PRELIMINARY DRAFT

IMPACT ASSESSMENT TECHNICAL MEMORANDUM

SEDIMENT TRANSPORT

Prepared By:

Arctic Environmental Information and Data Center
University of Alaska-Fairbanks
707 "A" Street
Anchorage, Alaska 99501

Submitted to:

Harza-Ebasco Susitna Joint Venture
711 "H" Street
Anchorage, Alaska 99501

1985

TABLE OF CONTENTS

INTRODUCTION

PURPOSE

effects of?

This document is a comprehensive assessment of with-project sediment transport on fish associated with the proposed upper Susitna River basin hydroelectric development. Impoundment of the upper Susitna River would cause a change in the natural pattern of stream discharge and, consequently, of suspended sediments, bedload, sedimentation, and river bed aggradation and degradation. Since suspended sediments and bedload are important variables a ~~effecting~~ habitat for Susitna River drainage fish, studies were initiated in the beginning phases of Susitna environmental investigations to identify potential adverse or beneficial with-project effects of the expected alteration.

This report is one in a series on aquatic impact issues associated with the Susitna Hydroelectric Project. These issues -- instream temperature, water quality, turbidity, instream ice, and sediment transport ~~bedload~~ -- are examined separately in five separate technical memoranda. Following review they will be integrated into a single draft impact assessment report. The Alaska Power Authority and Harza-Ebasco intends to utilize the final impact assessment technical memorandum to discuss issues with agencies and intervenors in the Susitna licensing process.

Impact issues addressed in this series of reports were defined in the course of the Susitna licensing process. Following Federal Energy Regulatory Commission (FERC) review of the original license application, the Alaska Power Authority corrected noted deficiencies and provided supplemental information. The license application was subsequently ruled acceptable. FERC then proceeded with the preparation of an Environmental Impact Statement (EIS).

This decision set in motion a chain of events in accordance with Council on Environmental Quality mandates on EIS preparation (Vide 40 CFR 1500). Significant issues to be analyzed in depth in the EIS were identified during scoping meetings. Twelve fishery were identified to this process; of these, Issues F-1, F-2, F-4, F-5, and F-6 identified the effects of with-project flows on salmon and resident fish habitats and populations as topics to be addressed.

APA commissioned a series of environmental field investigations and analyses of existing published and unpublished information to provide accurate statements of expected impact of the Susitna project on sediment transport and river morphology, and subsequently, on fish resources. Over the years the data base and statements of anticipated effects have been scrutinized by agency and intervenor representatives in a series of workshops and discussions.

This process has refined the data base and impact statements based on it. This document is intended to serve as a discussion document and as an aid to decision-making. It contains a presentation of the sediment transport issue, a brief synopsis of the relevant information base, the ramifications of altered sediment regimes to aquatic habitats and fish, and the projected effects on fish due to various modes of Susitna project operation. It does not contain voluminous data and analyses of sediment and river morphology. Statements of effect or of no effect and the confidence with which those statements are made are provided.

STATEMENT OF THE PROBLEM

The proposed project is sited in the upper Susitna River drainage basin and consists of two dams to be constructed over a period of about 15 years. The first dam, known as the Watana Dam, would be completed near RM 184 at a site three miles upstream from Tsusena Creek. It would include an underground powerhouse and an 885 ft high earthfill dam and a reservoir approximately 50 miles in length. This reservoir would have a surface area of 38,000 acres and a usable storage capacity of 3.7 million acre-feet (maf). The second dam, named Devil Canyon, would be built near RM 152 at a site 33 miles downstream of the Watana dam site. It would be 645 ft high and would impound a 26-mile-long reservoir, having a surface area of 7,800 acres and a usable storage capacity of 0.36 maf (Acres American, 1983).

Construction and subsequent operation of the two Susitna hydroelectric dams is expected to alter the normal sediment transport regime of the river, thereby influencing river bed morphology. With both dams on-line, the area between Devil Canyon (RM 152) and the Oshentna River (RM 235) would be converted from a lotic to a lentic system. After impoundment, these reservoirs would resemble naturally occurring, deep, glacial lakes (Acres 1983).

Sediment trap efficiencies of the Watana Dam alone and of the Watana and Devil Canyon dams together have been estimated by modeling and by fitting data to two different reservoir sedimentation curves (Harza-Ebasco Susitna Joint Venture 1984a). Results indicate that the dams would trap between 78 to 100% of all sediment entering the reservoirs (Harza-Ebasco Susitna Joint Venture 1984a). This, coupled with regulated with-project flows, would noticeably affect instream environments downstream of the dams in several ways.

Suspended load and bedload would be markedly reduced from those seen naturally. This situation would prevail to a point downstream of the Talkeetna and Chulitna rivers' respective confluences with the Susitna. Because of their very large sediment loads relative to the mainstem, input from the Talkeetna and Chulitna rivers with-project would dominate the Susitna's sediment load in a manner analogous to present (R&M 1982a; Harza-Ebasco Susitna Joint Venture 1984a). Partly as a consequence of reduced sediment load and partly because of the with-project flow regime, the main channel of the Susitna River above the confluence with the Talkeetna would have a tendency to narrow and, in spots, degrade (R&M 1982a; Harza-Ebasco Susitna Joint Venture 1985). Some sloughs and tributary streams would become perched and some mainstem habitats could become dewatered as a result (R&M 1982a; Harza-Ebasco Susitna Joint Venture 1985; R&M and EWT&A 1985). In time, the river bed would attain a new equilibrium with the with-project flows. The reservoirs would also dampen the effects of freshets, reducing instances of flood waters entering sloughs. These changes could affect fish population numbers.

need to say here that a great deal of aggradation is expected [illegible] continuous Chulitna sediment [illegible] into the confluence [illegible] dumped into Susitna [illegible] flows & [illegible] to carry [illegible] area [illegible] work to [illegible] away

OVERVIEW OF ENVIRONMENTAL ASSESSMENT TECHNIQUES

Over the past 30 or so years, a variety of methods have been developed for use in evaluating environmental impacts. The impetus behind this effort was, and remains, federal resource management law. Prominent federal environmental acts (table 1) were reviewed to identify fish and wildlife impact assessment requirements. Four broad areas of public interest form common themes in environmental law: species-populations, biological integrity, environmental values, and habitat. Common methods of addressing these themes are reviewed below, as is the methodology used in this analysis.

The first class of environmental assessment techniques examined is that of species-populations. Notable federal acts calling for this approach include the Endangered Species Act, the Federal Nonnuclear Energy Research and Development Act, the Surface Mining Control and Reclamation Act, and the Federal Water Pollution Control Act (table 1). Many and diverse schemes exist for estimating population numbers and density. The simplest technique, and possibly the one in widest use by managers, is the index. Population assessment indices are of two distinctly different types. The first is a count of animals made in a manner which does not allow direct population estimation by application of sampling theory. This technique employs a sample survey in the absence of known sampling probabilities. Many ADF&G fish escapement surveys are of this type. The second kind of index is one based on complete counts of some known portion of a population, e.g., salmon on redds in a given reach of river. This approach allows one to conduct a relatively intensive and statistically valid analysis by incoporating basic knowledge of a species life history with the count data. Multiple regression analysis is the most frequently used tool in this regard.

Table 1. Federal acts which independently and collectively establish minimum standards for environment impact assessment.

Archeological and Historic Preservation Act, 16 U.S.C. 469, et seq.
Clean Air Act, as amended, 42 U.S.C. 7401, et seq.
Coastal Zone Management Act, 16 U.S.C. 1451, et seq.
Endangered Species Act, 16 U.S. C 1531, et seq.
Estuary Protection Act, 16 U.S.C. 1221, et seq.
Federal Land Policy and Management Act, 43 U.S.C. 1701, et seq.
Federal Nonnuclear Energy Research and Development Act, 42 U.S.C. 5901 et seq.
Federal Water Pollution Control Act, 33 U.S.C. 1251, et seq.
Federal Water Project Recreation Act, 16 U.S.C. 460-1(12), et seq.
Fish and Wildlife Coordination Act, 16 U.S.C. 661, et seq.
Forest and Rangeland Renewable Resources Planning Act, 16 U.S.C. 1601, et seq.
Land and Water Conservation Fund Act, 16 U.S.C. 4601 - 4601-11, et seq.
Marine Protection, Research and Sanctuary Act, 33 U.S.C. 1401, et seq.
National Environmental Policy Act, 42 U.S.C. 4321m et seq,
National Historic Preservation Act, 16 U.S.C. 470a, et seq.
National Forest Management Act, 16 U.S.C. 472, et seq.
Rivers and Harbors Act, 33 U.S.C. 403, et seq.
Soil and Water Resources Conservation Act, 16 U.S.C. 2001, et seq.
Surface Mining Control and Reclamation Act, 30 U.S.C. 1201, et seq.
Water Resources Planning Act, 42 U.S.C. 1962, et seq.
Watershed Protection and Flood Prevention Act, 16 U.S.C. 1001, et seq.

More involved methods of population assessment include direct counts and variants of the mark, release, and subsequent recapture technique. Direct counts are best in terms of validity, but naturally turbid conditions in the Susitna drainage hamper its use there. Over the last decade, the ADF&G and the USFWS have expended much effort in improving electronic fish counters for use in turbid conditions. This work has greatly influenced census work in many glacially-moderated systems.

Mark-recapture techniques have a relatively long history of use in the United States. While widely used and under continual evolution, none of them produce overly satisfying results in a statistical sense. This is because all mark-recapture techniques rely on a range of assumptions which are difficult to meet in the wild (e.g., one common assumption is that there exists a well defined population of animals; another is that the average probability of observing a marked animal is equal to the average probability of observing an unmarked animal).

The chief pieces of legislation calling for its use are the Federal Water Pollution Control Act and the National Environmental Policy Act (table 1). If fully applied, such an approach would document energy flow through the system allowing one to precisely predict overall effects of change. In practice this is never done because it is very labor intensive and, thus too costly. Instead, it is common for a few representative species and/or relationships to be singled out for study, thereby narrowing its scope. Field study is typically undertaken to document seasonal numbers of target species in the study (often without regard to their relationship to local or regional populations), their habits (e.g., special use areas), and food resources. Biologically based on assessments have increasingly made use of models (some elaborate, some not) to predict with-project effects. Two factors limit the veracity of conclusions reached by this approach. First, a given model's ability to predict the future depends heavily on whether it is multidimensional or not and the assumptions used. Most models used are one dimensional limiting their utility. Second, conclusions reached in this approach are subjectively applied ad hoc to the system as a whole.

Consideration of economic and environmental values (the third of the four areas of public interest addressed by federal law) is the essence of the National Environmental Policy Act. This approach to impact assessment usually entails estimating the monetary and nonmonetary values of the resources to be affected. Implementation of a values approach to impact assessment is (and will continue to be) limited by the difficulty (some would say the impossibility) of setting values on often intangible environmental components such as aesthetics.

The fourth approach to environmental impact assessment recognized by federal law is habitat analysis. The principal laws legitimizing this approach are the Federal Land Policy and Management Act, the Fish and Wildlife Coordination Act, the Forest and Rangeland Renewable Resources Planning Act, the Endangered Species Act, and the Surface Mining Control and Reclamation Act (table 1). Various techniques are available for characterizing habitat quality. For example, species diversity is often used as an index of habitat quality. This type of index accounts for both numbers of species and numbers of individuals of each species in each habitat type. The approach has been challenged on a number of grounds. For example Wiens (1978) points out that it is insensitive to which species are present (i.e., it treats rare and common species alike), while Inhaber (1976) notes the absence of a standard of comparison (a problem of all biological indices).

Another habitat based impact assessment approach is the U.S. Fish and Wildlife Services Habitat Evaluation Procedures (HEP). HEP is a species-habitat approach; habitat quality being denoted through use of an index derived by evaluating the ability of key habitat components to supply the life requisites of the subject species. Its chief limitation is that predictions made are applicable only for the species being evaluated, i.e., it does not directly relate that species to other ecosystem components.

The U.S. Fish and Wildlife Service's Instream Flow Incremental Methodology (IFIM), another habitat based approach, is closely related to HEP in logic. It too focuses on target species relationships with their habitat, defined as Weighted Usable Area (WUA). Water depth, velocity, and substrate data are coupled with habitat suitability curves to compute WUA. The chief limitation of this approach is that it fails to take into account the effects of with-project change on factors such as growth, competition, mortality, and movement. These limitations are at the heart of a recent benchmark judicial ruling (Energy Management 1984) against use of the IFIM and in favor of a less rigorous, more qualitative, approach.

METHODS AND PROCEDURES

The existing Susitna River Information base consists of a mix of quantitative and qualitative data and model results: some is compatible, some is not. It is strongly biased towards habitat descriptors. Natural and with-project environmental parameters are well known, as are the likely responses of aquatic organisms to changes of the types predicted. Given this, a habitat based impact assessment is the logical technique of choice for the Susitna River study.

