodge immature insects by scouring action (Hynes 1968; Martin 1976). Catastrophic drift of benthic organisms may result (Elliott 1967; Waters 1972), and the fauna can perish from mechanical injury (Needham 1928) or by being carried out of the system. Rapid changes in flow can cause stranding of insects (Brusven, MacPhee, and Biggam 1974), particularly when the stream banks are gently sloping. Such events may inflict substantial losses on the benthic populations (Ulfstrand 1968; Ulfstrand, Nilsson, and Stergar 1974; Maitland 1966).

Accumulations of fine streambed sediments, as occurs in side channels and sloughs, are widely reported to reduce benthic invertebrate abundance (Cordone and Kelly 1961; DeMarch 1976; Gammon 1970; Koski 1972; Wagner 1959). In general, species diversity and density decrease progressively from cobble through gravel, sand and silt (Pennak and Van Gerpen 1974). Sediments may restrict access to the undersurface of cobbles (Brusven and Prather 1974), leaving only exposed surfaces for colonization (Phillips

1971). The undersurface of cobbles offers protection from predators and displacement by the current for many benthic invertebrates.

Consequently, macroinvertebrate abundance, particularly chironomid populations, is likely to be considerably higher in tributaries that have more suitable substrate and less sediment. However, drift of chironomids and other food organisms is probably greater in the side channels and tributaries than the side sloughs. Sloughs, when they become breached, will probably have increased drift through them. Juvenile chinook typically feed on drift by sight (Mundie 1974). The ability of fish to detect food items in the turbid water of the side channels is less and may explain the preference of juvenile chinook for shallower depths and lower velocities to enhance feeding on the drift in these areas. Juvenile chinook have been observed entering clearwater sloughs to feed on salmon eggs, leaving the cover of turbid water if the food stimulus is sufficiently strong.

The greatest densities of juvenile chinook occur in their natal tributaries, Indian River and Portage Creek. Indian River is also one of the principal coho rearing areas, and chironomids were the dominant food numerically in juvenile coho stomach samples (Dugan, ~~Sterritt, and Stratton~~ 1984). Lister and Genoe (1970) found that the habitat requirements of co-habiting chinook and coho fry were similar during the first three months of stream life. Thus, competition for food organisms could come into play in these tributaries. The physical environment of the middle Susitna River exercises limitations on the chinook population in mainstem associated habitats that prevent chinook from attaining a level where density dependent mechanisms operate. The quantity of drifting food items is widely variable at different sites and at different times of the growing season. Table 4 shows that juvenile chinook in tributary habitat displayed greater growth, in terms of length, than fish from side sloughs and side channels, even under a colder temperature regime (Figure 8). Hence, food availability in the side channels and side sloughs is likely to be a limiting factor to growth and thus overall survival.

## 4.7 Predation

The role of cover to avoid predation has been discussed in Section 4.5. Fish predators include rainbow trout, rearing coho, resident dolly varden, and sculpins. Juvenile chinook are most susceptible to predation in the tributaries due to the presence of higher numbers of fish predators compared to those in side channels or side sloughs. Mortality from fish predation is reduced for juvenile chinook that migrate to the side channels and obtain cover from the turbid water. When juvenile fish are in the shallower turbid water or clear water of the sloughs and tributaries, they may also be taken by piscivorous birds, notably kingfishers, dippers and mergansers. Mortality from predation, in comparison to other factors, is relatively minimal.

## 4.8 Space Requirements

Juvenile chinook salmon have space requirements that are probably related to the abundance of food (Chapman 1966). The interrelationship between cover, food abundance and microhabital preferences of rearing salmonids are not clearly understood, and thus the spatial needs are not adequately defined (Reiser and Bjornn 1979). Space requirements vary with size and

