BEFORE THE

FEDERAL ENERGY REGULATORY COMMISSION

APPLICATION FOR LICENSE FOR MAJOR PROJECT

SUSITNA HYDROELECTRIC PROJECT

VOLUME 6

DRAFT

EXHIBIT E

CHAPTER 1

CHAPTER 2

HARZA-EBASCO
SUSITNA JOINT VENTURE

Alaska Power Authority

NOTICE

A NOTATIONAL SYSTEM HAS BEEN USED
TO DENOTE DIFFERENCES BETWEEN THIS AMENDED LICENSE APPLICATION
AND
THE LICENSE APPLICATION AS ACCEPTED FOR FILING BY FERC
ON JULY 29, 1983

This system consists of placing one of the following notations beside each text heading:

(o) No change was made in this section, it remains the same as was presented in the July 29, 1983 License Application

(*) Only minor changes, largely of an editorial nature, have been made

(**) Major changes have been made in this section

(***) This is an entirely new section which did not appear in the July 29, 1983 License Application

VOLUME COMPARISON

VOLUME NUMBER COMPARISON

LICENSE APPLICATION AMENDMENT VS. JULY 29, 1983 LICENSE APPLICATION

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1 - GENERAL DESCRIPTION (*)

1.1 - General Setting (**)

The proposed Susitna Hydroelectric Project is located in the southcentral region of Alaska, approximately 120 miles north-northeast of Anchorage and 110 miles south-southwest of Fairbanks (Figure E.1.1.1). The southcentral region of the state is geographically bounded by the Alaska Range to the north and west, the Wrangell Mountains to the east, and the Chugach Mountains and the Gulf of Alaska to the south. This region encompasses 86,000 square miles of the total 586,000 square miles of the total state.

The southcentral region has wide geographic variety: broad, flat river valleys, rugged mountain ranges, glaciers, forests, and coastal waters. Mount McKinley, the highest mountain in North America at 20,320 feet, is located on the region's northwest border. Denali National Park, Denali State Park, and the diversity of landscapes and resources offer diverse recreational opportunities.

Because of its size, the large amount of publicly owned land, and the availability of services, most of Alaska's citizens live in two urban areas, Fairbanks and Anchorage. Over 75 percent of the state's 1985 estimated population of approximately 535,000 lives in southcentral Alaska. Anchorage is the state's largest city with a civilian population estimated in 1985 to be 247,237. The Fairbanks-North Star Borough, which lies just north of the southcentral region, is the state's second largest urban area with a population estimated to be 63,563 in 1985. The region's economy is based on support services, commercial fishing, mining, forestry, petroleum, and tourism. The southcentral region has seen rapid population growth during the last 15 years and a continuing improvement of basic public services. With the growth have come problems associated with urban development. For example, both Anchorage and Fairbanks have begun mandatory vehicle emission control testing because of air pollution.

Southcentral Alaska contains the most highly developed transportation system in the state (Figure E.1.1.2). An extensive airport system, ranging from the international level to gravel strips and water bodies, permits plane access into most remote areas. The Alaska Railroad serves the "Railbelt" between the ice-free port of Seward on the Kenai Peninsula, through Anchorage, to Fairbanks. The only railroad in the state, it is only 483 miles long. Although primarily a freight line, the railroad also provides a commuter service between Anchorage and Fairbanks with daily summer and weekly winter service, a trip of about

8 hours. The road network covers a limited area of the state and is concentrated in the Fairbanks and Anchorage areas. Although Anchorage is only 358 miles south of Fairbanks the drive along the sole highway connecting the two cities, a two lane, paved road, takes from 8 to 10 hours. Access to most of the state is by air or water and is limited by season and weather. Many of the state's river systems are used during summer for boat transportation and snowmobile transportation during winter months (Figure E.1.1.3).

The two proposed dams, Watana and Devil Canyon, would be within the east-to-west flowing section of the Susitna River, the sixth largest river in Alaska. At the Oshetna River confluence (RM 233) the river begins its westward leg and turns south-southwest at RM 150, below the Devil Canyon damsite. The two damsites are at river miles 152 and 184, respectively, upstream from the river's mouth at Cook Inlet. The nearest residents are along the railroad, approximately 12 miles from Devil Canyon. Fairbanks is some 110 miles from the Watana site while Anchorage is about 140 miles to the south. The Susitna Hydroelectric Project would, over time, serve as the primary source of electricity for the Railbelt portion of the state, the corridor along the Alaska Railroad from Seward to Fairbanks.

1.2 - Susitna Basin (*)

1.2.1 - Physiography and Topography (o)

The 19,400-square-mile Susitna River basin is bordered by the Alaska Range to the north, the Chulitna and Talkeetna Mountains to the west and south, and the northern Talkeetna plateau and Gulkana uplands to the east. This area is largely within the Coastal Trough province of south-central Alaska, a belt of lowlands extending the length of the Pacific Mountain System and interrupted by the Talkeetna, Clearwater, and Wrangell Mountains.

The basin has distinct and diverse combinations of landforms and waterforms. The deep V-shaped canyon of the Susitna River and tributary valleys, the Talkeetna Mountains, and upland plateau to the east are the dominant topographic forms. Elevations in the basin range from approximately 700 feet to over 6,000 feet. Distinctive landforms include tundra highlands, active and post-glacial valleys, and numerous lakes.

In the vicinity of the proposed impoundments (Figure E.1.2.1), the river cuts a narrow, steep-walled gorge up to 1,000 feet deep through the Clarence Lake Upland and Fog Lakes Upland, areas of broad, rounded summits 3,000 to 4,200 feet in elevation. Between these uplands, the gorge cuts through an extension of the Talkeetna Mountains, where rugged peaks are 6,900 feet high.

Downstream from its confluence with the Chulitna and Talkeetna rivers, near Talkeetna, the Susitna traverses the Cook Inlet-Susitna Lowland, a relatively flat region generally less than 500 feet in elevation. A portion of the proposed transmission facilities, between Healy and Fairbanks, would follow the narrow valley of the Nenana River through the northern foothills of the Alaska Range, traverse the Tanana-Kuskokwim Lowland in a flat region generally less than 650 feet in elevation (the Tanana Flats), and then parallel a ridge on the edge of the Yukon-Tanana Upland.

1.2.2 - Geology and Soils (*)

The regional geology of the Susitna Basin area has been extensively studied and documented. The upper Susitna Basin lies within what is geographically called the Talkeetna Mountains area. This area is geologically complex and has a history of at least three periods of major tectonic deformation. The oldest rocks exposed in the region are metamorphosed volcanic flows with local marble interbeds which were formed 250 to 300 million years before present (my BP) and which are overlain by sandstones and shales dated approximately 150 to 200 my BP. A tectonic event approximately 135 to 180 my BP resulted in the intrusion of large diorite and granite plutons, which caused intense thermal metamorphism. This was followed by marine deposition of silts and clays. The argillites and phyllites which predominate at Devil Canyon were formed from the silts and clays during faulting and folding of the Talkeetna Mountains area in the late Cretaceous period (65 to 100 my BP). As a result of this faulting and uplift, the eastern portion of the area was elevated and the oldest volcanics and sediments were thrust over the younger metamorphics and sediments. The major area of deformation during this period of activity was southeast of Devil Canyon and included the Watana area. The Talkeetna Thrust Fault, a well-known tectonic feature which has been identified in the literature, trends northwest through this region. This fault was one of the major mechanisms of this overthrusting from southeast to northwest. At Devil Canyon, the area was probably deformed and subjected to tectonic stress during the same period.

The diorite pluton that forms the bedrock of the Watana site was intruded into sediments and volcanics about 65 my BP. The andesite and basalt flows near the site have intruded the pluton. During the Tertiary period (20 to 40 my BP) the area surrounding the sites was again uplifted by as much as 3,000 feet. Since then, widespread erosion has removed much of the older sedimentary and volcanic rocks. During the last several million years, at least three alpine glaciations have carved the Talkeetna Mountains into the ridges, peaks, and broad glacial plateaus seen today. Postglacial uplift has induced downcutting of streams and rivers, resulting in the deep, V-shaped canyons that are evident today, particularly at the Vee and Devil Canyon damsites. This erosion is believed to be still occurring, and virtually all streams and rivers in the region are considered to be actively downcutting. This continuing erosion has removed much of the glacial debris at high elevations, but very little alluvial deposition has occurred.

The resulting landscape consists of barren bedrock mountains, glacial till-covered plains, and exposed bedrock cliffs in canyons and along streams. Climatic conditions have retarded thedevelopment of topsoil. Soils are typical of those formed in cold, wet climates and have developed from glacial till and outwash. They include the acidic, saturated, peaty soils of poorly drained areas; the acidic, relatively infertile soils of the forests; and raw gravels and sands along the river. The upper basin is generally underlain by discontinuous permafrost.

1.2.3 - Hydrology (*)

The entire drainage area of the Susitna River is about 19,400 square miles, of which the basin above Gold Creek comprises approximately 6,160 square miles (Figures E.1.2.2 and E.1.2.3). Three glaciers in the Alaska Range feed forks of the Susitna River and flow southward for about 18 miles before joining to form the mainstem of the Susitna River. The river flows an additional 55 miles southward through a broad valley, where much of the coarse sediment from the glaciers settles out. The river then flows westward about 96 miles through a narrow valley with the constrictions in the Devil Creek and Devil Canyon areas creating violent rapids. Numerous small, steep-gradient, clear-water tributaries flow to the Susitna in this reach of the river. Several of these tributaries traverse waterfalls as they enter the gorge. As the Susitna curves south past Gold Creek, 12 miles downstream from Devil Canyon, its gradient gradually decreases. The river is joined about 40 miles beyond Gold Creek in the vicinity of Talkeetna by two major rivers, the Chulitna and Talkeetna. A third major tributary, the Yentna River, joins the Susitna River about 70 miles downstream of this confluence and 27 miles upstream of the mouth. From the Chulitna-Talkeetna-Susitna confluence, the Susitna flows south through braided channels about 97 miles until it empties into Cook Inlet near Anchorage, approximately 318 miles from its source.

(a) Flows (*)

The Susitna River is typical of unregulated northern glacial rivers with high, turbid summer flow and low, clear winter flow. Runoff from snowmelt and rainfall in the spring causes a rapid increase in flow in May from the low discharges experienced throughout the winter. Peak annual floods usually occur during this period. Rainfall-related floods often occur in August and early September, but generally these floods are not as severe as the spring snowmelt floods. Approximately 80 percent of the annual flow occurs between May and September. At Gold Creek, average flows approach 6,000 cubic feet per second (cfs) in October, the start of the water year. The flow decreases in November and December as the river freezes. Low flows of about 1,000 cfs occur in March and April. Breakup of the river ice cover occurs in early to mid-May. Average monthly flows are over 13,000 cfs in May and peak at about 27,000 cfs in June. Average monthly flows gradually decrease to 24,000 cfs in July, 22,000 cfs in August, and 13,000 cfs in September.

Associated with the higher spring flows is a 100-fold increase in sediment transport, which persists throughout the summer. The high concentration of suspended sediment in the June-to-September time period causes the river to be highly turbid. Very finely ground rock known as glacial flour causes most of the turbidity of the river.

As the weather begins to cool in the fall, rainfall, runoff, the glacial melt rate and, as a result, flows in the river all gradually decrease. As runoff from the watershed and flows from the glaciated areas both decrease, the transport of fine material into the river is also reduced. The river then begins to clear. Freeze up normally begins in October and continues to progress up river through early December. The river breakup generally begins in late April or early May near the mouth and progresses upstream with breakup at the damsite occurring in mid-May.

(b) Water Quality (*)

The Susitna River is a fast-flowing, cold-water glacial stream of the calcium bicarbonate type containing soft to moderately hard water. Nutrient concentrations (namely, total nitrogen and total phosphorus) exist in moderate to high concentrations. Dissolved oxygen concentrations typically remain high, averaging about $\geq$12 mg/l during the summer and $\geq$13 mg/l during winter. Saturation of dissolved oxygen generally exceeds 80 percent and averages near 100 percent in the summer. Winter saturation levels decline slightly from the summer levels. Typically, pH values range between 7 and 8 and exhibit a wider range in the summer compared to the winter. During summer, pH occasionally drops below 7, possibly due to slightly acidic freshet meltwaters and/or organic acids in the tundra runoff. True color, also resulting from tundra runoff, displays a wider range during summer than winter. Values have been measured as high as 40 color units in the vicinity of the damsites. Temperature remains at or near 0°C during winter, and the summer maximum is 14°C. Alkalinity concentrations, with bicarbonate as the dominant anion, are low-to-moderate during summer and moderate-to- high during winter. The buffering capacity of the river is relatively low on occasion.

The concentrations of many trace elements monitored in the river were low or within the range characteristics of natural waters. However, the concentrations of some trace elements exceeded water quality guidelines for the protection of freshwater aquatic organisms. These concentrations are the result of natural processes because, with the exception of limited placer mining activities, there are no man-induced sources of these elements in the Susitna River Basin.

Concentrations of organic pesticides and herbicides, uranium, and gross alpha radioactivity were either less than their respective detection limits or were below levels considered to be potentially harmful to aquatic organisms.

1.2.4 - Climate (o)

As in most of Alaska, winters are long, summers are short, and there is considerable variation in daylight between these seasons. Higher elevations in the upper basin are characterized by a continental climate typical of interior Alaska. The lower floodplain falls within a zone of transition between maritime and continental climatic influences. From the upper to the lower basin, the climate becomes progressively wetter, with increased cloudiness and more moderate temperatures.

At Talkeetna, which is representative of the lower basin, average annual precipitation is about 28 inches, of which 68 percent falls between May and October, and annual snowfall is about 106 inches. Monthly average temperatures range from 9°F (-13°C) in December and January to 58°F (14°C) in July.

1.2.5 - Vegetation (*)

The Susitna Basin occurs within an ecoregion classified as the Alaska Range Province of the Subarctic Division. The major vegetation types in the Watana and Gold Creek watersheds[1/] are low mixed shrub, woodland and open black spruce, mesic graminoid herbaceous, mat and cushion dwarf shrub, and birch shrub. These vegetation types are typical of vast areas of interior Alaska and northern Canada, where plants exhibit slow or stunted growth in response to cold, wet conditions and short growing seasons. Deciduous and mixed conifer-deciduous forests occur at lower elevations in the upper basin, primarily along the Susitna River, but comprise less than three percent of the Watana and Gold Creek watersheds area. These forest types have more robust growth characteristics than the vegetation types at higher elevations and are more comparable to vegetation types occurring on the floodplain downstream.

The floodplain of the lower river is characterized by mature and decadent balsam poplar woodlands, birch-spruce forest, alder thickets, and willow-balsam poplar shrub communities. The willow-balsam poplar shrub and alder communities are the earliest to establish on new gravel bars, followed by balsam poplar woodlands and, eventually, by birch-spruce forest.

Each of the transmission corridors crosses several vegetation types. The Willow-to-Anchorage transmission corridor passes through closed birch forests, mixed conifer-deciduous forest, wet graminoid herbaceous marshes, and open and closed spruce stands. The Willow-to-Healy transmission corridor traverses a wide variety of vegetation types, from closed spruce-hardwood forests in the south to shrublands in the north. The Healy-to-Fairbanks transmission corridor includes ridges, wetlands, and rolling hills with areas of open spruce forests, open deciduous forests, mixed forests, shrublands, and wet graminoid herbaceous.

1.2.6 - Wildlife (*)

Big game in the upper basin include caribou, moose, brown bear, black bear, wolf, and Dall sheep. Caribou migrate through much of the open country in the Watana and Gold Creek watersheds, and important calving grounds are present outside the impoundment zone. Moose are fairly common in the vicinity of the proposed project, but high quality habitat is rather limited. Moose also frequent the downstream floodplain, especially in winter. Brown bear occur throughout the Middle Susitna Basin while black bear are largely confined to the forested habitat along the river; populations of both species are healthy and productive. Several wolf packs have been noted using the area. Dall sheep generally

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1/ Defined herein as the entire Susitna basin upstream from Gold Creek.

inhabit areas higher than 3,000 feet in elevation; thus, this species is for the most part well removed from the project area. However, the Watana Creek Hills population does utilize the Jay Creek mineral lick, located at the upper end of the Watana reservoir.

Furbearer species of the Watana and Gold Creek watersheds include red fox, wolverine, marten, mink, river otter, short-tailed weasel, least weasel, lynx, muskrat, and beaver. Beavers become increasingly evident farther downstream. Sixteen species of small mammals that are characteristic of interior Alaska are known to occur in the upper basin, including shrews, voles, lemmings, squirrels, marmots, snowshoe hares, and porcupines.

Bird species and densities are typical of interior Alaska. Generally, the forest and woodland habitats support higher densities of birds than do other habitats. Typical species found in the project area include ducks, eagles, ptarmigan, shorebirds, ravens, and songbirds. In regional perspective, ponds and lakes in the vicinity of the proposed impoundments support relatively few waterbirds. Ravens and raptors, including bald and golden eagles, occur in the Watana and Gold Creek watersheds. Bald eagles also nest downstream of the dam sites. No known peregrine falcon nests exist in or near the reservoir area, although one currently inactive historical nest exists near the northern leg of the transmission corridor.

1.2.7 - Fish (**)

Anadromous fish in the Susitna Basin include five species of Pacific salmon: pink (humpback); chum (dog); coho (silver); sockeye (red); and chinook (king) salmon. These fish utilize the basin as a migrational corridor and for spawning, egg incubation, and juvenile rearing. Spawning primarily occurs in the tributaries with some spawning in slough and side channels. Only limited spawning occurs in the mainstem.

The major potential impacts to anadromous species are expected in the middle river (Talkeetna to Devil Canyon). Project studies from 1981 through 1984 have found that only a small portion of the anadromous fish in the Susitna Basin utilize this reach. Instead they utilize tributaries downstream of Curry Station (RM 120). For example, in 1984, only approximately 6% of all coho, 12% of all chum, 2% of all sockeye, 10% of all chinooks, and 5% of all pink salmon spawning in the entire drainage basin travelled through the mainstem middle river to reach their natal grounds. Of these, most spawned in tributary streams. (Devil Canyon acts as almost impassable barrier to upstream migration due to turbulence and high water velocities.) Sloughs only accounted for about 5.5% of all salmon spawning activity above

Talkeetna Station (RM 103). Coho and chinook only spawn in tributary streams, pink salmon primarily in tributary streams (with a small number utilizing slough habitats), chum salmon in both tributary and slough habitats, and sockeye in this reach of the river spawn almost exclusively in sloughs. Of the latter two species, only about 2% of all chum and less than 0.5% of all sockeye in the Susitna Basin utilized sloughs for spawning in 1984.

Four of the five salmon species present utilize middle river associated habitats for rearing purposes. From May to September, juvenile chinook salmon rear in tributary and side channel environments, coho mostly rear in tributary and upland sloughs, and sockeye move from natal side sloughs to upland sloughs for rearing. From May to July rearing chum salmon are distributed throughout side slough and tributary stream habitats.

Grayling are widely distributed in the clear-water tributaries of the upper basin (Devil Canyon and upstream); these populations are relatively unexploited. Grayling as well as lake trout also inhabit many lakes. The mainstem Susitna has populations of burbot and round whitefish, often associated with the mouths of clear-water tributaries. Dolly Varden, humpback whitefish, sculpin, sticklebacks, and long-nosed suckers have also been found in the drainage. Rainbow trout, like the anadromous species, have not been found above Devil Canyon.

1.2.8 - Land Use (*)

Because of limited access, the project area in the upper basin has retained a wilderness character. There are no roads to the project vicinity, but there are several off-road vehicle and sled trails. Although rough, dirt landing strips for light planes are not uncommon, float planes provide the principal means of access via the many lakes in the upper basin.

One of the principal activities in the project area over the past three decades has been the study of hydropower potential of the Susitna River. Other activities include hunting, white-water boating, fishing, trapping, and mining. Raft float trips are taken from the Denali Highway on the Susitna or Tyone Rivers down to either Vee or Devil Canyons. Only a few highly skilled kayakers have navigated Devil Canyon rapids (only 27 attempts were made in the period 1976-82). Both guided and non-guided hunting occur within the project area, particularly near Stephan, Fog, Clarence, Watana, Deadman, Tsusena, and Big Lakes. A small number of wilderness recreation lodges and private cabins are scattered throughout the basin, especially on the larger lakes.

Mineral exploration and mining have been limited in the immediate project area. Mining in the upper Susitna River Basin has been low in claims density and characterized by intermittent activity since the 1930s.

The proposed transmission corridors outside the dam and impoundment areas (Willow to Anchorage and Healy to Fairbanks) traverse lands with a somewhat higher degree of use. Most of the land within the corridors, however, is undeveloped.

Wetlands cover large portions of the Upper Susitna River Basin, including riparian zones along the mainstem Susitna, sloughs and tributary streams, and numerous lakes and ponds on upland plateaus. In addition, extensive areas of wet sedge-grass tundra are classified as wetlands by the U.S. Army Corps of Engineers for purposes of Section 404 permitting. The U.S. Soil Conservation Service has determined that there are no prime farmlands, rangelands, or forests within the upper Susitna Basin.

1.2.9 - Recreation (*)

The large diversity of landscapes and resources in southcentral Alaska offer a wide variety of outdoor recreational opportunities. The region's largest and most popular attraction, the six-million-acre Denali National Park and Preserve, has its entrance on the Parks Highway 220 miles north of Anchorage, 125 miles south of Fairbanks, and over 80 road miles from the Watana damsite. The 325,000 acre Denali State Park, one of 53 state parks in the southcentral region of Alaska is situated along the Parks Highway abutting the project's study area. Other popular state parks in Southcentral Alaska include Nancy Lake State Recreation Area, 70 miles from Anchorage, and Chugach State Park, on the east side of Anchorage. All of the above parks offer facilities for hiking, camping, fishing, and picnicking.

North of the Susitna project site, the U.S. Bureau of Land Management (BLM) maintains the 4.4-million-acre Denali Planning Block. The BLM maintains several small campgrounds and picnic areas, boat launches, and a canoe trail.

Private facilities in the region provide additional formal and informal recreation opportunities. These include remote lodges, cabins, restaurants, airstrips, and flying and boat services.

2 - REFERENCES

Alaska Power Authority. 1982. The Susitna Hydro Studies. April 1982.

The Joint Federal State Land Use Planning Commission for Alaska. 1977. The D2 Book: Lands of National Interest in Alaska. Vol 2. Anchorage, Alaska.

3 - GLOSSARY

Alluvial deposition - fine-grained material left by rivers.

Anadromous fish - a fish that begins life in freshwater, migrates to the ocean where it resides until it matures, then returns to freshwater in order to spawn (e.g. salmon, shad).

Argillites - a compact rock which has undergone a somewhat higher degree of induration (hardening) than mudstone, claystone, but is less indurated than shale.

Conifer - cone-bearing trees, evergreens (e.g. spruce, pine).

Diorite - a coarse-grained, intrusive igneous rock; plutonic rock composed essentially of sodic plagioclase, hornblende, biotite, or pyroxene.

Escapement - the total annual spawning population of a salmon stock after it has passed intercepting fisheries.