This analysis was accomplished by comparing predictions of the with-project environment with information on fish distribution, abundance, and habits and on known fish and invertebrate response to perturbations of the types predicted. Professional judgement was used as necessary to interpret the relationship between various data base components, i.e., the relative comparability and utility of quantitative information vs. qualitative information vs. model runs.

To assess effects of with-project changes in sediment transport on instream biota, AEIDC first reviewed the information base on how suspended sediments affect aquatic organisms. Ideally, information used in an effects analysis is specific to the water body in question. Pertinent Susitna River specific information (i.e., data on sediment effects on the biota) is not broad in scope, consisting only of preliminary primary production data and ocular estimates of the appearance of in-slough spawning gravels following floods. Where necessary, information from other areas and latitudes was used to aid in the analysis. This factor imposed no constraint on conclusions reached because organisms respond to sediments in similar ways worldwide. Next, information on Susitna River fish stocks was assembled and synthesized.

Following this, estimates of with-project environmental changes (and the information and procedures used in deriving them) were reviewed. Both the information base on fish stocks and that on the with-project sediment transport regime are adequate for use in an effects analysis. These three steps (determining how various life forms are affected by sediments, compiling information on the fish resource, and reviewing project sediment transport studies) provided the basis for predicting effects of the with-project sediment transport regime on aquatic organisms.

Available information is sufficient to address with-project sediment transport effects on 13 of the 19 fish species present in the project area. These are all five salmon species, eulachon, Bering cisco, burbot, round and humpback whitefish, rainbow trout, Arctic grayling, and lake trout. Tables 11,12, and 13 summarize predicted with-project negative sediment transport-related effects on fish. Collectively, they provide an overview of anticipated negative effects by species, location, and time of year for both the Watana Dam and Watana and Devil Canyon dams together. A dimensionless ordinal scale identifies the relative severity of anticipated effects. Its values range from:

0 - given predictions of the with-project sediment transport regime and available knowledge of the fish species in question, no negative effects are likely.

1 - the with-project sediment transport regime could negatively influence a species life stage, but the effects should be relatively minor.

burbot, little is known of the life histories of resident fish at this season. A synopsis of available fish resource information follows.

IMPOUNDMENT ZONE

The principal source of information on fish distribution, abundance, habitat use, and life history in the impoundment zone is ADF&G 1981a and 1983d. Impoundment study area investigations were conducted in 1981 and 1982 by ADF&G Su-Hydro during the open water field season (May-October). These studies concentrated on Arctic grayling, making data on this species the most complete. Data on overwintering activities in this area is particularly scarce for all species. The major objectives of this study were to: 1) determine the seasonal distribution and abundance of fish populations in the proposed impoundment area; 2) identify spawning and rearing areas; and 3) determine the physical and chemical characteristics of these habitats (ADF&G 1981a, 1983d). More specific tasks dealt with determining the distribution, abundance, and migratory habits of Arctic grayling; determining the distribution and relative abundance of selected resident fish species; determining the abundance of lake trout and Arctic grayling in Sally Lake; recording biological information on selected resident fish populations to provide information on survival and growth; and identifying Arctic grayling spawning and rearing locations within and adjacent to the with-project impoundment areas (ADF&G 1983d).

Prior to initiation of the 1981 ADF&G Su-Hydro studies, fish resource data for this area were collected by the U.S. Fish & Wildlife Service (1952, 1954, 1957, 1959a, 1959b, 1960, 1965) and ADF&G (1978). These studies were preliminary Susitna environmental assessments designed primarily to define species composition. They also highlighted selected habitat locations of

2 - given available information, the with-project sediment transport regime would negatively affect fish productivity.

3 - available information indicates that the with-project sediment transport regime may negatively affect a species productivity, but more data are needed to so state with certainty.

The veracity of conclusions reached varies by species and by river reach in consequence of differences in available information quantity and type.

FISH RESOURCE

Judged against criteria for EIS preparation (40 CFR 1500), existing information on Susitna River fish resources is generally adequate for an assessment of with-project effects. (An EIS is simply an accounting tool whose chief purpose is to ensure that all elements deemed significant by the scoping process are considered in decision making.) Available information on open water season salmon-life stage activities (distribution, abundance, spawning timing and location, rearing, and migration) is quite complete; the overwinter salmon data base is much less so. Nonetheless, it is sufficient for the purposes used. Tables 2 and 3 respectively provide an overview of basinwide salmon escapements and the time of occurrence of their major life phases. As with salmon, information on resident species is much more complete for the open water season than it is for winter. Unlike salmon, however, it is heavily weighted towards selected species. It, too, is sufficient for EIS preparation purposes. Information on rainbow trout, burbot, and Arctic grayling in the open water season is more complete than for other residents. With the exception of limited winter radio-tagging data for rainbow trout and

Table 2. Susitna River Salmon Escapement Estimates, 1981-1984.

Year	Chinook	Sockeye[1]	Pink	Chum	Coho	Total[2]
1981	-	272,500	85,600	282,700	36,800	677,600
1982	-	265,200	890,500	458,200	79,800	1,693,700
1983	-	176,200	101,300	276,800	24,100	578,400
1984	250,000	605,800	3,629,900	812,700	190,100	5,488,500

[1] Second run sockeye only.

[2] The 1984 drainage wide escapement estimates. Escapement counts for 1981 through 1983 do not include chinooks or any escapements into tributaries downstream of RM 77, with the exception of those into the Yentna River.

Source: ADF&G 1983a; Barrett, Thompson, and Wick 1984, 1985.

Table 3. Susitna River Salmon Phenology.

	HABITAT	DATE RANGE	DATE PEAK
CHINOOK (KING) SALMON			
Adult Inmigration	Cook Inlet - Talkeetna	May 25 - Aug 18	Jun 18 - Jun 30
	Talkeetna - D.C.	Jun 07 - Aug 20	Jun 24 - Jul 04
	Middle River Tributaries	Jul 01 - Aug 06	
Juvenile Migration	Middle River	May 18 - Oct 03[1&3]	
Spawning	Middle River Tributaries	Jul 01 - Aug 26	Jul 20 - Jul 27
	Lower River Tributaries	Jul 07 - Aug 20	Jul 20 - Jul 27
COHO (SILVER) SALMON			
Adult Inmigration	Cook Inlet - Talkeetna	Jul 07 - Sep 28	Jul 27 - Aug 20
	Talkeetna - D.C.	Jul 18 - Sep 19	Aug 12 - Aug 26
	Middle River Tributaries	Aug 08 - Sep 27	
Juvenile Migration	Middle River	May 18 - Oct 12[1&3]	May 28 - Aug 21
Spawning	Middle River Tributaries	Sep 01 - Oct 08	Sep 05 - Sep 24
	Lower River Tributaries	Aug 08 - Oct 01	
CHUM (DOG) SALMON			
Adult Inmigration	Cook Inlet - Talkeetna	Jun 24 - Sep 28	Jul 27 - Aug 02
	Talkeetna - D.C.	Jul 10 - Sep 15	Aug 01 - Aug 17
	Middle River Tributaries	Jul 27 - Sep 06	
	Middle River Sloughs	Aug 06 - Sep 05	
Juvenile Migration	Middle River	May 18[3] - Aug 20	May 28 - Jul 17

Table 3. Susitna River Salmon Phenology.
(cont'd)

	HABITAT	DATE RANGE	DATE PEAK
Spawning	Middle River Tributaries	Jul 27 - Oct 01	Aug 05 - Sep 10
	Middle River Sloughs	Aug 05 - Oct 11	Aug 20 - Sep 25
	Middle River Mainstem	Sep 02 - Sep 19	
	Lower River Tributaries	Jul 27 - Sep 09	Aug 06 - Aug 14
SOCKEYE (RED) SALMON[2]			
Adult Inmigration	Cook Inlet - Talkeetna	Jul 04 - Aug 08	Jul 18 - Jul 27
	Talkeetna - D.C.	Jul 16 - Sep 18	Jul 31 - Aug 05
Juvenile Migration	Middle River	May 18 - Oct 11[1&3]	Jun 22 - Jul 17
Spawning	Middle River Sloughs	Aug 05 - Oct 11	Aug 25 - Sep 25
PINK (HUMPBACK) SALMON			
Adult Inmigration	Cook Inlet - Talkeetna	Jun 28 - Sep 10	Jul 26 - Aug 03
	Talkeetna - D.C.	Jul 10 - Aug 30	Aug 01 - Aug 08
	Middle River Tributaries	Jul 27 - Aug 23	
	Middle River Sloughs	Aug 04 - Aug 17	
Juvenile Migration	Middle River	May 18[3] - Jul 24	May 29 - Jun 08
Spawning	Middle River Tributaries	Jul 27 - Aug 30	Aug 10 - Aug 25
	Middle River Sloughs	Aug 04 - Aug 30	Aug 15 - Aug 30
	Lower River Tributaries	Jul 27 - Sep 09	Aug 06 - Aug 09

1 All migration (includes migration to and between habitat, not just outmigration).
2 Second run sockeye only.
3 No data available for pre-breakup movement; earlier date of given range refers to initiation of outmigrant trap operation.

Source: Barrett, Thompson and Wick 1984, 1985; Schmidt et al. 1984; ADF&G 1983a,c.

33RC1/007h/2

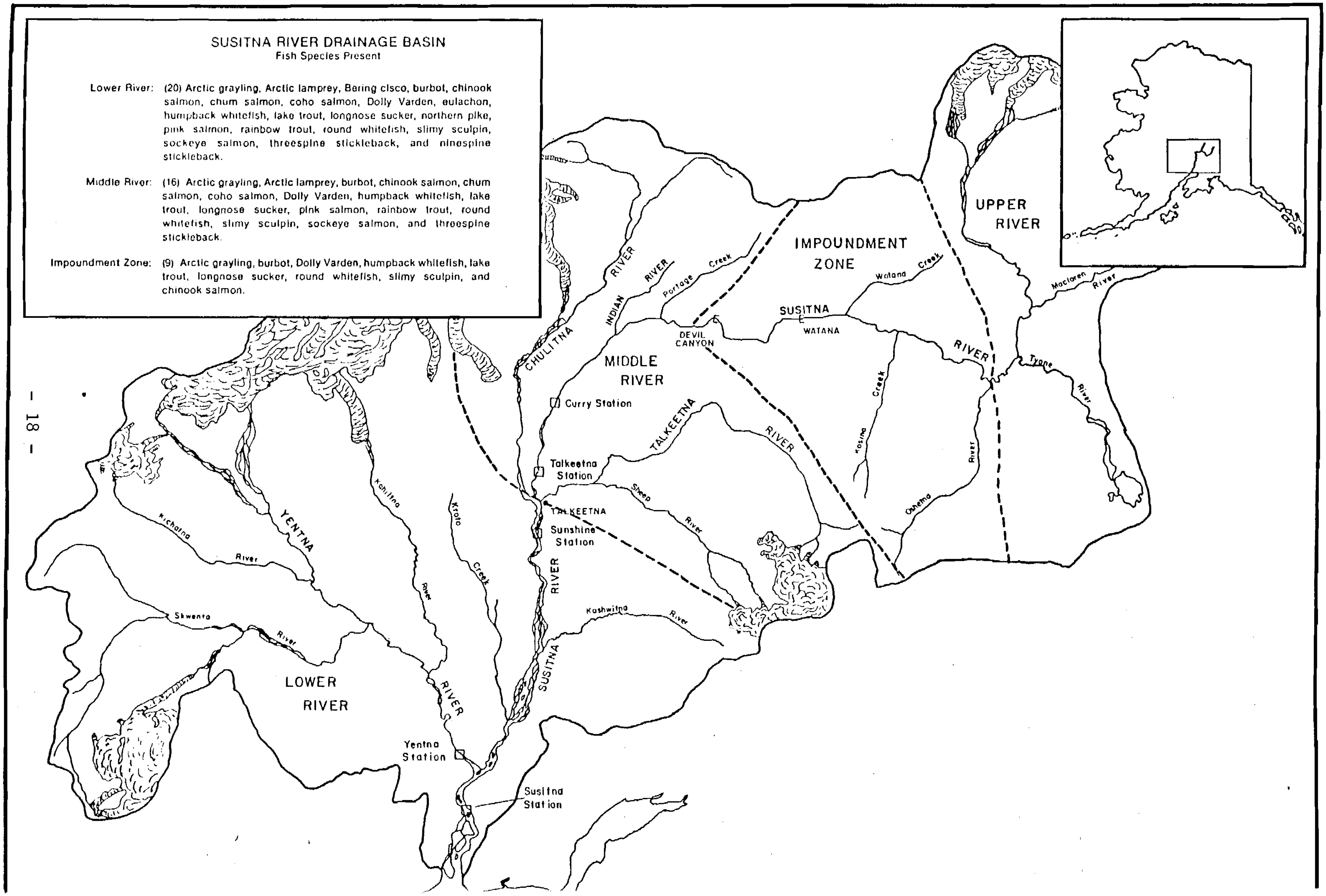
particular interest. Additional information on the fish resource in this area is found in the transmission corridor studies of Schmidt et al. 1984c.