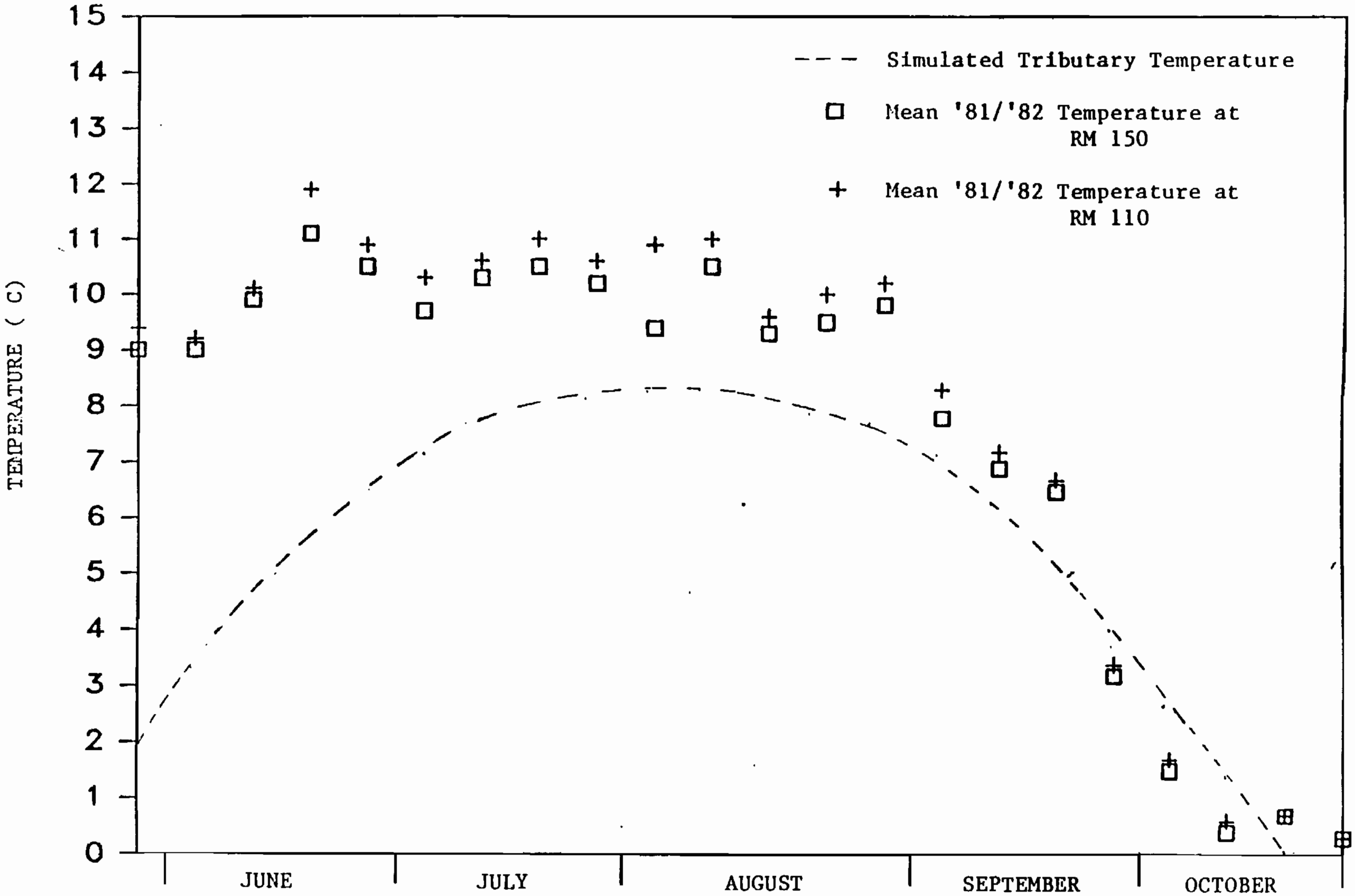



Figure 8. Comparison between average weekly stream temperatures for the Susitna River and its tributaries. (University of Alaska, Arctic Environmental Information and Data Center 1984a).

time of year. Studies in California by Burns (1971) showed significant correlations between living space and salmonid biomass. Juvenile chinook densities in the side channels and side sloughs do not appear high enough for space requirements to become a significant factor. However, in the natal tributaries, Indian River and Portage Creek, space requirements may regulate densities of emergent chinook fry, particularly with the presence of emergent coho. These factors, in association with competition for food and the high snowmelt streamflow, may account for the migration of significant numbers of juvenile chinook from the tributaries. Downstream migration may also occur as a function of innate behavior.

## 4.9 Temperature

Mainstem water temperatures normally range from $0^{\circ}$ C during the November-to-April period to $11^{\circ}$ C or $12^{\circ}$ C from late June to mid July. Water temperatures in side channels are similar to those of the mainstem. Unless overtopped, surface water temperatures in side sloughs are independent of the mainstem. Unbreached sloughs receive nearly all of their clear water flow from local runoff and groundwater inflow and display greater diurnal temperature fluctuations than other fish habitats. During the winter, slough flow is primarily maintained by upwelling groundwater with stable temperatures around $3^{\circ}$ C. The temperature of the upwelling groundwater significantly influences surface water temperatures in the slough, often maintaining them above $0^{\circ}$ C throughout most of the winter.

Salmonids are cold water fish with well-defined temperature requirements during rearing. Water temperature influences growth rate, activity and the ability to capture and use food. Brett (1952) lists the preferred temperature range for juvenile chinook to be 7.3 to 14.6° C and noted that chinook underyearlings displayed increasing percentage weight gains as temperature was increased from 10.0° to 15.7° C. When temperatures fell below the preferred minimum, growth rates became reduced. However, juvenile chinook of Susitna stock may be better adapted genetically to sustained growth at lower temperatures than fish from rivers in Oregon and Washington.

The principal growth period is from May to September when temperatures are probably in the optimum range. Table 4 indicates that there was only a small increase in length for juvenile chinook in the side channels and side sloughs from early September to mid-October, 1984, suggesting that the fall algal bloom does not seem to promote substantial chinook growth at that time. Kenai River chinook fry grew from an average total length of 43 mm in early May to an average of 71 mm by the end of October. Burger et al. (1983) consider this rate to be fairly typical for chinook growth at the end of the summer growing season in Alaskan drainages.

With the onset of freeze-up and colder water temperatures, minimal feeding and little growth occur. The maximum is likely to be a few millimeters. The average length of outmigrating 1+ smolt from the middle Susitna River was 90 mm in both 1981 and 1982. Assuming the 1985 value is likely to be similar, it indicates that significant growth may occur in the spring before outmigration, as the average length in mid-October was 65.5 mm. Condition and length of outmigrating smolt are important factors in ocean survival.

The effect of temperature on ice processes will be discussed further in Section 4.10 on overwintering survival.

## 4.10 Overwintering Survival

Overwintering survival is a significant factor in the production of juvenile rearing salmonids (Hynes 1970). Studies in the middle Susitna River to date have been minimal and the habitat requirements for overwintering chinook have not been clearly defined. A study was undertaken in the winter of 1984/85 by ADF&G to examine this subject.

Numbers of juvenile chinook increase in the side sloughs during September and October, as groundwater upwelling or salmon eggs from spawners may attract overwintering fish. Tributaries, mainstem and side channels are also known to be used by juvenile fish as overwintering areas. A comparison between measured surface water temperatures in side sloughs
Why not give actual data?
during the winter and simulated mainstem temperatures is given in Table 7. Upwelling in side sloughs and side channels may result in open leads throughout the winter.

Juvenile chinook become relatively inactive at low water temperatures. As drift of food organisms is reduced at the associated low flows, feeding activity is minimal. Cover is therefore an important factor, and when water temperatures fall below 6° C, juvenile chinook have been observed to move closer to cover (Burger et al. 1983). Due to the lack of glacier melt in winter, juvenile chinook no longer obtain cover from turbid water, and substrate becomes important as a velocity break and resting habitat. Burger et al. (1983) observed that the substrate plays a key role in the

| Location | RM | 1982 Feb | 1982 Mar | 1982 Apr | 1982 Aug | 1982 Sep | 1982 Oct | 1982 Nov | 1982 Dec | 1983 Jan | 1983 Feb | 1983 Mar | 1983 Apr | 1983 May |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Slough 8A Mouth | 125.4 | | | | | 6.5 | 2.4 | 1.7 | | 0 | 0 | 0.4 | 1.3 | |
| Slough 8A Upper | 126.4 | | | | | 5.8 | 4.4 | | | | | 2.5 | 3.8 | 3.3 |
| Slough 9 | 128.7 | | | | 8.9 | 5.9 | 2.3 | | | | | | 3.8 | 4.7 |
| Slough 11 | 135.7 | | 2.5 | 3.1 | | 3.3 | 3.1 | 2.9 | 2.9 | 2.9 | 2.9 | 3.0 | 3.5 | 6.0 |
| Slough 21 | 141.8 | 1.6 | 1.9 | 3.1 | | | 2.2 | 1.1 | 0.8 | | | | | |
| Mainstem | | | | | | | | | | | | | | |
| LRX 29 | 126.1 | 0.0 | 0.0 | 2.9 | 10.9 | 6.5 | 0.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 3.0 | --- |
| LRX 53 | 140.2 | 0.0 | 0.0 | 2.5 | 10.8 | 6.4 | 0.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.6 | --- |

Note: Mainstem temperatures are simulated without an ice cover and warm earlier in the spring than what naturally occurs. Thus the April mainstem temperatures are probably warmer than what would occur.

