PRELIMINARY DRAFT

IMPACT ASSESSMENT TECHNICAL MEMORANDUM

VOLUME II: APPENDICES

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APPENDIX A: FISH RESOURCE

INTRODUCTION

Existing information on Susitna River fish resources is relatively extensive but weighted toward salmon. The Susitna basin as a whole is a major producer of salmon in Cook Inlet; hence, salmon have drawn considerabe research effort. Tasks 1 and 2 respectively provide an overview of basinwide salmon escapements and the time of occurrence of their major life phases. Information on all species is more complete for the open water season than for winter. A synopsis of available information follows.

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 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 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).

Table 1. 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 2. Susitna River Salmon Phenology.

	HABITAT	DATE	
		RANGE	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 2. Susitna River Salmon Phenology.
(cont'd)

	HABITAT	DATE	
		RANGE	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.

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 throughout the deeper portions of aquatic environments. Susitna River long-nose 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.

INSERT FIGURE 1

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 3). 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 3). 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 4). 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.

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 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).

Table 3. Peak Salmon Survey Counts Above Talkeetna for Susitna River Tributary Streams.

STREAM	SURVEY DISTANCE	Coho 1974	Coho 1976	Coho 1981	Coho 1982	Coho 1983	Coho 1984	Chinook 1975	Chinook 1976	Chinook 1977	Chinook 1978	Chinook 1979	Chinook 1981	Chinook 1982	Chinook 1983	Chinook 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 3. 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 3. 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.

Table 4. 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	670	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.

Spawning habitat quality apparently varies greatly between sloughs as, in the last four years, the majority (>88%) of chum salmon spawners counted were in 10 of the 34 (tables 4 and 5). 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 4).

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).

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

Table 5. 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.

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.

In the Susitna River, salmon smolt outmigration generally occurs from mid-May through August (Schmidt et al. 1984). River ice breakup generally precedes a large part of the initial chum and pink salmon fry outmigration period. There are few data available on pink salmon outmigration, but this activity is believed to occur between mid-May and mid-June, peaking in early June. Outmigrating chum fry occur in the river mainstem from mid-May to mid-August, peaking in June. Coho, chinook, and sockeye juveniles outmigrate from mid-May to early October, with peaks occurring from June through August.

In addition to salmon smolt outmigration, there is also a migration between habitats as both resident and juvenile anadromous fish redistribute themselves into slough, side channel and mainstem habitats for overwintering. These emigrations generally peak in August for chinook and coho salmon (Schmidt et al. 1984). Rainbow trout and Arctic grayling generally move out of tributaries to overwintering areas in late August through September (Sundet and Wenger 1984).

Timing of smolt entrance to the sea is believed to influence survival rates. Several hatchery studies (Bilton 1978; Washington 1982) found that optimal size varied with time of release; e.g., maximum return of adult salmon in one study resulted when smolts weighing about 20g. a piece were released just prior to the summer solstice (Bilton 1978). Bilton (1978) found very large male smolts did not migrate at all, becoming jacks.

APPENDIX B: SYNOPSIS OF THE WATER TEMPERATURE DATA BASE

OVERVIEW

Temperature data for waters in the Susitna Basin have been collected by three different groups: the U.S. Geological Survey (USGS), Alaska Department of Fish and Game (ADF&G), and R&M Consultants. Prior to the 1980 field season, the only continuous temperature recorders were at three mainstem Susitna sites operated by the USGS since the mid-1970s. Of the new sites added specifically for the Susitna hydroelectric project, the majority are concentrated in the Watana-to-Sunshine reach of the river. Temperature data collection below the Parks Highway bridge (RM 83.5) was increased during the 1984 field season by ADF&G on request from AEIDC to provide additional data in the event that lower river temperature simulations were undertaken. Table 1, showing the available temperature data used for initial monthly stream temperature simulations (summers 1980 to 1982), illustrates the density and temporal consistency of these data.

There are a number of problems in the available water temperature data set with regard to its usefulness for temperature modeling. These primarily lie with the short period of record available and in the reliability of some of these data. These problems are discussed below.

Short length of record - Collection of most of the data needed for temperature modeling began in 1980. In order to predict instream temperatures covering a large range of meteorologic conditions, representative years were selected for simulation, some preceding 1980. For these early years, temperature data were synthesized using regression techniques (AEIDC 1983, 1984).

Table 1. Monthly stream temperatures, usable data June to September 1980, 1981, 1982. (From AEIDC 1983).

Mainstem/Tributary River Mile	River Name/Description	Number of Days											
		1980				1981				1982			
		J	J	A	S	J	J	A	S	J	J	A	S
10.1/0.5	Alexander Cr.					25	31	31	30				
10.1	Susitna above Alexander Cr.					25	31	31	1				
25.8	Susitna R., Su Station	30	31	31	30					10	--	--	--
28.0/2.0	Yentna R.					26	31	31	14				
28.0/4.0	Yentna R.									23	31	31	27
29.5	Susitna R. above Yentna R.									20	31	31	30
32.3	Susitna R. above Yentna R.					25	31	31	12				
40.6/1.2	Deshka R.					21	31	31	30				
49.8/4.9	**Deception Cr. near Willow	5	8	--	8								
49.8/11.6	**Willow Cr. near Willow	5	18	--	22								
50.5/1.0	Little Willow Cr.					7	31	31	30				
50.5	Susitna R. above Little Willow Cr.					7	31	31	24				
61.2	Susitna R. above Kashwitna R.					--	--	2	27				
77.2/0.0	Montana Creek					19	24	--	1				
77.5	Susitna R. above Montana Cr.					19	3	2	30				
83.8	Susitna R., east shore--Parks Hwy.					20	14	--	--	--	--	--	30
83.9	Susitna R., west shore--Parks Hwy.									23	9	10	30
97.0	Susitna R.--LRX1									17	--	--	--
97.2/5.0	**Talkeetna R. near Talkeetna	--	1	--	--								
97.0/1.0	Talkeetna R.					10	31	31	30				
97.2/1.5	Talkeetna R.									17	1	31	30
98.5/18.0	**Chulitna R. near Talkeetna	1	1	1	--					27	30	3	20
98.6/0.5	Chulitna R.					11	17	--	20				
98.6/0.6	Chulitna R.									17	--	10	25
103.0	Susitna R.--TKA fishwheel					11	10	19	22	7	28	31	25
113.0	Susitna R.--LRX 18									--	25	31	30
120.7	Susitna R.--Curry									--	25	31	30
126.0	Susitna R.--Slough 8A									--	4	31	30
126.1	Susitna R.--LRX 29									--	22	31	30
129.2	Susitna R.--Slough 9									--	4	31	24
130.8	Susitna R.--LRX 35									--	23	4	17
131.3	Susitna R. above 4th of July Cr.					15	31	30	26				
136.5	**Susitna R. near Gold Cr.	30	31	31	30	--	8	25	29	--	--	12	30
136.8/0.0	Gold Creek					11	7	3	--				
138.6/1.0	Indian R.									23	31	4	28
138.6/0.1	Indian R.					--	10	25	14				
138.7	Susitna R. above Indian R.					--	11	29	16				
140.0	Susitna R.--Slough 19					--	--	5	13				
140.1	Susitna R.--LRX 53									--	--	23	--
142.0	Susitna R.--Slough 21					--	--	4	29	--	4	31	30
148.8	Susitna R. above Portage Cr.					--	13	31	29				
148.8/0.1	Portage Cr.									13	26	28	--
181.3/0.0	Tsusena Cr.									12	7	31	30
184.4	*Susitna R. at Watana dam site					30	--	31	30				
194.1/0.0	Watana Cr.									11	31	15	16
206.8/0.0	Kosina Cr.									4	31	17	12
223.7	**Susitna R. near Cantwell	--	--	--	--					27	31	31	22
231.3/0.0	Goose Creek									--	31	31	30
233.4/0.0	Oshetna Creek									--	31	31	30

*R&M gages

**USGS gages

All others are ADF&G gages

Table 1 Cont. Monthly stream temperatures, usable data June to September 1980, 1981, 1982. (From AEIDC 1983).