The natural environment between Devil Canyon and the upstream end of the proposed Watana Reservoir provides habitats for nine fish species (ADF&G 1983d); eight are year-round residents and one (chinook salmon) is anadromous (Figure 1). Within Devil Canyon, Fog Creek (RM 176.7) marks the upstream limit of salmon migration in the mainstem Susitna River. Only three streams, in the canyon had salmon observed in them during 1984. These streams, (Cheechako, Chinook, and Fog creeks) had, in total, fewer than 100 chinook salmon observed using them for spawning (Barrett, Thompson and Wick 1985).

Arctic grayling are the most widely distributed and abundant species utilizing habitats above the canyon. The total 1982 Arctic grayling population above 15 cm in length in eight of the impoundment zone streams was estimated to be over 16,000 (ADF&G 1983b). Mainstem areas above the canyon provide essential overwintering habitat for Arctic grayling, which move into tributaries to spawn following breakup in late May or early June (ADF&G 1983d). Arctic grayling migrate out of natal tributaries in September as water levels and temperatures begin to drop. They overwinter in mainstem environments which become less turbid following freeze-up (ADF&G 1983d).

Except for documentation of their presence, little is known of the relative abundance of other species resident in the environments of the proposed impoundment zone. Based on limited capture data, it seems that both burbot and longnose sucker are relatively common there (ADF&G 1983d). Elsewhere in the Susitna River, burbot spawn under the ice in tributaries (such as the Deshka River) over gravel substrates from January to February, and radio tagged fish data suggests they also spawn in the mainstem (ADF&G 1983b). During the rest of the year, they apparently distribute themselves

Figure 1. Fish of the impoundment zone.



throughout the deeper portions of aquatic environments. Susitna River longnose sucker are spring spawners which move from overwinter habitats in the mainstem to tributary natal areas from late May to early June (ADF&G 1983d). Small numbers of round and humpback whitefish have been captured (at two locations) within the impoundment areas, but there are no estimates of their relative abundances (ADF&G 1983d). If they behave similarly to lower river and middle river whitefish, they also overwinter in mainstem environments. Although available information is scant, it appears that these two white fish species spawn in early October in clearwater tributary streams.

Although not currently present in mainstem areas, some lake trout might gain access to the reservoirs as a result of the project. Sally Lake, which supports a lake trout population of undetermined number, would be inundated by the Watana Reservoir (ADF&G 1983d). Lake trout generally spawn from August through December and require stable lake shore gravel substrates for reproduction. High lake (located immediately north of Devil Canyon) is a tributary system to Devil Creek which has a resident population of rainbow trout. Should the project be completed, it is possible that some rainbows might gain access to the Devil Canyon reservoir by outmigrating down Devil Creek. Elsewhere in the basin, rainbow trout typically overwinter in lakes and mainstem habitats, returning in the spring following breakup to spawn in tributary streams. Most rainbow trout spawn in clearwater streams whose beds are covered with relatively small cobbles and have relatively moderate velocities (ADF&G 1983b).

MIDDLE RIVER

Fish and aquatic habitat investigations have been conducted on the Susitna River since the 1950's to evaluate the proposed hydroelectric project

(U.S. Fish and Wildlife Service 1952, 1954, 1957, 1959a, 1959b, 1960, 1965; Barrett 1974; ADF&G 1976, 1978, 1981a, 1983a, 1983b, 1983c, 1985b; Barrett, Thompson, and Wick 1984, 1985; Riis 1977; Schmidt et al. 1984a, 1984b; and Wangaard and Burger 1983). In 1980, the Susitna Hydroelectric Aquatic Studies Program was initiated to collect data on the fish and aquatic habitat resources of the basin.

Extant Susitna River basin data on fish distribution, abundance, and habitat use focuses on salmon and are temporally and spatially limited. The studies, and therefore the information available, is more complete for the open water season and for the area upstream of the Chulitna River confluence. A summary of ADF&G's Su-Hydro studies of the fish resources downstream of Devil Canyon is available in a report by Woodward Clyde Consultants and Entrix (1985). ADF&G's Su-Hydro studies have documented migration timing of salmon runs in the Susitna River; estimated the population size and relative abundance of salmon in various sub-basins of the Susitna River; estimated the total salmon escapements into sloughs and tributaries upstream of RM 98.6; quantified selected biological characteristics of Susitna River salmon stocks (e.g., sex ratio, fecundity, length at age); identified important spawning areas for some resident species; documented timing and estimated the relative utilization of macrohabitat types by juvenile and adult salmon and some resident species; developed habitat suitability criteria for adult and juvenile salmon, eulachon, Bering cisco, and some resident species; estimated population size and survival for juvenile chum and sockeye; documented outmigration timing of juvenile salmon; collected baseline physical and chemical water quality data in identified macrohabitat types; developed understanding of site-specific habitat responses to various mainstem discharges; evaluated the capability of adult salmon to pass into selected sloughs; and confirmed the importance of groundwater upwelling for salmon spawning in sloughs.

Above the Chulitna River confluence (RM 98.5) salmon spawn in a variety of tributaries, sloughs, and a few mainstem sites. In this river reach, coho and chinook have only been found to spawn in tributary stream environments; pink salmon primarily in tributary streams (with a small number utilizing slough habitats); chum salmon in tributary, slough, and mainstem environments; and sockeye almost exclusively in sloughs (Barrett, Thompson and Wick 1985). Over 90% of salmon spawning in this reach occurs in tributaries (Barrett, Thompson & Wick 1985).

At least eighteen tributary streams in the middle river provide salmon spawning habitats (table 4). Over 96% of the total chinook escapement above the Chulitna confluence spawn in two streams; Portage Creek (RM 148.9) and Indian River (RM 138.6) (table 4). In 1984, these two streams had a combined escapement of over 13,000 fish which represented a little over 5% of the basin's total chinook resource (Barrett, Thompson and Wick 1985). Only about 10% of Susitna River coho salmon spawn above the Chulitna confluence; they apparently spawn only in tributaries in this reach (Barrett, Thompson and Wick 1985). Indian River (RM 138.6) is the most important tributary for coho, providing a little over 30% of the reproductive habitat available here (table 5). Portage and 4th of July (RM 131.1) creeks and Indian River provide reproductive habitats for over 80% of middle river pink salmon; this represents about 1% of the total Susitna escapement for pink salmon (Barrett, Thompson & Wick 1985). The same three streams provide over 98% of tributary spawning habitat for chum salmon in this reach (Barrett, Thompson and Wick 1985). In 1984, these tributaries accounted for about 1% of the total Susitna chum salmon escapement.

Table 4. Peak Salmon Survey Counts Above Talkeetna for Susitna River Tributary Streams.

STREAM	SURVEY DISTANCE	Coho						Chinook								
		1974	1976	1981	1982	1983	1984	1975	1976	1977	1978	1979	1981	1982	1983	1984
Whiskers Creek (RM 101.4)	0.25	27		70	176	115	301	22	8						3	67
Chase Creek (RM 106.9)	0.25	40		80	36	12	239							15		3
Slash Creek (RM 111.2)	0.75				6	2	5									
Gash Creek (RM 111.6)	1.0			141	74	19	234									
Lane Creek (RM 113.6)	0.5			3	5	2	24						40	47	12	23
Lower McKenzie (RM 116.2)	1.5			56	133	18	24									
McKenzie Creek (RM 116.7)	0.25															
Little Portage (RM 117.7)	0.25				8											
Fifth of July (RM 123.7)	0.25													3		17
Skull Creek (RM 124.7)	0.25															
Sherman Creek (RM 130.8)	0.25													3		
Fourth of July (RM 131.0)	0.25	26	17	1	4	3	8	1	14					56	6	92
Gold Creek (RM 136.7)	0.25				1									21	23	23
Indian River (RM 138.6)	15.0	64	30	85	101	53	465	10	537	393	114	285	422	1,053	1,193	1,456
Jack Long (RM 144.5)	0.25				1	1	6							2	6	7
Portage Creek (RM 148.9)	15.0	150	100	22	88	15	128	29	702	374	140	140	659	1,253	3,140	5,446
Cheechako Creek (RM 152.5)	3.0													16	25	29
Chinook Creek (RM 156.8)	2.0													4	8	15
TOTAL		307	147	458	633	240	1,434	62	1,261	767	254	425	1,121	2,473	4,416	7,178

Table 4. Peak Salmon Survey Counts Above Talkeetna for Susitna River Tributary Streams. (cont'd)

STREAM	SURVEY DISTANCE	Chum								Sockeye							
		1974	1975	1976	1977	1981	1982	1983	1984	1974	1975	1976	1977	1981	1982	1983	1984
Whiskers Creek (RM 101.4)	0.25					1											
Chase Creek (RM 106.9)	0.25					1			1								
Slash Creek (RM 111.2)	0.75																
Gash Creek (RM 111.6)	1.0																
Lane Creek (RM 113.6)	0.5		3		2	76	11		31								
Lower McKenzie (RM 116.2)	1.5					14		1	23					1			
McKenzie Creek (RM 116.7)	0.25										46						
Little Portage (RM 117.7)	0.25						31		18								
Fifth of July (RM 123.7)	0.25							6	2								
Skull Creek (RM 124.7)	0.25					10	1		4								
Sherman Creek (RM 130.8)	0.25					9			6								
Fourth of July (RM 131.0)	0.25	594		78	11	90	191	148	193		1						
Gold Creek (RM 136.7)	0.25																
Indian River (RM 138.6)	15.0	531	70	134	776	40	1,346	811	2,247		1	2	1			1	1
Jack Long (RM 144.5)	0.25						3	2	4								
Portage Creek (RM 148.9)	15.0	276		300			153	526	1,285								12
Cheechako Creek (RM 152.5)	3.0																
Chinook Creek (RM 156.8)	2.0																
TOTAL		1,401	73	512	789	241	1,736	1,494	3,814		48	2	1	1		1	13

Table 4. Peak Salmon Survey Counts Above Talkeetna for Susitna River Tributary Streams. (cont'd)

STREAM	SURVEY DISTANCE	Pink							
		1974	1975	1976	1977	1981	1982	1983	1984
Whiskers Creek (RM 101.4)	0.25			75		1	138		293
Chase Creek (RM 106.9)	0.25			50		38	107	6	438
Slash Creek (RM 111.2)	0.75								3
Gash Creek (RM 111.6)	1.0								6
Lane Creek (RM 113.6)	0.5	82	106		1,103	291	640	28	1,184
Maggot Creek (RM 115.6)	0.25								107
Lower McKenzie (RM 116.2)	1.5						23	17	585
McKenzie Creek (RM 116.7)	0.25						17		11
Little Portage (RM 117.7)	0.25						140	7	162
Deadhorse Creek (RM 120.8)	0.25								337
Fifth of July (RM 123.7)	0.25					2	113	9	411
Skull Creek (RM 124.7)	0.25					8	12	1	121
Sherman Creek (RM 130.8)	0.25					6	24		48
Fourth of July (RM 131.0)	0.25	159	148	4,000	612	29	702	78	1,842
Gold Creek (RM 136.7)	0.25			32			11	7	82
Indian River (RM 138.6)	15.0	577	321	5,000	1,611	2	738	886	9,066
Jack Long (RM 144.5)	0.25					1		5	14
Portage Creek (RM 148.9)	15.0	218		3,000			169	285	2,707
Cheechako Creek (RM 152.5)	3.0						21		
Chinook Creek (RM 156.8)	2.0								
TOTAL		1,036	575	12,157	3,326	378	2,855	1,329	17,417

Source: Barrett 1974; Barrett, Thompson and Wick 1984, 1985; Riis 1977; ADF&G 1976, 1978, 1981, 1983a.

33RC1/005a/3

in the last four years, the majority (>88%) of chum salmon spawners counted were in 10 of the 34 (tables 5 and 6). Three of these 10 (8A, 11, 21) have added significance in that they also accommodated over 90% of all sockeye spawning in the middle river (table 5).

Relatively few salmon spawn in mainstem nonslough habitats; of those which do, chum salmon predominate. Generally, spawning habitats within the mainstem proper are small areally and widely distributed. In 1984, ADF&G made a concerted effort to identify mainstem middle river spawning habitats; they identified 36 spawning sites. Numbers of fish counted at each of these sites varied from one to 131 with an average of 35 (Barrett, Thompson, and Wick 1985). The estimated total mainstem escapement was approximately 3,000 chum salmon (Barrett, Thompson and Wick 1985). This is less than 0.5% of the total Susitna escapement.