Table 7. Comparison between measured surface water temperatures (°C) in side sloughs and simulated average monthly mainstem temperatures. (Alaska Dept. of Fish and Game, Susitna Hydro Aquatic Studies 1983b).

overwintering strategy of juvenile chinook in the Kenai River. Bjornn (1971) also considers substrate to be essential for winter cover. Consequently, the quantity of deposited fine sediment in the channels may be an important factor in determining suitable overwintering habitat. Remnants of the fall algal bloom may also act as cover, particularly where maintenance has been possible in the warmer water of the open leads. Associated immature insect stages could provide a food source for the juvenile chinook. Predation pressure on juvenile chinook is probably much reduced during the winter, and the major mortality arises from unsuitable physical conditions. Ice processes dominate the hydrological and biological characteristics of the middle Susitna River from November to April. The most important factors affecting freeze-up of the Susitna River are air and water temperature, instream hydraulics and channel morphology. When side sloughs are occasionally overtopped by mainstem water during staging at freeze-up, the relatively warmer water is replaced by large volumes of $0^{o}$ water and slush ice. If the overtopped condition persists, the warming influence of the upwelling is diminished and the slough becomes a less favorable overwintering habitat.

The formation and characteristics of the common types of ice found in the middle reach of the Susitna River are summarized in the Instream Flow Relationships Report, Volume 1 (E. Woody Trihey and Associates and Woodward-Clyde Consultants 1985). Stream insects are well adapted to cold conditions and may survive in egg or diapause stages. They may also bury deeper into the substrate where water temperatures may be above freezing. In open water areas, anchor ice may have a damming effect and divert water out of established channels. Juvenile fish could move into the diverted channels and, should the flow be diverted suddenly back to its original channel, fish may be stranded and die. Needham and Jones (1959) report that ice dams were a major source of mortality in juvenile trout in Sierra Nevada streams. Anchor ice can encase the substrate, making it useless as cover to fish. However, the major source of mortality during the winter is believed to be dewatering and freezing. Side channels and side sloughs without significant groundwater upwelling may freeze completely. In severe cases, this may include the subsurface flow down to the water table. Tributaries like Indian River and Portage Creek are less likely to freeze completely and will have some flowing water.

Another problem caused by ice processes for juvenile chinook occurs during spring breakup. The duration of the breakup period depends on the intensity of solar radiation, air temperature, and precipitation. Tributaries have usually broken out in their lower elevations by late April, and open water exists at their confluences with the Susitna River. Increased flows from the tributaries erode the Susitna River ice cover for considerable distances downstream from their confluences. As water levels in the river begin to rise and fluctuate with spring snowmelt and precipitation, the ice cover erodes. Ice becomes undercut and collapses into the open leads, drifting to their downstream ends and accumulating in small ice jams. In this way, leads become steadily wider and longer. Major ice jams generally occur in shallow reaches of the mainstem, with a narrow confining thalweg channel along one bank, or at sharp river bends. Major jams are commonly found adjacent to side channels or sloughs. Breakup ice jams commonly cause rapid, local stage increases that continue rising until either the jam releases or the adjacent sloughs or side channels become flooded. While the jam holds, flow and large amounts of ice are diverted into side channels or sloughs, rapidly eroding away sections of riverbank and often pushing ice well up into the trees.

Generally, the final destruction of the ice cover occurs in early to mid May when a series of ice jams break in succession, adding their mass and momentum to the next jam downstream. This continues until the river is swept clean of ice except for stranded ice floes along shore. These events have detrimental effects on the biota. A substantial amount of the spring algal growth is dislodged and carried downstream. Benthic macroinvertebrate and 1+ chinook may become similarly displaced. Juvenile fish could be forced into refuge channels, which become cut off from the main channels as flows change with ice movements. It is difficult to estimate the mortality that arises from spring breakup, and it is probably highly variable from year to year.

## 5.0 EVALUATION OF WITH-PROJECT CONDITIONS

### 5.1 Introduction

This section of the report subjectively evaluates with-project effects on the abiotic and biotic factors outlined in Section 4 and discusses the possible implications for juvenile chinook salmon in the middle Susitna River. Tributary habitat should not be significantly altered under with-project conditions, and the factors discussed in Section 4.0 relating to this habitat will probably remain relatively unchanged. Therefore, tributary habitats are not discussed in detail in Section 5.0.

### 5.2 Flow Regime

In November 1984, the Alaska Power Authority submitted a report (Harza-Ebasco Susitna Joint Venture 1985a) to the Federal Energy Regulatory Commission evaluating alternative flow requirements to the flow regime specified in the original Susitna Hydroelectric Project License Application. In their evaluation, APA selected one alternative, Case E-VI, as the preferred alternative flow regime. The primary reasons to refine the earlier flow scenario were threefold.

1. The need to consider the use of mainstem and side channels for rearing fish in establishing flow requirements. This rational was not used in establishing Case C flow requirements in the license application.

2. The requirement for seasonal flow control over the entire year in order to maintain overall aquatic habitat values.

3. The necessity to have maximum flow constraints.

Case E-VI flows have been developed for four different reservoir operation scenarios. Scenarios A and B assume operation of the Watana Reservoir only, with electrical energy demand forecasts for 1996 and 2001, while Case C and D assumes both Watana and Devil Canyon reservoirs in operation and energy demand forecasts for 2002 and 2020. This subjective evaluation will focus on Case D, as it represents the long term scenario and the greatest change in flow regime from preproject conditions.

5.3 Discharge/Velocity

A controlled flow regime under with-project conditions will result in a decrease in average discharge during the summer and an increase in the winter in the middle Susitna River. Between June 3 and September 1, flow constraints provide for a minimum discharge of 9,000 cfs (Harza-Ebasco Susitna Joint Venture 1985a) (Table 8). These lower flows, as compared to natural conditions, will result in a reduction of side channel surface area. For example, a 50 percent reduction of mainstem discharge from 20,000 to 10,000 cfs will result in an approximate 28 percent reduction in side channel surface area (Figure 9). The minimum flow constraint of 9,000 cfs under Case E-VI was selected to maintain 75 percent of existing side channel rearing habitat for chinook salmon (Harza-Ebasco Susitna Joint Venture 1985a). Williams (1985) carried out a comparison between natural and with-project hydraulic conditions (Case E-VI-D) in four large side channels of the middle Susitna River for the open water rearing period (May 20 to September 15). The results showed that the surface area of side channels where suitable velocities would be available for juvenile chinook