Mainstem/Tributary River Mile	River Name/Description	Number of Days											
		1980				1981				1982			
		J	J	A	S	J	J	A	S	J	J	A	S
10.1/0.5	Alexander Cr.					18	31	31	26				
10.1	Susitna above Alexander Cr.					18	31	27	--				
25.8	Susitna R., Su Station	30	31	31	30					--	--	--	--
28.0/2.0	Yentna R.					20	31	31	--				
28.0/4.0	Yentna R.									14	31	31	24
29.5	Susitna R. above Yentna R.									10	31	31	30
32.3	Susitna R. above Yentna R.					18	31	29	6				
40.6/1.2	Deshka R.					10	31	31	30				
49.8/4.9	**Deception Cr. near Willow	--	--	--	2								
49.8/11.6	**Willow Cr. near Willow	--	13	--	4								
50.5/1.0	Little Willow Cr.					--	31	31	28				
50.5	Susitna R. above Little Willow Cr.					--	31	31	10				
61.2	Susitna R. above Kashwitna R.					--	--	--	22				
77.2/0.0	Montana Creek					6	17	--	--				
77.5	Susitna R. above Montana Cr.					8	--	--	30				
83.8	Susitna R., east shore--Parks Hwy.					8	--	--	--	--	--	--	30
83.9	Susitna R., west shore--Parks Hwy.									14	--	--	30
97.0	Susitna R.--LRX 1									14	--	--	--
97.2/5.0	**Talkeetna R. near Talkeetna	--	--	--	--								
97.0/1.0	Talkeetna R.					--	31	31	30				
97.2/1.5	Talkeetna R.									14	--	31	30
98.5/18.0	**Chulitna R. near Talkeetna	--	--	--	--					24	30	--	10
98.6/0.5	Chulitna R.					--	3	--	12				
98.6/0.6	Chulitna R.									14	--	--	18
103.0	Susitna R.--TKA fishwheel					--	--	17	13	--	21	31	16
113.0	Susitna R.--LRX 18									--	17	31	30
120.7	Susitna R.--Curry									--	17	31	30
126.0	Susitna R.--Slough 8A									--	--	29	30
126.1	Susitna R.--LRX 29									--	13	31	30
129.2	Susitna R.--Slough 9									--	--	31	20
130.8	Susitna R.--LRX 35									--	--	--	6
131.3	Susitna R. above 4th of July Cr.					--	31	26	22				
136.5	**Susitna R. above Gold Cr.	30	31	31	30	--	--	24	24	--	--	--	30
136.8/0.0	Gold Creek					--	--	--	--				
138.6/1.0	Indian R.									16	31	--	--
138.6/0.1	Indian R.					--	--	17	8				
138.7	Susitna R. above Indian R.					--	--	21	10				
140.0	Susitna R.--Slough 19					--	--	--	--				
140.1	Susitna R.--LRX 53									--	--	23	--
142.0	Susitna R.--Slough 21					--	--	--	28	--	--	31	30
148.8	Susitna R. above Portage Cr.					--	--	31	28				
148.8/0.1	Portage Cr.									--	15	25	--
181.3/0.0	Tsusena Cr.									--	31	31	30
184.4	*Susitna R. at Watana dam site					30	--	31	30				
194.1/0.0	Watana Cr.									--	31	--	6
206.8/0.0	Kosina Cr.									--	31	3	--
223.7	**Susitna R. near Cantwell	--	--	--	--					24	31	31	15
231.3/0.0	Goose Creek									--	31	31	30
233.4/0.0	Oshetna Creek									--	15	31	24

*R&M gages

**USGS gages

All others are ADF&G gages

Discontinuous records - Most of the temperature recorders used for the Susitna project are self-contained units, Omnidata Datapods and Ryan Thermographs. These instruments are designed for infrequent service, and thus are infrequently visited once they are in service. When these units malfunction, data may be lost for periods of two weeks or more. Throughout the study there were instances of data gaps resulting both from instrument failure and from tampering by people and wildlife.

Inaccurate data - There are a number of errors inherent in the data itself. The first is associated with the instrument. The accuracy of Datapods and Thermographs is ± 0.1 and ± 0.6 C respectively, provided the instruments are properly calibrated. Improper recorder placement may also lead to error. The USGS mainstem Susitna temperature recorder at Gold Creek was initially located in the plume of Gold Creek, inaccurately recording mainstem temperatures. The probe was later moved.

Further problems result from the fact that the recorders must be anchored to the shore. Thus, they lie close to shore possibly in the plume of a tributary or in a quiescent area unrepresentative of true mainstem temperatures. Even under the best conditions, when a recorder is properly calibrated and not located in a quiescent area or in a tributary plume, it is only recording the temperature at a single location. Temperatures across a river transect often show large variation; Schmidt (1984) found differences as high as 2.8 C across transects below the Talkeetna River confluence (RM 92.7), while the USGS (Bigelow, pers. comm.) reports deferences as high as 3.3 C across a transect at Sunshine (RM 83.5).

TEMPERATURE MODELS

DYRESM

The reservoir temperature simulation model, DYRESM, is used to predict the thermal stratification of both reservoirs under various meteorologic and power load demand conditions. The original model (Imberger and Patterson 1981) has been modified with the inclusion of an ice cover subroutine developed for Canadian lakes (Harza-Ebasco 1984). Results from DYRESM, coupled with those from the reservoir operations model, provide predictions of reservoir release volumes and temperatures at the downstream-most dam. These values serve as upstream boundary conditions for the stream temperature model.

Calibration.

The DYRESM model was calibrated for Alaska climatic conditions using Eklutna Lake data for the period June through December 1982 (Harza-Ebasco 1984). Eklutna is a glacial lake tapped for hydroelectric power. The main differences between it and the proposed reservoirs are the design of the intake structures, bathymetric shape near the intakes, and local meteorology.

Results from the Eklutna Lake study (Harza-Ebasco 1984) show accurate prediction of both summer and winter outflow temperatures to ± 1 C. Some instances of temporal differences of approximately 2 C were seen during periods of high summer winds. These differences were attributed to difficulty in modeling wind-induced mixing and internal wave motion near the intake structure using a one-dimensional model (Harza-Ebasco 1984).

Reliability.