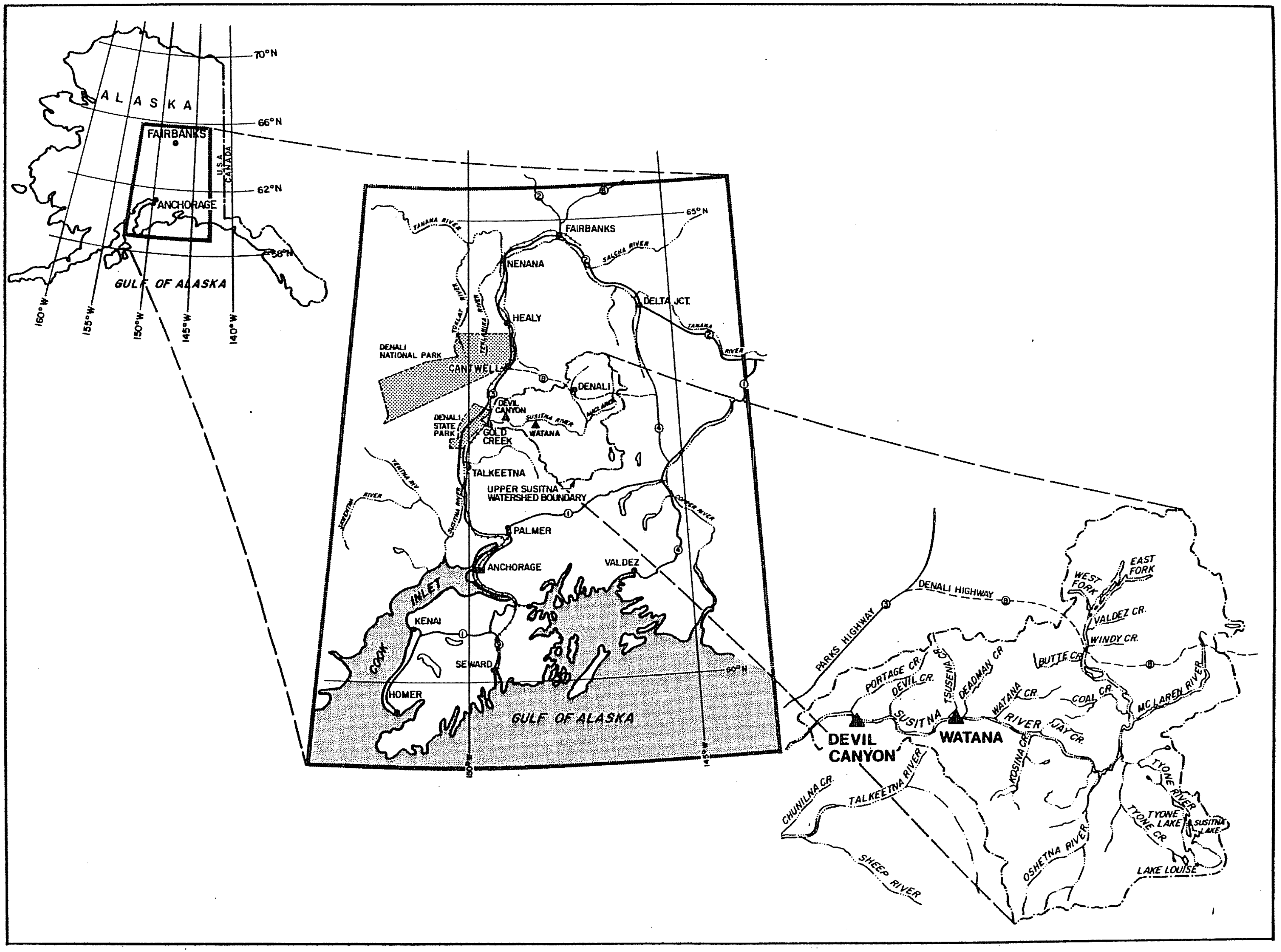
Igneous - formed by solidification from a molten or partially molten state.

Phyllites - an argillaceous rock which has undergone regional metamorphism and is intermediate in grade between slate and mica schist.

Schist - a medium or coarse-grained metamorphic rock with subparallel orientation of the mica material which is prominent.

Tectonic - of, pertaining to, or designating the rock structure and external forms resulting from the deformation of the earth's crust.

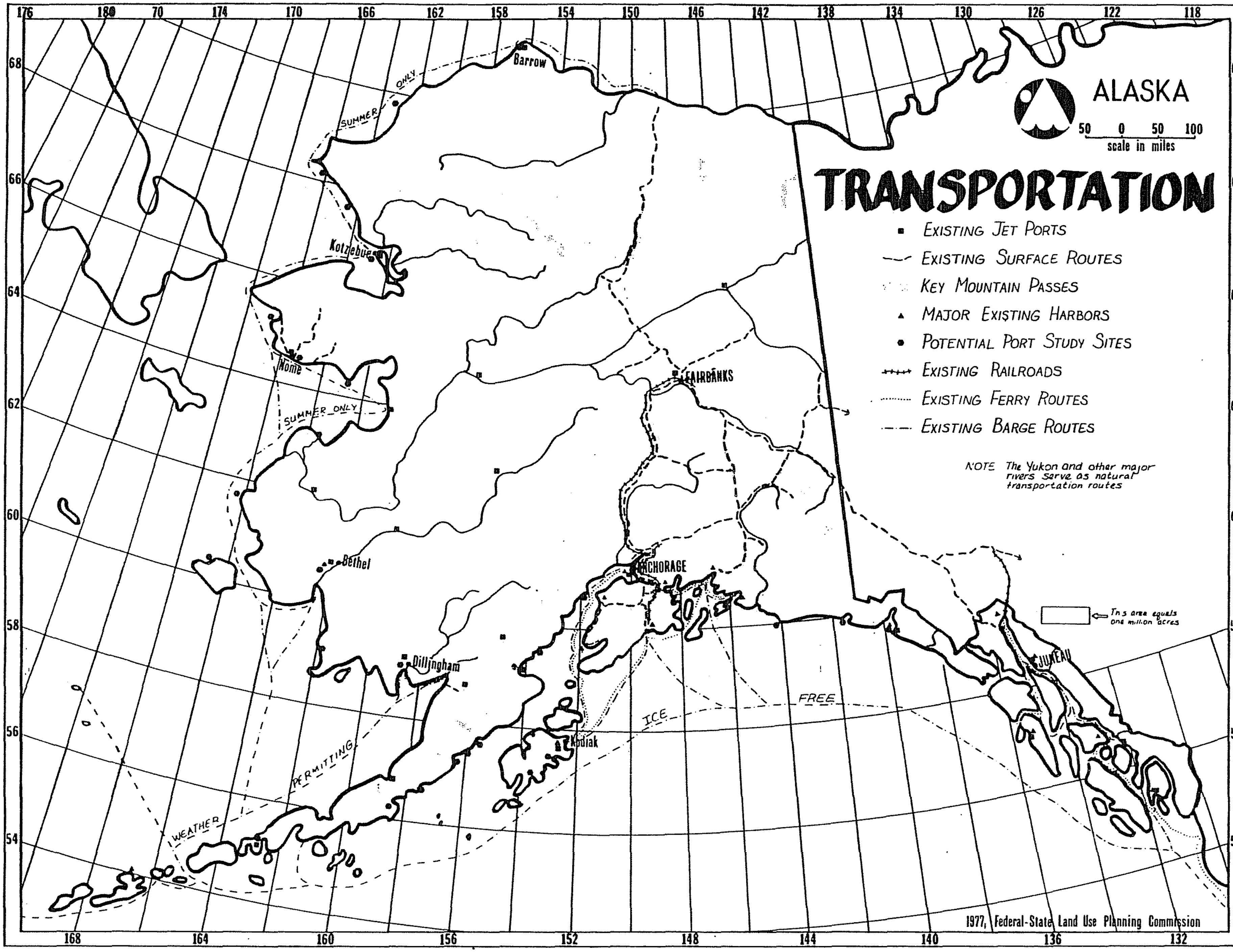
FIGURES



PROPOSED PROJECT LOCATION

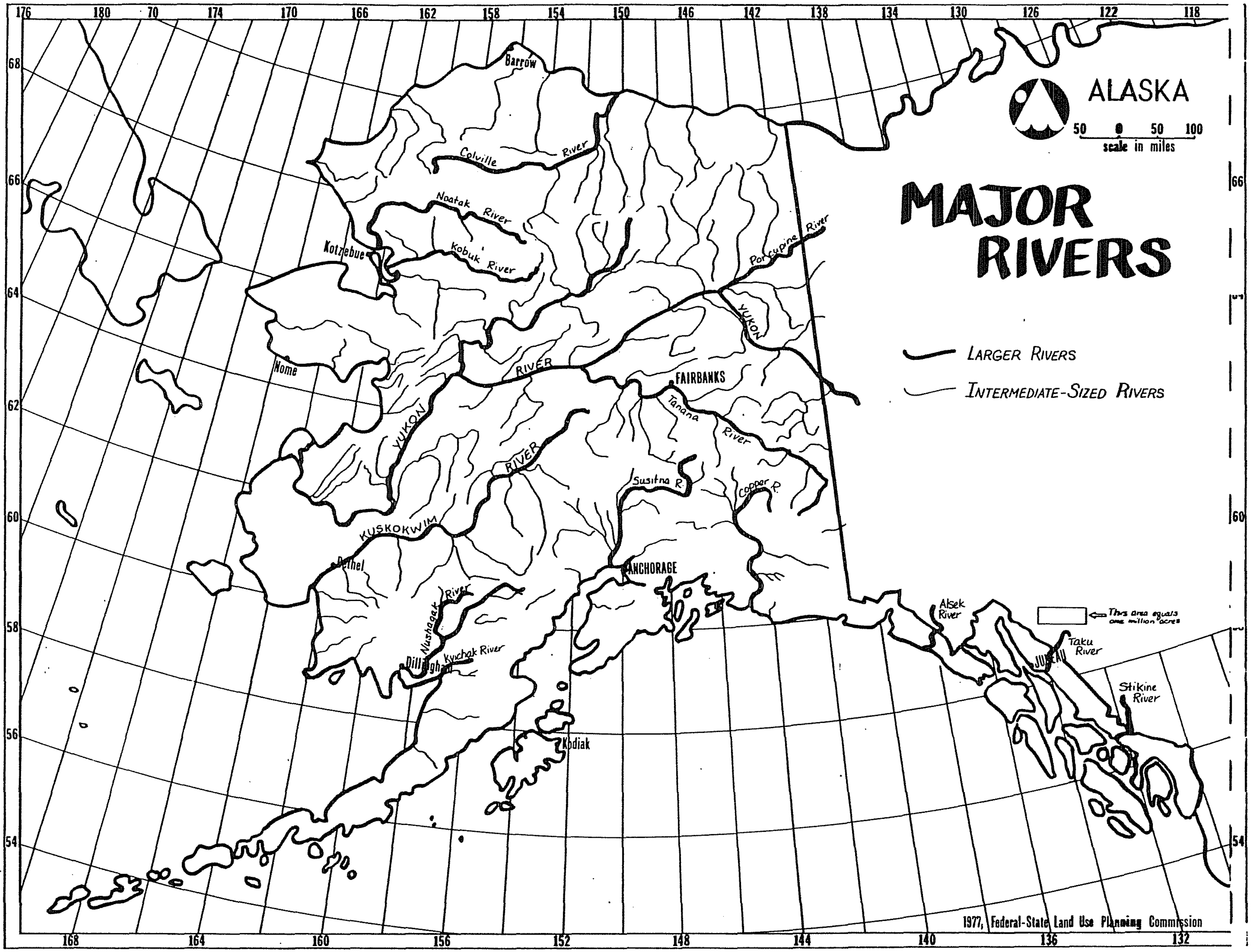
SOURCE: APA 1982

FIGURE E.1.1.1



SOURCE: JOINT FEDERAL STATE LAND USE PLANNING COMMISSION

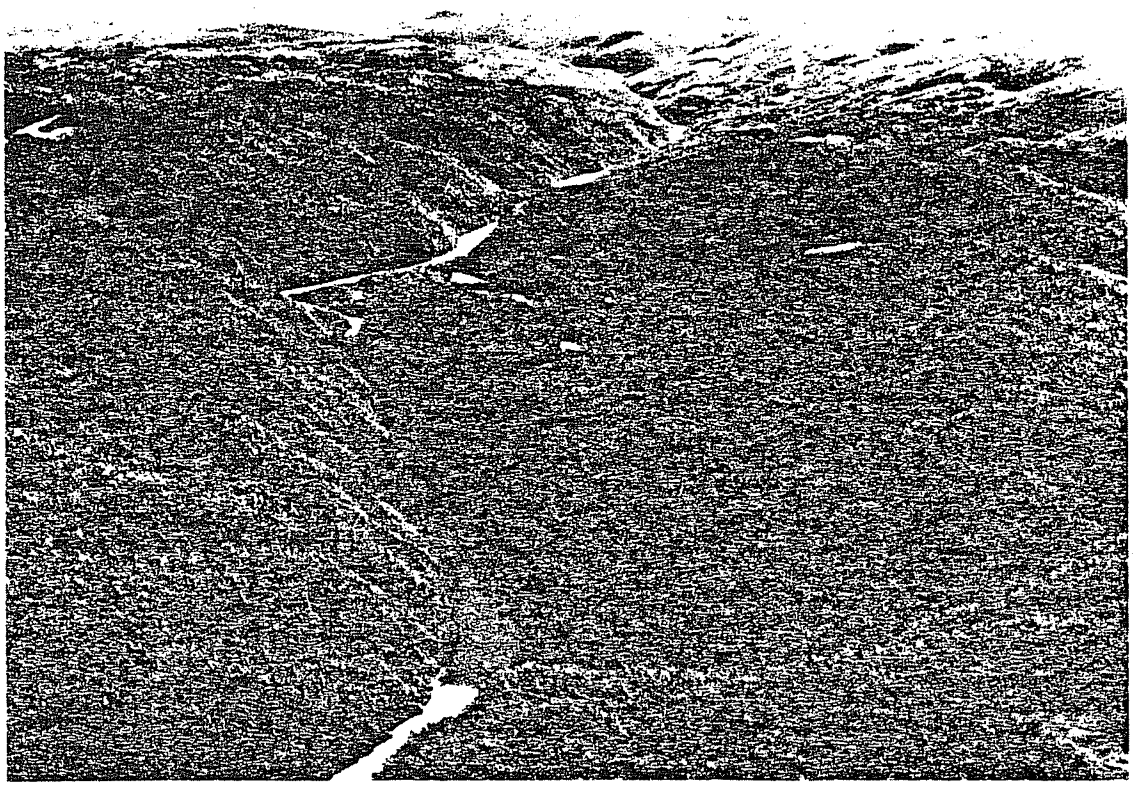
FIGURE E.1.1.2



SOURCE: JOINT FEDERAL STATE LAND USE PLANNING COMMISSION

FIGURE E.1.1.3

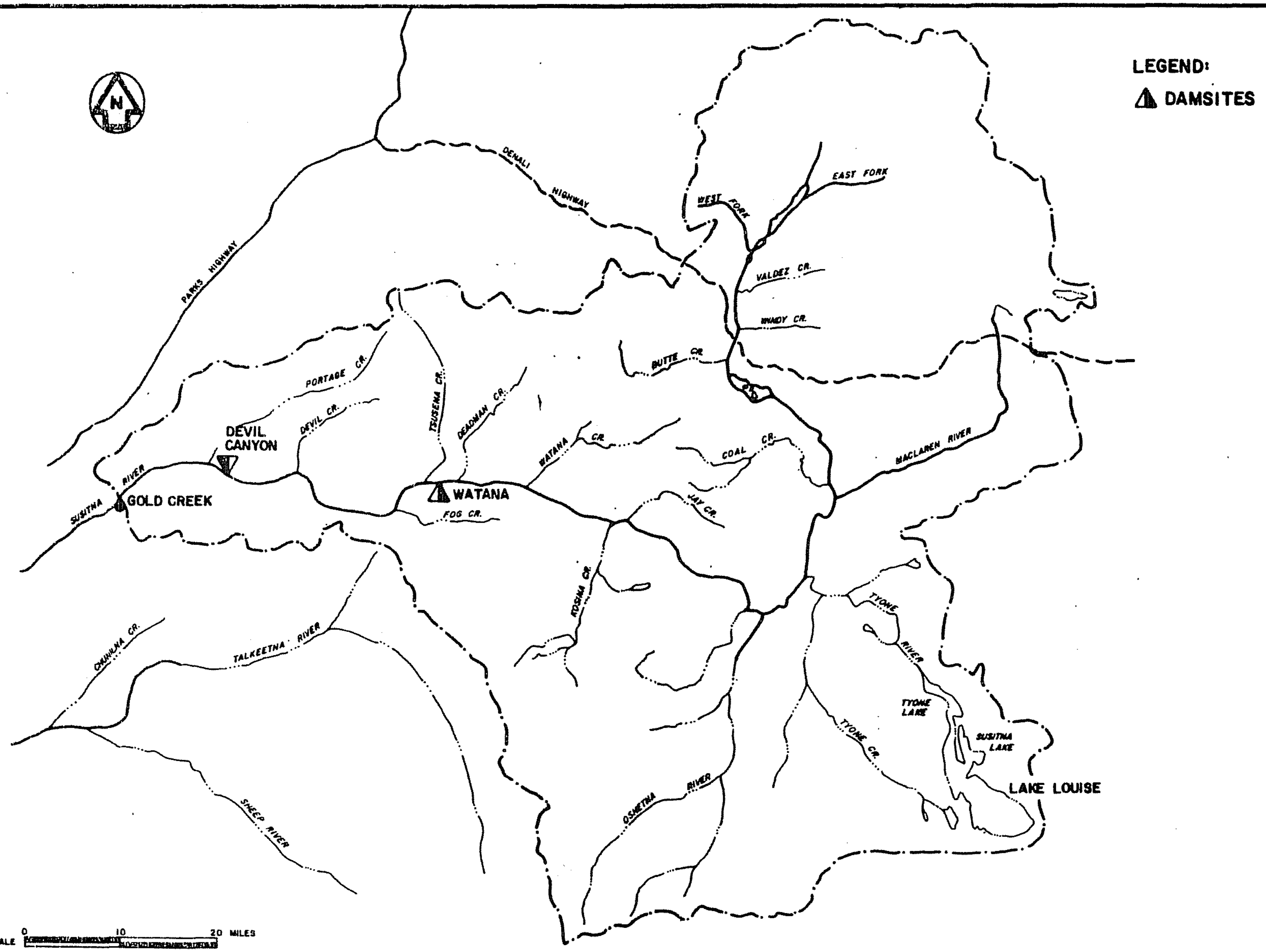
WATANA, VIEW UPSTREAM



DEVIL CANYON, VIEW UPSTREAM

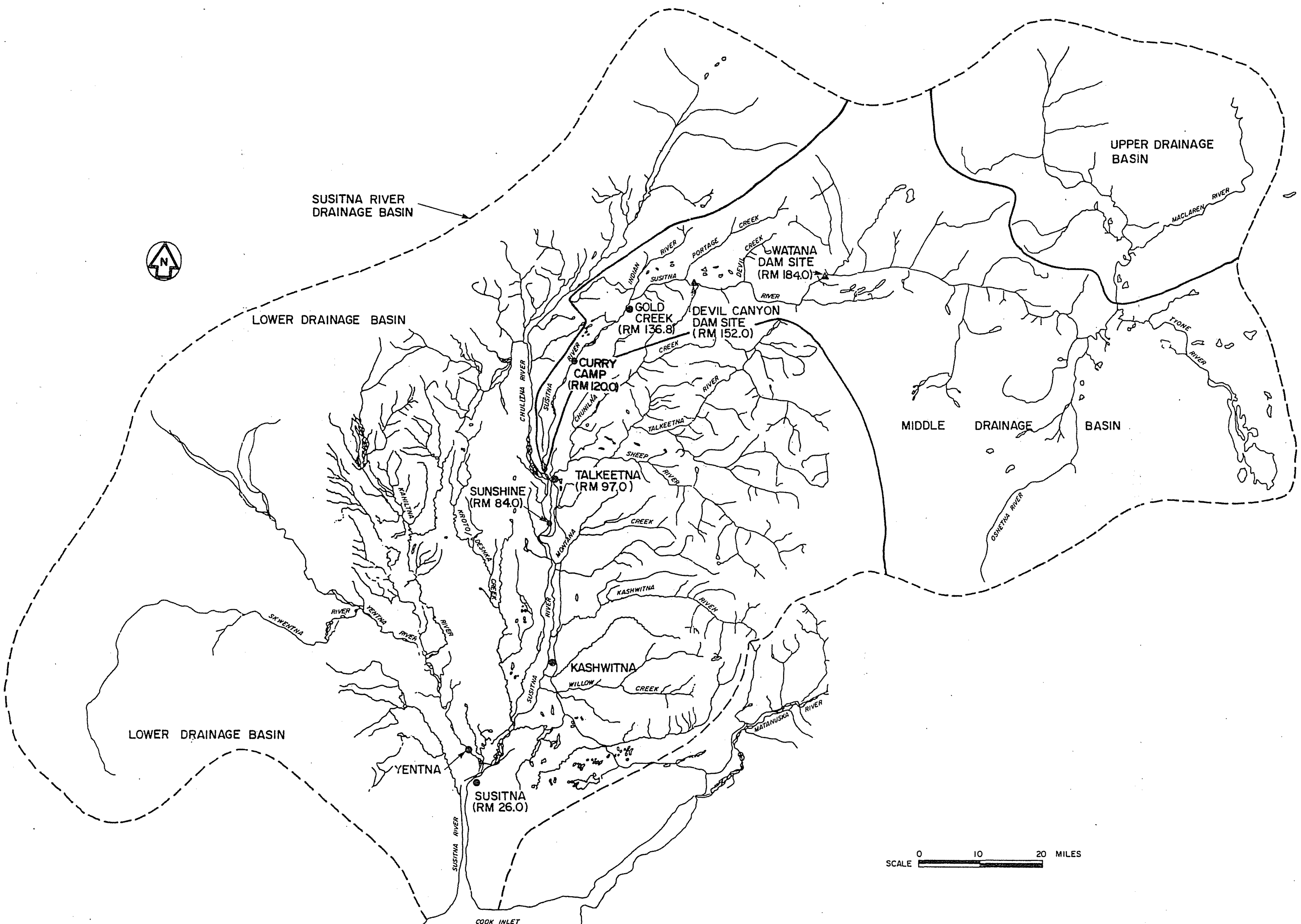
VICINITIES OF THE PROPOSED
DAM SITES, SUSITNA HYDROELECTRIC PROJECT

FIGURE E.1.2.1



SUSITNA RIVER BASIN UPSTREAM OF GOLD CREEK

FIGURE E.1.2.2



SUSITNA RIVER DRAINAGE BASIN

FIGURE E.1.2.3

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EXHIBIT E - CHAPTER 2
WATER USE AND QUALITY

LIST OF PHOTOS

1 - INTRODUCTION

EXHIBIT E - CHAPTER 2
WATER USE AND QUALITY

1 - INTRODUCTION (**)

Exhibit E Chapter 2 contains discussions of Water Use and Quality. These are divided into six sections:

1 - Introduction;
2 - Baseline Conditions;
3 - Operational Flow Regime Selection;
4 - Project Impacts;
5 - Agency Concerns and Recommendations; and
6 - Mitigative, Enhancement, and Protective Measures.

Within the sections on baseline conditions and project impacts, emphasis is placed on river morphology, flows, water quality parameters, ground water conditions and instream flow uses. The importance of flows and instream flow uses cannot be overstressed. For this reason, mean flows, flood flows, low flows and flow variability are discussed in detail.

The primary focus of the water quality discussion is on those parameters determined most critical for the maintenance of habitat for fish populations and other aquatic organisms. Detailed discussions are presented on water temperature, ice, suspended sediments, turbidity, dissolved oxygen, total dissolved gas concentration and nutrients. These parameters have been identified as areas of greatest concern. Mainstem surface water-habitat groundwater interaction downstream from Devil Canyon, which is important to successful salmonid spawning in the habitat areas, is also discussed.

The primary instream flow uses of the Susitna River are for fish, wildlife and riparian vegetation. Since these are discussed in Chapter 3, they are only briefly discussed in this chapter. Other instream flow uses discussed include navigation and transportation, recreation, waste assimilative capacity, and freshwater recruitment to the river's estuary in Cook Inlet. Since minimal out-of-river use is made of the water, limited discussions have been presented on this topic.

In the section on Operational Flow Regime Selection, the characteristics of the Watana and Devil Canyon Reservoirs are described and the alternative operating flow scenarios are discussed. The rationale for the selected operational flow regime is presented.

Project impacts have been separated into the three project stages (I,II, and III) of development. Impacts associated with each stage are presented in the order: construction, impoundment, and operation.

The agency concerns and recommendations that have been received are addressed. Section 5 of this chapter highlights the major concerns. Detailed responses to individual comments are addressed in Chapter 11 of Exhibit E.

The mitigation plans discussed in Section 6 of this Chapter incorporate the engineering and construction measures necessary to minimize potential impacts.

The outline for this chapter is essentially the same as for Exhibit E, Chapter 2 of the License Application accepted by the FERC on July 29, 1983. The major difference is the inclusion of material dealing with Stage III of the three-stage project in Sections 4 and 6.

A notational procedure has been developed to denote differences between this Amended License Application and that previously accepted. This system consists of marks made beside all headings as follows:

(o) No change was made in this section, it remains the same as was presented in the original License Application,

(*) Only minor changes, largely of an editorial nature have been made,

(**) Major rewriting with significant changes have been made in this section, and

(***) This is an entirely new section which did not appear in the original License Application.

In general most of Chapter 2 is identified as having major rewriting with significant changes or entirely new sections. These changes result from the refined analyses which have been made since the acceptance of the original License Application on July 29, 1983. These refinements have generally resulted from concerns of the FERC, other federal and state agencies, concerned organizations and private citizens. The major changes which are reflected in this chapter are the three-stage construction sequence for the project and the refinement and selection of the Case E-VI environmental flow requirements as submitted to the FERC in February 1985.

Studies which have been significantly refined include those relating to reservoir operation and river flow stability, river temperatures, river ice conditions and suspended sediment and turbidity. Considerable additional information has been developed on baseline conditions including river morphology, channel stability and groundwater conditions in peripheral habitat areas. These analyses are extended into with-project assessments.