Four of the five salmon species (all but pink) use middle river waters for rearing purposes (Schmidt et al. 1984b). At this time insufficient information exists to characterize the relative importance of mainstem rearing habitats relative to each other. From May to September juvenile chinook rear in tributary and side channel environments, coho mostly rear in tributary and upland sloughs, and sockeye move from noted side sloughs to upland sloughs for rearing. From May to July rearing chum juveniles are distributed throughout side slough and tributary stream environments (Dugan, Sterritt, and Stratton 1984).

Based on escapement counts for 1984, 34 middle river sloughs collectively provided habitat for approximately 5.5% of all salmon migrating above Talkeetna station (Barrett, Thompson and Wick 1985). These sloughs are of particular importance to middle river chum and sockeye salmon. About 50% of the chum and almost all of the sockeye spawning above the Chulitna confluence

Table 5. Peak Slough Escapement Counts Above Talkeetna.

		CHUM								SOCKEYE								PINK					
SLOUGH NO.	RIVER MILE	1974	1975	1976	1977	1981	1982	1983	1984	1974	1975	1976	1977	1981	1982	1983	1984	1976	1977	1981	1982	1983	1984
1	99.6					6			12								10						
2	100.4					27		49	129								7						2
3B	101.4		50					3	56		15			7		5	20			1			28
3A	101.9								17					1			11						56
Talkeetna St.	103.0																						
4	105.2																						
5	107.2						2	1									1						4
6	108.2	1																					
6A	112.3					11	2							1							35		
7	113.2																						
8	113.7					302			65								2			25			1
Bushrod	117.8								90														10
Curry St.	120.0																						
8D	121.8						23		49														
8C	121.9						48	4	121						2								1
8B	122.2					1	80	104	400				2		5		1						68
Moose	123.5					167	23	68	76						8	22	8				8		25
A'	124.6					140		77	111														24
A	124.7					34		2	2											2			
8A	125.1				51	620	336	37	917				70	177	68	66	128				28		134
B	126.3						58	7	108						8	2	9				32		
9	128.3	511	181		36	260	300	169	350	8			6	10	5	2	6				12		1
9B	129.2					90	5		73					81	1		7						
9A	133.3					182	118	105	303					2	1	1							
10	133.8				2		2	1	36							1							
11	135.3	33		66	116	411	459	238	1,586	79	84	78	214	893	456	248	564	1			131		121
12	135.4																						
13	135.7		1			4		4	13														
14	135.9	2							1														
15	137.2		1			1	1		100			1					1				132	1	500
16	137.3	2	12		4	3			15										13				
17	138.9	24				38	21	90	66					6		6	16						1
18	139.1								11														
19	139.7	4				3		3	45	3		32	8	23		5	11				1	1	
20	140.0	107		2	28	14	30	63	280		20			2							64	7	85
21	141.1	668	250	30	304	274	736	319	2,354	13	75	23		38	53	197	122				64		8
21A	145.5								10														
22	144.5					8		114	151								2						
TOTAL		1,352	495	98	541	2,596	2,244	1,458	7,547	103	194	134	300	1,241	607	555	926	1	13	28	507	9	1,069

Source: Barrett 1974; Barrett, Thompson and Wick 1984, 1985; Riis, 1977; ADF&G 1976, 1978, 1981, 1983a.

Table 6. Chum Salmon Escapement for the Ten Most Productive Sloughs Above RM 98.6, 1981-84.

Slough	River Mile	1981	1982	1983	1984	4-Year Average	Percent of Total Escapement
8	113.7	695	0	0	217	228	3.4
8B	122.2	0	99	261	860	305	4.5
Moose	123.5	222	59	86	284	163	2.4
A'	124.6	200	0	155	217	143	2.1
8A	125.1	480	1,062	112	2,383	1,009	14.9
9	128.3	368	603	430	304	426	6.3
9A	133.8	140	86	231	528	246	3.6
11	135.3	1,119	1,078	674	3,418	1,572	23.2
17	138.9	135	23	166	204	132	1.9
21	141.1	657	1,737	481	4,245	1,780	26.2

Source: Barrett, Thompson, and Wick, 1984, 1985.

occurs in sloughs. This represents about 2% of all chum and less than 0.5% of all sockeye spawning in the Susitna drainage (Barrett, Thompson and Wick 1985). Spawning habitat quality apparently varies greatly between sloughs as,

Of the five salmon species present, only chinook and coho were captured in the middle river during the 1981-82 winter field season (ADF&G 1983c). Preliminary studies indicate that significant numbers (perhaps 25 to 50%) of chinook and coho juveniles reared in this zone overwinter in side slough and tributary stream environments (ADF&G 1985a). Provisional capture data for the 1984-85 winter field season show that a few sockeye are also overwintering in this area of the river (Crawford 1985). Preliminary evidence indicates that few juvenile salmon utilize the mainstem proper for overwintering purposes (ADF&G 1985a).

Of the 11 resident middle river fish species (figure 1), capture data indicate that rainbow trout, Arctic grayling, round whitefish, longnose sucker, and slimy sculpin are common (ADF&G 1983c). Dolly Varden, burbot, humpback whitefish, threespine stickleback, and Arctic lamprey also occur, but all appear to be more abundant in the lower river (Sundet and Wenger 1984). Lake trout are found only in surrounding area lakes, none of which would be influenced by the project.

Less is known about most resident fish species in the middle river than about salmon. Rough population estimates made in 1983 showed there to be about 4,000 adult rainbow trout in the middle river. Catch data from 1981-84 in the middle river show round whitefish to be the most abundant species and that Arctic grayling and longnose sucker are more abundant than rainbow trout which are more common than burbot (Sundet and Wenger 1984). Lakes in the Portage Creek and Fourth of July drainages where rainbow trout are abundant probably contribute heavily to middle river rainbow populations (Crawford, Hale, and Schmidt 1985).

Given the naturally reduced winter flow regimes of tributary streams, the majority of resident fish (with the exception of lake trout) probably overwinter somewhere in the mainstem. It is generally believed that most resident fish which migrate to tributaries in the summer overwinter downstream of their natal tributaries in the mainstem (Sundet and Wenger 1984). Of the most common resident species, three (round whitefish, longnose sucker, and slimy sculpin) can occur year-round in the mainstem. Rainbow trout and Arctic grayling migrate out of tributaries by early October and most overwinter in the mainstem slightly downstream of these tributaries (Crawford, Hale, and Schmidt 1985).

LOWER RIVER

At least 17 tributary streams and six sloughs provide salmon reproductive habitats downstream of the Chulitna confluence. Tributary systems in this reach support more than 99% of all spawning salmon. To date, no chinook, sockeye, or pink salmon have been observed spawning in lower river mainstem waters; all apparently use tributary streams exclusively for this purpose (Barrett, Thompson and Wick 1985). Small numbers of chum and coho salmon have been seen spawning in 13 separate mainstem sites and six side sloughs; most members of these two species also spawn in tributary environments. ADF&G estimates that, in aggregate, the number of chum salmon spawning within mainstem environments in this reach represents roughly 0.3% of the 1984 basinwide escapement. The estimated number of spawning coho in the mainstem represents roughly 0.2% of the 1984 escapement (Barrett, Thompson and Wick 1985). Chum salmon were the principal users of side slough spawning environments, being present in five of the six sloughs used. Their estimated numbers represent roughly 0.1% of the total 1984 escapement. Only six coho were seen spawning in sloughs in 1984; all were in one slough (Barrett, Thompson and Wick 1985). Thus, lower river sloughs are less important than middle river sloughs for spawning purposes.

Less is known of salmon rearing and overwintering habitats in lower river mainstem environments than in the middle river. Coho, chinook, chum and sockeye juveniles primarily rear in tributaries; chinook, chum, and sockeye juveniles also make use of side channels. Sloughs are limited in occurrence and are not used heavily by any salmon species (Crawford, Hale, and Schmidt 1985). A few coho and chinook have been captured during winter in mainstem environments in this river reach (ADF&G 1983c).

Several million eulachon spawn in late May to early June in the lower 50 miles of the mainstem Susitna River. Most of these fish spawn below RM 29 in main channel habitats near cut banks over loose sand and gravel substrates (Barrett, Thompson and Wick 1984). Bering cisco return to the Susitna River in late August and spawning takes place from September through October. In 1981 and 1982, spawning activity peaked in the second week of October. Bering cisco are known to spawn only in main channel environments; the majority of spawning apparently takes place between RM 75 and RM 85 (Barrett, Thompson and Wick 1984).

Little is known about most resident fish life histories in the lower river. The 13 resident fish species found in the lower river, with the exception of lake trout, northern pike, and ninespine stickleback, are generally believed to be common (Sundet and Wenger 1984). As elsewhere in the drainage rainbow trout, Arctic grayling, and Dolly Varden spend most of the open water season in tributaries, using the mainstem principally for migration and overwintering (ADF&G 1983b). These species move into tributaries to spawn in the spring after breakup. Rainbow trout and Arctic grayling outmigrate from most eastside tributaries in September (Crawford, Hale, and Schmidt 1985). Burbot, whitefish, longnose sucker, sculpin, stickleback, and Arctic lamprey are found in both the mainstem and tributaries during the open water season. All of these species are believed to overwinter in the mainstem, but only rainbow trout, burbot, and slimy sculpin were captured there during 1982 winter sampling (ADF&G 1983b). Round whitefish are believed to spawn in October at either mainstem, tributary mouth, or tributary locations (Schmidt, et al. 1984b). Burbot spawning generally occurs between January and March under the ice in areas influenced by the mainstem or in tributaries like the Deshka.

Based on ongoing radio telemetry studies, it appears that favored mainstem overwinter habitats for adult rainbow trout and burbot differ principally by depth and location (Crawford 1985). Tagged rainbows are most frequently relocated in mainstem side channels, near tributaries, in waters generally less than five feet in depth. Tagged burbot are frequently located in winter in mainstem pools greater than six feet deep along river bends. However, most of the tagged burbot were found in the Deshka River. Both species seem to favor low velocity environments.

SEDIMENT EFFECTS ON AQUATIC ORGANISMS

The literature was searched for information describing the ways in which suspended sediment affects aquatic life to aid in evaluating the effects of the with-project sediement regime on them. A negative correlation exists between turbidity level and instream primary productivity (McCart and DeGraaf 1974). Turbid conditions reduce penetration of incident solar radiation and can limit growth of aquatic plants that are important food for stream invertebrates which in turn, are food for fish (Cordone and Kelly 1961).

Deposition of sediment can, overtime, reduce available habitat for stream invertebrates (Giger 1973). As sediment accumulates, the character of the substrate can change from being relatively diverse to one being relatively homogeneous. Many invertebrate species which are important salmonid food items are adapted to life on relatively stable gravel and rubble bottoms; they cannot inhabit relatively unstable areas of shifting sand and silt (McCart and deGraaf 1974).

Benthic macroinvertebrate numbers in reservoirs may be limited by a range of variables, of which siltation is one (Isom 1971). Accumulated silt can clog intragravel interstices reducing water flow and, hence, oxygen availability. This may negatively affect invertebrates also, (Ziebell 1960) especially those which respire through gills, such as caddisfly, mayfly, and stonefly larvae (McCart and deGraaf 1974), all of which are important fish food items. Silt may injure aquatic insect gills or membranes, thereby interfering with respiration (Usinger 1956). In silty environments, epifauna are often replaced by those more tolerant of low dissolved oxygen levels, such as dipterans and aquatic worms (Eustis and Hillen 1954), some of of which burrow into bottom sediments and offer reduced availability to fish (Phillips 1971).

Given extremely high concentrations over a prolonged time, suspended silt can accumulate in fish gill filaments, reducing oxygen exchange and eventually causing death (Cordone and Kelly 1961). However, this seldom happens naturally. Highly turbid waters may reduce forging efficiency and hence, survival rates in sight feeders, such as salmonids (Phillips 1971). Because suspended sediments eventually settle, major changes in bottom habitats might result from increased sediment deposition. Fine material accumulates on the stream bottom filling up spaces between stones and boulders. This decreases the permeability of the substrate resulting in decreased intragravel flow. Various authors have reported that increased sediment deposition can be detrimental to the survival of salmonid eggs and alevins, the most sensitive stages in the life cycle. Reduction in survival of salmon eggs and alevins is roughly in proportion to the reduction of water flow through the gravel, which in turn varies with the concentration of sediment--the greater the sediment concentration the greater the reduction in permeability. When permeability is reduced, eggs and fry are likely to suffer from oxygen deprivation and poisoning from waste metabolites which are not removed. Hall and Lantz (1969) found that a five percent increase of material smaller than 0.03 in (0.8 mm) in diameter in spawning substrate caused a decrease in survival of emergent coho fry. Sediment can also form a barrier to fry emergence by blocking interstitial gravel spaces through which fry move. Survival of fry after emergence can also be reduced by loss of escape cover if cracks and spaces fill with sediment. McCart and de Graaf (1974) noted that if sedimentation is of short duration, streams can recover quickly without any long-term consequences for the aquatic ecosystem. The rate of reinvasion of stream habitats is usually most rapid when short sections of stream rather than entire drainages are affected, adequate reservoirs of new organisms exist, and the degree of sediment deposition is slight.