DYRESM is a one-dimensional model, predicting only a vertical temperature distribution. This assumption is most seriously taxed during periods of high wind which induce mixing in the epilimion. It is treated in the model by corrections which affect deeper surface mixing (APA 1984). This problem is of some concern with both reservoir simulations, as wind speed predictions at the proposed reservoir surface level are somewhat speculative.

In order to maintain the ability for selected reservoir temperature releases, it is essential that the reservoirs' thermal stratification remain intact in the face of both wind-induced surface mixing and hydraulic mixing near the intake structures. The Federal Energy Regulatory Commission (FERC) (1984) predicted a weak thermal stratification of the Watana reservoir and questioned the ability of the intake structure to allow selective temperature withdrawal. FERC noted the same concern with the Devil Canyon reservoir, estimating cooler summer temperatures than those predicted by DYRESM. APA (1984) acknowledges that the stratification of both reservoirs would be weak relative to those in temperate climes, but maintains that the stratification should be strong enough around the intake structures to maintain stratification except during spring and fall turnover periods.

In the event that the thermal stratification could not be maintained, the ability to release the warmest available summer and coldest winter waters (i.e., those in the uppermost thermal strata) would be lost. Release temperatures throughout the year would be closer to the mean annual reservoir temperature, approximately 4 C, limiting its effectiveness as a mitigation measure.

Synopsis of Results.

DYRESM has been run for both a one- and two-dam configuration for myriad combinations of power demand, flow requirements, meteorology, intake operating rules and intake design. Consequently, generalizing these results is difficult and possibly misleading. Results from these DYRESM simulations are available in AEIDC (1984) for Case C simulations under the "inflow matching" operating rule. Results under Case E-VI flow requirements have not been published; however, river water temperatures immediately below the proposed Devil Canyon dam face (RM 150) are available in AEIDC (1985).

The ranges of outflow temperatures under the various combinations are shown for summer (here defined as water weeks 36-52, June 3 - September 30) and winter (weeks 5-30, October 29 - April 28) in Tables 2 and 3. Note that weeks during the spring and fall transitional periods are not represented in these tables. The number of simulations run for each of the categories vary. As few as one and as many as five seasons of meteorologic data have been run for some categories; different intake structure designs are represented in the table as well. Consequently, making direct comparisons between runs is not recommended.

Table 2. Synopsis of simulated summer (weeks 36-52) release temperature ranges (C).

Case C

Intake Operation	Watana 1996	Watana 2001	Devil Canyon 2002	Devil Canyon 2020
Warmest Water	--	2.1 - 12.6	4.6 - 10.0	--
Inflow Matching	2.4 - 11.2	2.4 - 11.1	3.2 - 10.2	3.0 - 11.2

Case E-VI

Intake Operation	Watana 1996	Watana 2001	Devil Canyon 2002	Devil Canyon 2020
Warmest Water	--	6.1 - 12.1	4.3 - 8.8	--
Inflow Matching	--	5.4 - 11.5	4.3 - 8.6	--

Table 3. Synopsis of simulated winter (weeks 5-30) release temperature ranges (C).

Case C

Intake Operation	Watana		Devil Canyon	
	1996	2001	2002	2020
Warmest Water	1.0 - 3.5	0.7 - 4.2	2.7 - 5.8	--
Inflow Matching	0.3 - 4.2	0.3 - 4.3	0.5 - 5.6	0.6 - 2.2

Case E-VI (winter of 1981-82 only)

Intake Operation	Watana		Devil Canyon	
	1996	2001	2002	2020
Warmest Water	--	2.8 - 4.1	2.7 - 5.5	--
Inflow Matching	--	2.3 - 4.1	2.2 - 5.5	--

In general terms, simulated summer release temperatures are cooler from the Devil Canyon reservoir than from the Watana reservoir. In later demand years under two-dam operation (represented by the year 2020); however, cone valves are used less frequently and warmer summer release temperatures result. During winter, the reverse occurs with warmer release temperatures resulting from two-dam operation.

SNTEMP

The SNTEMP instream temperature model has been used to simulate mainstem Susitna River temperatures in the Watana-to-Sunshine reach. Discussions of the model and its application to this project are available in Theurer et al. (1983) and AEIDC (1983, 1984).

As with all simulation models, SNTEMP is governed by a large set of assumptions (AEIDC 1983, 1984). Three of these are especially important when considering the applicability of model results.

1. One-dimensionality. The temperature at any given cross-section is represented by a single value, presumed to be the mean temperature along that cross-section. As mentioned previously, thermal variation across a transect may be greater than 2 C.

2. Instantaneous mixing of tributaries. The mass and associated heat content of influent tributaries are instantaneously mixed by the model at the tributary confluences. There is no accounting for the temperature plumes from influent tributaries found in the river system.

3. No ice cover. SNTEMP simulates openwater conditions throughout the year. This is of concern in the spring when simulated water temperatures rise in response to increased solar radiation and warmer air temperatures. Under an ice cover, water temperatures would warm much slower. Thus, simulated temperatures during this period are warmer than realistic until after breakup occurs.

Additional note should be made of the estimation methods employed for influent tributary temperatures. A temperature regression function for middle river tributaries was developed using data from three tributary sites (AEIDC 1984). Likewise, regression functions are used to predict water temperatures of the large tributaries (the Talkeetna and Chulitna rivers) when data are not available. As these two rivers contribute large volumes of flow to the mainstem Susitna, predicted temperatures below the three-river confluence must be given careful scrutiny.

The influence of mainstem river temperatures on the temperature of groundwater influent to adjacent sloughs has not been fully resolved at this time. Mean river temperatures are believed to drive nearby groundwater temperatures; thus, changes in mean annual mainstem temperatures (expected to be slight) may also be felt in sloughs. Of special concern is whether the timing of mainstem temperature changes would be felt in sloughs during key fish use periods, notably egg incubation. Hydrology studies on these sloughs note the variation in response between different sloughs; variation in temperature changes would likewise be expected. Additional study on this topic is presently being done by Harza-Ebasco.

Calibration.

SNTEMP was calibrated for the period of June through September 1981 and 1982 (AEIDC 1983). Calibration during the winter period is moot, as natural water temperatures are uniformly 0 C. Model validation was done on a monthly (AEIDC 1983) and weekly basis (AEIDC 1984). The 90% confidence interval (using the Z - statistic) for weekly water temperatures for water years 1981-1983 is 1.0 to 0.8 C.

Reliability.

To predict mainstem water temperatures, SNTEMP relies on upstream boundary conditions predicted by another simulation model (DYRESM), influent tributary temperatures estimated using regression techniques on short records of data, and meteorologic data extrapolated from the record at Talkeetna. The model has been calibrated using published data which is representative, but not infallible. Consequently, the resultant temperature predictions include the possibility of a variety of combined errors.

While the ability of SNTEMP to predict absolute temperatures is uncertain, much greater reliance may be placed on the relative temperature differences resulting between different simulation scenarios. Thus, the ability to assess the temperature changes resulting from operation of the project remains good.

Synopsis of Results.

SNTEMP results are summarized for Case C simulations ("inflow matching" intake operation only) in AEIDC (1984) and for Case E-VI and Case C ("warmest water" intake operation) in AEIDC (1985). These results are presented at three mainstem locations (RM 150, 130, and 100) in tabular and graphical form, comparing methods of powerhouse intake operation and power load demands. The reader is referred to these sources in lieu of extensive discussion here. A brief summary of simulation results and a table of mean summer temperatures (Table 10), both at a representative middle river location (RM 130) are included here. As these results are included to show relative differences between methods of operation, a single summer season (1982) is used, which represents normal air temperatures and hydrologic conditions.