Despite the large amount of refinement to the original License Application which is represented by this Amended Exhibit E Chapter 2, the conclusions of the original Exhibit E, Chapter 2 are still largely valid. The Case E-VI flow requirements introduce additional stability into the with-project flow regime to meet the fishery management objectives and provide power to meet the needs of the Alaska Railbelt. The reservoir and river temperature and ice simulations, are presented in great detail for all three stages. The simulations are also discussed in other reports by the Applicant and they support the conclusions in the original License Application (references in text). The same is true for groundwater, channel morphology, suspended sediment, gas supersaturation, and most other topics discussed in this chapter. The most notable exception is that winter turbidity levels, with-project, are now estimated to be higher than previously expected and higher than natural conditions. Summer suspended sediment concentrations and turbidity levels are still expected to be less than natural.

The three-stage project effects on water use and quality differ when compared to the original two-stage project as follows:

- Smaller reservoir volume and reduced storage capacity for the first two stages of the project;

- Decreased flow stability for Stage I and, to a lesser extent for Stage II, in comparison with Stage III and the two-stage project;

- Lower downstream river temperatures (about 1°C) in winter and somewhat greater ice cover development and water level increases in Stages I and II as compared to Stage III and the two-stage project; and

- Slightly greater downstream suspended sediment concentrations and turbidities in Stages I and II as compared to Stage III and the two-stage project.

Since the original License Application was accepted in July 1983, the Applicant has involved many federal and state agencies, concerned organizations and individuals in the process of refining the studies. This has been accomplished in workshops, meetings to discuss the issues, and in many informal meetings and discussions. As a result, the Applicant has developed a better understanding of concerns regarding the project. Section 5 of this chapter reflects this enhanced understanding.

The detailed studies which the Applicant has undertaken have also resulted in a better understanding of the Susitna River itself, and the effects of the project, as well as methods which can be employed to best utilize the resources of the river. This is reflected in the large number of sensitivity studies presented in the chapter and in the mitigation plans discussed in Section 6 of this chapter and in Chapter 3.

2 - BASELINE DESCRIPTION

2 - BASELINE DESCRIPTION (**)

The Susitna River originates in the East Fork and West Fork Susitna Glaciers at an altitude of about 7,800 ft msl and travels a distance of approximately 318 miles where it discharges into Cook Inlet at sea level. Major tributaries of the Susitna River are shown in the following table:

Major Susitna River Tributaries	Location of Confluence with Susitna River River Mile (RM)
Maclaren River	260
Tyone River	247
Oshetna River	233
Chulitna River	98
Talkeetna River	97
Yentna River	27

The U.S. Geological Survey maintains gaging stations on the Susitna River at the locations shown in the following table:

U.S. Geological Survey Gaging Station	Drainage Area (sq. mi.)	Altitude (ft. msl)	Location (RM)
Near Denali	950	2,440	291
Near Cantwell	4,140	1,900	223
At Gold Creek	6,160	680	137
At Sunshine	11,100	270	84
At Susitna Station	19,400	40	26

The Susitna Hydroelectric Project consists of the Watana and Devil Canyon Dams along with their appurtenant facilities. The locations of the dams are described in the followig table:

Dam	Drainage Area (sq. mi.)	Altitude (ft. msl)	Location (RM)
Watana	5,180	1,450	184
Devil Canyon	5,810	850	152

The entire drainage area of the Susitna River is about 19,400 square miles, 6,160 square miles of which are above Gold Creek (Figure E.2.2.1). Three glaciers in the Alaska Range feed forks of the Susitna River; these flow southward for about 18 miles and then join to form the Susitna River. The river flows an additional 55 miles southward through a broad valley where much of the coarse sediment from the glaciers settles out. The river then flows westward about 96 miles through a narrow valley, with constrictions at the Devil Creek and Devil Canyon areas creating violent rapids. Numerous small, steep gradient, clear-water tributaries flow into the Susitna in this reach of the river. Several of these tributaries cascade over waterfalls as they enter the gorge. As the Susitna curves south past Gold Creek, 13 miles downstream from the mouth of Devil Canyon, its gradient gradually decreases. The river is joined about 40 miles beyond Gold Creek near the town of Talkeetna by two major tributaries, the Chulitna and Talkeetna Rivers. A third major tributary, the Yentna River, joins the Susitna River about 70 miles downstream of this confluence and 27 miles upstream of the mouth. From the Chulitna - Talkeetna - Susitna confluence, the Susitna flows south through braided channels for 97 miles until it empties into Cook Inlet near Anchorage, approximately 318 miles from its source.

For ease of discussion, the watershed has been divided into three drainage basins. The upper basin and upper river (upper reach) extend from the glacial headwaters of the Susitna River to the confluence of the Tyone River (RM 247). The middle basin and middle river (middle reach) extends downstream from this point to the Chulitna-Susitna confluence (RM 98) and contains the Watana and Devil Canyon damsites. The middle basin is where the major project-related impacts will occur. The lower basin and lower river (lower reach) is defined as the drainage basin from the Chulitna-Susitna confluence to Cook Inlet. The approximate boundaries of the three basins are shown in Figure E.2.2.1.

The Susitna River is typical of unregulated northern glacial rivers with high, turbid summer flow and low, clear winter flow. Runoff from snow melt and rainfall in the spring causes a rapid increase in flow in May from the low discharges experienced throughout the winter.

Peak annual floods usually occur in June. Approximately 90 percent of the annual flow occurs between May and September. At Gold Creek, average flows approach 6,000 cubic feet per second (cfs) in October, the start of the water year. The flow decreases in November and December as the river freezes. Low flows of about 1,000 cfs occur in March and April. Breakup of the river ice cover occurs in early to mid May. Average monthly flows are more than 13,000 cfs in May and peak at about 27,000 cfs in June. Average flows gradually decrease to 24,000 cfs in July, 22,000 cfs in August, and 13,000 cfs in September.

Rainfall-related floods often occur in August and early September, but generally these floods are not as severe as the spring (May-June) snowmelt floods.

Associated with the higher spring flows is a 100-fold increase in sediment transport which persists throughout the summer. Between June and September, the large suspended sediment concentration causes the river to be highly turbid. Glacial silt (glacial flour) released by the glaciers when they begin to melt in late spring, picked up by the river from sediment deposited in the upper reaches, or re-entrained from the river banks by summer flows is responsible for most of the turbidity.

As the weather begins to cool in the fall, the glacial melt rate decreases and the flow in the river correspondingly decreases. As runoff from the watershed and flow from the glaciated areas decrease, the transport of fine material into the river is reduced, and the river begins to clear. Freeze-up normally begins in October when ice from the Susitna River and Yentna River combine to form an ice bridge near the mouth of the Susitna River. Accumulation of slush from upstream and intermittent bridging of the ice cover at natural lodgement points cause the ice to progress up stream. Freeze-up of the river generally takes 5 to 10 weeks. The river is generally ice covered between the mouth and Gold Creek between mid-December and early January. Freeze-up of the river at locations in the upper basin may begin prior to freeze-up of the lower river. The river break-up or melt-out generally begins in late April or early May near the mouth, and progresses upstream with break-up near the damsites occurring in mid-May.

2.1 - Susitna River Morphology (**)

2.1.1 - Mainstem (**)

The Susitna River originates in the glaciers of the southern slopes of the central Alaskan Range, flowing 318 miles from Susitna Glacier to the river's mouth at Cook Inlet. Throughout its course, the Susitna River is characterized by several reach types. These are defined and illustrated in Figures E.2.2.2 through E.2.2.5.

(a) Morphological Characteristics Upstream of Devil Canyon (*)

The headwaters of the Susitna River and the major upper basin tributaries are characterized by broad, braided, gravel floodplains below the glaciers, with several meltwater streams exiting from beneath the glaciers before they combine further downstream. The West Fork Susitna River joins the main river about 18 miles below Susitna Glacier. Below the West Fork confluence, the Susitna River develops a split-channel configuration with numerous islands. The river is generally constrained by low bluffs for about 55 miles. The Maclaren River, a significant glacial tributary, and the non-glacial Tyone River, which drains Lake Louise and the swampy lowlands of the southeastern upper basin, both enter the Susitna River from the east at River Mile (RM) 260 and RM 247 respectively.

Below the confluence with the Tyone River, the Susitna River flows west for 96 miles through steep-walled canyons before reaching the mouth of Devil Canyon. The reach contains the Watana and Devil Canyon damsites at RM 184.4 and 151.6, respectively. River gradients are high, averaging nearly 14 feet per mile in the 54 mile reach upstream of the Watana damsite where the Watana Reservoir will be located. Downstream from Watana to Devil Creek, the river gradient is approximately 10.4 feet per mile as illustrated in the profile contained in Figure E.2.2.6. In the 12 mile reach between Devil Creek and Devil Canyon, the river gradient averages 31 feet per mile.

This 96 mile-long reach is primarily a single channel with intermittent islands. Cross sections presented in the Hydraulic and Ice Studies Report (R&M 1982b) illustrate the single channel configuration. Bed material mainly consists of large gravel and cobbles. The mouth of Devil Canyon at RM 149 forms the lower limit of this reach.

(b) Morphological Characteristics Downstream from Devil Canyon (**)

Between Devil Canyon and the mouth at Cook Inlet, the river has been subdivided into nine separate reaches (R&M 1982d). These reaches are identified in Table E.2.2.1, together with the average slopes and predominant channel patterns. Additional cross section data for the reaches between RM 95 and RM 149, RM 85 and RM 99, and RM 9 and RM 84, are contained in Hydraulic and Ice Studies (R&M 1982b), Hydrographic Surveys Report (R&M 1982h), Susitna River Ice Study - 1984 Freezeup (R&M 1985a) and Lower Susitna River Aggradation Study, Field Data (R&M 1985b). The thalweg profiles between Portage Creek and Talkeetna and between Sunshine and Cook Inlet are shown in Figures E.2.2.7, E.2.2.8, and E.2.2.9. Figures E.2.2.10 and E.2.2.11 illustrate cross sections at RM 129.7 near Sherman and RM 87.7 a few miles upstream of the Parks Highway Bridge, respectively. Aerial photographs of the Susitna River between Portage Creek and Talkeetna are presented in Figures E.2.2.12 through E.2.2.21. Additional aerial photographs of the reach between RM 103 and RM 149 and the reach between Cook Inlet and Talkeetna are presented in reports by E.W. Trihey and Associates (1984) and R&M (1985c). The nine reaches are discussed below:

(i) RM 149 to RM 144 (*)

Through this reach, the Susitna flows predominantly in a single channel confined by valley walls. At locations where the valley bottom widens, deposition of gravel and cobble has formed mid-channel or side-channel bars. Occasionally, a vegetated island or fragmentary floodplain has formed with elevations above normal flood levels, and has become vegetated. Presence of cobbles and boulders in the bed material aids in stabilization of the channel geometry.

(ii) RM 144 to RM 139 (o)

A broadening of the valley bottom through this reach has allowed the river to develop a split channel with intermittent, well-vegetated islands. A correlation exists between bankfull stage and mean-annual flood. Where the main channel impinges on valley walls or terraces, a cobble armor layer has developed with a top elevation at roughly bankfull flood stage. At RM 144, a periglacial alluvial fan of coarse sediments confines the river to a single channel.

(iii) RM 139 to RM 129.5 (*)

This river reach is characterized by a well-defined split channel configuration. Vegetated islands separate the main channel from side channels. Side channels occur frequently in the alluvial floodplain and are inundated only at flows above 15,000 to 20,000 cfs. There is a good correlation between bankfull stage and the mean annual flood.

Where the main channel impinges on valley walls or terraces, a cobble armor layer has developed with a top elevation at roughly bankfull flood stage. The main channel bed has been frequently observed to be well armored.

Primary tributaries include Indian River, Gold Creek and Fourth of July Creek. Each has formed an alluvial fan extending into the valley bottom, constricting the Susitna to a single channel. Each constriction has established a hydraulic control point that regulates water surface profiles and associated hydraulic parameters at varying discharges.

(iv) RM 129.5 to RM 119 (o)

River patterns through this reach are similar to those in the previous reach. Prominent characteristics between Sherman and Curry include the main channel flowing against the west valley wall and the east floodplain having several side channels and sloughs. The alluvial fan at Curry constricts the Susitna to a single channel and terminates the above patterns. A fair correlation exists between bankfull stage and mean annual flood through this reach. Comparison of 1950 and 1980 aerial photographs reveal occasional local changes in banklines and island morphology.

The west valley wall is generally nonerodible and has occasional bedrock outcrops. The resistant boundary on one side of the main channel has generally forced a uniform channel configuration with a well armored perimeter. The west valley wall is relatively straight and uniform except at RM 128 and 125.5. At these locations, bedrock outcrops deflect the main channel to the east side of the floodplain.

(v) RM 119 to RM 104 (o)

Through this reach the river is predominantly a very stable, single incised channel with a few islands. The channel banks are well armored with cobbles and boulders, as is the bed. Several large boulders occur intermittently along the main channel and are believed to have been transported down the valley during glacial ice movement. They provide local obstruction to flow and navigation, but do not have a significant impact on channel morphology.

(vi) RM 104 to RM 95 (o)

At the confluence of the Susitna, Chulitna and Talkeetna Rivers, there is a dramatic change in the Susitna from a split channel to a braided channel. Emergence from confined mountainous basins into the unconfined lowland basin has enabled the river systems to develop laterally. Ample bedload transport and a gradient decrease also assist in establishing the braided pattern.

The glacial tributaries of the Chulitna River are much closer to the confluence than the Susitna glacial tributaries. As the Chulitna River emerges from an incised canyon 20 miles (32 km) upstream of the confluence, the river transforms into a braided pattern with moderate vegetation growth on the intermediate gravel bars. At about a midpoint between the canyon and the confluence, the Chulitna exhibits a highly braided pattern with no vegetation on intermediate gravel bars, which is evidence of recent lateral instability. This pattern continues beyond the confluence, giving the impression that the Susitna is tributary to the dominant Chulitna River. The split channel Talkeetna River is a tributary to the dominant braided pattern.

Terraces generally bound the broad floodplain, but provide little control over channel morphology. General floodplain instability results from the three-river system striving to balance out the combined flow and sediment regime.

(vii) RM 95 to 61 (*)

Downstream from the three-river confluence, the Susitna continues its braided pattern, with multiple channels interlaced through a sparsely vegetated floodplain.

The channel network consists of the main channel, usually one or two subchannels, and a number of minor channels. The main channel meanders irregularly through the wide gravel floodplain and intermittently flows against the vegetated floodplain. It has the ability to easily migrate laterally within the active gravel floodplain, as the main channel is simply reworking the gravel that the system previously deposited. When the main channel flows against vegetated bank lines, erosion is retarded due to the vegetation and/or bank materials that are more resistant to erosion. Flow in the main channel usually persists throughout the entire year.

Subchannels are usually positioned near or against the vegetated floodplain and are generally on the opposite side of the floodplain from the main channel. The subchannels normally bifurcate from the main channel when it crosses over to the opposite side of the floodplain and terminate where the main channel meanders back across the floodplain and intercepts them. The subchannels have smaller geometric dimensions than the main channel, and their thalweg is generally about 5 feet higher. Their flow regime is dependent on the main channel stage and hydraulic flow controls at the point of bifurcation. Flow may or may not persist throughout the year.

Minor channels are relatively shallow, wide channels that traverse the gravel floodplains and complete the interlaced braided pattern. These channels are very unstable and generally short-lived.

The main channel and subchannels are intermittently controlled laterally where they flow against terraces. Since the active floodplain is very wide, the presence of terraces has little significance except for determining the general orientation of the river system. An exception occurs where the terraces constrict the river to a single channel at the Parks Highway bridge. Minor channels react to both of the larger channels' behaviors.

(viii) RM 61 to RM 42 (o)

Downstream from the Kashwitna River confluence, the Susitna River branches into multiple channels separated by islands with established vegetation. This reach of the river is known as the Delta Islands because it resembles the distributary channel network common with large river deltas. The multiple channels are forced together by terraces just upstream of Kroto Creek (Deshka River).

Through this reach, the very broad floodplain and channel network can be divided into three categories:

- o Western braided channels;
- o Eastern split channels; and
- o Intermediate meandering channels.

The western braided channel network is considered to be the main portion of this very complex river system. Although not substantiated by river surveys, it appears to constitute the largest flow area and lowest thalweg elevation. The reason for this is that the western braided channels constitute the shortest distance between the point of bifurcation to the confluence of the Delta Island channels. Therefore it has the steepest gradient and highest potential energy for conveyance of water and sediment.

(ix) RM 42 to RM 0 (o)

Downstream from the Delta Islands, the Susitna River gradient decreases as it approaches Cook Inlet (Figure E.2.2.9). The river tends toward a split channel configuration as it adjusts to the lower energy slope. There are short reaches where a tendency to braid emerges. Downstream of RM 20, the river branches out into delta distributary channels.

Terraces constrict the floodplain near the Kroto Creek confluence and at Susitna Station. Further downstream, the terraces have little or no influence on the river.

The Yentna River joins the Susitna at RM 27 and is a major contributor of flow and sediment.

Tides in Cook Inlet rise above 30 feet and therefore control the water surface profile and to some degree the sediment regime of the lower river. A river elevation of 30 feet exists near RM 20 which corresponds to the location where the Susitna begins to branch out into its delta channels.

The above morphological reach descriptions characterize the Susitna River streambed as having various degrees of armoring. These were based on visual observations. In order to more accurately estimate the condition and stability of the mainstem and selected side channel streambeds under natural and with-project conditions, more refined analyses were undertaken. These studies are more fully discussed in Section 2.3.3. Sites considered are shown on Figures E.2.2.22 through E.2.2.26. Table E.2.2.2 shows bed material size distributions adopted for the analysis. Table E.2.2.3 shows transportable bed material sizes at these sites for various Susitna River flows. A comparison of the transportable bed material sizes and the representative bed material sizes indicates that most of the main channel and side channel sites are subject to temporal scour and/or deposition, depending upon the magnitude and characteristics of the sediment loads and high flows caused by floods or breaching of ice jams. Bed materials in the side channel sites appear stable at higher flows then main channel bed materials as discussed further in Section 2.1.2.

2.1.2 - Sloughs and Peripheral Habitat (**)

Specific areas of the middle river have been classified as aquatic habitat dependent on the quantity and quality of water supplied to the site. This hydrologic component of aquatic habitat was evaluated for the middle river (EWT&A 1984a, 1985) from aerial photos taken when middle river discharges at Gold Creek were 5,100, 7,400, 9,000, 10,600, 12,500, 16,000, 18,000, and 23,000 cfs. Water source and morphology were the principal variables used to discriminate among habitat types. Descriptions of each habitat type are as follows:

- Mainstem habitats are those channels of the river that convey more than approximately 10 percent of the total flow at a given site. During the open water season these channels are characterized by turbidity from glacial meltwater.

- Side channel habitats are those channels of the river that convey less than approximately 10 percent of the total flow. During the open water season these channels are characterized by turbidity from glacial meltwater.

- Side slough habitats contain clear water. Local surface water runoff and upwelling groundwater are the primary sources that supply these habitats. Side sloughs have nonvegetated upper thalwegs that are overtopped during periods of moderate to high mainstem discharge. Once overtopped, side sloughs are considered side channels.

- Upland sloughs are clearwater habitats that depend upon upwelling groundwater and/or local runoff for their water sources. Upland sloughs have vegetated upper thalwegs that are seldom overtopped by mainstem discharge.

- Tributary mouths are clearwater habitats at the confluences of tributaries, where clear water mixes with turbid water. In the summer these habitats are readily apparent as clearwater plumes that extend into the turbid glacial flow of the mainstem or a side channel. The size of the plume is a function of tributary discharge and mainstem stage. Tributary mouth habitats can also occur in the tributary channel as a result of mainstem stage causing a backwater at the tributary mouth. If a backwater occurs, tributary mouth habitat extends into the tributary channel to the upstream extent of the backwater.

- Tributary habitats are clearwater reaches of tributary streams upstream of the tributary mouth habitats.

Side sloughs have been identified as an important fishery habitat area of the middle river. They are generally spring-fed, overflow channels that exist along the edge of the floodplain, separated from the river by well-vegetated bars. An exposed alluvial berm often separates the head of the sloughs from the mainstem or side-channel flow. The controlling streambank elevations at the upstream end of the sloughs are less than the mainstem water surface elevations during median and high flow periods. At intermediate and low flows, the sloughs convey clear water from small tributaries and upwelling ground water (ADF&G 1982a).

Differences between mainstem water surface elevations and the streambed elevation of the sloughs are notably greater at the upstream entrance to the sloughs than at the mouth of the sloughs. The gradients within the sloughs are typically greater than in the adjacent mainstem because of their shorter path length from the upstream end to the downstream end, than along the mainstem. The upstream end of the sloughs generally has a higher gradient than the lower end. This is evidenced in Figure E.2.2.27, which illustrates the thalweg profile of a typical slough.

The sloughs vary in length from 2,000 to 6,000 feet. Cross-sections of sloughs are typically rectangular with flat bottoms as illustrated in Figure E.2.2.28. At the head of the sloughs, substrates are dominated by boulders and cobbles. Progressing downstream towards the slough mouth, substrate particles reduce in size with gravels and sands predominating (Figure E.2.2.27). Beavers frequently inhabit the sloughs. Active and abandoned dams are visible. Vegetation commonly covers the banks to the water's edge with bank cutting and slumping occurring during spring break-up flows and high summer flows.

The characterization of a habitat as a side slough or side channel depends primarily on mainstem flow. For example, a particular area which is a side channel at normal summer flows of approximately 20,000 cfs may become a side slough at lower mainstem flows as the water level and flow through the area decrease. The area may become separated from the mainstem, and the sources of flow may become groundwater and local tributary runoff. A further explanation of habitat transformation is explained in Chapter 3. The slough and side channel designations in Chapter 2 refer to their characterizations under natural conditions.

Bed stability analyses have also been carried out for selected side channels and side sloughs. These sites are shown on Figures E.2.2.22 through E.2.2.26. Tables E.2.2.2 and E.2.2.3 may be used to compare representative bed material sizes with transportable sizes. These tables indicate that slough bed material is also subject to temporal scour and deposition depending on the magnitude of flows. However, flows required to initiate bed material motion in sloughs are generally higher than at side channels and mainstem locations.

The importance of the side channels, sloughs and tributary mouths as salmon spawning and rearing habitat is discussed in detail in Chapter 3.

2.2 - Susitna River Water Quantity (**)

2.2.1 - Mean Monthly and Annual Flows (**)

Continuous historical streamflow records of various lengths (7 to 34 years) through water year (WY) 1983 exist for gaging stations on the Susitna River and its tributaries. USGS gages are located at Denali, Vee Canyon (denoted as "near Cantwell"), Gold Creek and Susitna Station on the Susitna River; on the Maclaren River near Paxson; on the Chulitna River near Talkeetna; at Talkeetna on the Talkeetna River; and at Skwentna on the Skwentna River.

In 1980 a USGS gaging station was installed on the Yentna River and in 1981 a USGS gaging station was installed at Sunshine on the Susitna River. Statistics on river mile, drainage area and years of record are shown in Table E.2.2.4, and a summary of the maximum, mean and minimum monthly flows for the period through water year 1981 are shown in Table E.2.2.5. Because of the short duration of the stream flow records at Sunshine and on the Yentna, summaries for these two stations have not been included. The station locations are illustrated in Figure E.2.2.1.

Monthly and seven-day streamflow sequences for the Susitna River at the Watana and Devil Canyon sites and at Gold Creek were calculated using procedures outlined in a previous report by the Applicant (HE 1985a, 1985b). Data are presented in Tables E.2.2.6 through E.2.2.11. Streamflow sequences for seven-day periods for the Susitna River at Sunshine and Susitna Station, the Chulitna River near Talkeetna, the Talkeetna River near Talkeetna, and the Skwentna River near Skwentna were generated using procedures in previous reports (HE 1984b, HE 1985a, 1985b). Flows for Sunshine and Susitna Stations are shown in Tables E.2.2.12 and E.2.2.13, respectively. The streamflow sequences shown in Tables E.2.2.6 through E.2.2.9 were used in weekly and monthly reservoir operation simulations. The 1969 low flow year was not modified for these sequences as it had been for the License Application accepted by the FERC on July 29, 1983. Table E.2.2.14 compares monthly mean, maximum and minimum flows at several sites in the basin. Monthly streamflow sequences for the Susitna River at Sunshine and Susitna Station and for the Chulitna and Talkeetna Rivers near Talkeetna are shown on Tables E.2.2.15 through E.2.2.18 respectively.

Comparison of mean annual flows in Table E.2.2.14 indicates that approximately 40 percent of the streamflow at Gold Creek originates above the Denali and Maclaren gages. It is in this catchment that the glaciers which contribute to the flow at Gold Creek are located.