SEDIMENT TRANSPORT

OVERVIEW

Sediment transport data pertaining to Susitna Basin waters have been collected and analyzed by the U.S. Geological Survey (USGS), the Alaska Department of Fish and Game (ADF&G), R&M Consultants, Inc. (R&M), Harza-Ebasco Susitna Joint Venture (H-E), Peratovich, Nottingham, and Drage Inc., and E. Woody Trihey and Associates (EWT&A). USGS information useful in addressing the sediment transport issue includes over 30 years of stream discharge data and some site-specific, systematically gathered, sediment and hydraulic data for the October 1981 to February 1984 period. The latter include suspended sediment concentration, bedload discharge, particle size distribution, and mainstem cross-sectional dimensions (Knott and Lipscomb 1983, 1985).

USGS field stations for the 1981-84 study were located on the Talkeetna and Chulitna rivers (near their respective confluences with the Susitna) and on the Susitna River (one station was just upstream of the Talkeetna River confluence, another was located near Sunshine, the last was near the mouth of Gold Creek). This study found that from November through March, suspended sediment concentrations at all stations were similar to each other, generally less than 10 mg/L (Knott and Lipscomb 1983, 1985). Suspended sediment concentrations rose rapidly in May of 1982 in concert with breakup; recorded concentrations were again somewhat similar in that all were in the low hundreds of mg/L (Knott and Lipscomb 1983, 1985). Great differences in suspended sediment concentrations were noted between sampling stations in July and August, the time of maximum glacial meltwater flow. Concentrations in this time period ranged from 90 to 768 mg/L for the Talkeetna and Susitna rivers (measured at the two stations located near the town of Talkeetna) and from 766 to 1270 mg/L for the Chulitna River (Knott and Lipscomb 1983, 1985).

At Sunshine (below the confluences of the Talkeetna and Chulitna rivers) the USGS found suspended sediment concentrations in the July - August timeframe to be between 424 to 1430 mg/L (Knott and Lipscomb 1983, 1985).

The USGS documented the fact that the Chulitna River was the major contributor of both suspended sediment and bedload to the mainstem Susitna below Talkeetna (Knott and Lipscomb 1983). For example, bedload discharges from the Susitna River (near Talkeetna) ranged from 106 to 2840 tons per day during the 1982 water year (October 1981 to September 1982); bedload at the Chulitna River site ranged from 2560 to 18,300 tons per day during the same interval (Knott and Lipscomb 1983). Between June and September 1982, the total bedload discharge at the USGS sample site upstream of Sunshine was two to five times greater than that at Sunshine (Knott and Lipscomb 1983), providing indirect evidence of aggradation in the mainstem. The same data also indicate that material deposited above Sunshine is transported under natural conditions by periodic high flows.

The USGS graphed water discharge against both suspended sediment and bedload concentrations and found a positive correlation to exist, i.e., sediment transport volumes increased with increasing water flow (Knott and Lipscomb 1983, 1985). However, the correlation was not directly proportional; Susitna River sediment transport rates increase exponentially above a point for each incremental change in water discharge (Knott and Lipscomb 1983, 1985). USGS sediment yield estimates for the 1982 water year are presented in table 7.

R&M (1982a) combined existing USGS stream discharge and suspended sediment data with aerial photographs of the Susitna River, information on bed material size, and cross-sectional transects of stream morphology to calibrate a water surface profile model (R&M 1982a). They concluded that the mainstem

Table 7. Estimated and recorded sediment yield.

Station Name and Number	Drainage Area (mi^2)	Period	Water Discharge (acre-ft)	Total Sediment (tons)			
				Silt-Clay	Sand	Gravel	Total[b]
Susitna River near Talkeetna (15292100)	6,320	May	920,000a	170,000	100,000	1,100	270,000
		June	1,700,000a	430,000	330,000	5,300	770,000
		July	1,500,000a	680,000	220,000	1,900	900,000
		August	1,000,000a	310,000	52,000	100	360,000
		September	1,100,000a	330,000	140,000	900	480,000
		May - Sep	6,200,000a	1,900,000	840,000	9,300	2,800,000
Chulitna River near Talkeetna (15292400)	2,570	May	386,700	88,000	73,000	48,000	210,000
		June	1,092,000	880,000	610,000	230,000	1,700,000
		July	1,575,000	1,900,000	910,000	190,000	3,000,000
		August	1,252,000	1,000,000	510,000	150,000	1,700,000
		September	1,085,000	1,200,000	350,000	66,000	1,600,000
		May - Sep	2,670,000	600,000	810,000	110,000	1,500,000
Susitna River at Sunshine (15292780)	11,100	May	1,633,000	280,000	260,000	15,000	550,000
		June	3,738,000	1,500,000	1,200,000	130,000	2,900,000
		July	3,876,000	2,800,000	1,400,000	75,000	4,300,000
		August	2,083,000	1,800,000	660,000	14,000	2,500,000
		September	2,906,000	1,900,000	880,000	46,000	2,800,000
		May - Sep	14,236,000	8,300,000	4,400,000	280,000	13,000,000

Source: Knott and Lipscomb 1983

a - Estimated
b - Rounded

Susitna River channel between Devil Canyon and the Chulitna River confluence would tend to narrow and become more defined under with-project conditions (R&M 1982a). Downstream of the Susitna-Chulitna confluence the river would stabilize with-project; there would be fewer subchannels and increased vegetation cover (as plants colonized barren bars now subject to periodic flooding). Specific with-project changes predicted in river morphology by R&M (1982a) are summarized in table 8.

R&M (1982b) also calculated reservoir sedimentation rates using assumed trap efficiencies (table 9). They note that the estimated deposit in Devil Canyon reservoir (assuming 100% trap efficiency of Watana Reservoir) (table 8) appears too low (R&M 1982b). Given knowledge of sediment size distribution and flow volumes, R&M (1982b) believes that the reservoir(s) would noticeably affect downstream environments; with-project summer turbidity between Devil Canyon and the Talkeetna River confluence would sharply decrease because of reservoir sediment trapping (R&M 1982b). Winter with-project turbidities are predicted to be near natural as in-reservoir near surface suspended sediments are likely to settle rapidly, especially following freeze-up (R&M 1982b).

R&M (1982c) and R&M and EWT&A (1985) also collected and analyzed streamflow and sediment transport mechanism data for 19 tributary stream mouths. The outlets of Jack Long, Sherman, and Deadhorse creeks are predicted to aggrade sufficiently to restrict fish access (R&M 1982c), while tributary mouths at RM 127.3 and RM 110.1, as well as Skull Creek, are predicted to significantly degrade (thereby threatening the railroad bridges there). The remaining 13 tributaries evaluated are predicted to either aggrade or degrade with-project, but without effects on fish access or other resources.

Table 8. Predicted morphologic change with-project.

	Mainstem	Slough	Tributary
RM 149 to 144	N/C	-----	Portage Creek will degrade with-project; it will not be perched.
RM 144 to 139	Less erosion of valley walls; distributaries may become inactive; channel will be more uniformly sinuous; less reworking of streambed deposits.	-----	Tributary at RM 144 could become perched.
RM 139 to 129.5	Less erosion of valley walls; channel will be more univormly sinuous.	Some sloughs could be dewatered.	Fourth of July Creek and Indian River will grade their beds to match regulated flows; Gold Creek will become perched.
RM 129.5 to 119	Less erosion of valley walls; channel will be more uniformly sinuous; river will continue to hug west bank.	Side channels and sloughs may become perched.	-----
RM 119 to 104	N/C	N/C	N/C
RM 104 to 95	Chulitna will extend alluvial deposits across mainstem Susitna; east bank of the Susitna could erode; Talkeetna River flow will maintain channel along east bank of the Susitna.	-----	-----
RM 95 to 61	Main channel of the Susitna River will stabilize.	-----	-----
RM 61 to 42	N/C	-----	-----
RM 42 to 0	N/C	-----	-----

N/C = No Change
Source: R&M 1982a

Table 9. Reservoir sedimentation.

	50-Year	100-Year
Watana		
100 percent trap efficiency	240,000 af	472,500 af
70 percent trap efficiency	170,000 af	334,000 af
Devil Canyon with 70 percent trap efficiency of Watana		
100 percent trap efficiency	79,000 af	155,000 af
70 percent trap efficiency	55,000 af	109,000 af
Devil Canyon with 100 percent trap efficiency of Watana		
100 percent trap efficiency	8,600 af	16,800 af
70 percent trap efficiency	6,100 af	--

Souce: R&M 1982b

The firm of Peratrovich, Nottingham & Drage, Inc. undertook an analysis of turbidity levels in the Watana Reservoir. Using a model (DEPOSITS) to compute turbidity at various depths, they concluded that particles less than three to four microns (about 20% of summer sediment input) would remain suspended (Peratrovich, Nottingham & Drage 1982). They predicted maximum outlet turbidity levels to be around 50 NTUs (roughly 200 to 400 mg/L); predicted minimum turbidity levels are around 10 NTUs (roughly 30 to 70 mg/L). Peratrovich, Nottingham & Drage (1982) predict that wind mixing in the ice-free season would keep sediments sized 12 microns or less in suspension, at least in the upper 50 ft of the water column. Resuspension of nearshore sediments are predicted to occur during storm intervals producing short-term higher than ambient turbidity levels (Peratrovich, Nottingham & Drage 1982).

Trihey (1982) analyzed field data collected by others on the mouths of Indian River and Portage Creek. His calculations (made for mainstem discharges of 8,000, 13,400, 21,500, and 34,500 cfs) indicate that both stream mouths would degrade with-project providing fish passage. He also analyzed with-project effects on salmon access to middle river sloughs. He focused analysis on Slough 9 arguing that it is a reasonable index of entrance conditions in all middle river sloughs. Trihey (1982) reports that access to Slough 9 would not appear to be restricted by flows at or above 18,000 cfs; access becomes increasingly difficult as flows decrease. At 12,000 cfs, Trihey (1982) reports that acute access problems would occur.

Harza-Ebasco Susitna Joint Venture used sediment discharge data for the Susitna River taken near Cantwell to estimate sediment inflow to the proposed reservoirs. Using the sediment rating-flow duration curve method and assuming 100% reservoir trap efficiency, they estimated that 6,730,000 tons of sediment would be trapped per year in the Watana Reservoir; the 100-year sediment deposit would be about 7% of the dead storage volume (Harza-Ebasco Susitna Joint Venture 1984a). Without Watana Reservoir, Harza-Ebasco Susitna Joint Venture (1984a) estimates sediment deposit in the Devil Canyon Reservoir would be about 7,240,000 tons per year; the 100-year deposit would be about 60% of the dead storage volume. With both dams on-line, sediment deposit in the Devil Canyon Reservoir is estimated to be about 515,000 tons per year; the 100-year deposit would be about 4% of dead storage capacity. Reduced sediment load below the dams would result in some mainstem degradation downstream to the vicinity of the Chulitna and Talkeetna confluences with the Susitna River (Harza-Ebasco Susitna Joint Venture 1984a).

Estimates of with-project mainstem degradation are provided in table 10. At certain mainstem sites, with-project bed degradation is predicted to vary from 1-1½ ft under a dominant discharge of about 30,000 cfs (Harza-Ebasco Susitna Joint Venture 1985). Flows of this volume are expected in the early years of Watana and Devil Canyon reservoirs (Harza-Ebasco Susitna Joint Venture 1984a). Predicted degradation of side channel and sloughs varies between 0 to 0.3 ft (Harza-Ebasco Susitna Joint Venture 1985; R&M and EWT&A 1985).

Because of channel degradation, higher than natural flows would be required to overtop slough berms. Using an assumed one-foot channel degradation as a bench mark, with-project flows necessary to overtop slough berms would need to be 4,000 to 12,000 cfs greater than natural (Harza-Ebasco Susitna Joint Venture 1985). Harza-Ebasco Susitna Joint Venture (1985) predict that if slough berms were overtopped, water velocity would be sufficient to carry out fines $\leq$.004 mm. However, coarser silt and fine sand entrained by overtopping water would settle in their stead (Harza-Ebasco Susitna Joint Venture 1985).

Table 10. Potential degradation at selected sloughs, side channels and mainstem sites.