| Water Week | Period | Gold Creek Flow (cfs) Minimum | Maximum | Water Week | Period | Gold Creek Flow (cfs) Minimum | Maximum |
|---|---|---|---|---|---|---|---|
| 14 | 31 Dec. - 06 Jan. | 2,000 | 16,000 | 40 | 01 July - 07 July | 9,000* | 35,000 |
| 15 | 07 Jan. - 13 Jan. | 2,000 | 16,000 | 41 | 08 July - 14 July | 9,000* | 35,000 |
| 16 | 14 Jan. - 20 Jan. | 2,000 | 16,000 | 42 | 15 July - 21 July | 9,000* | 35,000 |
| 17 | 21 Jan. - 27 Jan. | 2,000 | 16,000 | 43 | 22 July - 28 July | 9,000* | 35,000 |
| 18 | 28 Jan. - 03 Feb. | 2,000 | 16,000 | 44 | 29 July - 04 Aug. | 9,000* | 35,000 |
| 19 | 04 Feb. - 10 Feb. | 2,000 | 16,000 | 45 | 05 Aug. - 11 Aug. | 9,000* | 35,000 |
| 20 | 11 Feb. - 17 Feb. | 2,000 | 16,000 | 46 | 12 Aug. - 18 Aug. | 9,000* | 35,000 |
| 21 | 18 Feb. - 24 Feb. | 2,000 | 16,000 | 47 | 19 Aug. - 25 Aug. | 9,000* | 35,000 |
| 22 | 25 Feb. - 03 Mar. | 2,000 | 16,000 | 48 | 26 Aug. - 01 Sep. | 9,000* | 35,000 |
| 23 | 04 Mar. - 10 Mar. | 2,000 | 16,000 | 49 | 02 Sep. - 08 Sep. | 8,000 | 35,000 |
| 24 | 11 Mar. - 17 Mar. | 2,000 | 16,000 | 50 | 09 Sep. - 15 Sep. | 7,000 | 35,000 |
| 25 | 18 Mar. - 24 Mar. | 2,000 | 16,000 | 51 | 16 Sep. - 22 Sep. | 6,000 | 35,000 |
| 26 | 25 Mar. - 31 Mar. | 2,000 | 16,000 | 52 | 23 Sep. - 30. Sep. | 6,000 | 35,000 |
| 27 | 01 Apr. - 07 Apr. | 2,000 | 16,000 | 1 | 01 Oct. - 07 Oct. | 6,000 | 18,000 |
| 28 | 08 Apr. - 14 Apr. | 2,000 | 16,000 | 2 | 08 Oct. - 14 Oct. | 6,000 | 17,000 |
| 29 | 15 Apr. - 21 Apr. | 2,000 | 16,000 | 3 | 15 Oct. - 21 Oct. | 5,000 | 16,000 |
| 30 | 22 Apr. - 28 Apr. | 2,000 | 16,000 | 4 | 22 Oct. - 28 Oct. | 4,000 | 16,000 |
| 31 | 29 Apr. - 05 May | 2,000 | 16,000 | 5 | 29 Oct. - 04 Nov. | 3,000 | 16,000 |
| 32 | 06 May - 12 May | 4,000 | 16,000 | 6 | 05 Nov. - 11 Nov. | 3,000 | 16,000 |
| 33 | 13 May - 19 May | 6,000 | 16,000 | 7 | 12 Nov. - 18 Nov. | 3,000 | 16,000 |
| 34 | 20 May - 26 May | 6,000 | 16,000 | 8 | 19 Nov. - 25 Nov. | 3,000 | 16,000 |
| 35 | 27 May - 02 June | 6,000 | 16,000 | 9 | 26 Nov. - 02 Dec. | 3,000 | 16,000 |
| 36 | 03 June - 09 June | 9,000* | 35,000 | 10 | 03 Dec. - 09 Dec. | 2,000 | 16,000 |
| 37 | 10 June - 16 June | 9,000* | 35,000 | 11 | 10 Dec. - 16 Dec. | 2,000 | 16,000 |
| 38 | 17 June - 23 June | 9,000* | 35,000 | 12 | 17 Dec. - 23 Dec. | 2,000 | 16,000 |
| 39 | 24 June - 30 June | 9,000* | 35,000 | 13 | 24 Dec. - 30 Dec. | 2,000 | 16,000 |

* Minimum summer flows are 9,000 cfs except in dry years when the minimum will be 8,000 cfs. A dry year is defined by the one-in-ten year low flow.

Table 8. Susitna hydroelectric project flow constraints for environmental flow requirement Case E-VI. (Harza-Ebasco Susitna Joint Venture 1985a).