The Susitna River above Gold Creek contributes approximately 20 percent of the mean annual flow measured at Susitna Station near Cook Inlet. The Chulitna, and Talkeetna Rivers contribute approximately 20 and 10 percent of the mean annual Susitna Station flow, respectively. The Yentna provides approximately 40 percent of the flow, with the remaining 10 percent originating in miscellaneous tributaries.

Thus, the area controlled by the project contributes less than 20 percent of the Susitna River flow near Cook Inlet and for this reason, project effects on flows and floods in the lower river would be considerably less than effects in the middle river.

The variation between summer mean monthly flows and winter mean monthly flows is greater than a 10 to 1 ratio at all stations. This large seasonal difference is due to the characteristics of a glacial river system. Glacial melt, snow melt, and rainfall provide most of the annual river flow during the summer. At Gold Creek, for example, slightly less than 90 percent of the annual streamflow volume occurs from May to September.

A comparison of the maximum and minimum monthly flows for May through September indicates a high flow variability at all stations from year to year.

The glaciated portions of the Susitna River Basin above Gold Creek play a significant role in the hydrology of the area. Located on the southern slopes of the Alaska Range, the glaciated regions receive the greatest amount of snow and rainfall in the basin. During the summer months, these regions contribute significant amounts of snow and glacial melt. The glaciers, covering about 290 square miles, act as reservoirs that may produce a significant portion of the water in the basin above Gold Creek during drought periods. The drainage area upstream of the Denali and Maclaren gages comprises 19.9 percent of the basin above Gold Creek, yet contributes approximately 40 percent of the average annual flow at Gold Creek (approximately 50 percent of the flow at Watana). Stated another way, the area upstream of the Denali and Maclaren gages contributes 3.1 cubic feet per second (cfs) per square mile, and the area downstream to Gold Creek contributes 1.2 cfs per square mile. In the record drought year of 1969, the proportion of flow at Gold Creek contributed from upstream of the Denali and Maclaren gages was greater than 50 percent.

The Applicant has made several studies to determine the glacier characteristics including the potential for outburst floods, effects on river sediment and the importance as a source of water for the project (R&M 1982a, 1981b). These studies indicated that there is evidence from East Fork Glacier, a small glacier of 13.6 square miles, that glacier wasting has contributed to the runoff at Gold Creek since 1949. However, the magnitude of the runoff from glacier wasting was not well documented. There were potentially significant errors in the ice loss estimate at East Fork Glacier due to the lack of adequate survey control.

Therefore, the Applicant continued studies of the glaciers. Mass balance measurements were made between 1981 and 1983 (Harrison 1985). A second estimate of the altitude of the East Fork Glacier was made using an aerial survey technique (Clarke 1985). These studies indicate that the effect of "net glacial wasting" as a source of Susitna River flow during the 1949-1981 period may not be as high as was previously estimated. The studies are further described in the following paragraphs.

Clarke (1985) refined the estimate of wasting of East Fork Glacier. The altitude of various points in the glacier was computed using a helicopter with an altimeter calibrated to points of known elevation. The study indicated that the upper portions of the glacier may not have wasted since 1949 and that the average change in elevation of the glacier surface may have been only 13 m (water equivalent) in the period 1949-1982.

A limited study of the mass balance of the glaciers in the Susitna Basin was carried out for the period 1981-1983 by the Applicant (R&M 1981b, 1982a, Harrison 1985). Although the results of the study are subject to considerable uncertainty due to the limited nature of the surveys, the results indicate there was no net waste of the glaciers between 1981 and 1983. During the same period the Susitna River streamflows measured at Denali, Paxson and Gold Creek were slightly higher than the average, over long periods of record. The precipitation measured at Talkeetna for the same period was slightly higher than the long term average. It does not appear that the effect of "net" glacier waste on streamflows at the damsites is as high as was originally estimated.

For years of very low precipitation, runoff from the glaciers will be more important, and there may be substantial net wastes of glaciers. However, if long-term mean precipitation stays approximately the same, it is likely that net waste of glaciers in one year will be replenished by excess snow in another.

It is difficult to predict future trends. If the glaciers were to stop wasting due to, perhaps, a climate change, there could be implications for hydrological changes throughout the basin. On the other hand, the wasting of the glaciers could easily continue over the life of the project. There is no way to judge whether wasting would continue into the future; hence, no mechanism presently exists for analyzing what would occur during the life of the project.

2.2.2 - Floods (**)

The most common causes of floods in the Susitna River Basin are snow melt or a combination of snow melt and rainfall over a large area. This type of flood occurs in May and June with the majority occurring in June. Floods attributable to heavy rains have occurred in August and September. These floods are augmented by snow melt from higher elevations and glacial runoff.

Examples of flood hydrographs can be seen in the daily discharges for 1964, 1967, and 1970 for Cantwell, Watana, and Gold Creeks which are illustrated in Figures E.2.2.29 through E.2.2.31. The daily flow at Watana has been approximated using a linear drainage area-flow relationship between Cantwell and Gold Creek. Figure E.2.2.29 shows the largest snow-melt related flood on record at Gold Creek. The 1967 spring flood hydrograph shown in Figure E.2.2.30 has a instantaneous peak equal to the mean annual daily flood peak. In addition, the summer daily flood peak of 80,200 cfs is the fifth largest flood peak at Gold Creek on record. Figure E.2.2.31 illustrates a low flow spring flood hydrograph for 1970.

The maximum recorded instantaneous flood peaks for Denali, Cantwell, Gold Creek, and Maclaren, recorded by the USGS, are presented in Table E.2.2.19. Instantaneous peak flood frequency curves for individual stations are illustrated in Figures E.2.2.32 to E.2.2.41. Flood peak and volume frequency analyses for Gold Creek, Devil Canyon and Watana are presented in a report by the Applicant (HE 1984c). Tables E.2.2.20 and E.2.2.21 present flood peak and flood volume frequency analyses for the Watana and Devil Canyon damsites. Flood hydrographs for the 50 year annual series floods at Watana and Devil Canyon damsites are shown in Figures E.2.2.42 and E.2.2.43, respectively. A regional flood frequency analysis was also conducted, using recorded floods in the Susitna River and other Cook Inlet tributaries (R&M 1981f). A comparison of the flood frequency estimates based on the regional analyses and the station record is shown in Table E.2.2.22. The frequency curves based on the station record were adopted for further studies because the length of the record (34 years) is sufficient for estimating floods with return periods up to approximately 50 years.

Based on the station record, estimates of the 100-year, 1,000-year and 10,000 year floods at Gold Creek and the damsites have been made.

Recurrence Interval (years)	Flood Estimate Gold Creek	Devil Canyon	Watana	95% One-sided Upper Confidence Limit Gold Creek	Devil Canyon	Watana
100	108,000	105,000	99,000	138,000	132,000	125,000
1,000	147,000	143,000	135,000	200,000	194,000	184,000
10,000	190,000	184,000	174,000	270,000	262,000	248,000

Since the station records are only available for 34 years, estimates of the 95 percent upper confidence limit have been provided.

The mean annual flood at Gold Creek is the flood having a return period of 2.33 years (Chow 1964) estimated to be approximately 50,000 cfs. The mean annual floods at Watana and Devil Canyon would be approximately 45,000 cfs and 48,000 cfs, respectively.

Probable maximum flood (PMF) studies were conducted for both the Watana and Devil Canyon damsites for use in the design of project spillways and related facilities (Exhibit F, Appendix F3). The PMF floods were determined by using the SSARR watershed model developed by the Portland District, U.S. Army Corps of Engineers (1975) and are based on Susitna Basin climatic data and hydrology. The probable maximum precipitation was derived from a maximization study of historical storms. The studies indicate that the PMF peak at the Watana damsite is 326,000 cfs.

2.2.3 - Flow Variability (**)

The variability of flow in a river system is important to all instream flow uses. To illustrate the variability of flow in the Susitna River, monthly and annual flow duration curves showing the proportion of time that the discharge equals or exceeds a given value were developed for three mainstem Susitna River gaging stations (Gold Creek, Sunshine, Susitna Station) and three major tributaries (Maclaren, Chulitna, and Talkeetna Rivers) (R&M 1982f). These curves, based on mean daily flows, are illustrated in Figures E.2.2.44 through E.2.2.47. Weekly flow duration curves for the Susitna River at Gold Creek, Sunshine and Susitna Station are also available (HE 1985f Appendix E).

The shape of the monthly and annual flow duration curves is similar for each of the stations and is indicative of flow from northern glacial rivers (R&M 1982f). Streamflow is low in the winter months, with little variation in flow and no unusual peaks. Ground water contributions are the primary source of the small but relatively constant winter flows. Flow begins to increase slightly in April as breakup approaches. Peak flows in May are an order of magnitude greater than in April. Flow in May also shows the greatest variation for any month, as low flows may continue into May before the high snow melt/breakup flows occur. June has the highest peaks and the highest median flow for the middle and upper basin stations. The months of July and August have relatively flat flow duration curves. This situation is indicative of rivers with strong base flow characteristics, as is the case on the Susitna with its contributions from snow and glacial melt during the summer. More variability of flow is evident in September and October as cooler weather becomes more prevalent accompanied by a decrease in rainfall, runoff, glacial melt and hence discharge.

From the flow duration curve for Gold Creek (Figure E.2.2.44), it can be seen that flows at Gold Creek are less than 20,000 cfs from October through April. As a result of the spring breakup in May, flows of 20,000 cfs are exceeded 30 percent of the time. During June and July, the percent of time Gold Creek flows exceed 20,000 cfs increases to 80 percent. This percentage decreases to 65 percent in August and further decreases to only about 15 percent in September. On an annual basis, a flow of 20,000 cfs is exceeded 20 percent of the time.

The 1-day, 3-day, 7-day and 15-day high and the 1-day, 3-day, 7-day and 14-day low flow values were determined for each month of the year for the period of record at Gold Creek and from May through October for the periods of record at the Chulitna River near Talkeetna, the Talkeetna River near Talkeetna and the Susitna River at Susitna Station (R&M 1982f). The high and low flow values are presented for Gold Creek in the form of frequency curves in Figures E.2.2.48 through E.2.2.67. May exhibits substantial variability. Both low winter flows and high breakup flows usually occur during May and thus significant changes occur from year to year. June exhibits more variability than July. Flow variability increases again in the August through October period. Heavy rainstorms often occur in August, with 28 percent of the annual floods occurring in this month. Flow variability in the winter months is reduced considerably reflecting the low base flow.

The daily hydrographs for 1964, 1967, and 1970 shown in Figures E.2.2.29 to E.2.2.31 illustrate the daily variability of the Susitna River at Gold Creek and Cantwell. The years 1964, 1967, and 1970 represent wet, average and dry hydrological years on an annual flow basis.

2.2.4 - Water Levels (**)

(a) Mainstem (**)

Water surface elevations for various Watana discharges in the reach between Deadman Creek (RM 186.8) and Devil Creek (RM 162.1) are listed in Table E.2.2.23. The elevations were determined with the use of the HEC-2 computer program "Water Surface Profiles", developed by the U.S. Army Corps of Engineers (1981).

The HEC-2 program was also used to predict water levels for the reach between Devil Canyon and Talkeetna. The water surface elevations are presented in Table E.2.2.24 (HE 1984d). The water levels presented for the Gold Creek flow of 52,000 cfs would be slightly higher than those associated with the mean annual flood.

In addition to the water levels presented in Table E.2.2.24 for the selected flow cases, the HEC-2 program was used to determine water levels for the 1:100 year flood and the PMF in the reach between Devil Canyon and Talkeetna. The 1:100 year floodplain boundary is illustrated in Figures E.2.2.13 through E.2.2.21. The water surface profile associated with the 1:100-year flood and the PMF water surface profile are presented in Figures E.2.2.7 and E.2.2.8.

Water depths, velocities and water surface profiles are included in the previously referenced report (HE 1984d).

(b) Sloughs (**)

The water surface elevation of the mainstem generally causes a backwater effect at the mouth of the sloughs. The back-water effects in Slough 9, resulting from several mainstem Susitna discharges are shown in Figure E.2.2.68. The backwater profiles were determined using the stage-discharge relationship shown in Figure E.2.2.69 and the HEC-2 program. The stage-discharge curve was obtained from 1982 field data.

Upstream of the backwater effects, the sloughs function like small stream systems conveying water from local runoff and groundwater upwelling during low flow periods and mainstem water during high flow periods when the upstream end of the slough is overtopped by the mainstem flow.

2.3 - Susitna River Water Quality (**)

As previously described in Section 2, the Susitna River is characterized by large seasonal fluctuations in discharge. These flow variations, along with the glacial origins of the river, essentially dictate the water quality of the river.

Water quality data collected by the U.S. Geological Survey (USGS) and R&M Consultants (R&M), have been compiled for the mainstem Susitna River from monitoring stations located at Denali, Cantwell (Vee Canyon), Gold Creek, Sunshine, and Susitna Station. In addition, data from the tributary Chulitna and Talkeetna Rivers, have also been compiled. Water quality monitoring station information is presented in Table E.2.2.4. Locations of the respective stations are depicted in Figure E.2.2.1.

Water quality data were compiled according to season: breakup, summer and winter. Breakup is usually short and extends from the time ice begins to move down river until the recession of spring runoff. However, it was often difficult to assess the termination of spring runoff so for the purpose of this report, breakup water quality data were considered to be data collected during the month of May. The summer data period was considered to extend from the end of breakup (June 1) until the water temperature dropped to essentially 0°C (32°F). Winter data were compiled from the end of summer to the beginning of breakup (May 1). In the event that no water temperature data were available to delineate the termination of summer and the onset of the winter period, October 15 was utilized as the cutoff. The water quality parameters measured, and the respective detection limits of the methods used to analyze the samples, are provided in Table E.2.2.25. Water quality was evaluated using criteria and guidelines set forth in the following references:

- ADEC. 1979. Water Quality Standards. Alaska Department of Environmental Conservation, Juneau, Alaska.

- USEPA. 1976. Quality Criteria for Water. U.S. Environmental Protection Agency, Washington, D.C.

- McNeely, R.N., V.P. Neismanism and K. Dwyer. 1979. Water Quality Sourcebook-A Guide to Water Quality Parameters. Environment Canada, Inland Waters Directorate, Water Quality Branch Ottawa, Canada.

- Sittig, M. 1981. Handbook of Toxic and Hazardous Chemicals. Noyes Publications, Park Ridge, New Jersey.

- USEPA. 1980. Water Quality Criteria Documents: Availability. Environmental Protection Agency, Federal Register, 45, 79318-79379.

The criteria used for each parameter were chosen based on a priority system. The Alaska Department of Environmental Conservation's Water Quality Standards (1979) were the first choice, followed by criteria presented in USEPA's Quality Criteria for Water (1976). If a criterion expressed as a specific concentration was not presented in either of these references, the other references were used.

A second priority system was necessary for selecting the criteria used for each parameter. This was required because the various references cite levels of parameters that provide for the protection of water quality for specific uses, such as (1) the propagation of fish and other aquatic organisms; (2) water supply for drinking and food preparation, (3) industrial processes and/or agriculture; and (4) water recreation. Given the limited direct human use of the river, the first priority was to present the criteria that apply to the protection of freshwater aquatic organisms. The second priority was to present levels of parameters that are acceptable for water supply and the third priority was to present other guidelines if available. Criteria and guideline values are provided in Table E.2.2.25 and in each of the individual water quality data summary figures to be discussed later in this document.

Although the Susitna River is a pristine area, 22 parameters exceeded their respective criteria. These parameters, the location and the season during which the criteria were exceeded, and the respective source of the criteria limits, are identified in Table E.2.2.26. In addition, information for establishment of the criteria levels are provided in the individual water quality data summary figures.

Note that water quality standards apply to man-induced alterations and constitute the degree of degradation which may not be exceeded. Because there are no industries except for placer mining operations, no significant agricultural areas, and no major cities adjacent to the Susitna, Talkeetna, and Chulitna Rivers, the measured levels of these parameters are considered to be natural conditions. In addition, the Susitna River basin supports diverse populations of fish and other aquatic life. Consequently, it was concluded that the parameters exceeding their criteria probably do not have significant adverse effects on aquatic organisms. As such, limited additional discussions will be given to criteria exceedance.

In the following sections, breakup data will generally not be discussed since the limited amount of data available normally indicate transition values between winter and summer extremes. Breakup data are provided in the water quality data summary figures. When available, summer and winter data are briefly highlighted at one monitoring station in each of the three Susitna River reaches (i.e., upper, middle, and lower). Typically the three monitoring stations discussed are Denali, Gold Creek, and Susitna Station. Levels of water quality parameters discussed in the following sections are extracted from updated information in R&M (1982g) unless otherwise noted.

2.3.1 - Water Temperature (**)

(a) Mainstem (**)

Generally during winter (October through April), the entire mainstem Susitna River is at or near 0°C (32°F). However, there are a number of small discontinuous areas with ground water inflow at a temperature of approximately 2°C (35.6°F). As spring breakup occurs the water temperature begins to rise, with the downstream reaches of the river warming first.

During summer (June through September), glacial melt is near 0°C (32°F) when it leaves the glaciers but, as it flows across the wide gravel floodplains downstream from the glaciers, the water begins to warm. As the water winds its way downstream to the Watana damsite, temperatures are as high as 14°C (57.2°F). Further downstream there is additional warming but temperatures are cooler at some locations due to the effect of tributary inflow. Maximum recorded temperatures at Gold Creek and Susitna Station are 15°C (59°F) and 16.5°C (61.7°F), respectively. In August, temperatures begin to drop, reaching 0°C (32°F), in late September or October.

The seasonal temperature variation on a daily average basis for the Susitna River at Denali and Vee Canyon during 1980, and for Denali and Watana during 1981 are displayed in Figures E.2.2.70 and E.2.2.71. Weekly averages for Watana during 1981 are shown in Figure E.2.2.72. The shaded area in this figure is indicative of the range of temperatures measured on a mean daily basis. The temperature variations for eight summer days at Denali, Vee Canyon and Susitna Station are compared in Figure E.2.2.73.

The recorded variations in water temperatures at seven USGS gaging stations are displayed in Figure E.2.2.74. The data in this figure represent discrete measurements recorded by the USGS and, thus, do not reflect the continuously recording thermographs located at Denali, Vee Canyon, Gold Creek, Chulitna or Sunshine. Because of the influence of the Gold Creek tributary inflow on the location of the Gold Creek thermograph prior to 1982, and since all seven stations did not have continuous recording equipment, the USGS discrete measurements were used to provide both accuracy and consistency in this figure.

Additional data on water temperature are available in the annual reports of the USGS (1949-1984), the Alaska Department of Fish & Game (ADF&G 1981, 1982a, 1984a, 1984b, 1985a), and in other reports by the Applicant (R&M 1981h, 1981i).

(b) Sloughs and Peripheral Habitat Areas (**)

The sloughs downstream of Devil Canyon have a temperature regime that differs from the mainstem. During the period 1982-1984 intergravel and surface water temperatures were measured in sloughs 8A, 9, 11, 19, 20 and 21, the locations of which are illustrated in Figure E.2.2.75. A discussion of temperatures in sloughs and side channels is presented in a report by the Applicant (APA 1984a Appendix VII). Intergravel temperatures in the upwelling areas in sloughs generally are fairly constant between 3°C and 5°C all year. This apparently reflects a temperature buffering effect on infiltration from the mainstem. Heat exchange between groundwater and soil materials and mechanical dispersion during groundwater transport through the aquifer are reasonable mechanisms to account for this. Figures E.2.2.76 through E.2.2.80 show measured intergravel and surface water temperatures during 1983 and 1984. Intergravel temperatures in side channels vary somewhat more than the intergravel temperatures in sloughs. The temperature of the component of upwelling resulting from infiltration from the mainstem appears to be approximately equal to the mean annual (time-weighted) temperature of the mainstem.

Surface water temperatures in sloughs and side channels reflect climatic conditions and the degree to which flow in the side channel or slough is dependent on mainstem flow. When the berm at the head of the slough or side channel is overtopped by mainstem flow, the surface temperature of the habitat area flow will be similar to the mainstem temperature. When the habitat berm is not overtopped the temperature in the habitat area will generally reflect climatic conditions. The temperature of upwelling also influences the surface temperature. Surface water temperatures are generally warm (6°C - 14°C) in the summer and cold (near 0°C) in the winter. In the winter, the warm upwelling may prevent the formation of an ice cover in habitat areas. Figures E.2.2.76 through E.2.2.80 show typical measured habitat surface water temperature.

Figure E.2.2.81 illustrates the importance of climate to slough water temperatures when the slough is not overtopped. It compares weekly diel surface water temperature variations during September 1981 in Slough 21 with the mainstem Susitna

River at Portage Creek (ADF&G 1982a). The slough temperatures show a marked diurnal variation caused by increased solar warming of the shallow slough water during the day and subsequent long wave back radiation at night. Thermograph measurements taken in Slough 21 during the summer of 1981 illustrated a diurnal temperature fluctuation ranging from 4.5 - 8.5°C (40.1-47.3°F) at the water surface with a constant intergravel water temperature of 3°C (37.4°F). Mainstem water temperatures are more constant because of the buffering capability offered by the large volume of the river and the extensive mixing that occurs.

(c) Tributaries (**)

The tributaries to the Susitna River generally exhibit cooler water temperatures than does the mainstem. Continuous water temperatures have been monitored by both the USGS and ADF&G in the Chulitna and Talkeetna Rivers near Talkeetna, and by ADF&G in Portage, Tsusena, Watana, Kosina, and Goose Creeks, and the Indian and Oshetna Rivers.

The 1982 mean daily temperature records for Indian River and Portage Creek are compared in Figure E.2.2.82 (ADF&G 1983g). Portage Creek was consistently cooler than Indian River by 0.7°C to 1.9°C (1.3°C-3.4°F). The flatter terrain in the lower reaches of the Indian River valley is apparently more conducive to solar and convective heating than the steep-walled canyon of Portage Creek. Figure E.2.2.82 also presents water temperature data from the mainstem Susitna for the same period, showing the consistently warmer temperatures in the mainstem. There are noticeable diurnal fluctuations in the tributary temperatures, though not as extreme as in the sloughs.

Similar data are available from 1983 (ADF&G 1984b) as shown on Figures E.2.2.83 and E.2.2.84. These plots show that by early August, Indian River and Portage Creek temperatures are similar to mainstem temperatures and by mid-September to October, tributary temperatures may exceed mainstem temperatures.

The major tributaries joining the Susitna at Talkeetna show uniform variation in temperature from the mainstem as illustrated in Figure E.2.2.85. Compared to the Susitna River, the Talkeetna River temperature is 1-3°C (1.8-5.4°F) cooler on an average daily basis. The Chulitna River, being closer to its glacial headwaters, is from 0 to 2°C (0 to 3.6°F) cooler than the Talkeetna River, and has less diurnal fluctuation.

Similar data are available from 1983 (Figure E.2.2.86) and confirm the trends observed in 1982. Yentna River temperatures are also generally colder than mainstem Susitna River temperatures (Figure E.2.2.87).

Winter stream temperatures are usually very close to 0°C (32°F), as all the tributaries become ice covered. Ground water inflow at some locations creates local conditions above freezing, but the overall temperature regime is dominated by the extremely cold ambient air temperatures.

2.3.2 - Ice (**)

Observation of natural ice conditions are contained in reports prepared for the Applicant by R&M Consultants Inc. (R&M 1981e, 1982h, 1983, 1984, 1985a).

(a) Freezeup (**)

Air temperatures in the Susitna basin increase from the headwaters to the lower reaches. While this temperature gradient is partially due to the two-degree latitudinal span of the river, for the most part it is due to the 3,300-foot elevation difference between the lower and upper basins, and the climate-moderating effect of Cook Inlet on the lower river reaches. The gradient results in a period (late October - early November) during which the air temperatures in the lower basin are above freezing, while upper basin temperatures are subfreezing.

Frazil ice (Photograph E.2.2.1) forms in the upper segment of the river first in late September or October, due to the initial cold temperatures of glacial melt and the earlier cold ambient air temperatures. Additional frazil ice is generated in the fastflowing rapids between Vee Canyon and Devil Canyon.

This ice accumulates into frazil pans or slush rafts which float downstream. Due to generally warmer air temperatures in the lower reaches of the river this ice may melt before reaching Cook Inlet. By late October air temperatures throughout the basin may be below freezing and frazil generated in the middle and upper reaches of the river remains intact. Additional ice is generated on tributaries and in the lower reach of the river. However, ice produced in the Chulitna and Talkeetna Rivers has been observed to be only about 20 percent of the amount in the Susitna River. Ice produced in the Yentna River has been observed to be approximately equal to that generated in the Susitna River upstream of the Yentna - Susitna confluence. An ice bridge normally forms near the mouth of the Susitna River at Cook Inlet in late October due to lower flow velocities in this area. Discharges measured at Susitna Station are on the order of 25,000 cfs during this period.