Two general observations should first be noted concerning river temperatures under with-project conditions relative to natural conditions. First, the magnitude of variation between winter and summer temperatures would be lessened; winter temperatures would be warmer than natural and summer temperatures cooler. Second, there would be a general delay of the normal temperature variation pattern; cooling would occur later than normal in the fall, and warming would occur later in the spring/summer. A synopsis of summer and winter simulation results follow.

As noted previously, no temperature simulation has been done downstream of the Parks Highway bridge. This is largely due to the impracticality of modeling the lower river with the limited available data and the limitation of a one-dimensional model in a region of river with very distinct temperature plumes resulting from the inflowing Chulitna and Talkeetna rivers.

Under natural conditions, flows from the three rivers remain relatively distinct, mixing slowly until approximately RM 75.0 (Schmidt 1987). The effect of lower with-project flows on the rate of mixing is uncertain; however, slightly cooler summer temperatures from the Susitna will probably not substantially alter the mainstem temperatures below RM 75.0.

Table 4. Simulated mean summer 1982 river temperatures for water weeks 31-52 at RM 130.

Dam Configuration	Load Demand	Case C Inflow Matching	Case C Warmest Water	Case E-VI Inflow Matching	Case E-VI Warrant Water
Watana Only	1996	7.8	NR	NR	NR
	2001	7.7	8.3	7.7	8.3
Watana/ Devil Canyon	2002	7.0	6.9	6.6	6.7
	2020	7.2	NR	NR	NR
Natural		8.8			

NR = not run for this case

Summer. Simulated summer temperatures are cooler then natural temperatures under all project configurations, flow requirements, and methods of intake operations. Simulated river temperatures under two-dam operation are cooler than under Watana only. This is a result of two conditions: generally cooler reservoir release temperatures, and 30 miles less river available for reservoir releases to warm through normal heat-transfer processes.

Simulated mean summer river temperatures tend to be cooler under increased load demands. This trend, however, is contradicted under the Devil Canyon operation scenario for 2020, as the higher power demand results in fewer cold-water non-power releases through the cone valve structures. There is an additional tendency with increasing load demands for delaying both summer warming and fall cooling. Differences in mean summer temperatures between Case C and Case E-VI simulations are negligible under a Watana-only configuration and only slightly cooler (less than 0.5 C for any set of conditions at RM 130) for Case E-VI under the two-dam project.

Winter. The simulated selection of water from the thermally stratified reservoirs during the winter is based in part on meeting desired ice conditions downriver. While releasing near 0 C water during the winter may be an option in some cases, resulting ice conditions with the ten-fold increased flow may be devastating. In such cases, releasing the warmest available water in order to suppress ice formation may be desirable. Thus, the gauge of judging with-project summer temperatures, deviation from natural temperatures, is not applicable during the winter. For a complete discussion of river temperature/ice simulations, the reader is referred to Harza-Ebasco (1984, 1985a, 1985b).

In most general terms, reservoir releases during the winter (water weeks 5 through 30) range from 0.3 C to 5.8 C. Release waters begin cooling immediately once exposed to the cold air temperatures. With increased load demands in later years of operation, larger amounts of water would be released requiring longer distances to cool to 0 C. Under a single-dam configuration, 30 additional miles of river are available for this cooling process to occur.

APPENDIX C: SYNOPSIS OF SALMON LIFE HISTORY WITH RESPECT TO TEMPERATURE

As an aid to defining the extent of possible effects on fish from with-project temperature changes, the literature was searched for pertinent information on the influence of temperature on migration, spawning, alevin and juvenile behaviors, and on incubation success and the smoltification process. Interpretation and subsequent application of the very large body of information on Pacific salmon to this analysis is confounded by the fact that it is specific to a vast number of drainages stretching over nearly 20 degrees of latitude. Timing of major physiological and behavioral characteristics are shaped by genetic selection and are specific to individual drainages (and, often, portions of given drainages) somewhat constraining the applicability of this information to the Susitna Drainage. A synopsis of this information follows.

ADULT INMIGRATION

Upstream migration of salmon is closely related to the temperature regime characteristic of each spawning stream (Sheridan 1962). The reported temperatures at which natural migration occurs vary between species and location but appear to be influenced by latitude. In general, average annual freshwater temperatures are progressively cooler with increasing latitude (Wetzel 1975). At latitudes above 55°N, inmigrating chinook, coho, sockeye, and chum salmon have been observed in streams having water temperatures of 4 C or colder (Bell 1983).

Temperatures above the upper tolerance range have been reported to stop fish migration (Bell 1960). The upper tolerance range for Pacific salmon is reported to be between 20 to 24 C (Bell 1980; Reiser and Bjornn 1979). Temperatures between 6 and 6.5 C reported by stopped pink salmon inmigration to the Main Bay Hatchery in Prince William Sound (Krasnowski 1984). At these temperatures, pink salmon were seen milling in seawater which as at a temperature between 10 and 12 C (Krasnowski 1984). When the hatcheries raceway water temperature was artificially raised to 8.5 C, the salmon quickly entered the holding pond (Krasnowski 1984).

Adult salmon throughout the Talkeetna to Devil Canyon reach experience natural water temperatures ranging from approximately 2.5 to 16 C during the chinook inmigration, 4 to 15 C during the coho inimigration, and 5 to 16 C during the pink, chum, and sockeye inmigration (AEIDC 1984).

ADULT SPAWNING

Spawning of adult Pacific salmon has been reported to occur in water temperatures ranging from approximately 4 to 18 C, although the preferred temperature range for all five North American species is reported by McNeil and Bailey (1975) to be between 7 to 13 C. Chum salmon have been observed spawning in upper Susitna mainstem habitats at temperatures as cold as 3.3 C (ADF&G 1983b).

Burbot and round whitefish are the most numerous species using mainstem habitats for spawning. Burbot is one of the few species of freshwater fish to spawn in winter. Elsewhere, burbot spawning has been observed to take place in water between 0.5 to 1.5 C (Scott and Crossman 1973; Alabaster and Lloyd 1982). Temperatures between 0 and 0.7 C were observed in Susitna River mainstem burbot spawning areas in 1983 (ADF&G 1983c). Round whitefish spawning has been observed at temperatures between 0 and 4.5 C (Scott and Crossman 1973; Bryan and Kato 1975). This species is believed to spawn in the Susitna River during October while water temperatures are dropping rapidly.

EMBRYO DEVELOPMENT

Compared to other life history phases, embryo development is perhaps the most influenced by water temperature. Temperature ranges that cause no increased embryo motality are much narrower than those for adults (Alabaster and Lloyd 1982). In the freshwater species for which data on embryonic development are available, the preferred range of temperatures is 3.5 to 11.1 C (Alabaster and Lloyd 1982). Generally, the lower and upper temperature limits for successful initial incubation of salmon embryos are 4.5 and 14.5 C, respectively (Reiser and Bjornn 1979). In laboratory studies conducted in Washington (Combs 1965) and from a literature review conducted by Bams (1967), salmon embryos are reportedly most vulnerable to temperature stress before closure of the blastopore, which occurs at about 140 accumulated Celsius temperature units. (A temperature unit is one degree above freezing experienced by developing fish embryos per day.) After the period of initial sensitivity to low temperatures has passed (approximately 30 days at 4.5 C), embryos and alevins can tolerate temperatures near 0 C (McNeil and Bailey 1975).