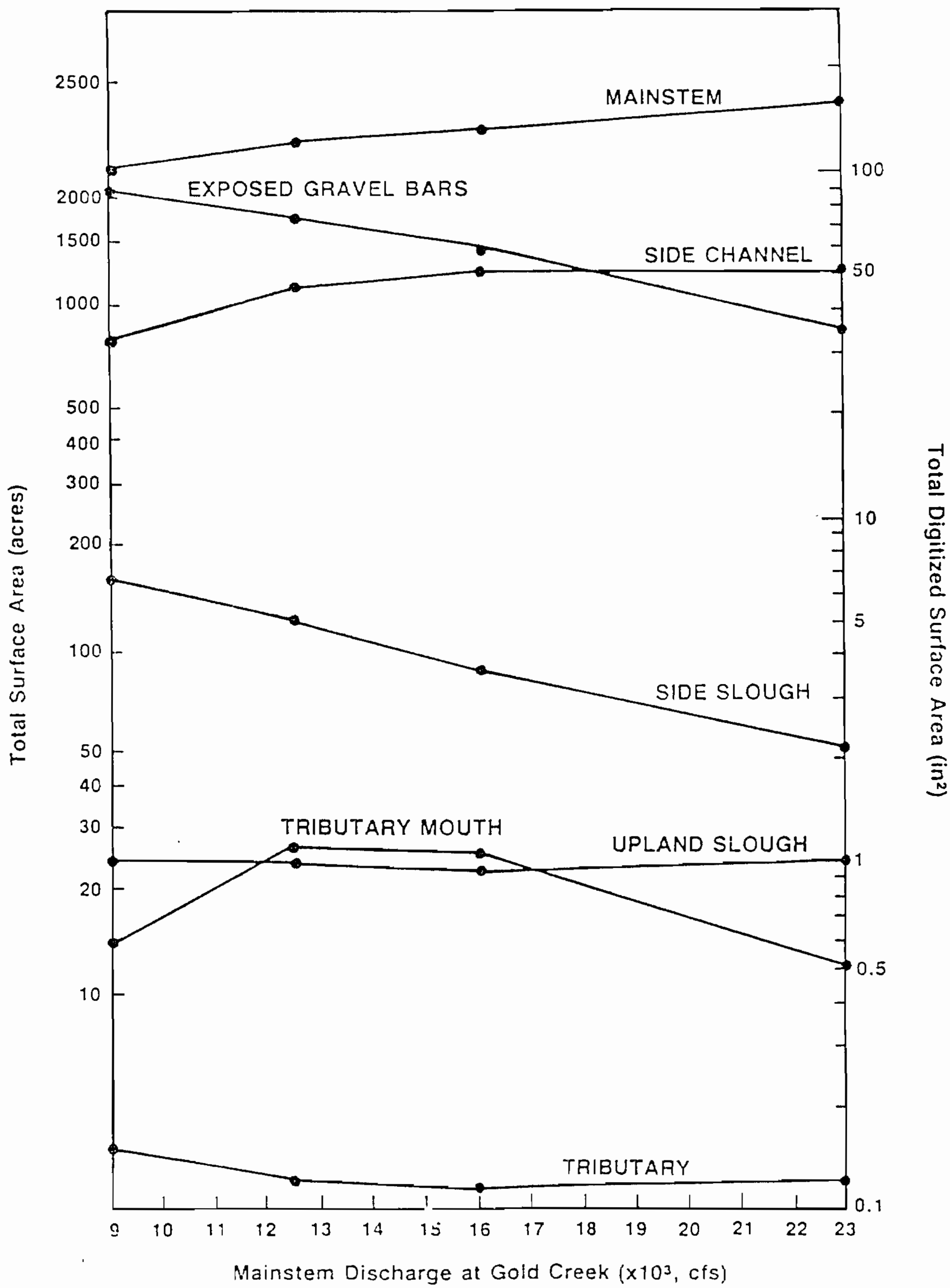


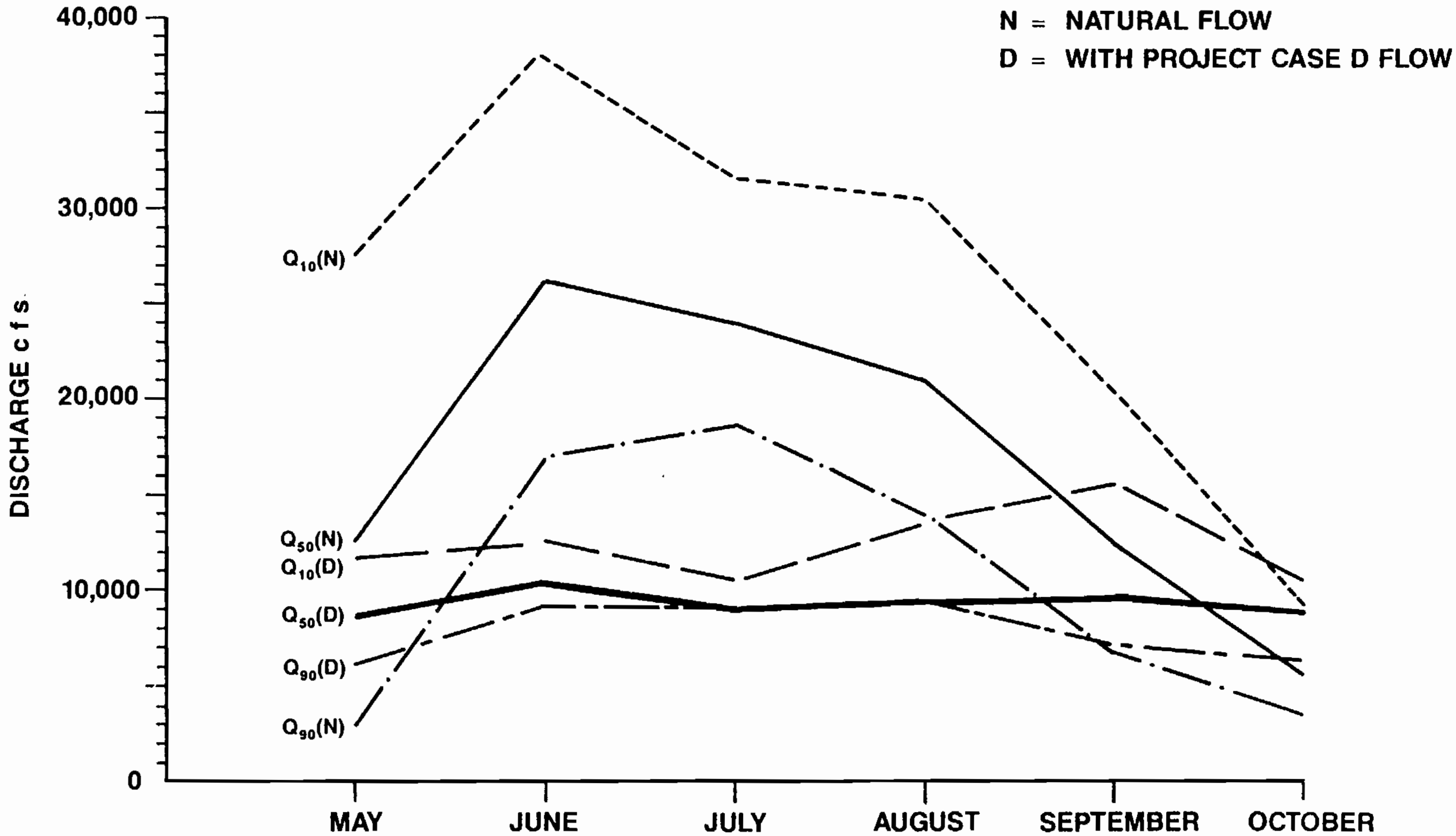

Figure 9. Surface area responses to mainstem discharge in the Talkeetna-to-Devil Canyon reach of the Susitna River (RM 101 to 149). (Klinger and Trihey 1984).

would in fact be larger and more persistent under with-project conditions. This is particularly evident in side channels with a broad relatively flat bottomed profile. Similarly, a reduction in mainstem flow from 20,000 cfs to 10,000 cfs would cause an approximate 138 percent increase in side slough surface area. The side sloughs will become more independent of the mainstem, as overtopping of the head berms will be less frequent.

With-project conditions under a base load supply will provide for discharge and velocity levels with greater stability and less fluctuations throughout the growing season of juvenile chinook. Flow variations from year to year within this period will also be less. Although the simulated 34-year record (1950-1983) indicates that high flow events will reach 37,000 cfs, the frequency of these events during the growing season will be markedly less, particularly in June and July (Figure 10). These flows will generally reduce the downstream displacement of juvenile chinook from the middle Susitna River and the mortality that can result if fish seek out refuge in lateral pools.

## 5.4 Water Depth

In Section 4.3 water depth was considered unlikely to be a limiting factor in juvenile chinook rearing in the middle Susitna River. The greater stability of discharges under with-project conditions will result in less temporal depth variations, particularly in the side channels.