When this ice bridge occurs it causes ice generated upstream to accumulate at the upstream or leading edge of the ice cover. The ice cover then generally progresses upstream. Intermittent bridging of the ice may occur upstream of the ice cover at natural lodgment points. The tendency for this to occur in braided sections of the river is greater than in single channels. This can cause the ice front to advance upstream rapidly through the lower reaches of the river. After the ice cover forms in an area, open leads may develop as the ice cover is eroded in higher velocity areas. Some of these leads may remain open all winter.

The mechanisms of upstream ice progression are described in the report on calibration of the ICECAL model (HE 1984e).

As the ice cover progresses upstream, the water surface level increases due to the increased resistance to flow and the displacement of the ice. Water levels generally increase approximately 2-4 feet in the lower reach due to ice. This results in flooding of many side channels and sloughs. Staging of approximately 8 feet has been observed near Montana Creek.

When the ice cover has progressed to near the Chulitna - Talkeetna - Susitna confluence, progression of an ice front will begin up the Susitna River upstream of the confluence. The initiation of this progression may be caused by:

- o progression of the lower reach ice cover to the confluence,
- o backwater from the lower reach ice cover or backwater caused by shore ice,
- o accumulation of ice at the confluence independent of the lower reach ice cover.

Progression of ice into the middle reach normally begins between early November and early December. The manner of progression is similar to the lower reach. However, staging between Gold Creek and the confluence is generally higher, from four to six feet. The ice cover generally advances to near Gold Creek, RM 137, by mid December to early January. As the cover advances, many side channels and some side sloughs, are subject to being overtopped by cold mainstem water.

Upstream of Gold Creek, the Susitna River ice cover generally does not form as a result of progression of the ice front. Shore ice generally causes constrictions which may close the river.

Upstream of Devil Canyon, the ice cover forms independently of conditions downstream. Due to the colder air temperatures, intermittent bridging due to shore ice development at natural lodgement points may cause an ice cover to form before the ice front on the middle reach reaches Gold Creek. This reduces the flow of ice to the middle reach and reduces the rate of progression of the ice front downstream of Devil Canyon. Ice bridges have been observed upstream of Devil Canyon as early as mid-November.

Table E.2.2.27 is a tabulation of water surface levels during freeze-up in 1983-84 (R&M 1984) illustrating staging caused by the ice cover. Figure E.2.2.88 shows staging during freeze-up in 1980-81 (R&M 1981e).

The variability in discharge at freeze-up, and resulting variability in water level increase, coupled with the varying berm elevations at the upstream ends of sloughs results in some sloughs being overtopped during freeze-up, other sloughs occasionally being overtopped, and still others not being overtopped. For example, Photograph E.2.2.3 shows the flow through Slough 9 during the 1982 freeze-up and Photographs E.2.2.4 through E.2.2.8 illustrate the increased water level and flow through Slough 8A during the same freeze-up. It is estimated that Slough 8A was overtopped with a discharge of 140 cfs.

Ice simulations of natural conditions for the winter of 1971-72, 1976-77, 1981-82 and 1982-83 have been made (HE 1984f, APA 1984a, Appendix VI). These simulations may be used to determine which habitat areas may be subject to overtopping for natural conditions.

(b) <u>Winter Ice Conditions</u> (**)

After the initial ice cover is formed by the accumulation of frazil pans it does not remain static. In some main channel areas the cover is eroded by higher velocities. These areas may later freeze over as air temperatures remain cold. Additionally, mainstem flow rates decrease throughout the winter, as noted above. This causes water levels to drop in the main channel and causes the ice cover to sag, often leaving ice along the main channel banks above water levels. Additionally heat loss throughout the winter causes the solidifying of the frazil ice cover and the formation of additional ice within and below the initial ice cover. The ice cover averages over four feet thick by break-up (R&M 1982d), but a thickness of over 10 feet has been recorded near Vee Canyon. In some peripheral areas, such as side channels and side sloughs, warm ground water upwelling may tend to melt the ice cover and open leads will form. These leads may open and close intermittently in response to climate conditions.

Table E.2.2.28 is a compilation of observed velocity and groundwater induced leads.

The staging effect in the mainstem has two principle influences on peripheral habitats. The most severe effect is that the degree of staging may be sufficient to cause diversion of mainstem water into side channels and side sloughs which otherwise do not convey mainstem water unless discharge is considerably greater. In addition to diverting cold mainstem water into the peripheral habitats, the staging effects cause frazil ice accumulation and an ice cover in the peripheral habitats with the ice front progressing up the channels along with progressing up the mainstem. The diversion of mainstem water into the peripheral habitats, under natural conditions, can affect fish habitats and populations as discussed in the following sections.

A second influence of staging on peripheral habitats is that, with the increased mainstem water surface elevation, groundwater upwelling in the peripheral habitats may be enhanced.

(c) Breakup (**)

The final phase of the ice processes that will be altered by the Susitna Hydroelectic Project is the deterioration and breakup of the ice cover in the spring. This phase of the process begins in late March, continues through April and is generally complete by mid May.

Between November and February, solar radiation (insolation) is an insignificant heat source to the Susitna River, because of the short duration of exposure to sunlight. Beginning in early March solar radiation increases. Air temperatures generally remain below freezing until late April or early May when the ice cover may begin to melt. Generally, river discharges remain low until late April, because the basin is snow covered and there is little surface run-off. By late April the net heat transfer is positive and significant run-off from the basin snow pack begins. Precipitation which may occur in this period is in the form of rain. These two factors: snowmelt and precipitation run-off, tend to increase the flow in the river. Increased flows and water levels lift the ice cover causing it to fracture and move downstream in the form of solid blocks, generally in early to mid-May. These ice blocks have sufficient strength that when they come together at constrictions and low velocity areas they may form jams which constrict the flow of water and raise upstream water levels. In areas where ice jams occur, trees are often scarred by the ice at levels 10 to 15 feet above the normal summer water levels. These tree scars denote the maximum level of the ice jam.

When the upstream water level reaches a critical elevation, the force on the ice blocks is sufficient to break the jam. This results in a sudden release or surge of water and ice downstream. The force of the water and ice is sufficient to scour river banks and the streambed, and to knock over vegetation. Where stream banks are undercut, trees along the bank may become unstable and fall. Local velocities near the dowstream end of ice jams may reach 10 feet per second (fps).

The strength of the ice cover at break-up and prevailing air temperatures at break-up influence the character of jamming. In general, if the ice cover has deteriorated sufficiently in March and April, air temperatures remain above freezing at break-up, and snowmelt and precipitation run-off increase gradually, then break-up jamming will not be severe. However, in many cases, the ice cover is still strong at break-up, discharges increase rapidly and break-up jamming is dramatic. A sudden cold spell during break-up will tend to cause the floating ice blocks and ice jams to freeze together more strongly.

The locations where ice jams occur are somewhat similar. They tend to occur at constrictions of the channel or at bends in the river. However, the actual occurrence or severity of an ice jam cannot be predicted. Flooding due to ice jams can cause changes in river morphology. For example, prior to the 1972-1973 winter, Slough 11 at RM 127.1 was considered an upland slough. During the break-up of 1973, an ice jam formed near the head of the slough. The flooding which resulted from the jam caused water to be diverted onto the floodplain and through the slough channel. Slough 11 was sufficiently deepened and broadened such that it is now considered a side slough. Similar occurrences at other locations may have formed other side sloughs and side channels in the middle reach of the Susitna River.

Break-up floods result in high flows through the side channels and sloughs in the reach above Talkeetna. The flooding and erosion during break-up are believed to influence river morphology in the reach between Devil Canyon and Talkeetna (R&M 1982d). The following is an excerpt from the Winter 1981-82, Ice Observations Report (R&M 1982g): "By May 7 even minimum daily temperatures (ed. note-air temperatures) averaged 4°C (39.2°F) and ice movement began. Jams occurred in most of the areas described in 1981 but with greater consequences, ranging from scarring and denuding of vegetation to flooding and washing away railroad ties from under the tracks. In several areas below Talkeetna, massive amounts of soil were removed from cutbanks, jeopardizing at least one residence."

Although ice jams and related flooding may cause some morphological changes in the Susitna River, the effects of normal spring and summer floods on scour and deposition of streambed material may have a greater influence on the channel form. Analyses were made to determine the importance of these events and are described in the following section.

2.3.3 - Bedload and Suspended Sediments (**)

(a) Bedload (**)

Beginning in 1981, systematic measurements of bedload and related hydraulic properties were initiated to define the amount and distribution of bedload transported by the Susitna River and its major tributaries, the Chulitna and Talkeetna Rivers. The locations and number of samples collected before February 1984 are listed in Table E.2.2.29. The monthly bedload transport data is given in Table E.2.2.30. The data indicate that the Chulitna River is the primary contributor of bedload at the confluence. The May through September bedloads for 1982 and 1983 for the Chulitna River are estimated to be about 1,227,000 and 834,000 tons respectively. The corresponding bedloads for the Susitna River above the confluence are about 43,600 tons and 71,900 tons, respectively and for the Talkeetna River, 222,700 tons and 77,700 tons, respectively (Knott and Lipscomb 1983 and 1985). The size distribution of bedload also was determined by the USGS. Table E.2.2.31 provides the average size distribution based on a number of samples collected from 1981 through February 1984.

The Applicant has made studies to determine the condition and stability of the Susitna River streambed between Devil Canyon and the Chulitna-Susitna confluence. The purpose of these was threefold: to characterize the bed material; to determine how the bed is influenced by flows under natural conditions; and to determine the effects during project operation. These studies have ranged from visual observations to bed material sampling and detailed computations. The description of river morphology in Section 2.1.1 is an example of the visual observations undertaken early in the study. The more refined analysis is presented here. These analyses were made for mainstem as well as slough and side channel habitat areas.

As a result of the study, relationships between armoring bed material size and river flow were developed which allow an estimation of the effect on bed stability of project operation. The estimates of project induced changes are included in Section 4 of this report. The study concluded that the Susitna River streambed is not naturally armored against all flood flows, but is subject to temporal deposition and scour by high flows, caused by either floods or by breaching of ice jams. It further concluded that although project operation would result in initial degradation of the main channel, with time the bed would stabilize and become more stable than under natural conditions.

Bed material samples were taken at selected locations on the Susitna River by the USGS and by the Applicant (HE 1984a, R&M 1982f, 1985b). The size distribution of bed material at selected locations on the Susitna River main and side channels and on the tributaries are given in Table E.2.2.32. Bed materials of the Susitna River consist mostly of gravel and cobbles with some percentage of sand. The substrates in the sloughs and side channels vary significantly along the channel length. Moderate to heavy deposits of silt, sand, gravel and cobbles are visible in the pool areas. The substrate at riffles is generally of clean gravel, cobbles or sometimes boulders.

The Susitna River between Devil Canyon and above the confluence of the Susitna and Chulitna rivers has a single channel or a split channel configuration. Downstream of the confluence, the Susitna River has a braided pattern with multiple channels interlaced through a sparsely vegetated floodplain or separated by islands with well established vegetation (R&M 1982d).

The sloughs and side channels are generally separated from the mainstem by vegetated islands. These sloughs and side channels normally exist on a bank of the river at locations where the main river channel is confined towards the opposite bank. The flows enter into these sloughs and side channels depending upon the elevations of berms at their heads, relative to the water surface elevation in the main river.

Sediment particles are generally transported by the flow as bedload and suspended load. The amount of bedload is generally a small percentage of the suspended load in gravel-bed streams like the Susitna River. The data in Table E.2.2.30 indicate that the percentage can vary between 1 and 15. Although the bedload is small, it is important because it shapes the bed and affects the channel stability.

The stability of sediment particles resting on the bed or channel bank, and the transportation of dislodged particles or deposition of sediment in a stream depend upon the interaction between variables representing the characteristics of the sediment being transported and the capacity of the stream to transport the sediment. The variables are not independent and in some cases the effect of a variable is not definitely known (Simons, Li and Associates 1982).

A number of investigators notably Lane (1955), Leopold and Maddock (1983), Schumm (1971) and Santos and Simmons (1972), have studied the response of channel pattern and longitudinal gradient to variation in the variables. The important variables affecting channel stability are:

- o Characteristics of the flow;
- o Sediment (suspended and bedload) concentration and its characteristics;
- o Characteristics of the bed material;
- o Irregularities in the river bed;
- o Geometric and hydraulic characteristics of the river channel; and
- o Existence and location of hydraulic control points in the channel.

Stability criteria for the Susitna River were developed using the concept of "transportable" or "armoring" bed material size. The armoring size is defined as the limiting size which will not be dislodged under a given set of hydraulic conditions (defined by magnitude of flow and resulting velocity) in a channel. All sizes less than the armoring size will have the tendency to move. However, if the magnitude of flow increases, the size computed for a lower flow also becomes mobile.

The general movements of a stream bed under a given set of hydraulic conditions are generally studied by comparing the d_{50}[1/] of the bed material with the armoring size. Because the armoring size depends upon the magnitude of flow, the movement of bed would not occur until the armoring size is greater than d_{50}. The d_{50} sizes at various locations on the Susitna River were computed from the bed material size distribution and are given in Table E.2.2.32.

A number of empirical relationships are available to estimate armoring size under given hydraulic conditions. For the purpose of this analysis, the armoring size for a given channel reach, was estimated using the following five methods:

- o The competent bottom velocity concept of Mavis and Laushey (1948) presented in the USBR Design of Small Dams (USDI 1974);

- o Tractive force versus transportable size relationship derived by Lane and Carlson (1953);

- o The Meyer-Peter, Muller formula (USDI 1974);

- o The Schoklitsch formula (USDI 1974); and

- o The Shields Criteria (Simons, Li and Associates 1982).

The representative armoring size for a given flow rate was taken as the average of the five sizes. Graphical relationships between armoring sizes and discharges at various locations were developed. Figure E.2.2.89 shows four of these relationships. Hydraulic parameters such as stage discharge relationships, channel widths, average channel depths, measured velocities and bed slopes were taken from various reports (R&M 1982i, 1982f, ADF&G 1983b, 1983c, 1983d, 1983e, 1984a, 1984d and HE 1984d).

1/ The size such that 50 percent of the mass of the material is composed of particles larger than this size and the other 50 percent is composed of particles smaller than this size.

It was concluded that the channel bed is subject to temporal deposition of material and scour under natural conditions. This is a result of the active exchange of particles between the channel bed and the bedload sediment carried by the flow. The extent of scour and/or deposition for any event would be dependent on the magnitude of the flow (caused by floods or breaching of ice jams) and the characteristics of the sediment load being transported. Further, as discussed in Section 4, it was concluded that operation of the project might, initially, result in an average degradation (lowering) of the streambed by approximately 1 foot, but that, with time, the bed would be more stable than under natural conditions.

A second study by the Applicant (AEIDC 1985b), has evaluated morphological changes in the Susitna River based on photographs taken during 1949 through 1951 and 1977 through 1980. Results of the evaluation indicate that both aggradation and degradation have occurred in the Susitna River over the past years.

(b) Suspended Sediment (**)

The Susitna River and many of its tributaries are glacial rivers which experience large variations in suspended sediment concentrations because of glacial melt, snowmelt and run-off resulting from rainfall. Commencing with spring break-up, suspended sediment concentrations begin to increase from their minimum winter range of about 0 to 10 mg/l to higher values in the summer. During summer, values as high 5,690 mg/l have been recorded on the Susitna River near Denali (HE 1984a). At Gold Creek, the highest value recorded was about 2,620 mg/l (USGS 1960). Table E.2.2.33 gives the maximum, minimum and median suspended sediment concentrations based on the data collected by the USGS periodically from 1962 through 1982. The data in this table indicate a general decrease in the concentration from the Susitna River-near Cantwell-gaging station to the Susitna River-near Talkeetna Station. This is because of dilution by clear tributary flow and because there is no significant source of new sediment in this river reach. After the confluence with the Chulitna and Talkeetna rivers, the concentration increases because of contribution from the glaciers in those basins.

A sufficient number of suspended sediment samples are not available to precisely define the concentration for each month. However, by comparing the data for various stations, some indicative values of monthly concentrations for the Susitna River at Gold Creek and at Sunshine can be obtained and are presented on Figure E.2.2.90.

The suspended sediment commonly carried by the Susitna River consists of fine material (silt and clay finer than 0.062 mm, also called the wash load) and fine to medium sand particles (sizes between .062 mm and up to 1.00 mm). The fine material is derived from sheet erosion, glacial melt and bank erosion. The quantity of fine material being transported appears to depend upon its availability because, for the observed range of flow, the Susitna River can transport a much larger quantity of fine material. The sand particles are derived either from river bed erosion or from glacial melt and other erosion processes. The maximum quantity of sand being transported depends upon the magnitude of flow.

The size distributions of suspended sediment at various stations are given in Table E.2.2.34. These are based on samples collected by the USGS from May through October. Smoothed size distribution curves for five stations on the Susitna River are shown on Figure E.2.2.91. The percentages of fine material and sand particles at various locations are given below.

DESCRIPTION OF SUSPENDED SEDIMENT AT SEVERAL LOCATIONS

PERCENTAGES OF FINE MATERIAL AND SAND IN SUSPENDED SEDIMENT

Station	Fine Material (less than .062 mm)	Sand (more than .062 mm)	d_{50}
Susitna River near Denali	52	48	.056
Susitna River near Cantwell	54	46	.049
Susitna River near Gold Creek	61	39	.038
Susitna River above Confluence	70	30	.015
Chulitna River near Talkeetna	62	38	.024
Talkeetna River near Talkeetna	51	49	.060
Susitna River at Sunshine	69	31	.014
Susitna River at Susitna Station	61	39	.030

Based on periodically observed sediment concentrations and the corresponding water discharges, Knott and Lipscomb (1983, 1985) computed monthly suspended sediment transport rates for the Susitna, Chulitna and Talkeetna Rivers (Table E.2.2.30). The table indicates that in some months, the suspended sediments transported by the Chulitna River are more than twice those of the Susitna River above the confluence. Suspended sediment concentrations in the lower river during those months are affected by the Chulitna River more so than by the portion of the middle river controlled by the proposed project.

The Applicant also estimated the average annual suspended sediment transport for the Susitna River near Cantwell and at Gold Creek using the sediment rating, flow duration curve method (HE 1984a). The resulting estimates are about 5,660,000 and 7,260,000 tons per year, respectively.

2.3.4 - Turbidity (**)

Turbidity is a measure of the light transmitting properties of water. It is generally measured in Nephelometric Turbidity Units (NTU). Low values represent high levels of light transmittance and high values represent low levels of light transmittance. Turbidity is affected by inorganic and organic material suspended or dissolved in the water such as sediment or dye. The size, shape, chemistry and minerology of the material in the water influence its ability to reflect or refract light and thus affect turbidity. In the Susitna River, the primary cause of turbidity, for natural conditions, is the fine, inorganic sediment suspended in the flow known as glacial flour. This material is very small, resulting from glacial action on rock.

The occurrence of turbidity in the river is dependent on the source of flow and sediment as discussed in Section 2.3.3. During the summer months, a large portion of the flow originates in the glacial headwaters and picks up its sediment load in this area. Thus summer flows naturally contain large amounts of fine material and have high turbidities.

During the winter, the proportion of flow which is derived from the glacial areas is much less than in the summer. Groundwater flow from storage is more important and thus there is little glacial sediment and, correspondingly, little turbidity.

(a) Mainstem (**)

The Susitna River is typically clear during the winter months with turbidity values at or near zero. Turbidity values measured by the USGS in January and April 1982 were 1.1 Nephelometric Turbidity Units (NTU) or less at Gold Creek, Sunshine, and Susitna Station. Turbidity increases as snow melt and break-up commence. Maximal turbidity values frequently occur when glacial input is greatest.

As presented in Table E.2.2.35, during 1982, measurements of up to 720 and 728 NTU were recorded at Vee Canyon and Chase, respectively. A value of 1,920 NTU was observed at the USGS gaging station on the Chulitna River. In contrast, the maximum recorded value on the Talkeetna River, with its minimal glacial input, was 272 NTU. Turbidity values decrease downstream on the lower Susitna River with maximums of 1,056 and 790 NTU measured at Sunshine and Susitna Station, respectively.

A summary of the turbidity data collected through 1982 is presented in Figure E.2.2.92. Figure E.2.2.93 shows the relationship between suspended sediment concentration and turbidity as measured on the Susitna River at Cantwell, Gold Creek, and Chase (Peratrovich, Nottingham and Drage 1982).

A summary of turbidity data collected at Gold Creek during 1983 is provided in Table E.2.2.36 and Figure E.2.2.94. A summary of turbidity data collected in 1983 at several mainstem and tributary stations is exhibited in Figure E.2.2.95.

Turbidity, discharge, and temperature versus time are graphically displayed for the Talkeetna Fishwheel camp station during the open water season in 1983 in Figure E.2.2.96.

A summary of the turbidity data collected at Gold Creek during 1984 is provided in Table E.2.2.37 and Figure E.2.2.97.

(b) Sloughs and Peripheral Habitat Areas (**)

Turbidity values for Sloughs 8A, 9, 16B, 19, and 21 were measured by ADF&G during June, July, and September 1981 (ADF&G 1981). June measurements were taken on June 23, 24, and 25 at a Gold Creek discharge of approximately 17,000 cfs. No sloughs were overtopped with mainstem flow and turbidity in all the sloughs was less than 1 NTU. The corresponding turbidity at Gold Creek was 100 NTU.

During the July measurements, Gold Creek flow was in excess of 35,000 cfs and the upstream ends of Sloughs 8A, 9, 16B and 21 were overtopped. However, Slough 19 was not. Turbidity values in the overtopped sloughs were 130, 43, and 150 NTU, respectively. Turbidity in Slough 19 was 2.5 NTU and turbidity at Gold Creek was 170 NTU.

September measurements were taken with a Gold Creek discharge of about 8,500 cfs. Maximum slough turbidity was 1.1 NTU and the turbidity at Gold Creek was 5.5 NTU.

Turbidity in sloughs and side channels of the middle river generally remain very low (0-5 NTU) until mainstem stages reach levels high enough to breach the upstream berms of these peripheral areas. Turbidity levels of breached sloughs and side channels were found to elevate rapidly (Figures E.2.2.98 and E.2.2.99, and turbidity values were found to remain elevated for a short period after the breaching event ceased. Turbidities of overtopped sloughs and side channels were usually found to display slightly lower values than those of the mainstem, presumably due to dilution of turbid mainstem waters by upwelling groundwater and/or surface water runoff. As mainstem discharge increases, the dilution of turbid mainstem water which was overtopping into the sloughs by upwelling water is often decreased. Turbidity values of overtopped sloughs and side channels may occasionally exceed mainstem turbidities due to resuspension of previously deposited particulates within these peripheral habitats.

These data indicate that sloughs are generally clear with low turbidity until the upstream ends are overtopped. During overtopping, slough turbidities reflect mainstem values. Even with overtopping, some sloughs maintained lower turbidity due to the dilution effect of ground water or tributary inflow.

2.3.5 - Vertical Illumination (**)

In general, vertical illumination through the water column varies directly but inversely with turbidity and hence follows the same temporal and spatial patterns described above. Summer vertical illumination in the mainstem Susitna River is generally a few inches. During winter months, the river bottom can be seen in areas without-ice cover, since the river is exceptionally clear. However, vertical illumination under an ice cover is inhibited especially when the ice is not clear or when a snow cover is present.

Empirical measurements have been used to produce an approximate relationship between turbidity and the maximum euphotic zone depth Figure E.2.2.100. The euphotic zone depth is generally defined as the depth to which 1.0 percent of the photosynthetically available radiation (PAR) incident at the surface can penetrate. It roughly corresponds to the maximum depth at which photosynthesis can occur.

2.3.6 - Dissolved Gases (**)

(a) Dissolved Oxygen (**)

Dissolved oxygen (D.O.) concentrations generally remain high throughout the drainage basin. Winter values average 11.6 to 13.9 mg/1, while average summer concentrations are between 11.5 and 12.0 mg/1. These average concentrations equate to summer saturation levels between 97-105 percent. Winter saturation levels decline slightly from summer levels, averaging 98 percent at Gold Creek and 80 percent at Susitna Station. Figures E.2.2.101 and E.2.2.102 contain additional dissolved oxygen data. Additional dissolved oxygen data were obtained from Susitna River mainstem and tributary habitats during field surveys in 1983 (Figures E.2.2.103 and E.2.2.104).