From his work on Sashin Creek in southeast Alaska, Merrell (1962) suggested that pink salmon embryo survival may be related to water temperatures during spawning. McNeil (1969) further examined Sashin Creek data and discussed the relationship between initial incubation temperature and survival. These two investigations determined that embryos exposed to cooler spawning temperature experienced greater incubation mortality than embryos which began incubation at warmer temperatures. Abnormal embryonic development could occur if, during initial stages of development, embryos are exposed to temperatures below 6 C (Bailey 1983). Bailey and Evans (1971) reported an increase in pink salmon embryo mortalities when initial incubation water temperatures were held below 2 C during this initial incubation period.

Of the species found in the Susitna River, the most sensitive embryos to temperature change are those of burbot with a tolerance range of only 0 to 3 C and a perferred range of 0.5 to 1.0 C (Alabaster and Lloyd 1982). The next most sensitive would be the coregonids followed by the salmonids, of which the most sensitive appear to be pink salmon. The most tolerant species would be those spawning in quite shallow waters experiencing diurnal fluctuations of temperature (Alabaster and Lloyd) 1982).

ALEVINS

Alevin intragravel movement rates are known to be influenced by environmental temperatures. Early in their development, alevins move downward in their natal redds where they remain until shortly before emerging (Dill 1967). Both the descending and ascending rates of movement are primarily influenced by temperature (Bams 1969); size of gravel interstices, dissolved gases, gravel size, and sedimentation also effect movement rates (Bams 1967; Hausle and Coble 1976; Witzel and MacCrimmon 1981; Fast et al. 1982), but temperature is the chief determinant (Bams 1967).

REARING

Water temperature affects immature fish metabolism, growth, food capture, swimming performance, and disease resistance. Juvenile salmonids can usually tolerate a wider range of water temperatures than embryos. They can also survive short exposure to temperatures which would be ultimately lethal, and can live for longer periods at temperatures at which they abstain from feeding (Alabaster and Lloyd 1982).

Juvenile salmon activity slows at water temperatures lower than 4 C; at these temperatures, fish tend to be less active and spend more time resting in secluded, covered habitats (Chapman and Bjornn 1969). In Carnation Creek, British Columbia, Bustard and Narver (1975) reported that at water temperatures below 7 C, fish stopped feeding and moved into deeper water or closer to objects providing cover. In Grant Creek near Seward, Alaska, juvenile salmonids were inactive at water temperatures of 1.0 to 4.5 C inhabiting cover afforded by streambed cobbles and other large gravels (AEIDC 1982).

Generally, the tolerable temperature range for rearing salmonids is between 4 and 16 C. However, rearing juvenile salmonids ahve been observed in side sloughs in the upper Susitna River where, from June through September, water temperatures were between 2.4 and 15.5 C (ADF&G 1983d), a slightly wider range. Juvenile coho and chinook salmon have been successfully reared in Alaska hatcheries at temperatures between 2 and 4 C (Pratt 1984). In an experiment at the U.S. National Marine Fisheries Service Auke Bay Laboratory, coho salmon grew temperatures of 0.2, 2 and 4 C. No mortality was seen in unfed fish held at these temperatures except for those at 4 C (Koski 1984).

This suggests that at temperatures at and above 4 C, coho are sufficiently active to require food, whereas below this temperatures they are inactive and do not require food.

SMOLTIFICATION

Salmon fry are physiologically adapted to life in fresh water environments, and before they can successfully undertake life at sea (and, hence, mature) they must undergo a comples phsiological and morphological transformation. This process is termed smoltification. The overall controlling force is endogenous and has the characteristics of a circannual rhythm (Hoar 1976; Wedemeyer et al. 1980). Timing of transformation is dependent on numerous environmental factors which influence metabolism and which act as behavioral releasers (Schreck 1982).

Photoperiod is the major environmental factor influencing smolt transformation in Atlantic salmon, steelhead trout, and coho and sockeye salmon (Wagner 1974; Wedemeyer et al. 1980). Photoperiod is apparently subordinate to other as yet unidentified environmental factors in chinook salmon (clarke et al. 1981). In species where photoperiod is controlling, its chief influence appears to be that of synchronizing endogenous rhythm with natural season change (Groot 1982). Temperature affects the smoltification process by regulating physiological response to photoperiod; it causes effects to occur sooner the higher the temperature or later the lower temperature (Clarke et al. 1981). In short, temperatures exerts influence on the smolting process by controlling growth, and it regulates both the magnitude and duration of the smolting process (Clarke et al. 1978; Grau 1982; cf. Groot 1982).

Na^+K^+ ATPase gill activity has been associated with the smolt transformation process and is believed to be an indicator of physiological readiness for life at sea (Wedemeyer et al. 1980). This activity can be correlated with smolt size, but, large smolts do not necessarily display the highest level of activity (Wedemeyer et al. 1980). However, there does appear to be a minimum threshold size necessary for initiating the gill ATPase cycle (e.g. 80 to 90mm in spring run chinook and 90mm in coho) (Wedemeyer et al. 1980).

FRY/SMOLT OUTMIGRATION

Dispersal (migratory) movements of salmon fry may be categorized into one of three types: dispersal within their natal reproductive habitat, dispersal to nursery lakes, of dispersal to an estuary (Godin 1982). Natural incident light intensity appears to be the most important environmental variable influencing daily onset and termination of salmonid migratory movements (Godin 1982), but water temperature has at times been correlated with peak migration rates (Sano 1966; Coburn and McHart 1967; Thomas 1975). Presumably, this is due to increased fry mobility at higher temperatures (Godin 1982).

Northcoste (1962, 1969) has shown experimentally that temperature determines the direction of rainbow trout fry movements and Raymond (1979) has correlated juvenile chinook outmigrations from the Salmon River with sudden rises in water temperature. Temperature may interact with genetic factors to determine sockeye salmon (Raleigh 1971) and cutthroat trout (Raleigh and

Chapman 1971) upstream movement rates. Temperatures at or below 6 C seem to slow instream migrations of coho, cutthroat, and steelhead fry (Cederholm and Scarlett 1982); temperatures above 7 C stimulate chinook salmon to migrate (Raymond 1979).

Godin (1982) hypothesizes that the annual timing of gravel emergence and subsequent dispersal of salmonid fry to initial feeding habitats is determined genetically as a result of natural selection determined by predictable annual changes in environmental variables which include water temperature. Godin (1982) further argues that annual timing of dispersal is "...optimized evolutionarily by natural selection to maximize the fitness of individual fish." Solomon (1982) suggests that the role of increasing water temperatures in the ice-free season is in enhancing the physiological readiness of the fish for migration through stimulation of the endocrine system.