Note: $Q_{10}$ is the typical high flow, $Q_{50}$ is the typical median flow, and $Q_{90}$ is the typical low flow.

Figure 10. Comparison of the middle Susitna River natural and with-project (Case D) exceedance flow (cfs) for the months May to October calculated from weekly streamflows for the water years 1950-1983.

## 5.5 Cover

Turbid water is important as cover for rearing juvenile chinook in the middle Susitna River.

The Watana and Devil Canyon reservoirs have been estimated to trap between 80 to 100 percent of the incoming sediment (R & M Consultants, Inc. 1982). Particles smaller than 0.003 mm are likely to remain in suspension in the water released downstream. Peratrovich, Nottingham and Drage, Inc. (1982) estimate that turbidity levels downstream of the Watana and Devil Canyon dams will range from 20 to 50 NTU in the summer and 10 to 20 NTU in the winter months. A theoretical plot of turbidity against depth of light penetration to the compensation point (depth at which light intensity is one percent of that at the surface) indicates that at 50 NTU, this depth is over three feet (Figure 11). At typical preproject summer turbidities of 200 NTU, the compensation point is approximately 1.2 feet. Although ADF&G (Suchanek et al. 1984) found that juvenile chinook densities increased at turbidities greater than 30 NTU, this result does not define the value of 40 to 50 NTU water as cover compared to 200 NTU. Although light penetration is greater at 40 to 50 NTU, the water may still be sufficiently turbid to provide significant cover for juvenile chinook. However, water in the lower with-project range of 20 to 30 NTU has a compensation point of five feet or greater and its cover value is likely to be less.

Presently, the amount of sediment transport during the summer in the middle Susitna River is extremely variable, with high rates generally occurring during periods of peak flow events. However, under with-project conditions, virtually all sand sized (greater than 0.05 mm) and larger

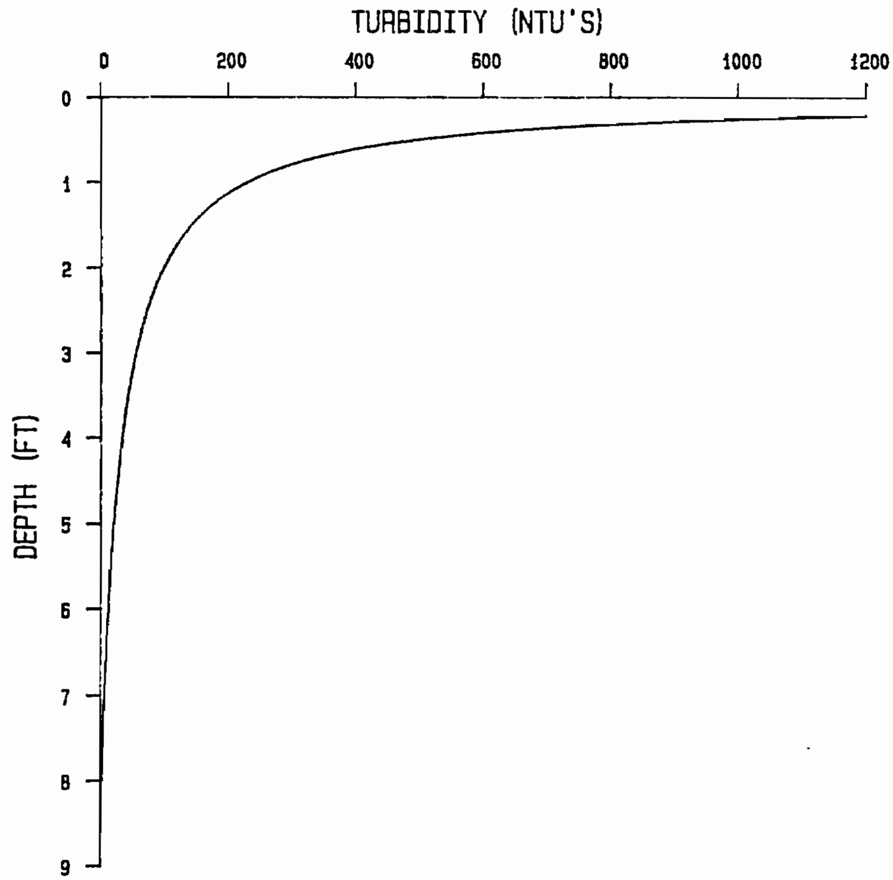



Figure 11. Theoretical curve of turbidity versus depth of compensation point. (Reub, Trihey, and Wilkinson 1985).

particles will be removed by deposition in the reservoirs. A greater percentage of the sediment load released downstream of the dams will probably remain in suspension and be carried through the middle reach. Under with-project conditions, the principal source of the sediment transported through the middle Susitna River will be coarse material eroded from the banks downstream of the dam and material brought down from the tributaries. More energy should be available for transporting sediment than is required to transport the available sediment supply; and hence, it has the potential to scour out and carry downstream fine sediments. Without the further deposition from high sediment loads, the availability of substrate as suitable cover will increase in side channels with larger bed elements. Similar conditions may occur in a number of side sloughs if suitable flushing flows operate after dam construction.

The reduced variation in discharge, the greater degree of light penetration, and the reduction in streambed sediment should enhance algal growth throughout the summer in side channels and a number of side sloughs. If this algal growth forms filamentous mats, as has been observed in localized areas of the middle Susitna River at certain times of the year, it could provide a source of cover for juvenile chinook. In addition, the reduction in streamflow variation will allow a more stable shoreline condition, thereby permitting a zone of riparian vegetation to potentially develop. This vegetation could reduce channel bank erosion and provide cover for juvenile fish. However, ice processes, in association with the higher winter flows, may limit riparian vegetation development.

In summary, turbidities in the lower range of anticipated with-project values will not provide the same amount of cover, but other types of cover should become more available and adequately compensate. These trade-offs appear to favor with-project conditions for cover when the positive effects of lower turbidities on other significant rearing habitat factors are considered.

## 5.6 Food Availability

If, as discussed in Section 5.5, an overall increase in primary production may be postulated under with-project conditions, then a general promotion of food organism production for juvenile chinook will result. Additionally, increased flow stability and a decrease in fine sediment on the streambed should directly enhance the numbers of benthic invertebrates, including chironomids.

Less high flow events will probably reduce catastrophic drift of organisms. However, the overall rise in numbers of benthic invertebrates is likely to increase density dependent drift. Overall, the quantity of drift in mainstem associated habitats should be higher and drift rates of food organisms will be more uniform and constant throughout the growing season. In addition to increased food availability, the ability of juvenile chinook to locate the drifting prey items will be improved due to lower turbidity levels. The amount of drift entering a number of side sloughs during the summer will, however, be reduced due to less overtopping events from lower average flows under with-project conditions. Terrestrial insects associated with vegetation may become more significant in the diet of juvenile chinook if riparian zones are able to become established to any extent along the margins of side channels and side sloughs.