Location	Discharge at Gold Creek (cfs)										
	5000	7000	10000	15000	20000	25000	30000	35000	40000	45000	55000
	Estimated Degradation (ft)										
*Main Channel near Cross Section 4	0.1	0.2	0.3	0.6	0.8	1.1	1.3	1.5	1.7	1.9	2.4
Main Channel between Cross Sections 12 & 13	0.1	0.2	0.3	0.4	0.6	0.8	1.1	1.3	1.8	2.4	3.7
Main Channel upstream from Lane Creek	0.2	0.2	0.3	0.4	0.6	0.8	1.0	1.2	1.5	1.8	2.5
Mainstem 2 Side Channel at Cross Section 18.2											
Main Channel	0	0	0	0	0	0.1	0.2	0.3	0.5	0.7	1.2
Northeast Fork	0	0	0	0	0	0	0	0.1	0.1	0.2	0.2
Northwest Fork	0	0	0	0	0	0	0	0.1	0.1	0.2	0.2
Slough 8A	0	0	0	0	0	0	0	0	0	0	0
Slough 9	0	0	0	0	0	0	0	0.1	0.2	0.3	0.5
Main Channel upstream from Fourth of July Creek	0.3	0.3	0.4	0.6	0.8	1.1	1.3	1.5	1.7	2.0	2.5
Side Channel 10	0	0	0	0	0	0.1	0.2	0.4	0.6	1.0	2.0
Lower Side Channel 11	0	0	0	0.1	0.2	0.3	0.5	0.7	1.0	1.3	2.1
Slough 11	0	0	0	0	0	0	0	0	0	0	0.1
Upper Side Channel 11	0	0	0	0	0	0.1	0.2	0.3	0.6	0.9	1.8
Main Channel between Cross Sections 46 & 48	0.3	0.4	0.6	0.9	1.2	1.4	1.7	1.9	2.1	2.4	2.8
Side Channel 21	0	0	0	0	0	0	0.1	0.1	0.2	0.2	0.3
Slough 21	0	0	0	0	0	0	0	0	0.1	0.2	0.5

Source: Harza-Ebasco Susitna Joint Venture 1985

*Locations are defined on pages 7 to 11 in Harza-Ebasco Susitna Joint Venture 1985.

AEIDC (1985) analyzed natural geomorphic change in the Susitna River between Devil Canyon and the Chulitna confluence by comparing aerial photographs taken over the last 36 years. AEIDC (1985) concluded that the reach in question is slowly degrading its bed under natural flows as it has ice age. Sloughs were found to be transitory in nature, being continually created and destroyed by natural sediment transport mechanisms (AEIDC 1985).

SYNOPSIS OF RESULTS

The Watana and Devil Canyon reservoirs are predicted to trap most sediment reaching them. The consequences of this are varied. First, the reservoir environments would be characterized as highly turbid (~50 NTUs) with relatively high sedimentation rates. Second, reduction in sediment load downstream of the Devil Canyon Dam would induce some channel degradation to about the confluences of the Talkeetna and Chulitna rivers with the Susitna. Channel degradation coupled with regulated with-project flows would reduce the incidence of floods which overtopped slough berms. Floodwaters, while still capable of resuspending intragravel fines, would deposit significant amounts of sand and silt in their place. Some naturally occurring patterns of stream aggradation near the Talkeetna and Chulitna confluences with the Susitna River could be enhanced, but natural discharges from the Talkeetna River should be sufficient to keep a channel open.

Predictions of the with-project environment (based on the studies outlined above) are sufficiently detailed and verifiable to allow an evaluation of the with-project sediment transport regime on fish. The chief limiting factor confronting all investigators is the apparent hysteresis between sediment load and water discharge, a problem common to glacial meltwater streams (R&M 1982; Knott and Lipscomb 1983, 1985). The net result of this is to make long-term predictions relatively more accurate than those for the short-term. This condition, while potentially troubling to engineers, is of small importance to the effects analysis which, of necessity, has a long-term focus.

ANALYSIS

ANTICIPATED NEGATIVE EFFECTS

IMPOUNDMENT ZONE

The following discussion explains predictions summarized in table 11. Predicted with-project sedimentation and suspended sediment levels in the impoundments would negatively influence to varying degrees all fish species present. Anticipated with-project suspended sediment loads in the reservoirs vary seasonally from a summer high of between 200 to 400 mg/L (50 NTU's) to a winter low of between 30 to 70 mg/L (10 NTU's) (Peratovich, Nottingham, and Drage 1982). Summer levels could occasionally be higher than this, especially nearshore, as storm runoff is expected to re-entrain sediment deposited during winter drawdown (Peratovich, Nottingham and Drage 1982). Following extensive review of sediment effects on North American benthic and planktonic communities and on population, reproduction, and species composition of fish, Newport and Moyer (1974) concluded that water bodies having suspended sediment concentrations above 100 mg/L year round were unlikely to support a viable sport fishery. The reasons for this are many but chiefly concern the effects of sediment on aquatic organism respiration efficiency. Suspended inorganic sediment can mechanically damage and interfere with oxygen transport across membranes (McCart and DeGraaf 1974; Cordone and Kelley 1961).

Table 11. Anticipated relative negative with-project sediment transport effects on impoundment zone fish.

Fish Species	Watana Operation Effects Scale[1]	Watana Operation Date	Devil Canyon Operation Effects Scale	Devil Canyon Operation Date
Chinook salmon	--	--	0[2]	--
Arctic Grayling				
adult migration	0	--	0	--
spawning	0		0	
incubation	0	--	0	--
rearing	1	Oct-Apr	1	Oct-Apr
Lake Trout				
adult migration	0	--	0	--
spawning	2	Aug-Dec	2	Aug-Dec
incubation	2	--	2	--
rearing	1	Oct-Apr	1	Oct-Apr
Whitefish[3]				
adult migration	0	--	0	--
spawning	0	--	0	--
incubation	0		0	
rearing	1	Oct-Apr	1	Oct-Apr
Rainbow Trout				
adult migration	0	--	0	--
spawning	0	--	0	--
incubation	0	--	0	--
rearing	1	Oct-Apr	1	Oct-Apr
Burbot				
adult migration	0	--	0	--
spawning	1	Jan-Feb	1	Jan-Feb
Incubation	3	--	3	--
rearing	1	--	1	--
Longnose Sucker				
adult migration	0	--	0	--
spawning	0	--	0	--
incubation	0		0	
rearing	1	Oct-Apr	1	Oct-Apr

[1] 0 - no concern
1 - low
2 - moderate to severe
3 - possible

[2] The Devil Canyon dam would block upstream passage of chinook salmon, a few of which spawn in Cheechako Creek (RM 152.5) and Chinook Creek (RM 156.8); with-project sediment transport would not negatively influence habitats there.

[3] This table is applicable to both humpback and round whitefish.

The with-project sediment transport regime would most affect lake trout and burbot, the only two impoundment zone species which naturally reproduce in lake environments. Lake trout normally spawn in fall over the gravel substrates of clearwater lakes. The combined effects of lake drawdown and winter sedimentation would generally limit in-reservoir reproduction rates by this species. Embryos which were not dehydrated by receding reservoir water levels in winter (i.e., those spawned below the lower low water level) would face the consequences of sediment build-up on natal beds (i.e., oxygen deprivation). Burbot spawn in winter under the ice and over gravel in either lakes or streams. This species population could be held in check by the anticipated pattern of winter sedimentation also, but too little is known of the precise pattern of sedimentation to allow an accurate assessment of the degree, or magnitude, of its effects on burbot embyros. Burbot are broadcast spawners and can spawn in a wide range of depths. It may be that some embryos in some areas might find favorable conditions for reproduction and growth (e.g. local hydraulic conditions might produce eddies where sedimentation rates were relatively low).

Reservoir rearing habitat quality for all species would be low (table 11). Given the predicted reservoir environment in winter, it is likely that invertebrate populations there would become dominated by infauna capable of living in low oxygenated environments (see p. 32 of this report), rather than by epifaunal fish foods such as caddis fly larvae. This would translate into lowered food availability for fish. Sedimentation would also reduce available cover afforded by cobbles and boulders making fry somewhat more susceptible to predation.

MIDDLE RIVER ZONE

Tables 12 and 13 summarize anticipated with-project negative sediment transport effects on middle river zone anadromous and resident fish. These effects can be placed into one of two categories; those centered on the mainstem proper and those centered on slough spawning habitats. Immediately after project startup and regardless of whether one or two dams are on-line, the mainstem between Devil Canyon and its confluence with both the Talkeetna and Chulitna rivers would begin to degrade (R&M, Woodward-Clyde Consultants, and Harza Ebasco Susitna Joint Venture 1985). Mainstem degradation would continue until the bed adjusted to the new (regulated) flow volume. The river's channel would narrow as it entrenched (R&M 1982; Harza-Ebasco Susitna Joint Venture 1985). With-project mainstem degradation (coupled with regulated flows) would accelerate the natural process of slough senescence noted by AEIDC (1985). Sloughs in the natural (i.e., unregulated) environment are continually created and destroyed over time as a consequence of the slow but continuous process of river bed degradation. In its essence, the process of slough senescence begins with the perching of slough mouths by the degrading river (AEIDC 1985). In time the slough is left behind by the river and eventually it evolves into dry land (AEIDC 1985). Under natural conditions new sloughs are constantly and coincidentally created as entrained bed material is redeposited (AEIDC 1985).

Unlike natural, with-project sloughs would not complete their life cycle, nor would new sloughs be created. With-project, the effect of freshets necessary to entrain bed material for slough building would be greatly diminished. Once the bed achieved equilibrium with with-project flows, the process of slough perching would cease (Harza-Ebasco Susitna Joint Venture 1985). With-project sloughs, following a period of environmental adjustment delimited by the period of mainstem degradation, would superficially appear to be in stasis with the environment, i.e., they would not gradually make the transition to dry land. Change would be occurring, however. The dams would reduce the incidence of freshet-induced overtopping of slough berms (Harza-Ebasco Susitna Joint Venture 1984a). This would lead to a build-up of fines and coarser bed material (Harza-Ebasco Susitna Joint Venture 1984a; Blakely et al., 1985).

Immediately downstream of the Chulitna confluence with the mainstem, a zone of with-project aggradation is predicted to occur (R&M 1982, Harza-Ebasco Susitna Joint Venture 1984a). Aggradation here is likely to be significant and it may have consequence to the built as well as natural environment (R&M 1982). However, natural flow from the Talkeetna River is believed sufficient to maintain a distinct channel through this zone (R&M 1982; Harza-Ebasco Susitna Joint Venture 1984a).

The chief sediment transport problem concerns degradation of traditional slough spawning habitats for chum, pink, and sockeye salmon (table 12). As indicated above, the with-project rate of flood-induced overtopping of slough berms would be greatly diminished over natural conditions. This is predicted to result in both a buildup of intragravel fines (floods are necessary to re-entrain deposited fines thereby rehabilitating spawning beds) and a buildup of larger, coarser material deposited during each flood event (Harza-Ebasco Susitna Joint Venture 1984a, 1985). Unless mitigated, this process would eventually destroy all in-slough salmon spawning habitats by filling in gravel interstices and by altering the character of spawning substrates. Since no new sloughs would be created under the with-project sediment transport regime, this means that unless mitigated, the annual average drainagewide escapements would in time be reduced by as many as 20,000 adult chum (eight-year average

Table 12. Anticipated relative negative with-project sediment transport effects on middle river zone anadromous fish.

	Watana Operation			Devil Canyon Operation		
Fish Species	Effects Scale[1]	Location	Date	Scale	Effects Location	Date
Chinook salmon						
adult inmigration	0	--	--	--	--	--
spawning	0	--	--	0	--	--
incubation	0	--	--	0	--	--
rearing/smolting	1	sloughs	year-round	1	sloughs	year-round
outmigration	0	--	--	0	--	--
Chum salmon						
adult inmigration	0	--	--	0	--	--
spawning	1	sloughs	Aug-Sept	1	sloughs	Aug-Sept
incubation	2	sloughs	Sept-May	2	sloughs	Sept-May
rearing/smolting	1	sloughs	May-June	1	sloughs	May-June
outmigration	0	--	--	0	--	--
Pink salmon						
adult inmigration	0	--	--	0	--	--
spawning	1	sloughs	Aug	1	sloughs	
incubation	2	sloughs	Sept-May	2	sloughs	Sept-May
rearing/smolting	0	--	--	0	--	--
outmigration	0	--	--	0	--	--
Coho salmon						
adult inmigration	0	--	--	0	--	--
spawning	0	--	--	0	--	--
incubation	0	--	--	0	--	--
rearing/smolting	1	sloughs	year-round	1	sloughs	year-round
outmigration	0	--	--	0	--	--
Sockeye salmon						
adult inmigration	0	--	--	0	--	--
spawning	1	sloughs	Aug-Sept	1	sloughs	Aug-Sept
incubation	2	sloughs	Sept-May	2	sloughs	Sept-May
rearing/smolting	1	sloughs	year-round	1	sloughs	year-round
outmigration	0	--	--	0	--	--

[1] 0 - no concern
1 - low
2 - moderate
3 - possible

See text for a complete description of the effects scale.

from table 5), 500 adult sockeye (eight-year average from table 5), and 270 adult pink salmon (six-year average from table 5) unless mitigated. These numbers represent 2.4%, .08%, and .007% respectively of all chum, sockeye, and pink salmon spawning in the Susitna drainage basin in 1984.