(b) Total Dissolved Gas Concentration (**)

Total dissolved gas (nitrogen) concentrations were monitored in the vicinity of Devil Canyon during 1981 and 1982. Data from 1981 revealed saturated conditions of approximately 100 percent above the Devil Creek rapids. However, downstream concentrations immediatly above and below the Devil Canyon damsite were measured in the supersaturated range of 105-117 percent, respectively (Schmidt 1981).

From August 8 to October 6, 1982, a continuous recording tensionmeter was installed immediately downstream of Devil Canyon. As noted in Figure E.2.2.105, the data reveals a linear relationship between dissolved gas concentration and discharge at Gold Creek. Gas concentrations ranged from 106 to 115 percent for discharges from 11,700 to 32,500 cfs (ADF&G 1983f) often exceeding Alaska water quality standards for maximum dissolved gas concentrations of 110 percent.

Measurements of total gas percent saturation at 16,000 cfs and 32,500 cfs at several distances downstream of Devil's Canyon rapids indicates substantial dissipation of gas supersaturation (Figure E.2.2.106) as the gas concentration of the mainstem water equilibrates with the atmosphere. Multiple regression analysis of several variables (discharge, temperature, distance downstream) was used to isolate those variables which could best predict dissolved gas concentrations. High predictability of mainstem dissolved gas concentrations could be made using values for discharge and distance downstream from Devil Canyon rapids. Analysis of the data reveals that regardless of the initial dissolved gas concentrations, approximately 20 miles of downstream passage results in a 50 percent dissipation of total gas supersaturation. Dissipation rates below the first 20 miles downstream of Devil Canyon rapids are less accurately predictable, but more rapid dissipation may occur due to shallower channel depths, more surface area in braided channel areas and dilution of dissolved gas concentrations by non-supersaturated tributary waters.

2.3.7 - Nutrients (**)

Of the four major nutrients (carbon, silica, nitrogen and phosphorus) the limiting nutrients in the Susitna River are most likely to be phosphorus and nitrogen. Although total phosphorus concentrations regularily exceed established criteria (Figure E.2.2.107), the majority of the total phosphorus content is believed to be bound to inorganic particulates, and only a relatively small portion of it is believed to be readily available for use by the microflora. At the present time high turbidity values during the open water season, and ice and snow cover during winter and early spring, cause a light limited riverine habitat with respect to aquatic primary productivity.

Studies of glacial lakes in Alaska (ADF&G 1982b) and Canada (St. John et al. 1976) indicate that over 50 percent of the total phosphorus concentration in the lakes studied was in the biologically inactive particulate form (Peterson and Nichols 1982). The more bio-availabe phosphorous, namely orthophosphates, are 0.1 mg/l or less throughout the Susitna drainage basin. Although one measurement at Vee Canyon was 0.49 mg/l, this value was disregarded since it was considered unrealistic (R&M and L.A. Peterson & Associates 1982). Data are depicted in Figure E.2.2.108).

Nitrate nitrogen concentrations exist in low to moderate concentrations (<0.9 mg/l) in the Susitna River. Gold Creek summer levels vary between 0.02 mg/l and 0.86 mg/l. During winter, the range of variability is reduced with the concentration varying between 0.05 and 0.34 mg/l. Maximum recorded concentrations in the watershed of 1.2 mg/l are from the Talkeetna River monitoring station during the summer. Total nitrogen exists in moderate to high levels in the Susitna River. Nitrate data for six gaging stations are illustrated in Figure E.2.2.109). Total nitrogen concentrations at various Susitna River sampling stations are illustrated in Figure E.2.2.110).

2.3.8 - Other Parameters (*)

(a) Total Dissolved Solids (*)

Total dissolved solids (TDS), or dissolved salts as they are often referred to, are higher during the winter low-flow periods than during summer. The TDS concentrations generally decrease in a downstream direction.

At Gold Creek, TDS winter values are 100-188 mg/l, while summer concentrations are between 55 and 140 mg/l. Downstream, measurements at Susitna Station range from 109-139 mg/l during winter, and between 56 and 114 mg/l in the summer. Figure E.2.2.111 presents the data collected.

Salinity data for Cook Inlet are presented in Section 2.6.7.

(b) Specific Conductance (Conductivity) (*)

Conductivity values, which generally show an excellent correlation with TDS concentrations if salinity contents are reasonably low (Cole 1975), are also higher during the winter and lower during the summer. In the upstream reaches of the Susitna, conductivity values are generally higher than downstream values.

At Denali, values range from 351-467 umhos/cm^2 in the winter to 121-226 umhos/cm^2 in the summer. Gold Creek conductivities vary from 84-300 umhos/cm^2 in the winter to 75-227 umhos/cm^2 in the summer. Specific conductance levels at Susitna Station range from 182-225 umhos/cm^2 during winter to 90-160 umhos/cm^2 during summer. Figure E.2.2.112 provides the conductivity data for the seven USGS gaging stations.

Additional conductivity data were collected during 1983 for several mainstem Susitna River sites, and at the mouths of the Talkeetna River and Chulitna River tributaries (Figure E.2.2.113).

(c) Significant Ions (*)

Concentrations of seven significant ions; namely bicarbonate, sulfate, chloride, and the dissolved fractions of calcium, magnesium, sodium and potassium; which comprise a major portion of the total dissolved solids, are generally low to moderate, with summer concentrations lower than winter values. The ranges of concentrations recorded upstream of the project at Denali and Vee Canyon, and downstream of the project at Gold Creek, Sunshine and Susitna Station are compared in Table E.2.2.38. The ranges of anion and cation concentrations at each monitoring station are presented in Figures E.2.2.114 through E.2.2.119. Data on bicarbonate are presented in the discussion of Total Alkalinity.

(d) Total Hardness (o)

Waters of the Susitna River are moderately hard in the winter, and soft to moderately hard during break-up and summer. In addition, there is a general trend towards softer water in the downstream direction.

Total hardness, measured as the sum of the calcium and magnesium hardness and reported in terms of $CaCO_3$ ranges from 60-121 mg/l at Gold Creek during winter to 31-107 mg/l in the summer. At Susitna Station, values are 73-96 mg/l and 44-66 mg/l during the winter and summer, respectively. Figure E.2.2.120 presents the available data.

(e) pH (*)

The Susitna River is slightly alkaline with average pH ranging between 6.9 and 7.7. Maximum pH levels occasionally exceed 8.0, while a value as low as 6.0 has also been recorded. Low pH levels are common in Alaskan streams and are attributable to the acidic tundra runoff.

At Denali Station, pH variations between 7.1 and 7.6 occur during winter, while the summer fluctuation is 7.2 to 7.9. Winter pH levels at the Gold Creek station are between 7.0 and 8.1. The range of summer values is 6.5 to 7.9. Figure E.2.2.121 displays the pH data for the seven stations.

Additional pH data were collected during 1983 for several mainstem Susitna River sites, and at the mouths of the Talkeetna River and Chulitna River tributaries (Figure E.2.2.122).

(f) Total Alkalinity (*)

Total alkalinity concentrations, with bicarbonate typically the only form of alkalinity present, exhibit moderate to high levels during winter and low to moderate levels during summer. In addition, upstream concentrations are generally higher than downstream concentrations.

Concentrations at Denali Station during winter are 112-161 mg/l, and 42-75 mg/l during summer. At Gold Creek Station, winter values range between 46 and 88 mg/l, while summer concentrations are in the range of 23-87 mg/l. In the lower river at Susitna Station, winter concentrations are 60-75 mg/l, and summer levels are 36-57 mg/l.

Figure E.2.2.123 provides total alkalinity data in the form of $CaCO_3$.

(g) Free Carbon Dioxide (o)

Free carbon dioxide (CO_2) in combination with carbonic acid and the previously discussed bicarbonates (alkalinity) constitute the total inorganic carbon components present in the Susitna River.

In the upper basin, summer measurements of free CO_2 at Denali yield values that range from 1.5 to 5.2 mg/l. Winter data indicate levels from 5.5 mg/l to 25 mg/l.

At Gold Creek, the summer and winter ranges are virtually identical. Minimum values are 1.1 mg/l during summer, and 1.2 mg/l during winter. Maximum concentrations are 20 mg/l during both seasons.

In the lower river basin at the Susitna Station, summer data indicate a variability between 0.6 and 8 mg/l. Winter data range from a minimum of 1.8 mg/l to a maximum of 17 mg/l.

Free CO_2 data are illustrated in Figure E.2.2.124.

(h) Total Organic Carbon (*)

Total organic carbon (TOC) varies with the composition of the organic matter present (McNeely et al 1979).

At Gold Creek Station, summer TOC levels vary from 1.4 to 3.8 mg/l. Winter concentrations range from 1.0 mg/l to 5.5 mg/l. Downstream at Susitna Station, TOC ranges between 2.7 and 11.0 mg/l and 0.4 and 4.0 mg/l, during summer and winter, respectively.

A criterion for TOC has been suggested by McNeely et al. (1979) as 3.0 mg/l, since water with lower levels have been observed to be relatively clean. However, as is evidenced above, streams and rivers in Alaska receiving tundra runoff frequently exceed this criterion (R&M and L.A. Peterson & Associates 1982).

A summary of the TOC data is presented in Figure E.2.2.125.

(i) Chemical Oxygen Demand (o)

Chemical oxygen demand (COD) data are limited to observations at Vee Canyon and Gold Creek. Summer concentrations at Vee Canyon range between 8 and 39 mg/l. Winter values are 6-13 mg/l. Below the proposed reservoirs, at the Gold Creek monitoring station, summer levels vary from 1.3-24 mg/l, while winter concentrations are in the range of 2-16 mg/l. The available COD data are presented in Figure E.2.2.126.

(j) True Color (*)

True color, measured in platinum cobalt units, typically displays a wider range during summer than winter. This phenomenon is attributable to humic acids characteristically present in the summer tundra runoff.

Data gathered at Denali Station, with its dominant glacial origins, ranged between 0 and 5 units and 0 and 10 units, during winter and summer, respectively. However, color levels at Gold Creek, with its significant tundra runoff, vary between 0 and 40 color units during winter and 0 to 110 units in summer. Although they are extremely high, it is not uncommon for color levels in Alaska to reach 100 units for streams receiving tundra runoff (R&M and L.A. Peterson & Associates 1982).

Figure E.2.2.127 displays the data collected.

(k) Metals (o)

The concentrations of many metals monitored in the Susitna River were low or within the range characteristic of natural waters. In addition, 15 parameters were below detectable limits when both the dissolved (d) fraction and the total recoverable (t) quantities are counted. For antimony, boron, gold, platinum, tin, radium, and zirconium, both (d) and (t) were below detection limits. The dissolved fraction of molybdenum was also not detectable.

The concentrations of some trace elements, however, exceeded water quality guidelines for the protection of freshwater organisms (Table E.2.2.26). These concentrations are the result of natural processes, since with the exception of some placer mining activities, there are no man-induced sources of these elements in the Susitna River basin. Metals which exceeded criteria include both dissolved and total recoverable aluminum, cadmium, copper, manganese, mercury, and zinc. In addition, the dissolved fraction of bismuth, and the total recoverable quantities of iron, lead, and nickel also exceeded criteria.

Figures E.2.2.128 through E.2.2.143 summarize the data for those metals that exceeded criteria. Information pertaining to metals, that did not surpass established or suggested guidelines are presented by R&M and L.A. Peterson & Associates (1982).

(l) Chlorophyll-a (**)

Chlorophyll-a, as a measure of algal biomass, is low in the Susitna River, due to the poor light transmissivity of the sediment laden waters. Chlorophyll-a data for the Susitna River were collected at the Susitna Station gage where values up to 1.2 mg/m^3 (chlorophyll-a periphyton uncorrected) were recorded. However, when the chromospectropic technique was used, values ranged from 0.004 to 0.029 mg/m^3 for three samples in 1976 and 1977. All recorded values from 1978 through 1980 were less than detectable limits when analyzed using the chromographic fluorometer technique.

(m) Bacteria (**)

No data are available for bacteria in the upper and middle river basins. However, because of the glacial origins of the river and the absence of domestic, agricultural, and industrial development in the watershed, bacteria levels are expected to be low.

Limited data on bacterial indicators are available from the lower river basin, namely for the Talkeetna River since 1972, and from the Susitna River at Susitna Station since 1975. Indicator organisms monitored include total coliforms, fecal coliforms, and fecal streptococci.

Total coliform counts were generally low, with the three samples at Susitna Station and 70 percent of the samples on the Talkeetna River registering less than 20 colonies per 100 ml. Occasional high values have been recorded during summer months, with a maximum value of 130 colonies per 100 ml. Total numbers of coliform bacteria per 100 ml. are used as indicators of possible sewage pollution. The lower the total coliform bacteria concentration the less likely that the tested water source is contaminated.

Fecal coliforms were also low, usually registering less than 20 colonies per 100 ml. The maximum recorded summer values were 92 and 91 colonies per 100 ml in the Talkeetna and Susitna Rivers, respectively. Fecal coliform bacterial are present in the intestine or feces of warm blooded animals. They are often used as indicators of the sanitary quality of water.

Fecal streptococci data also display the same pattern; low values in winter months, with occasional high counts during the summer months. Fecal streptococci are bacteria found in the intestine or feces of warm blooded animals. Their presence in water is considered to verify fecal pollution.

All recorded values are believed to reflect natural variation within the river, as there are no significant human influences throughout the Susitna River basin that would affect bacterial counts.

(n) Miscellaneous (**)

Concentrations of organic pesticides and herbicides were present in concentrations lower than their detection limit; uranium, and gross alpha radioactivity were below levels considered to be potentially harmful (R&M Consultants, Inc. and L.A. Peterson and Associates 1982). No significant sources of these parameters are known to exist in the drainage basin, with the exception of herbicides (amitrole, 2-4, D, bromicil and Garlon) used along the railroad right-of-way. Since no pesticides, herbicides, or radioactive materials will be used during the construction, filling or operation of the project, no further discussions will be pursued.

2.3.9 - Water Quality Summary (**)

The Susitna River is a fast flowing, cold water river with glacial origins and large seasonal flow variations that greatly influence its character. During winter, river temperatures remain at or near 0°C (32°F) throughout the mainstem. Localized areas, especially sloughs, experience ground water upwelling which maintains winter temperatures slightly above freezing. Maximum summer mainstem temperatures at Gold Creek reach 15.0°C (59.0°F). Ice formation commonly begins during October in the upper reaches of the river. Break-up usually occurs in the project area during May. Suspended sediment concentrations and turbidity levels experience extreme seasonal fluctuations as the result of glacial melt, snow melt, rainfall, sheet erosion and bank erosion. Suspended sediment measurements up to 5690 mg/l have been documented at Denali Station.

Dissolved oxygen concentrations are high throughout the basin with winter values near 13 mg/l. Summer measurements average near 12 mg/l. Dissolved oxygen concentration in the middle and upper basin averages near 100 percent saturation. Total dissolved gas concentrations exceed criteria levels below the Devil Canyon rapids with supersaturated values up to 117 percent recorded.

Macro nutrient concentrations, namely total nitrogen and phosphorus, exist in low to moderate concentrations throughout the basin.

Total dissolved solids (TDS) concentrations are higher during the winter low-flow periods than during summer. Correspondingly, conductivity values are also higher during the winter, and lower during summer. Concentrations of the seven significant ions are generally low to moderate with lower levels during summer. The Susitna is moderately hard during winter and soft to moderately hard during break-up and summer. Typically, pH values range between 7 and 8, although values often fall below 7 due to the organic nature of tundra runoff. Total alkalinity concentrations are moderate to high during winter, and low to moderate during summer.

Total organic carbon and true color both exceed their respective criteria because of the influence of tundra runoff.

The concentrations of many trace elements monitored in the river were low or within the range characteristic of natural waters. However, the concentrations of some trace elements exceeded water quality guidelines for the protection of freshwater aquatic organisms. These concentrations are the result of natural processes since there are no man-induced sources of these elements in the Susitna River basin, with the exception of some intermittent placer mining activities.

Chlorophyll-a measurements are low as a result of the poor light transmissivity of the sediment-laden waters and resultant reduced primary productivity. Bacterial indicators exhibit generally low concentrations.

Concentrations of organic pesticides and herbicides, uranium, and gross alpha radioactivity were either less than their respective detection limits or were below levels considered to be potentially harmful to aquatic organisms.

2.4 - Baseline Ground Water Conditions (**)

2.4.1 - Description of Water Table and Artesian Conditions (**)

The landscape of the upper and middle basin consists of relatively barren bedrock mountains with exposed bedrock cliffs in canyons and along streams, and areas of unconsolidated sediments (outwash, till, and alluvium) generally in the U-shaped glaciated valleys. The regional bedrock is mainly crystalline and metamorphic rocks. Any bedrock aquifers that may be present are anticipated to be localized to joints in the rock and not carriers of significant amounts of water. The arctic climate has retarded development of topsoil and although there may be watertable regimes detectable in the shallow till layers in the uplands, very little ground water storage or flow is available. For the most part, precipitation on the higher elevation terrain runs off quickly, immediately after rainfall events or when thaw occurs.

In the valleys, however, unconfined (water table) and artesian aquifers exist in the alluvium and outwash sediments. Runoff from the uplands generally enters the valleys across alluvial fans and recharges the lowland aquifer system in the process. Ground water in the valley bottom generally flows beneath and parallel to the river channel, with lesser amounts coming in from the valley sides. In a few places ("sloughs", see Section 2.4.4), where a section of river channel has become cut off from the main channel by deposition of a gravel bar or "berm", ground water crosses the separation and causes flow to continue in the cut-off slough, an example of lateral flow in the valley ground water.

The alluvium is a source of water for domestic and limited public water supplies. Potential yields along the river in the middle basin (upstream of Talkeetna) may be 20-50 gallons per minute (gpm), while in the wider valley below Talkeetna they are higher, in the range of 100-1,000 gpm (Freethey and Scully 1980). A 100-foot well in Talkeetna was pump tested at 310 gpm. Specific capacities in this and other wells in the vicinity indicate hydraulic conductivities in the alluvium of between 167 and 1,000 gpd/ft2 (8x10-3 to 5x10-2 cm/sec) (APA 1984a Appendix VII, p 4-9). Broad gravel floodplains further upstream beneath glaciers in the upper basin store vast supplies of groundwater which appear to constitute the source of much of the river flow, especially in winter (Acres 1983).

2.4.2 - Hydraulic Connection of Ground Water and Surface Water (**)

Much of the ground water in the system is stored in unconfined aquifers in the valley bottoms and in alluvial fans along the slopes. Streams coming down from the mountains recharge the fan aquifers during periods of runoff, and are in turn fed from ground water when runoff from the uplands is reduced. There are many such direct connections between the ground water and surface water systems along the Susitna River. Sloughs (see Section 2.4.4) are prime examples of such interconnections.

2.4.3 - Locations of Springs, Wells, and Artesian Flows (*)

Due to the remote character of the basin, there are no data on the location of springs, wells, and artesian flows other than within the sloughs. Winter aufeis buildups have been observed between Vee Canyon and Fog Creek, indicating the presence of ground water discharges. Ground water is the main source of flow during winter months, when precipitation falls as snow and there is no glacial melt. It is believed that much of this water comes from the unconfined aquifers (Freethey and Scully 1980).

2.4.4 - Hydraulic Connection of Mainstem and Sloughs (**)

The sloughs downstream from Devil Canyon are used by salmonid species for spawning, and provide valuable rearing habitat for anadromous and resident fish. Ground water upwelling within the sloughs provides appropriate conditions for egg incubation.

A number of geohydrologic studies have been carried out (particularly in Sloughs 8A, 9, 11, and 21) that elucidate the flow regimes which feed the upwelling phenomenon. Conditions vary from slough to slough, but the results have generally indicated that the main source of the slough flow is the mainstem Susitna River. The upwelling currents are usually increased by ground water originating from runoff from adjacent upland areas, and the slough flows are also supplemented by flows in various tributaries.

Studies which have been carried out to better understand the ground water flow regime include:

- correlations between observed flows in the sloughs and flows (or water surface elevations) in the mainstem;
- observation of seepage rates into the sloughs and correlation to mainstem flows;
- installation of standpipes (wells) in the vicinity of the sloughs to observe the piezometric level (water table) and chart the flow pattern;
- numerical modeling of the ground water flow pattern;
- conducting tests in the slough vicinity wells to evaluate aquifer properties;

- evaluation of water table fluctuations in the wells as a function of river stage, using a analytical solution for the flow problem as a comparison;

- calculation of water balances for water flows into and out of the sloughs, both on a long term (e.g. monthly) basis as well as for individual storm runoff periods;

- observation of water temperatures in the sloughs and wells, and comparison to analytical solutions.

The result of these intensive investigations (APA 1984a, Appendix VII, R&M 1985d) is a general understanding of the slough geohydrology and the capability of predicting the effects of construction and operation of the proposed project on stream flows in the sloughs.

The overall effect of the project will be to stabilize and somewhat reduce, flows in the sloughs. Summer flows in the sloughs will, in general, be lower than during existing conditions, due to the lower flows in the river. Winter flows will be about the same or higher. Water temperatures will remain at the mean annual temperature of the mainstem river and therefore, during operation, may slightly increase.

2.5 - Existing Lakes, Reservoirs, and Streams (**)

2.5.1 - Lakes and Reservoirs (**)

There are no reservoirs on the Susitna River or on any of the tributaries flowing into the Susitna River in the area of the proposed Watana or Devil Canyon Reservoirs. There are 27 lakes less than five acres in surface area, one between five and ten acres, and one over 60 acres on the north side of the river between RM 191 and 197. Most of these are small tundra lakes, except for Sally Lake (63 acres). A small lake (less than 5 acres) lies on the south shore of the Susitna River at RM 195.5 and another of about 10 acres lies on the north side of the river at RM 204. Most of the lakes appear to be perched, but several are either connected by small streams to Watana Creek or empty directly into the Susitna River. A small lake (2.5 acres) lies on the south shore of the river just downstream from the Devil Canyon damsite at RM 151.30.

The normal Stage I maximum operating level of Watana Reservoir will be 2,000 feet, causing the inundation of eight of the unnamed, tundra lakes between RM 191 and 197.

The normal Stage II maximum operating level of Devil Canyon Reservoir will not inundate any lakes. One small lake may be affected during construction of the saddle dam.

The normal Stage III, maximum operating level of 2,185 feet will result in the inundation of 19 lakes between RM 191 and 197, including Sally Lake.

No lakes downstream of the reservoirs will be directly impacted by project construction, impoundment, or operation. Secondary impacts, such as increased fishing pressure, may result from improved access due to access roads or transmission line maintenance roads. The major lakes potentially affected are listed in Table E.2.2.39.

2.5.2 - Streams (**)

Numerous streams within the reservoir boundaries will be partially or completely inundated during each stage of the project. Several sloughs within each impoundment will also be completely inundated. These are shown in Figures E.2.2.144, 145, and 146, and are listed in Tables E.2.2.40, 41, and 42.

Aside from the streams to be inundated by the project impoundments, there are several tributaries downstream of the project which may be affected by changes in the Susitna River flow regime. Analyses were done on 19 streams between Devil Canyon and Talkeetna which were determined important for fishery resources or for maintenance of existing railway crossings (R&M 1982f, HE 1984a). Those streams where the with-project flow regime may have a potential impact are listed in Table E.2.2.43.

2.6 - Existing Instream Flow Uses (o)

Instream flow uses are uses made of water in the river channel as opposed to water withdrawn from the river. Instream flow uses include hydroelectric power generation; commercial or recreational navigation; waste assimilation; downstream water rights; water requirements for riparian vegetation, fisheries and wildlife habitat; recreation; freshwater recruitment to estuaries; and water required to maintain the desirable aesthetic characteristics of the river itself. Existing instream flow uses on the Susitna River involve all of these uses except hydroelectric power operation.

2.6.1 - Downstream Water Rights (o)

In 1966, "The Alaska Water Use Act" was established. This legislation, which was amended in 1979, authorized the Alaska

Department of Natural Resources (ADNR) to determine and adjudicate water rights for use of the state's water resources (ADNR 1981).

Existing water rights users at that time were eligible for "grandfather rights" and were required to formalize their interests as of April 1968. Currently, the statutory procedure for formalization of water rights requires the filing of an Application for Water Rights with the Commissioner of the ADNR. After issuance of a permit and subsequent to the beneficial utilization of the water as noted in the permit, ADNR personnel may elect to conduct a field investigation. Provided the ADNR concur that the water rights have been perfected, a Certificate of Appropriation is then issued. This certificate provides legal rights against conflicting users of the water who do not have water rights or are junior in priority (ADNR 1981).

Existing surface and ground water rights in the Susitna River basin were investigated by Dwight (1981). To facilitate this search, the basin was divided into 18 township grids (Figure E.2.2.147). The investigation noted that the only significant surface water rights exist in the headwaters of the Willow Creek (18.3 cfs) and Kahiltna (125 cfs) township grids where placer mining operations occur on a seasonal basis (Table E.2.2.44). Neither of these areas will be affected by the project.