In the Susitna River, salmon smolt outmigration generally occurs from mid-May through August (Schmidt et at. 1984). River ice breakup generally precedes a large part of the initial chum and pink salmon fry outmigration period. There are few data available on pink salmon outmigration, but this activity is believed to occur between mid-May and mid-June, peaking in early June. Outmigrating chum fry occur in the river mainstem from mid-May to mid-August, peaking in June. Coho, chinook, and sockeye juveniles outmigrate from mid-May to early October, with peaks occurring from June through August.

In addition to salmon smolt outmigration, there is also a migration between habitats as both resident and juvenile anadromous fish redistribute themselves into slough, side channel and mainstem habitats for overwintering. These emigrations generally peak in August for chinook and coho salmon

(Schmidt et al. 1984). Rainbow trout and Arctic grayling generally move out of tributaries to overwintering areas in late August through September (Sundet and Wenger 1984).

Timing of smolt entrance to the sea is believed to influence survival rates. Several hatchery studies (Bilton 1978; Washington 1982) found that optimal size varied with time of release; e.g., maximum return of adult salmon in one study resulted when smolts weighing about 20g. a piece were released just prior to the summer solstice (Bilton 1978). Bilton (1978) found very large male smolts did not migrate at all, becoming jacks.

APPENDIX D: SEDIMENT TRANSPORT DATA BASE

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 1.

Table 1. 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

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 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 2.

R&M (1982b) also calculated reservoir sedimentation rates using assumed trap efficiencies (table 3). 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

Table 2. 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 3. 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

remaining 13 tributaries evaluated are predicted to either aggrade or degrade with-project, but without effects on fish access or other resources.

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 4. 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

Table 4. 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.

sufficient to carry out fines <.004 mm. However, coarser silt and fine sand entrained by overtopping water would settle in their stead (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.

APPENDIX E: SYNOPSIS OF 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 sediment 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 gravel interstices reducing water flow and, hence, oxygen availability. This may negatively affect invertebrates, (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.

APPENDIX F: WATER QUALITY DATA BASE

The main body of data describing the natural water quality characteristics of the Susitna River is found in the U.S. Geological Survey (USGS) "Water Resources Data for Alaska" annual report series. This information is summarized through 1981 in R&M Consultants, Inc. and L.A. Peterson and Assoc. (1981a, b). These data are collected routinely on a monthly basis by the USGS at its gauging stations located at Denali (1957-), Vee Canyon (1962-), and Gold Creek (1949-) on the upper and middle Susitna River; the Chulitna River (1958-); the Talkeetna River (1954-); and at its Sunshine (1971-) and Susitna stations (1955-) on the lower Susitna River. Data collected by R&M Consultants at Vee Canyon and Gold Creek from 1980-82 are summarized in R&M Consultants, Inc. (1982). Limited additional data for mainstem, slough, and tributary sites can be found in various Alaska Department of Fish and Game reports (ADF&G, Su-Hydro 1981).

Water quality data collected at Vee Canyon can be used to describe some of the chemical characteristics of the water that will flow into Watana reservoir (Table 1). The basic pattern these data present for the upper river is similar in most respects to the annual cycle displayed in the middle river for which a much more complete and longer data record is available. The most significant difference is the absence of dissolved gas supersaturation at Vee Canyon. Other minor differences (e.g., higher mean pH, potassium, and chemical oxygen demand levels in summer and a lower mean turbidity) can be attributed either to the influence of clearwater tributaries entering upstream of the station or to the relatively small number of data points available for analysis.

Table 1. Mean baseline water quality characteristics for upper Susitna River at Vee Canyon under summer (May-August) and winter (October-April) conditions.

Parameter (Symbol of Abbreviation)	Units of Measure	Summer USGS[1]	Summer R&M[2]	Winter USGS[1]	Winter R&M[2]
Total Suspended Solids (TSS)	mg/l	799	358	14	6.0
Turbidity	NTU	70	156	0	1.3
Total Dissolved Solids (TDS)	mg/l	94	98	136	141
Conductivity	(μmhos cm^{-1}, 25°C)	146	129	250	212
pH	pH Units	7.7	7.6	7.4	7.1
Alkalinity	mg/l as Ca CO_3	52	61	112	81
Hardness	mg/l as Ca CO_3	63	58	96	103
Sulfate (SO_4^{-2})	mg/l	14	6	13	14
Chloride (Cl)	mg/l	5.3	6.7	17	17.5
Dissolved Calcium (Ca^{+2})	mg/l	21	18	30	33
Dissolved Magnesium (Mg^{+2})	mg/l	2.7	2.4	3.8	5.2
Sodium (Na^{+})	mg/l	3.8	3.4	6.5	8.0
Dissolved Potassium (K^{+})	mg/l	3.5	2.3	3.7	5.2
Dissolved Oxygen (DO)	mg/l	11.5	11.9	12.6	13.1
DO (% Satu.ation)	%	99	101	97	98
Chemical Oxygen Demand (COD)	mg/l	20	20	9	10
Total Organic Carbon (TOC)	mg/l	--	--	--	2
True Color	pcu	10	70	--	15
Total Phosphorus	μg/l	Dissolved 60	140	40	Dissolved 50
Nitrate-Nitrogen as N (NO_3-N)	mg/l	0.20	0.14	0	0.30
Dissolved Cadmium (Cd)	μg/l	--	--	--	--
Dissolved Copper (Cu)	μg/l	--	--	--	--
Dissolved Iron (Fe)	μg/l	--	1.10	--	0.37
Dissolved Lead (Pb)	g/l	--	--	--	--
Dissolved Mercury (Hg)	μg/l	--	--	--	--
Dissolved Nickel (Ni)	μg/l	--	--	--	--
Dissolved Zinc (Zn)	μg/l	--	.07	--	--

1 R&M Consultants, Inc. 1982; R&M Consultants L.A. Peterson and Assoc. 1981.

2 R&M Consultants, Inc. 1982.

The water quality records for Gold Creek (RM 136) provide the best possible description of baseline conditions in the middle river and can also be used to approximate many characteristics of the Watana reservoir inflow (Table 2).

Natural water quality conditions the middle river change seasonally as a result of changes in mainstem flow and sediment content. During winter, surface flows average less than 2,000 cfs and are derived almost entirely from groundwater or outflow from the Tyone River system. Thus, total dissolved solids (TDS) and alkalinity, for example, are at their highest annual levels, while temperature, total gas concentrations, total suspended solids (TSS), turbidity, and the trace metals and phosphorus associated with inorganic particulates are at their lowest levels of the year. The maximum observed dissolved Cd, Cu, Hg, and Zn concentrations recorded at Gold Creek were 1, 5, 0.2, and 14 μg/l, respectively. Most of the riverbed surface area is covered in winter by thick ice and deep snow with the exception of peripheral channels bearing upwelling groundwater and channels carrying very fast moving mainstem water (velocity leads).

Although surface flow is low and water temperatures are between 0 and 4 C, benthic algal and invertebrate growth is taking place during this five- to six-month period and supporting a large percentage of the overwintering fish community of the system.

Breakup usually occurs in May following a brief (three to four week) spring transition period of increasing temperatures, lengthened photoperiod, and accelerating ice and snow melt. Middle river stream flow rapidly increases from approximately 5,000 cfs to 20,000 cfs, while fluctuating suspended sediment concentrations average approximately 360 mg/l (Peratrovich et al. 1982) generating mean turbidities of less than 50 NTU.