## 5.7 Predation

The predation of juvenile chinook by piscivorous birds may increase in side channels under with-project conditions as a result of their being more visible in the lower turbidity water. However, alternative types of cover should become available and overall mortality from this source is likely to remain comparatively negligible.

## 5.8 Space Requirements

Downstream migration by juvenile chinook from the Indian River and Portage Creek tributaries may be related to competition for food and space. Densities of redistributed fish in side channels are low as conditions are relatively unfavorable for rearing fish. Under a with-project scenario of reduced flow variation, less high flow events, and increased food availability, fish that previously migrated from the middle Susitna River may remain in the more favorable rearing conditions of the side channels and densities should increase. However, it is unlikely that densities will attain levels where space requirements become significant. The retention of greater numbers of rearing juveniles and improved rearing conditions should enhance survival and may lead to an overall improvement in smolt production from the middle Susitna River. Competition for space may actually intensify in the tributaries if seeded at higher levels as a consequence of increases of numbers of returning spawners.

5.9 Temperature

Project operation will have a notable influence on the temperature of water discharged below the dams. The reservoirs will store heat in the summer while releasing water with lower-than-natural temperatures between spring breakup and mid-summer. For the remainder of the year, temperatures of the released water would be higher than under natural conditions (Table 9).

| Location | Month | Natural | Devil Canyon Dam (2020) | Difference |
|---|---|---|---|---|
| Portage Creek (148.9) | May | 6.2 | 3.1 | -3.1 |
| | June | 9.9 | 5.7 | -4.2 |
| | July | 10.4 | 7.6 | -2.8 |
| | Aug | 9.9 | 8.0 | -1.9 |
| | Sept | 5.9 | 8.5 | +2.6 |
| | Oct | 0.6 | 6.1 | +5.5 |
| Sherman (130.8) | May | 6.2 | 3.8 | -2.4 |
| | June | 9.8 | 6.5 | -3.3 |
| | July | 10.4 | 8.1 | -2.3 |
| | Aug | 10.0 | 8.3 | -1.7 |
| | Sept | 6.2 | 8.3 | +2.1 |
| | Oct | 0.6 | 5.3 | +4.7 |
| Whiskers Creek (101.4) | May | 6.8 | 5.1 | -1.7 |
| | June | 10.4 | 8.3 | -2.1 |
| | July | 11.0 | 9.6 | -1.4 |
| | Aug | 10.5 | 9.2 | -1.3 |
| | Sept | 6.4 | 8.3 | +1.9 |
| | Oct | 0.6 | 4.3 | +3.7 |

Table 9. Simulated monthly mean temperatures (°C) for the mainstem Susitna River, Devil Canyon to Talkeetna. (University of Alaska, Arctic Environmental Information and Data Center 1984).

Water temperatures from May through October may potentially reduce the growth rates of juvenile chinook. AEIDC produced estimates of seasonal fish growth as a function of water temperatures and body weight of the fish (University of Alaska, Arctic Environmental Information and Data Center i.e. Table 4 only shows Indian R. data and no temp. data from Indian have been presented

1984a). The growth function used was derived by Brett (1974) from observations on sockeye salmon. Results showed that for simulated mainstem temperatures at RM 130, juvenile fish would potentially have a 24 to 29 percent reduction in body weight over the May to October growing season. However, these predictions are based on studies in the laboratory and may have little relevance to juvenile chinook of Susitna stock in the natural situation. Table 4 showed that juvenile chinook in the tributaries under a colder temperature regime displayed greater growth, in terms of length, over the May to October period than juvenile fish from side channels and side sloughs. Greater food availability in the tributaries was probably the dominant factor accounting for increased growth. Hence, under with-project conditions, if increased food availability is sustained, as previously discussed, then the potential detrimental effects of lower temperatures on growth rates, as compared to natural conditions, would be negated. With warmer temperatures extending through October, growth rates may indeed be improved over natural conditions in mainstem associated habitats and enhance the condition of fish entering the winter period.

The colder spring with-project conditions could delay outmigration of chinook smolt from the middle Susitna River until a water temperature of 7° C is reached in late June. The delay of two to three weeks compared to natural conditions is unlikely to have a detrimental effect on smolt survival.

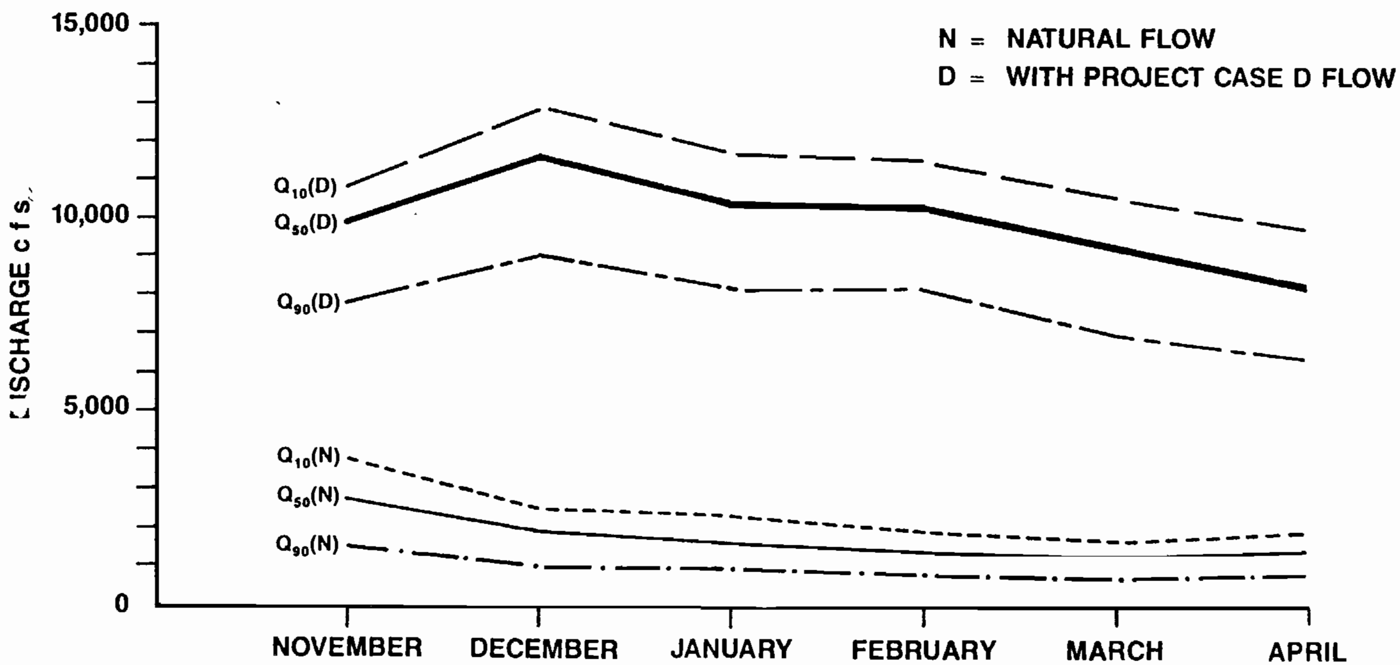
Why?