Stream degradation at the mouths of all major middle river salmon spawning sloughs is predicted to be slight (table 10). Taken by itself, this can be interpreted to mean that there would be no with-project access problems for salmon. However, comparison of existing information on minimum mainstem flows necessary to allow passage of adult spawners into natal habitats (Blakely et al., 1985; Sautner, Vining, and Rundquist 1984) and knowledge of the ability of salmon to traverse stream reaches under given flows (Blakely et al., 1985; Sautner, Vining, and Rundquist 1984; Trihey 1982) to predictions of Case E-VI flows (Harza-Ebasco Susitna Joint Venture 1984b) and with-project mainstem degradation patterns (Harza-Ebasco Susitna Joint Venture 1985) leads to the conclusion that in some years some pink, chum, and sockeye salmon would not be able to reach traditional natal slough environments (table 12). With present information, it is impossible to accurately predict which sloughs would be most affected, and hence, the number of fish affected. Additional study is not likely to improve this situation. Variables affecting flow estimates (e.g., climate and energy demand) and the lack of a clear relationship between flow volume and sediment transport, make it unlikely that materially greater predictive precision is achievable, regardless of whether additional study effort is expended.

Predicted with-project aggradation at the mouths of Deadhorse (RM 120.8), Sherman (RM 130.8), and Jack Long (RM 144.5) creeks would likely restrict access to spawning habitats for some salmon (R&M 1982a, 1985). Escapement counts made to evolve indices of abundance indicate that relatively few salmon spawn in these streams (table 4). Based on the 1984 count (the highest on record), 399 adult pink, 10 chum, 6 coho, and 7 chinook salmon could be displaced from traditional natal grounds as a result of with-project aggradation. This represents .01%, .001%, .003%, and .003% respectively of all pink, chum, coho, and chinook salmon spawning in the Susitna River basin in 1984. These counts are not direct censuses, so numbers reported under-estimate salmon use to some extent. However, as table 4 shows, relatively few salmon of any species have been tallied over the years in any of the subject streams.

Unless mitigated, slough rearing habitat quality for chinook, chum, sockeye, and coho salmon would diminish as a result of the with-project sediment transport regime (table 12). Reduction in the number of yearly floods would result in a change in character of in-slough substrates. The change would be away from heterogeneity, as irregularly sized gravel and cobble material, was gradually covered by fines and sand. The net result would be a diminishment in cover (EWT&A and Milner 1985) and, ultimately, food availability (the invertebrate fauna would predictably shift towards one dominated by infauna -- see p. 32 of this report). Again, existing information does not permit an estimate of how many fish would be affected or of their ultimate fates.

The with-project sediment transport regime would pose no problems to any of the resident middle river fish species (table 13), because with-project sediment loads would be lower than natural (cf. Knott and Lipscomb 1983 to the predictions of Harza-Ebasco Susitna Joint Venture 1984a, 1985). This would be true even in the early years of project operation when scouring of the mainstem is predicted to occur. Potential with-project beneficial effects are discussed on pp. 57 to 58 of this report.

Table 13. Anticipated relative negative with-project sediment transport effects on middle river zone resident fish species.

	Watana Operation			Devil Canyon Operation		
Fish Species	Effects[1] Scale	Location	Date	Effects[1] Scale	Location	Date
Burbot						
adult migration	0	--	--	0	--	--
spawning	0	--	--	0	--	--
incubation	0	--	--	0	--	--
rearing	0	--	--	0	--	--
Whitefish[2]						
adult migration	0	--	--	0	--	--
Rainbow trout						
adult migration	0	--	--	0	--	--
spawning	0	--	--	0	--	--
incubation	0	--	--	0	--	--
rearing	0	--	--	0	--	--
Arctic grayling						
adult migration	0	--	--	0	--	--
spawning	0	--	--	0	--	--
incubation	0	--	--	0	--	--
rearing	0	--	--	0	--	--

[1]
0 - no concern
1 - low
2 - moderate
3 - possible

See text for a complete description of the effects scale

[2] This table is applicable to both broad and humpback whitefish.

LOWER RIVER ZONE

With-project sediment transport effects in the lower river are more difficult to predict than elsewhere in the study area. This is due to the braided nature of the mainstem (braided streams are difficult to model) and to the fact that relatively little study effort has been directed there. Project team members believe that more data are required to define with-project effects on the lower river (Bredthauer 1985). Prominent data gaps are listed in table 14.

Based on USGS data (Knott and Lipscomb 1983, 1985) the with-project sediment transport regime would be moderated below RM 97 by tributary input, especially those from the Talkeetna, Chulitna, and Yentna rivers (R&M and EWT&A 1985). As indicated earlier (see p. 44), a significant zone of aggradation is predicted to occur near the Chulitna River's confluence with the mainstem ((Harza-Ebasco Susitna Joint Venture 1984a). Downstream of that point, little else is known of with-project effects on sediment transport, and hence, its effect on fish.

R&M and EWT&A (1985) believe that tributary mouths in this reach should become more stable as a result of with-project regulated flows. R&M and EWT&A (1985) estimate that with-project summer flows of around 25,000 to 30,000 cfs would be sufficient to allow passage into all lower river tributaries. However, they note that the mouths of Rolly (RM 39.0), Caswell (RM 64.0), Goose (RM 72.0), Montana (RM 77.0), Rabiduex (RM 83.1) and Trapper (RM 91.5) creeks have possible inherent access problems which might become manifest under some with-project flows (R&M and EWT&A 1985). They further note that due to the braided nature of the mainstem in this reach, quantification of change would be difficult (R&M and EWT&A 1985). Salmon index counts were made by ADF&G in these streams in 1984; around 3,000 chinook, 300 sockeye, 900

Table 14. Prominent data gaps in the lower Susitna River information base.

Sediment aggradation/morphology
Backwater effects at tributary mouths
Turbidity regime (local, plumes)
Relationship of flow and fish access to streams, sloughs, side-channels
Survey of mainstream spawning sites found in 1984
Timing and magnitude of ice staging and relationship to upwelling
Timing of flows - increased spawning area, later dewatering
Relate flows to rearing areas, spawning areas, access consideration
Fish abundance, rearing curves
Fisheries use of tributaries
Effect of with-project flows on salt-water intrusion

Source: Bredthauer 1985

pink, 590 chum, and 700 coho were counted (Barrett, Thompson, and Wick 1985). Although these counts do not indicate total escapement, they do provide some measure of the relative importance of each stream to each species. From this perspective, Montana Creek is the most important of the six streams for chinook (total count of 2,309) and pink (total count of 469) salmon, Trapper Creek is the most important of the group for sockeye salmon (total count of 200), Goose Creek is the most important of the six for chum salmon (total count of 383), and Rabideux Creek is the most important of the group for coho (total count of 480) (Barrett, Thompson, and Wick 1985).

The with-project sediment transport regime probably would not negatively affect any species spawning or overwintering in the mainstem lower river proper. This conclusion is based on the fact that overall sediment loads would be diminished with-project (although only slightly) from natural, thereby somewhat enhancing the quality of the environment. A discussion of the with-project beneficial effects is found in the next section.

POTENTIAL WITH-PROJECT BENEFICIAL EFFECTS

The with-project in-reservoir sediment transport process would not convey or otherwise impart any beneficial effects to fish or their food organisms. However, with-project sediment transport in the middle river might lead to an increase in primary productivity. Once the bed restabilized, sediment load in this reach would be less than natural (see pp. 35 to 45 of this report). An increase in aquatic primary production could lead to an increase in consumers which, in turn, might equate with an incremental gain in fish habitat quality. Existing information is insufficient to gauge or even to characterize the magnitude of this effect. With-project turbidity in the middle river would still be substantial due to suspended glacial flour (the reservoirs could not trap all sizes of fines, some of which are present as colloids). (This topic is addressed in length in the Turbidity Memorandum, another rpeort of this series). Also unknown is whether natural invertebrate numbers and kinds limit present fish numbers. This latter point is central to a determination of whether there would be a gain in fish habitat quality. An ongoing AEIDC study seeks to understand natural primary rates of production in this reach; its results may shed light on the question of with-project primary productivity, but not necessarily on its effect on fish.

The with-project reduction in sediment load could lead to an increase in available mainstem salmon spawning habitats. The with-project sediment transport regime is predicted to keep the bed downstream of Devil Canyon relatively free of fines. This effect would diminish with distance downstream as tributaries added their sediment loads to the mainstem. It would not be noticeable below the Talkeetna and Chulitna confluence with the mainstem due to their moderating influence. Present information does not allow estimation of the magnitude of this.

No major (i.e., demonstrable) beneficial gains in primary production are likely to occur as a result of the with-project sediment regime in the lower river. This is due to the moderating influence of sediment inputs from the Talkeetna, Chulitna, and Yentna rivers (see pp. 35 to 45 of this report). Existing information is insufficient to assess whether any other sediment transport associated beneficial effects could occur in the lower river. However, the slight reduction in suspended load and bed load caused by the dams might improve fish habitat quality somewhat.

SUMMARY

This report presents the results of an analysis of existing information of the effects of the with-project sediment transport regime on fish. It is based on a comparison of predictions of the with-project environment with information on fish instream flow needs and their response to sedimentation.

Based on existing data (sediment transport calculations and model runs and life history information) and professional judgement, with-project sediment transport phenomena (unless mitigated) would limit fish numbers in the impoundment zone and in the middle river. Reservoir sedimentation (coupled with winter drawdown) would limit reproduction by lake trout and possibly burbot. In the middle river, with-project reduction of the number and intensity of floods would eventually diminish slough spawning habitats for salmon. Unless action was periodically taken to clean slough spawning beds, sedimentation attendant to periodic floods would eventually lead to a loss of these habitats. Comparison of estimates of released water flow variability and estimates of with-project mainstem degradation to salmon life history data and information on minimum water depth necessary at slough mouths to provide salmon access, leads to the conclusion that in some years some sloughs would be blocked to salmon. However, given the relatively small amount of with-project channel degradation predicted for the mouths of the principal spawning sloughs, this should not be a major problem. Potential with-project beneficial effects in the middle river are limited to a possible increase in primary production and an increase in salmon spawning habitat. An ongoing study may shed light on the primary production question. With-project sediment loads below the Devil Canyon dam would be markedly reduced over those occuring naturally. Following bed stabilization, it is possible that portions

of the mainstem could function as salmon spawning habitat (the bed should be swept relatively clean of fines). Present information does not allow a prediction of the degree of this type of change, so no estimate of effected fish numbers is possible. Information is also too scant to allow an accurate appraisal of the effects of the lower river with-project sediment regime on fish. It is generally believed by APA's contractors that regulated with-project flows should help stabilize stream mouths in this reach. Although unquantifiable, the slight reduction over natural conditions of with-project mainstem sediment loads should improve habitat quality for fish somewhat; natural suspended sediment loads generally exceed the limits thought minimally acceptable for maintenance of vigorous resident fish populations.

REFERENCES

Acres American, Inc. 1983. Application for license for major project, Susitna Hydroelectric Project, before the Federal Energy Regulatory Commission. Vol. 5A. Exhibit E, Chaps. 1 and 2. Alaska Power Authority. Susitna Hydroelectric Project. 1 vol.

Alaska Dept. of Fish & Game. 1976. Fish and wildlife studies related to the Corps of Engineers Devil Canyon, Watana Reservoir Hydroelectric Project. Anchorage, AK. Report for U.S. Fish & Wildlife Service. 1 vol.

__________. 1978. Preliminary environmental assessment of hydroelectric development on the Susitna River. Anchorage, AK. Report for U.S. Fish & Wildlife Service. 1 vol.

__________. 1981. Resident fish investigation on the upper Susitna River. Final Draft Report. Anchorage, AK. Alaska Power Authority. Susitna Hydro Aquatic Studies. Report for Acres American, Inc. 1 vol.

__________. 1983a. Susitna hydro aquatic studies, phase 2 final data report. Vol. 2. Adult anadromous fish studies, 1982. Final Report. Anchorage, AK. Alaska Power Authority. Susitna Hydro Aquatic Studies. Report for Acres American, Inc. 2 vols.

Alaska Dept. of Fish & Game. 1983b. Susitna hydro aquatic studies, phase 2 basic data report. Vol. 3. Resident and juvenile anadromous fish studies on the Susitna River below Devil Canyon, 1982. Final Report. Anchorage, AK. Alaska Power Authority. Susitna Hydro Aquatic Studies. Report for Acres American, Inc. 2 vols.

__________. 1983c. Susitna hydro aquatic studies, phase 2 baseline data report. Vol. 4. Aquatic habitat and instream flow studies, 1982. Final Report. Anchorage, AK. Alaska Power Authority. Susitna Hydro Aquatic Studies. Report for Acres American, Inc. 3 vols.

__________. 1983d. Susitna hydro aquatic studies, phase 2 basic data report. Vol. 5. Upper Susitna River impoundment studies, 1982. Final Report. Anchorage, AK. Alaska Power Authority. Susitna Hydro Aquatic Studies. Report for Acres American, Inc. 150 pp.