Table 2. Mean baseline water quality characteristics for middle Susitna River at Gold Creek under summer (May - September) and winter (October - April) conditions.

Parameter (Symbol or Abbreviation)	Units of Measure	Summer	Winter
Total Suspended Solids (TSS)	mg/l	740	12
Turbidity	NTU	126	<1
Total Dissolved Solids (TDS)	mg/l	93	154
Conductivity	(µmhos cm^{-1}, 25°C)	128	279
pH	pH units	7.3	7.5
Alkalinity	mg/l as $CaCO_3$	51	72
Hardness	mg/l as $CaCO_3$	64	98
Sulfate (SO_4^{-2})	mg/l	16	21
Chloride (Cl^{-1})	mg/l	5.5	22
Dissolved Calcium (Ca^{+2})	mg/l	20	30
Dissolved Magnesium (Mg^{+2})	mg/l	3.2	5.4
Sodium (Na^{+})	mg/l	4.1	11.3
Dissolved Potassium (K^{+})	mg/l	2.4	2.3
Dissolved Oxygen (DO)	mg/l	11.9	13.9
DO (% Saturation)	%	102	97
Chemical Oxygen Demand (COD)	mg/l	10.9	8.4
Total Organic Carbon (TOC)	mg/l	2.0	2.6
True Color	pcu	10	5
Total Phosphorus	µg/l	130	30
Nitrate-nitrogen as N (NO_3-N)[1]	mg/l	0.12	0.16

Table 2. (cont'd)

Parameter (Symbol or Abbreviation)	Units of Measure	Turbid (Summer)	Clear (Winter)
Total Recoverable Cadmium[2] [Cd(t)]	μg/l	1	-
Total Recoverable Copper [Cu(t)]	μg/l	65	ND
Total Recoverable Iron [Fe(t)]	μg/l	16,000	ND
Total Recoverable Lead [Pb(t)]	μg/l	50	ND
Total Recoverable Mercury [Hg(t)]	μg/l	0.12	0.04
Total Recoverable Nickel [Ni(t)]	μg/l	65	45
Total Recoverable Zinc [Zn(t)]	μg/l	50	50

ND = None Detected

Source: U.S. Geological Survey as summarized in R&M Consultants (1982).

[1] Data collected by R&M Consultants, 1980-82 (R&M Consultants 1982).

[2] All trace metals are U.S.G.S. data as summarized in R&M Consultants (1981); winter values are for Sunshine Station.

Under normal weather conditions, approximately 90% of the total annual streamflow occurs between May and September with maximal discharges in June, July, and August. These summer discharge maxima are typically between 30,000 and 40,000 cfs. These high summer flows, resulting largely from surface runoff and glacial melting in the headwaters, serve to dilute the dissolved solids load derived from bedrock and soil weathering. Thus, such parameters as TDS and alkalinity are at their lowest annual levels, while temperature, TSS, turbidity, total recoverable trace metals, and total phosphorus are at their highest annual levels.

Water entering Devil Canyon in summer is generally nearly saturated with dissolved gases (mostly oxygen, nitrogen, and minute amounts of argon), but becomes supersaturated by the aerating action of rapids and the pressurization which occurs in plunge pools within Devil Canyon. The degree of gas supersaturation increases with discharge. This flow effect has been documented for discharges ranging between 10,000 and 32,500 cfs (ADF&G Su-Hydro 1983 Basic Data Report) and naturally occurring supersaturation conditions as high as 116% have been observed at the mouth of Devil Canyon. Water can remain supersaturated as far downstream as Curry (Dana Schmidt, ADF&G Su-Hydro, personal comm.). No instances of gas bubble disease embolisms in fish have been documented to date, however.

A brief (one-month) fall transition period typically begins in late September and extends through most of October during which mainstem flows average between 6,000-12,000 cfs. TSS concentrations and turbidity levels decline rapidly and the resulting hydraulic and light transmission properties of the river are generally at their most favorable for algal growth wherever suitable substrate exists. Preliminary estimates indicate that the quantity of algal biomass produced daily in the middle river alone during this period may exceed 30,000 metric tons.

The water quality records for Susitna Station (RM 25) provide the best possible description of baseline conditions in the lower river (Table 3). By the time water flowing from the middle river reaches the Susitna gauging station, it has been diluted over fivefold by flows from the glacial Talkeetna, Chulitna, and Yentna Rivers as well as numerous smaller clearwater tributaries. The annual pattern of water quality conditions in the lower river is similar to the pattern displayed by the middle river. Generally, the lower river displays lower TDS concentrations year-round than the middle river, while mean TSS concentrations are approximately the same. Despite the similarity of mean TSS concentration, lower river water tends to be nearly twice as turbid and higher in total phosphorus and most trace metal concentrations than the middle river. This indicates a longitudinal change in the particle size composition of the sediment load as it is transported through the system (i.e., lower river water carries a higher proportion of finer sediment particles which exert a greater turbidity per unit weight and offer more surface area for adsorption of phosphorus and trace metals than the relatively larger particle sizes transported in the middle river). This increase in total recoverable concentrations does not appear to be attended by increased concentrations of dissolved phosphorus or trace metals, either in winter or summer. The maximum observed dissolved Cd, Cu, Hg, and Zn concentrations recorded at Susitna station were 1, 7, 0.2., and 20 μg/l, respectively.

Table 3. Mean baseline water quality characteristics for lower Susitna River at Susitna Station under summer (May - September) and winter (October - April) conditions.

Parameter	Units	Summer	Winter
Total Suspended Solids (TSS)	mg/l	745	5
Turbidity	NTU	233	1.5
Total Dissolved Solids (TDS)	mg/l	73	123
Conductivity	µmhos cm^{-1}, 25°C	122	205
pH	pH units	7.7	7.3
Alkalinity	mg/l as $CaCO_3$	44	69
Hardness	mg/l as $CaCO_3$	54	85
Sulfate (SO_4^{-2})	mg/l	13.2	17.3
Chloride (Cl)	mg/l	2.7	13
Dissolved Calcium (Ca^{+2})	mg/l	17	27
Dissolved Magnesium (Mg^{+2})	mg/l	2.5	4.3
Sodium (Na^{+})	mg/l	2.7	7.7
Dissolved Potassium (K^{+})	mg/l	1.4	1.7
Dissolved Oxygen (DO)	mg/l	11.5	11.6
DO (% Saturation)	%	97	80
Chemical Oxygen Demand (COD)	mg/l	-	-
Total Organic Carbon (TOC)	mg/l	4.4	1.6
True Color	pcu	10	0
Total Phosphorus	µg/l	400	50
Nitrate-nitrogen as N (NO_3-N)	mg/l	.0	0.19
Total Recoverable Cadmium [Cd(t)]	µg/l	9	8
Total Recoverable Copper [Cu(t)]	µg/l	50	30
Total Recoverable Iron [Fe(t)]	µg/l	20,000	500
Total Recoverable Lead (Pb(t)]	µg/l	100	80
Total Recoverable Mercury [Ng(t)]	µg/l	0.12	0.04
Total Recoverable Nickel (Ni(t)]	µg/l	75	13
Total Recoverable Zinc [Zn(t)]	µg/l	50	50

FORECASTED DATA

Few quantitative forecasts of with-project water quality conditions in the impoundment zone or downstream are presently available. Detailed, quantitative predictions regarding reservoir temperature profiles and middle river temperatures under a wide range of meteorological and hydrological scenarios are found in APA (1984) and AEIDC (1984). The results of these intensive modeling efforts and a discussion of environmental consequences are presented in a separate issue paper and will only be briefly summarized here.