Average September to April mainstem temperatures below the Devil Canyon dam under with-project conditions will range from 1.4 to 2.7° C just upstream of the Chulitna River confluence and 2.3 to 4.0° C near Portage Creek. These temperatures are respectively 0.4 to 1.4° C and 1.9 to 2.9° C warmer than natural temperatures (University of Alaska, Arctic Environmental Information and Data Center 1984a). Consequently, a better mainstem incubating habitat for salmonid embryos should exist under with-project scenarios, due to the warmer mainstem water temperatures during the winter incubation period. This factor, in conjunction with stabler flows and less fine sediment on the streambed, may induce chinook spawning in the mainstem and side channel habitats.

## 5.10 Overwintering Survival

The operation of the hydroelectric project will have significant effects on the ice processess of the Susitna River, due to changes in flows and water temperatures in the river below the dams. Generally, winter flows will be several times greater than under natural winter conditions. Fifty percent exceedance values for with-project conditions (Case E-VI-D) are on the order of six to eight times greater than flows under natural conditions for the months November through April (Figure 12).

Upstream of the ice front, staging levels will be lower due to lack of freeze-up, despite increased winter flows, and groundwater upwelling may be reduced in side sloughs. Anchor ice may form in open water areas during cold periods, affecting flow distribution between channels and adversely influencing overwintering fish. Downstream of the ice front, the higher winter flows are likely to increase upwelling rates and may lead to an increase in the surface area of openwater, low velocity side channel and side slough habitat. However, the benefit of upwelling areas for overwintering chinook may be lessened if, due to the higher flows, side




Note: $Q_{10}$ is the typical high flow, $Q_{50}$ is the typical median flow, and $Q_{90}$ is the typical low flow.

Figure 12. Comparison of the middle Susitna River natural and with-project (Case D) exceedance flows (cfs) for the months November to April calculated from average weekly streamflows for the water years 1950-1983.

sloughs and side channels become overtopped with near 0° C water more frequently.

The reduction in fine sediment on the streambed will improve winter cover for juvenile chinook. A potential problem with regard to the effect of ice processes on overwintering chinook under with-project conditions is the degree of daily fluctuations in flow. If significant variations do take place, then localized flooding and dewatering could occur with detrimental effects and increase chinook mortality.

Average temperatures for the November to April period will be 0.5 to 3.0° C warmer under with-project conditions (Table 10), although from December to March they will be near 0° C. With the warmer temperatures extending through the fall, freeze-up of the river below the dam would be delayed (Table 11). Since the maximum upstream extent of the ice cover below the dams would be somewhere between RM 124 and RM 142, there would be no continuous ice cover between this area and the damsite, and consequently, no breakup or meltout in that reach. With warmer and more stable flows, a slower meltout of ice cover in place will occur. This gradual spring meltout is predicted to be 7 to 8 weeks earlier than normal with both dams in operation. With the slower meltout, extensive volumes of broken ice would not be floating downstream and accumulating against unbroken ice cover, thereby lessening the incidence of ice jamming. This would substantially reduce river staging and localized flooding in the spring. The overall shorter winter period of extremely low temperatures and less severe spring breakup conditions has the potential to improve the overwintering survival of chinook.

| 1971 - 1972 | | | | |
| --- | --- | --- | --- | --- |
| | Natural | | Devil Canyon 2020 | |
| RM | Range | Mean | Range | Mean |
| 150 | 0 - 6.8 | 0.7 | 0.6 - 8.4 | 2.6 |
| 130 | 0 - 6.9 | 0.8 | 0 - 8.3 | 2.0 |
| 100 | 0 - 7.1 | 0.8 | 0 - 8.5 | 1.6 |

| 1974 - 1975 | | | | |
| --- | --- | --- | --- | --- |
| | Natural | | Devil Canyon 2020 | |
| RM | Range | Mean | Range | Mean |
| 150 | 0 - 8.5 | 0.9 | 0.5 - 10.0 | 3.0 |
| 130 | 0 - 8.6 | 1.0 | 0 - 9.9 | 2.3 |
| 100 | 0 - 9.1 | 1.1 | 0 - 10.3 | 1.9 |

| 1981 - 1982 | | | | |
| --- | --- | --- | --- | --- |
| | Natural | | Devil Canyon 2020 | |
| RM | Range | Mean | Range | Mean |
| 150 | 0 - 7.7 | 1.1 | 0.8 - 8.6 | 3.9 |
| 130 | 0 - 7.9 | 1.1 | 0 - 8.5 | 3.4 |
| 100 | 0 - 8.4 | 1.3 | 0 - 9.0 | 2.7 |

| 1982 - 1983 | | | | |
| --- | --- | --- | --- | --- |
| | Natural | | Devil Canyon 2020 | |
| RM | Range | Mean | Range | Mean |
| 150 | 0 - 7.9 | 1.1 | 0.6 - 9.1 | 3.2 |
| 130 | 0 - 8.0 | 1.2 | 0 - 9.0 | 2.7 |
| 100 | 0 - 8.4 | 1.3 | 0 - 9.3 | 2.1 |

Table 10. Susitna River temperature ranges (°C) for the period September through April under natural and with-project conditions (both dams - 2020 demand). (University of Alaska, Arctic Environmental Information and Data Center 1984a).

| | Starting Date at Chulitna Confluence | Melt-out Date | Maximum Upstream Extent (RM) |
|---|---|---|---|
| Natural Conditions | | | |
| 1971 - 72 | Nov 5 | - | 137 |
| 1976 - 77 | Dec 8 | - | 137 |
| 1981 - 82 | Nov 18 | May 10-15 | 137 |
| 1982 - 83 | Nov 5 | May 10 | 137 |
| Both Dams - 2020 Demand | | | |
| 1971 - 72 | Dec 5 | April 15 | 133 |
| 1982 - 83 | Dec 14 | March 12 | 127 |

Table 11. Comparison of timing of freeze-up and ice break-up in the middle Susitna River under natural and with-project conditions (both dams - 2020 demand). (Harza-Ebasco Susitna Joint Venture 1984).

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