The only appropriation on record in the area of the proposed reservoirs (Susitna Reservoir township grid) is permit ADL-203386 currently held by the Applicant for the 44 man Watana camp. The permit for the camp, from which field work for the project has been conducted, is for 3,000 gpd (0.00465 cfs or 11,355 liters per day) from a nearby unnamed lake.

Downstream of the proposed facilities, in the Susitna township grid, surface water rights amount to 0.153 cfs while ground water appropriations total 0.56 acre-feet/year or 0.0498 cfs (Table E.2.2.45). No surface water rights on file with the ADNR withdraw directly from the Susitna River mainstem. In addition, an analysis of topographic maps and overlays denoting the specific location of each recorded appropriation indicate that all surface water diversions from tributaries, as well as all ground water withdrawals from wells, are located at elevations that will be unaffected by water level changes and/or flow regulation resulting from the construction, filling, and operation of the proposed Susitna Hydroelectric Project (Dwight 1981). As such, no further discussions regarding potential impacts to existing downstream water rights appropriations will be presented.

2.6.2 - Fishery Resources (*)

The Susitna River supports populations of both anadromous and resident fish. Important commercial, recreational, and subsistence species include pink, chum, coho, sockeye and chinook salmon, eulachon, rainbow trout, Arctic grayling, burbot, and Dolly Varden. Natural flows presently provide for fish passage, spawning, incubation, rearing, overwintering, and outmigration. Salmon migrate upstream and spawn throughout most of the summer and early fall. The eggs incubate through the low-flow winter period, and juvenile out-migration peaks in the late spring or early summer. Rainbow trout and grayling spawn in tributaries during break-up with embryo development occurring during the early summer. Further detail on the fishery resources is presented in Chapter 3.

2.6.3 - Navigation and Transportation (**)

Boating is the primary navigational and transportation use of the Susitna River. Approximately 3,700 boat trips and 10,400 boaters are estimated to have used the major launch areas of the Susitna River during the summer of 1984. Recreational purposes comprise the major portion (approximately 70 percent in 1984) of the boat trips. Approximately 85 percent of the recreational trips are for sport fishing, the remainder are for hunting. Transportation and private supply purposes comprise about 20 percent of the boat trips. The remaining boat use of the river is for commercial and other purposes, including delivering supplies, and river tours.

The river is also used by whitewater kayakers, fixed-wing aircraft, snow machines and dogsleds. Kayaking is the principal recreational use of the river in the project area and is discussed in more detail in Exhibit E, Chapter 7. The other uses occur primarily in the area downstream of Devil Canyon and are discussed here. Project operation will affect flows in the reach between Devil Canyon and Talkeetna to a greater extent than the reach downstream of Talkeetna. Morphological characteristics and boating uses differ in these two reaches; therefore, they are treated separately in this section.

(a) Boating Upstream of Devil Canyon (**)

The river upstream of Devil Creek, although steep and swift, is navigable by most types of watercraft. Numerous rapids exist, but they are navigable. The most serious rapid is located at Vee Canyon, where several large standing waves occur. Upstream of Vee Canyon, the river is deep and relatively easy to navigate. Access to this portion of the river is from the Denali Highway (RM 291). Boaters float down the Susitna River and motor up the Tyone River to Lake Louise or exit near Vee Canyon and portage to Clarence Lake. An estimated two to four groups of whitewater boaters per year continue through Vee Canyon where they exit and portage to Stephan Lake. The Devil Canyon reach, from RM 150 to Devil Creek (RM 162), is the steepest (gradient of 31 feet/mile) and most treacherous reach of the Susitna River, and is navigable only by expert whitewater kayakers at low-to-moderate flows. Access is gained by air or by floating down from the Denali Highway. A few (four to five per year) experienced kayakers have attempted to run the Devil Canyon rapids downstream of Devil Creek. This is more fully discussed in Exhibit E, Chapter 7.

(b) Boating Downstream of Devil Canyon (**)

(i) River Use and Access (***)

The Susitna River, in this reach, is considered navigable by the U.S. Department of the Interior, Bureau of Land Management (BLM) (TES 1982). The river is used for navigation up to Portage Creek (RM 149). This entire reach is navigable under most flow conditions although abundant floating debris during extreme high water and occasional shallow areas during low water can make navigation difficult.

Boating on the Susitna River downstream of Devil Canyon consists of jet boats, air boats, flat bottom skiffs, canoes, rafts, kayaks, and propeller-driven boats. Boaters use the Susitna River principally for fishing, hunting, access to remote land parcels, whitewater boating, and riverboat tours, with access to sport fish locations being the primary boating purpose. Access to the river is gained from four principal boat launching sites (Figure E.2.2.148): Talkeetna (RM 97), Sunshine Bridge at the Parks Highway (RM 84), Susitna Landing (RM 61), and Willow Creek (RM 49); from several of the minor tributaries between Talkeetna and Cook Inlet; and from Cook Inlet. Other primary tributaries accessible by road are Sheep Creek, and Montana Creek.

Susitna Landing is located on the Kashwitna River 200 yards upstream of its confluence with the Susitna. It is the most developed of these access points, with two boat ramps and a parking area. Susitna Landing is affected both by flows in the Kashwitna and by backwater effects of the Susitna. During low flows on the Susitna, access from the upstream ramps is made difficult by a gravel bar downstream of the ramp. Willow Landing is on Willow Creek, located adjacent to the Parks Highway and approximately seven miles upstream from the Susitna River. The State of Alaska is planning to construct a road to the mouth of Willow Creek and to build a boat ramp there (ADNR 1984).

Boating is most prevalent within the reach of the Susitna below Talkeetna, according to results of a 1984 ADF&G survey of boating on the Susitna River. The heavier use in downstream portions of the river is due to their proximity to Anchorage and to preferred fishing destinations such as the Deshka River and tributaries to the Yentna River.

During the ADF&G study, the operators of 2,407 boats departing the river at four sites (Willow Creek, Susitna Landing, and the Talkeetna boat launches) were surveyed (ADF&G 1985). Based on projections from this survey, approximately 2,700 boats and 8,600 boaters departed the river at Susitna Landing, 600 boats and 1,800 boaters departed at Willow Creek, and 400 boats and 1,000 boaters departed at the Talkeetna launches during the months of May through September, 1984. Results of the ADF&G study indicate that over one-half of the boaters departing the river were boating primarily for sport fishing. Boating for access to fishing locations was most prevalent at the downstream launch sites. An estimated 60 percent of the boats at Susitna Landing and Willow Creek had sport fishing as their primary activity (Table E.2.2.46). At Talkeetna, only 39 percent (estimated) had sport fishing as the primary purpose of their trip.

During the fishing season, the primary boating destinations on the lower Susitna River are those tributaries which are not easily accessible by road. These tributaries include the Deshka and Yentna Rivers. An estimated 80 percent of the boats departing the river at Susitna Landing and 38 percent at Willow went to these two destinations. The mouths of clearwater tributaries that have salmon runs are also frequented by boaters. Because many of these tributaries have access from the Parks Highway, boating pressure is not as high as it is on the Yentna and Deshka Rivers.

The Susitna River is also used for transportation and for access to remote land parcels and hunting areas. Many of the remote parcels are located along tributary creeks in the vicinity of Talkeetna or within the upper Deshka and Yentna river valleys. Boaters travel down the tributaries to the Susitna and boat to Talkeetna or other smaller communities along the river for supplies. An estimated 10 percent of the boats departing the river at Susitna Landing and Willow Creek, and 15 percent of those departing at Talkeetna had transportation as the primary purpose of their trip. Private supply was the primary purpose of an estimated 12 percent of the boats departing at Susitna Landing, 6 percent at Willow, and 4 percent at Talkeetna. Approximately 8 percent were projected as having hunting as their main activity (ADF&G 1985).

Commercial riverboats constitute a relatively small portion of the river traffic. Riverboat operators provide various services, such as scenic tours of the river, transportation for hunting and fishing, and freight deliveries. An estimated thirty boats departing the river had commercial supply as their primary purpose (ADF&G 1985).

Whitewater boating also occurs downstream of the Devil Canyon dam site (see Exhibit E chapter 7). Because of the prevalence of jet boats and the open braided character of the river, relatively little canoeing and kayaking occurs downstream of Talkeetna. An estimated 15 boats or 0.4 percent of the boats departing the river at Susitna Landing, Willow Creek, and Talkeetna were whitewater boats. In the reach upstream of Talkeetna whitewater boating is more popular because this area is more remote than downstream portions and, until recently, it had been accessible by train.

(ii) Navigability (***)

- Talkeetna to Cook Inlet (***)

The lower Susitna River, with its numerous braided channels, creates a boating situation in which shallow water is often encountered. This, combined with the low visibility due to silty water, dictates the use of a shallow-draft craft for most boating situations. The use of this type of craft was verified in a 1984 survey (ADF&G 1985), when boats with drafts of 8.0 inches or less comprised over 90 percent of the boats surveyed. These shallow draft boats were comprised of jetboats (92 percent) and airboats.

The lower portion of the Susitna River is constantly changing. A deep main channel exists from Talkeetna to Cook Inlet. In most places this main channel has numerous side channels branching from it. Depth of water in these side channels is dependent on flow rate and channel morphology. Side channels navigable at high flow will sometimes dewater or have long shallow reaches at lower flows. At high flows, several routes are usually available to the boater to reach his destination. At lower flows, boaters may have to take a more circuitious route in order to have sufficient depth to navigate. High flows sometimes increase navigation hazards. During a flood, there are usually a large number of floating trees. Many familiar landmarks are covered by water and new channels are opened. The highly turbid water makes it difficult to determine the depth in the new channels and along the edges of gravel bars.

The boater's experience on the river and type of boat also determine navigation routes. Those who use the river often are familiar with its characteristics under a variety of flow conditions. They also know how their boat reacts, and what its limitations are. These boaters are familiar with the best routes for their particular craft, and may quickly react to varying conditions. Those boaters with less experience on the lower Susitna River often find it confusing at first, due to its broad floodplain and multiple channels. It is quite possible to select a channel which looks good at its entrance, only to find that it may rapidly become shallow with no place left to take the boat. As boaters gain more experience on a particular reach of river, their navigation problems tend to decrease.

At times, even experienced boaters may have navigation problems on the Susitna River. Large flood events tend to cause significant bed material transport, with major channels sometimes shifting several hundred yards in a few days. Log and debris jams may block previously navigable channels and cause channel shifts. Gravel bars may have moved to new locations. Boaters have no option but to alter their use pattern when they encounter these new conditions. Navigation problems encountered along the Susitna River have been identified by the Applicant (R&M 1985e).

A deep channel exists from the Yentna River downstream to Cook Inlet. The major destination for boaters in this reach of river is Alexander Creek. During moderate-to-high flows, boaters often travel through Alexander Slough, which is actually a major side channel west of the main channel. Numerous shifting sand bars exist in this side channel. As flows drop, insufficient flow enters the channel at the upstream end (RM 19) and Alexander Slough generally becomes unnavigable except for airboats. When this occurs, boaters have the options of either going through Powerline Slough at RM 6.5 or continuing to Cook Inlet and then going up the west channel. Use of Powerline Slough is common for residents of Susitna Station (Hawley 1984). Examination of aerial photographs indicates that Alexander Slough is navigable by jetboats at flows of 67,800 cfs, but that only airboats could navigate it at flows of 51,400 cfs. Consequently, a flow of 60,000 cfs is estimated to be required for navigation of Alexander Slough by jet boat.

The reach of river from the Yentna confluence (RM 28) to Susitna Landing (RM 61) is the most frequently used on the Susitna River, because it includes the Willow Creek, Deshka River, and Yentna River salmon fishing areas, and the Willow Creek and Susitna Landing access points. The reach has multiple channels separated by vegetated islands, and includes the segment known as Delta Islands (RM 51 to RM 42). Jet boats have been observed in this reach when flows at the Sunshine gage were as low as 17,800 cfs.

Table E.2.2.47 summarizes the navigational problems indicated in the 1984 ADF&G survey (ADF&G 1985c). The survey indicated only if navigational problems were encountered, not the severity of the problem or its location. At Susitna Landing, boaters indicated more problems with debris and high velocities in May and June, with sand bars becoming more prevalent in late summer when the flow decreased. Boaters at Willow Creek indicated more problems with bars and rocks. It is likely that many of these problems were encountered on Willow Creek itself, as boaters must travel along its narrow, winding course for seven miles before reaching the Susitna River. The types of boats used changed during the summer, with airboats becoming more common late in the summer.

During low flows at Susitna Landing (mouth of Kashwitna River), boaters may encounter problems reaching the main channel when they utilize the Susitna side channel, into which the Kashwitna River empties. However, no problems are encountered when entering or leaving the downstream end of this channel.

Downstream of Susitna Landing, the main channel is located in a braided segment on the west side of the floodplain. The channel can be easily followed, although some problems may be encountered when boaters attempt to take shortcuts through other channels. Three major channels flow through the Delta Islands. Boaters from Susitna Landing usually travel down the western channel, as it is the shorter and quicker route to the Deshka and Yentna Rivers. Although the center channel is sometimes used, it is generally narrower and shallower than the other channels. Since Willow Creek flows into the eastern channel, boaters commonly continue down it to the Deshka River and beyond.

Near RM 51 where the river enters the Delta Islands reach, shifting gravel bars and falling trees create a navigation problem. The Delta Islands are considered to end where the eastern and western channels meet at RM 42.5. A well-defined, deep channel exists from this point past the confluence with the Deshka River (RM 40.5) to the confluence with the Yentna River (RM 28). Numerous side-channels branch off in this reach, but they do not provide access to any additional fishing areas. Kroto Slough branches off to the southwest as a side-channel at RM 40. Two gravel bars control flow through this channel, one at the head of the side-channel at RM 40, and another at the head of the slough where it branches off from the side-channel and continues to the Yentna River. Kroto Slough provides limited access during high water to a number of remote parcels along its length. Flow is maintained in its lower reaches by several small tributary streams.

Only a small number of boaters appear to use the reach of river from Susitna Landing (RM 61) to Talkeetna (RM 97), with the possible exception of during hunting season. No major salmon spawning streams are located on the west side of the river. Several important salmon spawning streams, including Sheep Creek, Goose Creek, Montana Creek, Sunshine Creek, and Birch Creek, join the Susitna River or its side channels along the east bank. The backwater zone at the mouth of Caswell Creek is also an important salmon fishing area. Except for Sheep Creek and Birch Creek, the mouth of each of the above streams can be reached by short walks from roads leading off the Parks Highway, limiting the need to boat to those areas.

Sheep Creek empties into a side-channel at about RM 66. Jetboats were observed up to RM 64.5 on this side-channel at Sunshine flows of 22,700 cfs. It appeared that they could continue to the confluence with Sheep Creek, although navigation past a gravel bar may have been difficult. Airboats would have had no problems.

Birch Creek joins a Susitna side channel at about RM 88.2. Travel down the side-channel past gravel bars controlling flow may be difficult at low flow, but access is feasible up the lower end of the side channel.

Jetboats were observed to be navigating this reach of the river at a flow of 22,700 cfs, measured at Sunshine. The major navigational problems are in the braided sections of the river where numerous channels branch off. Jetboats and airboats should not have problems, but riverboats using propellers without a lift could encounter difficulties at low flows.

- Devil Canyon to Talkeetna (***)

  The reach of the Susitna River between Devil Canyon (RM 150) and Talkeetna (RM 97) is characterized by a single channel confined by valley walls, with occasional islands (Figure E.2.2.148). Access to the reach from Talkeetna (RM 97) to Devil Canyon (RM 150) is primarily from Talkeetna. For most of the summer, boats leaving the Talkeetna River at RM 97 go upstream along the east side-channel to reach the mainstem of the Susitna River. However, this route becomes increasingly difficult at low flows, and boaters sometimes go downstream to where the channel joins the mainstem at RM 95, then continue up the Susitna River.

Upstream of its confluence with the Chulitna River, the Susitna becomes more channelized, with either a single channel or split channel morphology up to Devil Canyon. Numerous side channels exist which are navigable at high water, but which dewater at lower flows. The main channel is navigable by jetboat to Devil Canyon. Isolated large boulders exist in some portions of the channel but they are easily avoided. The only potential navigation problem area was identified as a broad shallow reach below Sherman at RM 128, where the main channel crosses the floodplain (ADNR 1982). This area was subsequently surveyed (R&M 1982j) and a deepwater channel was found. This location was later navigated without problem by jetboat at a flow rate of 6,300 cfs (measured at the Gold Creek gage).

A local guide, who has traveled this reach of the Susitna River for nine years, has reported no navigational problems (Mahay 1984). He did comment that after a flood it is a bit more difficult to read the river due to shifting gravel bars.

(c) Other Navigation and Transportation Uses (**)

The Susitna is used by several modes of non-boat transportation at various times of the year. Fixed-wing aircraft on floats make use of the river for landings and take-offs during the open water season, primarily at locations in the first 50 miles (80 km) above the mouth. The previously mentioned aerial survey conducted during moose season (September 17, 1981), located 12 planes on the mainstem and its tributaries below Talkeetna (TES 1982). Among the most common landing sites for floatplanes are Kashwitna River, Willow Creek, Little Willow Creek, Deshka River (Kroto Creek), Susitna River near the mouth of Alexander Creek, and Alexander Slough near the mouth of the river. Floatplane access also occurs on occasion within the middle and upper Susitna reaches.

After the river ice cover has solidly formed in the fall, the river is used extensively for access by ground methods in several areas. Snow machines and dogsleds are commonly used below Talkeetna; the Iditarod Trail crosses the river near the Yentna River confluence and is used for an annual dogsled race in February. Occasional crossings are also made by automobiles and skiers, primarily near Talkeetna and near the mouth.

2.6.4 - Recreation (**)

The summer recreation uses of the Susitna River include recreational boating, kayaking, canoeing, sport fishing, hunters' access, and sightseeing. In winter, recreation uses include snow machines and dogsleds. These uses were discussed in Section 2.6.3 and Chapter 7 of Exhibit E.

2.6.5 - Riparian Vegetation and Wildlife Habitat (**)

Wetlands cover large portions of the Susitna River basin, including riparian zones along the mainstem Susitna, sloughs, and tributary streams. Wetlands are biologically important because they generally support a greater diversity of wildlife species per unit area than most other habitat types in Alaska. In addition, riparian wetlands provide winter browse for moose and, during severe winters, can be a critical survival factor for this species. They also help to maintain water quality throughout regional watersheds. Detailed information on riparian wetlands and wildlife habitat can be found in Chapter 3.

The processes affecting riparian vegetation include freezeup, spring ice jams and flooding (see Section 2.3.2). Spring ice jams can have a major impact on vegetation although they are generally confined to specific areas in the Devil Canyon to Talkeetna reach. Both flooding and ice processes are believed to be important factors affecting vegetation in this reach. Because of the braided channel pattern downstream of Talkeetna, flooding is expected to be the dominant factor influencing riparian vegetation (see Chapter 3, Section 3.2.2. for further discussion).

2.6.6 - Waste Assimilative Capacity (**)

The primary source of pollution to the Susitna River watershed are placer mining operations (ADEC 1978). Numerous claims exist, although many are inactive. Active operations may introduce large amounts of suspended sediment into the watershed, but no biochemical oxygen demand (BOD) is placed on the system, and the waste assimilative capacity remains unaffected.

As for BOD discharges in the watershed, personal communication with Julie Howe of the Alaska Department of Environmental Conservation (ADEC 1985) revealed that there are no known domestic wastewater discharges into the watershed. Solid waste disposal sites are located at Talkeetna and Sunshine, but no leachate data are available.

In the absence of regulated flows and significant wastewater discharges, the ADEC has not established minimum flow requirements necessary for the maintenance of the waste assimilative capacity of the river, at this time.

2.6.7 - Freshwater Recruitment to Cook Inlet Estuary (*)

The Susitna River is the most significant contributor of freshwater to Cook Inlet and, as such, has a major influence on the salinity of Upper Cook Inlet. The drainage area controlled by the proposed project contributes less than 20 percent of the total Susitna flow into Cook Inlet (Section 2.2.1) and, therefore has a much smaller influence on Cook Inlet salinity. High summer flows caused by snow melt, rainfall, and glacial melt reduce salinities. During winter, low flows lead to increased Cook Inlet salinities.

A second major factor influencing the salinity levels in Cook Inlet are the large tidal variations. These tides, which are among the largest in the world, cause increased mixing of freshwater and saltwater.

A numerical water quality model of Cook Inlet was developed for the U.S. Army Corp of Engineers (Tetra Tech Inc. 1977). The results of this model compareed well with the available Cook Inlet surface salinity data from May 21-28, 1968; August 22-23, 1972; and September 25-29, 1972 (COE 1979).

Using this model, Resource Management Associates (1983) simulated pre-project monthly salinity concentrations throughout the Inlet using average freshwater flows from the Cook Inlet tributaries. Figure E.2.2.149 shows five selected locations where salinities were computed. Near the mouth of the Susitna River (Node 27), the study results indicated a natural salinity of 5,800 mg/l in August and 21,000 mg/l during April, or a range of 15,200 mg/l (Table E.2.2.48). The temporal salinity variation at this location is provided in Figure E.2.2.150.

In the center of Cook Inlet near East Foreland, approximately 45 miles southwest of the Susitna River mouth (Node 12), normal salinity values were estimated to vary between 21,100 mg/l during September and 26,800 mg/l in April, or a range of 5700 mg/l. Near the mouth of Cook Inlet (Node 1) the annual salinity range is 2100 mg/l with maximum and minimum average monthly values of 30,200 mg/l in April and 28,100 mg/l in August.

In addition to these three locations, estimated pre-project salinity values for the centers of Turnagain and Knik Arms (Nodes 55 and 46, respectively) are also provided in Table E.2.2.48.

Salinity was recorded at the mouth of the Susitna River during spring tides on August 18 and 19, 1982 to determine if, and to what extent saltwater intruded upstream. No saltwater intrusion was detected. Flow was approximately 90,000 cfs at the mouth of the Susitna River at the time the measurements were made. Additional salinity measurements were made on February 14, 1983 to determine if saltwater penetration occurs upstream of the mouth of the river during low flow periods. Salinity was monitored over a tidal cycle at approximately RM 1. No salinity was detected.

2.7 - Access Plan (**)

2.7.1 - Flows (o)

The flow regime of the streams to be crossed by the access road is typical of subarctic, snow-dominated streams, in which a snow melt flood in spring is followed by generally moderate flows through the summer, punctuated by periodic rainstorm floods. Between October and April, precipitation falls as snow and remains on the ground. The annual low flow occurs during this period, and is predominately base flow.

Streamflow records for these small streams are sparse. Consequently, regression equations developed by the U.S. Geological Survey (Freethey and Scully 1980) have been utilized to estimate the 30-day low flows for recurrence intervals of 2, 10, and 20 years, and the peak flows for recurrence intervals of 2, 10, 25, and 50 years. These flows are tabulated in Table E.2.2.49 for the three access route segments: (1) Denali Highway to Watana Dam; (2) Watana Dam to Devil Canyon Dam; and (3) the Devil Canyon to Gold Creek railroad. Only named streams are presented.

2.7.2 - Water Quality (**)

Water quality and fish population data for the streams in the vicinity of the proposed access routes are in the report entitled "Access and Transmission Corridor Aquatic Investigations" (ADF&G 1984h).

Many of the major streams scheduled for crossing are known to support fish populations, including Arctic grayling (see Chapter 3). Arctic grayling are generally residents of clear, cold streams of good water quality (Scott and Crossman 1973).

Water quality conditions associated with tundra runoff site are also expected. Anticipated conditions are pH levels in the 6-7 range, total organic carbon concentrations exceeding the suggested criterion level of 3.0 mg/1 (McNeely et al. 1979), and true color values as high as 100 units.

During periods of high flow resulting from spring snow melt and summer rainstorms, elevated suspended sediment and turbidity levels are experienced.

2.8 - Transmission Corridor (**)

The transmission corridor consists of four segments: the Anchorage-Willow line and the Fairbanks-Healy line (called "Stubs"), the Willow-Healy Intertie, and the Gold Creek-Watana line.

The Intertie extends from Willow to Healy. It will ultimately connect with Susitna Hydroelectric Project features. The Intertie began service in 1985. It is a 170-mile long facility constructed of guyed steel "X" poles. Angle structures are three separate vertical pole structures with single-pole hillside structures. The line will be energized at 138 kV until Stage I Watana is on line.

The Stage I Watana will come on line in 1999 with a second line parallel to the Intertie. The lines will be energized at 345 kV, A switchyard built near Gold Creek will connect with the Watana Stage I power house switchyard. In 2012, when Watana Stage III comes on-line, a third parallel line will be built on the Gold Creek to Willow portion of the right-of-way. The Willow to Anchorage stub will also have a third line to Knik Arm substation.