The temperature profile of any reservoir varies with hydrologic and meteorologic conditions as well as the morphology of the reservoir and its operational schedule for any given year. The Watana reservoir will be long, narrow, and deep with a relatively short hydraulic residence time (Table 4). The topography of the impoundment area will provide little opportunity for the development of an extensive littoral zone. The general annual temperature profile pattern for Watana Reservoir will be characterized by a fall turnover in November roughly coincident with the formation of an ice cover during which isothermal conditions of approximately 4 C will prevail. This will be followed by inverse stratification in which epilimnetic temperatures will drop from near 0 C at the surface to approximately 2.5 C near the metalimnion. Hypolimnetic temperatures will approach 4 C. This condition will usually persist until May or June. During the summer, the epilimnion will gradually warm with maximal surface temperatures of 10-13 C occurring in August and September. Stratification will remain in place until the turnover in November. Available forecasts indicate that a spring turnover might also occur in June during unusually dry years (e.g., 1974-75).

Table 4. Selected morphometric and hydrologic features of the Watana and Devil Canyon reservoirs.

Parameter	Watana	Devil Canyon
Maximum Length (l)	48 mi (77 km)	26 mi (42 km)
Mean Width ($\bar{b}$)	1.25 mi	0.46 mi
Maximum Surface Area (A_m)	60 mi^2	12 mi^2
Volume (V)	$9.5x10^6$ ac ft ($11.7x10^9 m^3$)	$1.1x10^6$ ac ft ($1.4x10^9 m^3$)
Maximum Depth (Z_m)	735 ft (223 m)	565 ft (171 m)
Mean Depth ($\bar{Z}$)	250 ft (76 m)	140 ft (42 m)
Relative Depth (Zr)	1.6%	2.7%
Shoreline (L)	183 mi (295 km)	76 mi (123 km)
Shoreline Development (D_L)	6.7	6.2
Mean Hydraulic Residence Time	1.65 yrs	60 days
Normal Drawdown	120 ft (36.6 m)	50 ft (15.2 m)

Based on: Acres American 1983.

(Sus. Hydro Project, Fed. Energy Reg. Comm. License App, Exhibit F, Supporting Design Report, (Preliminary), Feb. 1983, by Acres.)

Model forecasts for downstream river temperatures show a general dampening of the variations that occur naturally and this will affect conditions as far downstream as Talkeetna. Mean summer river temperatures under Watana only would be approximately 1 C cooler than natural at river miles (RM) 150 and 130, and 0.6 C cooler at RM 100. Addition of the Devil Canyon dam would increase this seasonal change to approximately 2.0, 1.7, and 1.2 C cooler at RM 150, 130, and 100, respectively. Under both scenarios, downstream temperatures would peak later in the summer with the greatest deviation from natural temperatures occurring in September-October. Winter releases would range from 0.4 to 6.4 C from October to April. Natural winter temperatures are 0 C. These alterations in the natural temperature regime are well within the tolerance limits for adult and juvenile salmon and are not expected to significantly impact migration or spawning activity with the exception of a possible delay in chinook inmigration to Portage Creek. Some reduction of juvenile growth might occur due to cooler summer temperatures. The anticipated warmer fall and winter river temperatures could sufficiently alter both burbot and whitefish spawning and incubation timing to eliminate these species from the middle river.

A preliminary, crude estimate of with-project TSS concentrations and turbidity levels can be found in Peratrovich, et al. (1982) and a discussion of their potential ecological consequences appears in EWTA and WCC (1984). A formal reservoir modelling effort is currently underway to provide more precise estimates of anticipated TSS concentrations (Tom Stuart, Harza-Ebasco, personal communication).

Predictions regarding some of the parameters addressed in this paper are found in the original license application and these are based largely on a study conducted by L.A. Peterson and Assoc. and R&M Consultants (1982).

This study concluded that:

1. Both the Devil Canyon and Watana reservoirs will be oligotrophic based on the results obtained from the Vollenweider phosphorus loading model (Vollenweider 1976).
2. A short-term unquantifiable increase in dissolved solids, conductivity, and most of the major ions may occur after closure due to inundation and leaching of rocks and soils in the impoundment area.
3. Approximately 70-97 percent of the suspended sediment load carried into the Watana reservoir by the inflow will settle, resulting in significantly less turbid conditions in summer, but higher turbidity levels in winter.
4. Evaporative losses from both reservoirs will not exceed 1 percent of their total volume and will thus not produce a significant increase in dissolved solids concentrations.
5. The amplitude and phase of the river's annual temperature cycle will change under with-project conditions.
6. The concentrations of "many" metals will be reduced in Watana Reservoir due to precipitation and settling.
7. Both reservoirs will maintain relatively high oxygen levels because existing oxygen demand is low.
8. The reservoirs will support only low levels of phytoplankton production which will be limited by high turbidities and the presence of an ice and snow cover during the winter.

Field studies are currently being conducted by AEIDC and EWTA to develop a model that will provide quantitative estimates of the trophic status of the middle river under with-project conditions. Preliminary results will be available in June 1985.

DATA GAPS

The USGS water quality records for the Susitna River and some of its major tributaries provide the best available information with which to perform a rigorous hydrochemical analysis. To date, this has not been done. However, the data summaries conducted by R&M Consultants do provide mean, maximum, and minimum values for a large number of water quality parameters. These values are grouped according to three seasons: winter, summer, and breakup. The use of such seasonal means, however, does not provide the best possible level of resolution for the purposes of biological interpretation and can lead to distortions. For example, R&M Consultants (1982) reports a summer mean TSS concentration for Gold Creek of 740 mg/l based on the USGS data records and a mean of 268 mg/l based on its own field work conducted during 1980-82. The much higher value obtained from the USGS records reflects the fact that during the glacial surges which occurred in the 1950s, USGS gathered water samples almost daily, while in later years sampling frequency dropped to just a few each year (Jim Knott, USGS, Anchorage, personal communication). Also, the use of means unaccompanied by any statistical measure of confidence interval is highly irregular.

The lack of a formal hydrochemical analysis in which the water chemistry characteristics of the Susitna River are interpreted in the context of the vegetation, soils, geology, and hydrology of its watershed makes it difficult to provide quantitative estimates of project impacts on water quality. This is exacerbated by the relative paucity of heavy metal data (especially for Vee Canyon and at all stations during the winter months) and by the lack of any quantitative baseline information on the trophic dynamics of the river. Another important data gap is the absence of any data on baseline tissue Hg levels for resident fish and land otters inhabiting the middle river or on Hg speciation. Also, only very limited water chemistry data are available for middle river sloughs and tributaries where most of the fish production of this reach originates.

For the most part these shortcomings, however, do not prevent qualitative estimates which should provide a reasonable degree of certainty regarding potential ecological impacts.