__________. 1985a. Proposed Task Statement for FY86 Su-Hydro Scope of Work.

__________. 1985b. An evaluation of the incubation life phase of chum salmon in the middle Susitna River. Draft. Anchorage, AK. Susitna Hydro Aquatic Studies Winter Aquatic Investigations, September 1983 - May 1984. 1985 Report 5. Vol. 1. Report for Alaska Power Authority. 157 pp.

Alaska, University of, Arctic Environmental Information and Data Center. 1985. Geomorphic change in the middle Susitna River since 1949. Second Draft. Report for Harza-Ebasco Susitna Joint Venture. Anchorage, AK. 1 vol.

Barrett, B.M. 1974. An assessment of the anadromous fish populations in the upper Susitna River watershed between Devil Canyon and the Chulitna River. Alaska Div. of Commercial Fisheries, Anchorage, AK. 56 pp.

Barrett, B.M., F.M. Thompson, and S.N. Wick. 1984. Adult anadromous fish investigations: May - October 1983. Alaska Dept. of Fish & Game, Anchorage, AK. Susitna Hydro Aquatic Studies. Report 1. Report for Alaska Power Authority. 1 vol.

__________. 1985. Adult anadromous fish investigations (May - October 1984). Draft report. Alaska Dept. of Fish & Game, Anchorage, AK. Susitna Hydro Aquatic Studies. Report 1. Report for Alaska Power Authority. 1 vol.

Blakely, J.S. et al. 1985. Salmon passage validation studies (August - October 1984). Addendum to Report No. 3, Chapter 6. Draft report. Alaska Dept. of Fish & Game, Anchorage, AK. Susitna Hydro Aquatic Studies. Report 3, Chapter 6. Report for the Alaska Power Authority. 1 vol.

Bredthauer, S. 1985. Minutes, Lower Susitna coordination meeting, April 4, 1985. R&M Consultants, Inc., Anchorage, AK. 3 pp.

Coker, R.E. 1968. Streams, lakes, and ponds. Harper and Row, N.Y. 327 pp.

Cordone, A.J., and D.W. Kelley. 1961. The influences of inorganic sediments on the aquatic life of streams. California Fish and Game. 47(2):189-228.

Crawford, D. 1985. Resident and juvenile anadromous studies bi-monthly report (December 1984 and January 1985). Memorandum to Larry Bartlett, Alaska Dept. of Fish & Game, Anchorage, AK. Susitna Aquatic Studies Program. January 25, 1985.

Crawford, D.L., S.S. Hale, and D.C. Schmidt, eds. 1985. Resident and juvenile anadromous fish investigations (May - October 1983). Draft report. Alaska Dept. of Fish & Game, Anchorage, AK. Susitna Aquatic Studies Program. Report 7. Report for Alaska Power Authority. 1 vol.

Dugan, L., D. Sterritt, and M. Stratton. 1984. The distribution and relative abundance of juvenile salmon in the Susitna River drainage above the Chulitna River confluence. Draft report. Part 2 of D.C. Schmidt, S.S. Hale, and D.L. Crawford, eds. Resident and juvenile anadromous fish investigations (May - October 1983). Alaska Dept. of Fish & Game, Anchorage, AK. Susitna Hydro Aquatic Studies. Report 2. 1 vol.

E. Woody Trihey & Associates and A.M. Milner. 1985. A framework for the assessment of chinook salmon rearing in the middle Susitna River under altered flow, temperature, and sediment regimes. Draft report. Anchorage, AK. Alaska Power Authority. Susitna Hydroelectric Project. Report for Harza-Ebasco Susitna Joint Venture. 69 pp.

Energy Management. 1984. (Commerce Clearing House) Paragraph #63111. (March 30) [Energy Mgmt. (CCH) Paragraph #63111 (March 30, 1984)]

Eustis, A.B., and R.H. Hillen. 1954. Stream sediment removal by controlled reservoir releases. Progressive Fish-Culturist. 16(1):30-35.

Giger, R.D. 1973. Streamflow requirements of salmonids. Oregon Wildlife Commission, Portland, OR. Federal Aid in Fish Restoration Progress Reports. Final Report. Anadromous Fish Project AFS 62-1. Portland, OR. 117 pp.

Hall, J.D., and R.L. Lantz. 1969. Effects of logging on the habitat of coho salmon and cutthroat trout in coastal streams. Pages 355-375 in T.G. Northcote, ed. Symposium on salmon and trout in streams. University of British Columbia, Vancouver, B.C., Canada. H.R. MacMillan Lectures in Fisheries.

Harza-Ebasco Susitna Joint Venture. 1984a. Susitna Hydroelectric Project reservoir and river sedimentation. Report for the Alaska Power Authority. Anchorage, AK. 1 vol.

Harza-Ebasco Susitna Joint Venture. 1984b. Evaluation of alternative flow requirements. Final report. Alaska Power Authority. Susitna Hydroelectric Project. 55 pp.

__________. 1985. Middle Susitna River Sedimentation Study - stream channel stability analysis of selected sloughs, side channels, and main channel locations. Report for Alaska Power Authority. Anchorage, AK. 1 vol.

Inhaber, H. 1976. Environmental indices. John Wiley and Sons, New York, NY. 178 pp.

Isom, B.J. 1971. Effects of storage and mainstream reservoirs on benthic macro invertebrates in the Tennessee Valley. Pages 179 to 191 in Proceedings of the American Fisheries Society Symposium, Reservoir Fisheries and Limnology. Washington, D.C. Special Publication No. 8.

Knott, J.M., and S.W. Lipscomb. 1983. Sediment discharge data for selected sites in the Susitna River basin, Alaska, 1981-82. U.S. Geological Survey. Open File Report No. 83-870. Anchorage, AK. 1 vol.

__________. 1985. Sediment discharge data for selected sites in the Susitna River basin, Alaska, October 1982 to February 1984. U.S. Geological Survey. Open File Report 85-157. Anchorage, AK. 68 pp.

McCart, P.J., and D. de Graff. 1974. Effects of disturbance on the benthic fauna of small streams in the vicinity of Norman Wells, N.W.T. Pages 1-27 in P.J. McCart, ed. Fisheries research associated with proposed gas pipeline routes in Alaska, Yukon, and Northwest Territories. Canadian Arctic Gas Study Ltd./Alaskan Arctic Gas Study Company. Biological Report Series 15(4).

Newport, B.D., and J.E. Moyer. 1974. State-of-the-art: Sand and gravel industry. U.S. Environmental Protection Agency. EPA 660/2 74-066. Corvallis, OR. 40 pp.

Peratrovich, Nottingham & Drage, Inc., and I.P.G. Hutchison. 1982. Susitna reservoir sedimentation and water clarity study. Report for Acres American, Inc. Anchorage, AK. 1 vol.

Phillips, R.W. 1971. Effects of sediment on the gravel environment and fish production. Pages 64-75 in Forest land uses and stream environment. Proceedings of a symposium. Oregon State University, Corvallis, OR. (Cited in Meehan 1974.)

R&M Consultants, Inc. 1982a. Susitna Hydroelectric Project river morphology. Report for Acres American, Inc. Anchorage, AK. 1 vol.

__________. 1982b. Susitna Hydroelectric Project reservoir sedimentation. Report for Acres American, Inc. Anchorage, AK. 1 vol.

R&M Consultants, Inc. 1982c. Susitna Hydroelectric Project, tributary stability analysis. Report for Acres American, Inc. Anchorage, AK. 1 vol.

R&M Consultants, Inc., and E. Woody Trihey & Associates. 1985. Assessment of access by spawning salmon into tributaries of the lower Susitna River. Draft report. Alaska Power Authority. Susitna Hydroelectric Project. Report for Harza-Ebasco Susitna Joint Venture. 1 vol.

R&M Consultants, Inc., Woodward-Clyde Consultants, and Harza-Ebasco Susitna Joint Venture. 1985. Instream flow relationships report. Technical Report No. 2. Physical Processes. Draft report. Anchorage, AK. Report for Alaska Power Authority. 1 vol.

Riis, J.C. 1977. Pre-authorization assessment of the proposed Susitna River Hydroelectric Projects: Preliminary investigations of water quality and aquatic species composition. Alaska Div. of Sport Fish, Anchorage, AK. 91 pp.

Saunders, J.W., and M.W. Smith. 1962. Physical alteration of stream habitat to improve brook trout production. Transactions of the American Fisheries Society. 91(2):185-188.

Sautner, J., L.J. Vining, and L.A. Rundquist. 1984. An evaluation of passage conditions for adult salmon in sloughs and side channels of the middle Susitna River. Chapter 6 in Report No. 3: Aquatic habitat and instream flow investigations (May - October 1983). Alaska Dept. of Fish & Game, Anchorage, AK. Susitna Hydro Aquatic Studies. Report for the Alaska Power Authority. 1 vol.

Schmidt, D.C., et al., eds. 1984a. Access and transmission corridor aquatic investigations (July - October 1983). Parts 1 and 2. Alaska Dept. of Fish & Game, Anchorage, AK. Susitna Hydro Aquatic Studies. Report 4. Report for Alaska Power Authority. 1 vol.

__________. 1984b. Resident and juvenile anadromous fish investigations (May - October 1983). July 1984. Alaska Dept. of Fish & Game, Anchorage, AK. Susitna Hydro Aquatic Studies. Report 2. Report for Alaska Power Authority. Document 1784. 1 vol.

__________. 1984c. Resident and juvenile anadromous fish investigations (May - October 1983). Parts 1-7. Alaska Dept. of Fish & Game, Anchorage, AK. Susitna Hydro Aquatic Studies. Report 2. Report for Alaska Power Authority. 1 vol.

Sundet, R., and M. Wenger. 1984. Resident fish distribution and population dynamics in the Susitna River below Devil Canyon. Draft report. Part 5 of D.C. Schmidt, S.S. Hale, and D.L. Crawford, eds. Resident and juvenile anadromous fish investigations (May - October 1983). Alaska Dept. of Fish & Game, Anchorage, AK. Susitna Hydro Aquatic Studies. Report 2. 1 vol.

Trihey, E.W. 1982. Preliminary assessment of access by spawning salmon to side slough habitat above Talkeetna. Report for Acres American, Inc. Anchorage, AK. 26 pp.

__________. 1983. Preliminary assessment of access by spawning salmon into Portage Creek and Indian River. Susitna Hydro Aquatic Studies. Report for the Alaska Power Authority. Anchorage, AK. 63 pp.

U.S. Fish & Wildlife Service. 1952. A preliminary statement of fish and wildlife resources of the Susitna Basin in relation to water development projects.

__________. 1954. A progress report on the fishery resources of the Susitna River Basin. Juneau, AK.

__________. 1957. Progress report, 1956 field investigations Devil Canyon Damsite, Susitna River Basin. Juneau, AK.

U.S. Fish & Wildlife Service. 1959a. Progress report, 1957 field investigations Devil Canyon Damsite and reservoir area, Susitna River Basin. Juneau, AK.

__________. 1959b. 1958 field investigations Denali and Vee Canyon Damsites and reservoir areas, Susitna River Basin. Juneau, AK.

__________. 1960. A detailed report on fish and wildlife resources affected by the Devil Canyon Project. Bureau of Commercial Fisheries, Juneau, AK.

__________. 1965. A detailed report on fish and wildlife resources affected by Vee Project, Susitna River, Alaska. Juneau, AK. 16 pp.

Usinger, B.G. 1956. Aquatic insects of California. University of California Press, Berkeley, CA. 508 pp.

Wangaard, D.B., and C.V. Burger. 1983. Effects of various water temperature regimes on the egg and alevin incubation of Susitna River chum and sockeye salmon. Final report. National Fishery Research Center, U.S. Fish & Wildlife Service, Anchorage, AK. 43 pp.

Wiens, J.A. 1978. Nongame bird communities in northwestern coniferous forests. Pages 19 to 31 in R.M. DeGraaf, ed. Proceeding of the workshop on nongame bird habitat management in the coniferous forests of the western United States. U.S. Forest Service General Technical Report PNW-64. Portland, OR.

Woodward-Clyde Consultants. 1984. Fish mitigation plan. Alaska Power Authority. Susitna Hydroelectric Project. Report for Harza-Ebasco Susitna Joint Venture. 1 vol.

Woodward-Clyde Consultants, and Entrix, Inc. 1985. Fish resources and habitats in the middle Susitna River. Draft final report. Anchorage, AK. Alaska Power Authority. Susitna Hydroelectric Project. Instream Flow Relationships Report Series. Technical Report 1. Report for Harza-Ebasco Susitna Joint Venture. 159 pp.

Ziebell, C.D. 1960. Problems associated with spawning and growth of salmonids in northwest watersheds. Page in Seventh Symposium on Water Pollution Res. U.S. Dept. of Health, Education, and Welfare. Portland, OR.