2.8.1 - Flows (*)

Water bodies in each of the four sections will be crossed by the transmission line. Most of these are small creeks in remote areas, but each segment has some major stream crossings. Most of the major crossings have been gaged at some point along their length by the USGS. Major stream crossings are identified below. Pertinent gage records are summarized in Table E.2.2.50.

The Anchorage-Willow segment will cross Knik Arm of Cook Inlet with a submarine cable. Farther north, major stream crossings include the Little Susitna River and Willow Creek, both of which have been gaged.

The Fairbanks-Healy line will make two crossings of the Nenana River and one of the Tanana River, both large, gaged rivers.

The Intertie route between Willow and Healy crosses several dozen small creeks, many of which are unnamed. Major streams include the Talkeetna, Susitna, and Indian Rivers; the East Fork and Middle Fork of the Chulitna River; the Nenana River; Yanert Fork of the Nenana River; and Healy Creek.

The final leg of the transmission corridor, from Gold Creek to Watana Dam, will cross only one major river: the Susitna. Two smaller but sizeable tributaries that will be crossed are Devil Creek and Tsusena Creek.

2.8.2 - Water Quality (**)

Information on water quality for some streams and rivers near the proposed transmission corridors is found in ADF&G's report "Access and Transmission Corridor Aquatic Investigations" (1984h). One continuous sampling location on the Nenana River at Healy has been identified (Dwight 1982). In addition, periodic data are available for monitoring stations at Nenana River near Windy, Healy Creek near Suntrana, Healy Creek at Suntrana, Healy Creek 0.1 mile above French Gulch near Usibelli, Lignite Creek 0.5 mile above mouth near Healy, Lignite Creek near Healy and Francis Creek 100 feet above Lignite Creek near Suntrana.

At the USGS Station No. 15518000 on the Nenana River near Healy, 13 years of continuous records revealed mean daily summer sediment concentrations ranging up to 8,330 mg/l. Late September and October measurements were approaching concentrations of near zero. These data indicate the glacial origins of the river. It is assumed that previously noted characteristics associated with tundra runoff will also be present in the Nenana and its tributaries.

3 – OPERATIONAL FLOW REGIME SELECTION

3 - OPERATIONAL FLOW REGIME SELECTION (***)

This section describes the process that was used to arrive at an operational flow regime for the Susitna Hydroelectric Project. It includes:

- o Descriptions of the Watana and Devil Canyon reservoirs including the operations of each in meeting project objectives (Section 3.1);
- o The manner of simulating project operation to meet environmental and energy requirements (Section 3.2);
- o The development of the alternative environmental flow requirements including the objectives of each (Sections 3.3. and 3.4);
- o The selection of the Case E-VI flow requirements (Section 3.5);
- o A discussion of other project operating considerations including flow stability, dam safety and emergency situation criteria (Section 3.6); and
- o A summary of the power and energy production for Case E-VI (Sections 3.5 and 3.7).

3.1 - Project Reservoir Characteristics (***)

The Susitna development scheme is as follows:

- o Watana Stage I is the initial project. It provides 2.37 million acre-feet of active storage. This is roughly 40 percent of the mean annual flow at the damsite, and affords some seasonal regulation. All Stage I units will be operational in 1999.
- o Devil Canyon is Stage II. It will be constructed in a narrow canyon with little active storage. Hence, it mainly develops head, relying upon Watana to regulate flows for power production. All Stage II units will be operational in 2005.
- o Stage III involves raising the Watana Dam 180 feet to its ultimate height. The active storage will be 3.7 million acre-feet, about 64 percent of the mean annual flow. Commercial operation of the two additional units will be in 2012.

Storage characteristics of the Watana Reservoir will differ depending on whether Stage I or Stage III is operating. Devil Canyon storage characteristics are unchanged throughout its operation period. Area and volume versus elevation curves for both Watana and Devil Canyon reservoirs are shown on Figures E.2.3.1 and E.2.3.2. The following sections briefly describe the reservoir characteristics.

3.1.1 - Watana Stage I (***)

The Watana Stage I Reservoir will have a normal operating level at el. 2,000 ft. At this level, the reservoir will be approximately 39 miles long, with a maximum width on the order of three miles. The total volume and surface area at the normal operating level will be 4.25 million acre-feet and 19,900 acres, respectively. The minimum operating level is at el. 1,850 ft, resulting in a 150-ft maximum drawdown. The active storage is 2.37 million acre-feet.

3.1.2 - Devil Canyon Stage II (***)

The Devil Canyon Reservoir will have a normal maximum operating level at el. 1,455 ft. At this level, the reservoir will be approximately 26 miles long, with a maximum width of approximately one-half mile. The total volume and surface area at the normal operating level will be 1.1 million acre-feet and 7,800 acres, respectively. The minimum operating level is at el. 1,405 ft. resulting in a 50 ft. maximum drawdown. The active storage is 350,000 acre-feet.

3.1.3 - Watana Stage III (***)

The Watana Stage III Reservoir will have a normal operating level at el. 2,185 ft. At this elevation, the reservoir will be approximately 48 miles long, with a maximum width of about five miles. The total volume and surface area at the normal operating level will be 9.5 million acre-feet and 38,000 acres, respectively. The minimum operating level is at el. 2,065 ft. resulting in a 120-ft maximum drawdown. The active storage is 3.7 million acre-feet.

3.2 - Reservoir Operation Modeling (***)

3.2.1 - Reservoir Operation Models (***)

The computer models used to simulate the operation of the reservoirs are: the monthly operation program (Monthly RESOP); and the weekly operation program (Weekly RESOP). The monthly RESOP was originally developed for the Susitna feasibility study and subsequently updated. The weekly RESOP was developed using selected subroutines from the monthly RESOP. The objectives of the reservoir operation study are to determine the operation which maximizes the Susitna Project benefits under the specified constraints and to provide estimated reservoir outflows and water levels for environmental impact analyses.

The time increment used for the simulation affects both the computational effort required and the accuracy of the results obtained. The monthly program is used to provide input to the economic analyses, while the weekly simulation is used for flow regime studies and impact analyses. A weekly time step is used for flow regime studies because the results more precisely show the fluctuation of reservoir outflows and water surface elevations and more accurately define the critical conditions. Weekly simulations also yield more gradual changes in outflow discharges from week to week than monthly operation. This discussion addresses only the weekly simulation.

The reservoir operation analysis simulates Susitna operation over 34 years of historical streamflow records (January 1950 - December 1983). Key inputs to the model are the reservoir and powerplant characteristics, power demand distribution, and environmental constraints. The RESOP models simulate the reservoir storage, power generation, turbine discharge, outlet works release, and spill as a function of time. The resulting water levels, and releases from turbines, outlet works, and the spillway, are used for evaluation of environmental impacts of flow stability, fishery habitat, flood frequency, temperature, stage fluctuation, and ice conditions in the river downstream.

3.2.2 - Basic Concept and Algorithm of Reservoir Operation (***)

Reservoir operation simulation is basically an accounting procedure which monitors the reservoir inflow, outflow, and storage over time. The storage at the end of each week is equal to the initial storage plus inflow minus outflow within the week. Key constraints on the simulation are the operating guide and the minimum instream flow requirement at Gold Creek which must be satisifed each week. The operating guide governs the release for power, with the total powerhouse release restricted by the discharge required to meet the system power demand. Any additional flow required to meet the downstream flow requirement is released through the outlet works. Flood releases to maintain dam safety requirements are made first through the outlet works and, if the water level exceeds the 50-year flood surcharge level, through the spillway (see Section 3.6.2).

In Stages II and III the reservoir operation method attempts to keep the Devil Canyon Reservoir close to its normal maximum operating level while using Watana's storage to provide the necessary seasonal flow regulation. Therefore, the modeling effort in both the single and double reservoir operation simulation is focused on the Watana operation. The operation level constraints are summarized in Table E.2.3.1.

(a) Watana Stage I (***)

An initial iteration is done for each time step to begin the simulation. In the initial iteration, the powerhouse flow required to meet a minimum target energy for each one week time period is released. The algorithm is explained in detail in Exhibit B, Chapter 3, Section 3.2.

The energy generated by these releases is compared to the system energy demand, in each time step, and adjusted to meet the energy demand in successive iterations by increasing or decreasing the powerhouse discharge.

An operating guide is applied to make the desired Watana powerhouse release in order to optimize project energy generation. The release prescribed by the operating guide depends upon the present release rate, the time of year, and the present water level in the reservoir. The operating guide is developed through a procedure described in Exhibit B, Chapter 3, Section 3.2 and in Section 3.6.1(a) of this chapter.

A minimum instream flow requirement is prescribed at Gold Creek to ensure that the project will release flows for environmental purposes. The historical intervening flow between Watana and Gold Creek is assumed to be available to supplement the project releases to meet the minimum flow requirement. If the flow prescribed by the operating guide does not meet the environmental requirement, the simulation will attempt to release more water through the powerhouse in order to meet the requirement. If the release required to meet environmental flow requirements exceeds the maximum powerhouse flow to meet energy demands, the difference between the required outflow and the maximum powerhouse discharge is released through the outlet works. This outlet works release is called an environmental release since it is made only to meet the environmental flow requirement and is not used for power generation.

The outlet works capacity at Watana I is 24,000 cfs, while the powerhouse capacity is about 14,000 cfs. In the event that a flood could not be passed through the powerhouse and outlet works, because of energy demand and hydraulic capacity limitations, the reservoir is allowed to surcharge above the normal maximum water surface elevation. This surcharging is done to avoid the use of the spillway for floods less than the 50-year event. A maximum surcharge level of el. 2,014 ft. is permitted before the spillway operates. This surcharge is explained more fully in Section 3.6 of this Chapter.

(b) Watana Stage I or Stage III with Devil Canyon Stage II (***)

For simulation of double reservoir operation, the initial iteration for each time step is the same as that for the single reservoir. Devil Canyon operates as run-of-river as long as the reservoir is full. The Devil Canyon Reservoir is to be refilled if the reservoir is not full, so long as the total inflow is greater than the release required to meet the environmental flow requirement. After the initial iteration, the total energy generated at Watana and Devil Canyon is compared to the system energy demand and adjusted in successive iterations by increasing or decreasing powerhouse discharges to meet system energy demands.

An operating guide is again developed and applied to optimize the Watana powerhouse releases for power generation (see Exhibit B, Chapter 3, Section 3.2). Minimum instream flow requirements and constraints on rate of change of discharge are also applied.

The intervening flow between Devil Canyon and Gold Creek is assumed to be available to supplement the project releases to meet the minimum flow requirements. If the environmental flow requirement is not met by powerhouse discharges, more water is released through the Devil Canyon powerhouse in order to meet the requirement and the Devil Canyon Reservoir will draw down. If the increased release through the Devil Canyon powerplant would cause the total energy generation to be greater than the system demand, the release from the Watana powerplant is reduced. As explained in Section 3.6 of this chapter, this is done to minimize Devil Canyon outlet works releases which may result in reduced temperatures downstream.

If the release required to meet environmental flow requirements exceeds the Devil Canyon powerhouse discharge required to meet energy demands, then the difference is released from the Devil Canyon outlet works. In the summer of dry years when the system energy demand is low and the downstream flow requirement is high, Devil Canyon may be drawn down continuously. If the water level at Devil Canyon reaches the minimum operating level of el 1,405 ft, Watana must then release water to satisfy the minimum flow requirement. If the release from Watana for the minimum flow requirement would generate more energy than the required amount, part of the release would be diverted to the Watana outlet works.

The powerhouse hydraulic capacities are about 14,000 cfs at both Watana Stage I and Devil Canyon. The capacity is about 22,000 cfs for Watana Stage III. The outlet works capacity at Devil Canyon is 42,000 cfs while the capacity at Watana is 24,000 cfs in Stage I and 30,000 cfs in Stage III. In the event that a flood could not be passed through the powerhouse and outlet works, because of energy demand and hydraulic capacity limitations, Watana is allowed to surcharge above its normal maximum level. The maximum surcharge level is el. 2,014 ft. for the Watana Stage I Dam and el. 2,193 ft, for the Stage III Dam. This allowable surcharge is more fully explained in Section 3.6 of this Chapter.

3.3 - Development of Alternative Environmental Flow Cases (***)

3.3.1 - Background (***)

The February 1983 License Application (APA 1983c pp. B-2-121 through B-2-130) presented ten alternative flow regimes ranging from the regime that would maximize project power and energy benefits (Case A) to a regime that would approximate natural, average, run-of-river conditions (Case G). Seven of the cases (C, C_1, C_2, D, E, F, G) emphasized the use of flow control and planned releases to mitigate potential impacts on downstream aquatic habitats. The major difference among these environmental cases was a gradual, incremental decrease of summer minimum flows from Case G through Case A (APA 1983c Table B54). Emphasis was placed on maintaining higher flows (i.e. smaller incremental decreases) during mid-July to mid-September to mitigate impacts on access conditions into side sloughs for spawning adult salmon (APA 1983c B-2-127 and B-2-128).

Results of numerous fishery and aquatic habitat studies and analyses have become available since that time. This accumulated information has provided a more detailed and complete understanding of habitat use by the evaluation species and the importance of certain physical processes in the Susitna system as they relate to the quantity and quality of aquatic habitats. The new information is sufficient to refine the flow constraints to more adequately provide for habitat requirements of the evaluation species. As detailed below, the primary reasons to refine the flow restraints relate to (1) mainstem and side channel rearing habitats, (2) seasonal flow constraints, and (3) maximum flow constraints.

(a) Mainstem and Side Channel Rearing Habitats (***)

The use of mainstem associated habitats for rearing during the summer open water season is more common than previously perceived. Chinook salmon juveniles use side channel habitats for rearing during the summer (ADF&G 1984g). They are found in the side channels in greatest densities when flow is dominated by turbid water overflow from the mainstem. Conditions in the side channels are directly influenced by mainstem discharge at these times. Chum salmon also use turbid water, low velocity, mainstem sites for short-term rearing during their downstream migration to Cook Inlet.

(b) Seasonal Flow Constraints (***)

Environmental flow constraints for the entire year are necessary to maintain overall aquatic habitat values. Environmental considerations focused on summer flow, and winter minimum flows were based on reservoir operations for an extremely dry year (1969). There are important uses of the aquatic habitats throughout the year so there is a parallel need to establish appropriate environmental flow requirements for the entire year, rather than focusing only on the summer flow period.

(c) Maximum Flow Constraints (***)

The flow cases presented in the July, 1983 License Application did not include maximum flow constraints. Maximum constraints are not critical during summer since the project will be storing flows. Maximum flow constraints established for the summer will not be exceeded except during infrequent flood events (See Section 3.6.2 in this Chapter). Winter maxima can serve to maintain a desired level of flow stability, protect peripheral habitats, and enhance the feasibility of certain mitigation alternatives, such as artificial berms and other structural modifications in side sloughs.

3.3.2 - Selection Criteria (***)

Several criteria were established for selection of alternative flow cases. These criteria were:

- The flow case had to be goal oriented. That is, the case had to be designed to achieve a specified level of habitat quantity and quality (Section 3.3.2(a)).

- The flow case had to emphasize critical or sensitive species and habitat combinations (Section 3.3.2(b)).

- The flow case had to be compatible with mitigation policy. That is, it had to focus on evaluation species, emphasize preservation of habitats in a state of natural production, and integrate with other mitigation efforts (Section 3.3.2.c).

(a) Management Objectives (***)

The programming of flow regulation to mitigate for potential downstream project impacts requires a clear statement of objectives. A particular objective will dictate the quantity and timing of flow releases and set a standard by which the success of flow regulation can be measured.

The management objectives chosen by the Applicant emphasized chum salmon spawning in side sloughs and chinook salmon rearing in side channels (the reasons for this emphasis are detailed in Sections 3.3.2.b and 3.3.2.c below). The specific objectives for alternative flow cases were:

- To maintain quantity and quality of existing habitats (ie., no loss in habitat value);
- To maximize chinook salmon production (rearing) in existing habitats;
- To maintain 75 percent of existing side slough spawning habitat for chum salmon;
- To maintain 75 percent of existing side channel rearing habitat for chinook salmon;
- To maintain 75 percent of existing side slough and side channel habitats for chum salmon spawning and chinook salmon rearing, respectively;
- To maintain 75 percent of existing side channel rearing habitat for chinook salmon and provide flows (spikes) for access by spawning chum salmon into side sloughs (minimum structural modification of critical reaches for access); and
- To maintain 75 percent of existing side channel rearing habitat for chinook rearing and provide flows (spikes) for access by spawning chum salmon into side sloughs by spawning chum salmon (moderate structural modification of critical reaches for access).

It is important to understand that, in developing these management goals, a principle guideline for the establishment of the percentage levels is that they are designed to maintain the actual habitats utilized under natural conditions. The percentages (i.e. 75 percent) do not account for the possible acquisition of other habitat areas made available as a result of the altered flow regime. That is, the management goals were directed at use of water to maintain presently utilized habitat at the prescribed levels. The addition of new habitat areas to the total suitable habitat would replace the loss of existing habitat. This would, then, satisfy the overall policy of no-net-loss of habitat value.

The Applicant applied these objectives and developed eight alternative flow cases for evaluation and comparison (HE 1984h). This process included an analysis of characteristics of habitat types and identification of project-sensitive habitat use by the evaluation species. These factors are detailed below.

(b) Critical Species And Habitat Combinations (***)

The primary change from natural riverine conditions due to project operations will be altered streamflows in the mainstem Susitna River. The project will change the annual sequence of streamflows by storing high summer flows for release during the normally low flow period in winter. This primary change will also alter factors associated with mainstem flow such as water temperature, turbidity and suspended sediment. These changes will not affect all habitats equally. The magnitude of effect will depend on the level of influence that mainstem conditions have on physical characteristics of the various habitat types. In addition, the habitats are not used uniformly by all species at all times. Therefore, some prioritization is necessary for effective allocation of flows. The timing and volume of flow discharge should be planned to produce the greatest possible mitigative effect for the aquatic habitats and evaluation species.

The Applicant evaluated habitat characteristics and seasonal habitat used by the evaluation species, in order to develop a rationale for establishing environmental flow requirements and to plan project operations. The general approach was to find the most important uses, based on density, frequency and duration, of the aquatic habitats that are most sensitive to mainstem flows. This process and its results were also reviewed to avoid overlooking a critical use of a less sensitive habitat that would be adversely impacted by project operation. No such circumstance was found.

(i) <u>Habitat Sensitivity to Mainstem Conditions</u> (***)

Changes due to project operation will be greatest in the middle river reach. The magnitude of discharge changes in the middle river will be dampened in the lower river by the dominating influence of inflow from the Chulitna, Talkeetna and Yentna Rivers, especially during spring and summer as discussed in Exhibit E, Chapter 2, Section 2.2 and Section 4. Therefore, flow regulation intended to mitigate project impacts will have limited effectiveness for lower river habitats. Other factors associated with mainstem discharge, such as temperature, turbidity, and suspended sediment, will follow the same trend. The magnitude of change will decrease with distance downstream from the project site and the effect of any design or operational measures to mitigate these changes will be "masked" by the influence of inflow from the major tributaries. This is discussed in Exhibit E, Chapter 2, Section 2.3 and Section 4. Therefore, the current analysis focuses on evaluation species and habitats found in the middle river.

Seven habitat types have been defined in the middle river basin. These are tributary, tributary mouth, lake, upland slough, side slough, side channel, and mainstem. Each was characterized and compared based on the level of influence mainstem conditions have on particular physical attributes of the habitats (Table E.2.3.2). These habitat types are defined in Exhibit E, Chapter 2, Section 2.1.

Tributary and lake habitat types are isolated from mainstem influence and their physical attributes will not be affected by project operation. Upland sloughs are usually in old overflow channels and oxbows that are presently isolated from the mainstem. They receive mainstem water only during infrequent and high flood events. Mainstem influence is limited to small backwater areas at the slough mouths so project operation will have little effect on upland slough habitats.

Side channels and side sloughs are active overflow channels that differ primarily in the frequency of receiving mainstem flow. Side sloughs are the most lateral channels and receive mainstem flow less often than side channels. Habitat characteristics of the side sloughs are controlled by local climate, runoff and groundwater upwelling during periods of relative isolation from the mainstem. Side channels are more closely associated with the mainstem and some receive mainstem flows through most of the year. Side channels may completely dewater during periods of low mainstem flow or, if groundwater or intergravel flow is sufficient, their habitat characteristics may resemble side sloughs. Both side channel and side slough habitat types are influenced by mainstem flows and several of their physical habitat components are sensitive to changes in mainstem discharge.

Tributary mouth habitat is the area bounded by the uppermost point of mainstem induced backwater effect in a tributary and the area of clearwater plume from tributary flow into the mainstem. The areal extent and physical attributes of this habitat type are controlled by both mainstem and tributary conditions.

The relative influence of mainstem flow on primary characteristics of the major habitat types is summarized in Table E.2.3.2. This summary shows that mainstem, side channel, side slough and tributary mouth habitat types are influenced by the mainstem. Several of their physical attributes are sensitive to change in mainstem discharge.

(ii) Habitat Use By The Evaluation Species (***)

The next step in the development of the refinement to Case C was to evaluate use of the habitat types by each of the evaluation species (Table E.2.3.3)

The information used for this step is contained in reports by ADF&G (1984f and 1984g). Lake habitat was not included due to its isolation from mainstem influence. Tributary habitat, although isolated from mainstem influence, was included because of its role in overall production in the middle river for most of the evaluation species.

Habitat use by each evaluation species was separated into major life history and behavioral components: migration, spawning/incubation, and rearing. Migration includes both directed movement to particular sites, such as the upstream migration of adult salmon to spawning sites, and more non-directed activity, such as movement by rearing fish from one habitat site to another. Spawning and incubation were combined because they are limited to the same habitat sites and, although their specific habitat criteria (needs) may differ, each limits the habitat flexibility of the other. Rearing is used broadly in this analysis to include the relatively active period of feeding and rapid growth during the summer and the less active overwintering period.

The habitat uses noted in Table E.2.3.3 are those judged to be the most important or predominant for each species. For example, although chinook salmon juveniles are found in upland slough and tributary mouth habitats, their use of these habitats for rearing is much less important than use of side channel, side slough and tributary sites.

- Chinook Salmon (***)

Most of the upstream migrant adult chinook enter the middle river from mid-June to mid-July. They pass through mainstem and tributary mouth habitats to their natal tributary streams to spawn from late July to mid-August. All chinook spawning and incubation occurs in the tributaries.

Juvenile chinook salmon (AGE 0+) begin rearing in their natal tributaries immediately after emergence. This early rearing during May and June is limited almost entirely to tributary sites. Beginning in late June, there is a gradual redistribution of large numbers of juveniles from tributary to side channel and side slough habitats. The major rearing sites during July and August are in tributaries and side channels. The juvenile chinook rearing in side channels begin moving into side sloughs in September and by November, the greatest densities are found in tributaries and side sloughs, which are the major overwintering habitats. The juvenile chinook (AGE 1+) move out of their overwintering habitats and migrate to Cook Inlet during the spring and early summer. Downstream migrant chinook are out of the middle river by mid-July.

- Coho Salmon (***)

Adult coho salmon migrate into the middle river from early August to early September to spawn. Essentially all coho spawning occurs in tributary habitat sites from late August to early October. Coho juveniles begin rearing in natal tributary habitats immediately after emergence. Many of the juveniles leave the tributaries and redistribute into upland sloughs and side sloughs during late June and early July. The major rearing habitats during July to October are tributaries and upland sloughs. Data regarding overwintering sites suggest that upland sloughs are most important.

- Chum Salmon (***)

  Adult chum salmon enter the middle river from mid-July to early September. Most spawn in either tributary or side slough habitats and a few spawn in side channels with suitable upwelling conditions. Major spawning occurs from mid-August through September. Chum salmon juveniles begin rearing in their natal habitats after emergence in the spring. They tend to remain in these sites until they begin a gradual downstream migration to Cook Inlet in June. Juvenile chum will use low velocity, backwater areas in the mainstem for holding and, perhaps, some short term rearing during downstream migration. The chum salmon juveniles move out of the middle river by mid-July.

- Sockeye Salmon (***)

  Adult sockeye salmon (second run) move into the middle river from mid-July through August. They spawn almost exclusively in side sloughs, from mid-August to early October. Sockeye juveniles begin rearing in their natal side sloughs after emergence in late spring. They are most abundant in side sloughs during May and June and begin moving into upland sloughs in late June. They are most abundant in upland sloughs from July through mid-September. Their densities in the middle river decline abruptly in all habitats by mid-August. Most of the juveniles apparently move out of the middle river at this time and the few that remain overwinter in side sloughs.

- Pink Salmon (***)

  Adult pink salmon migrate into the middle river from mid-July to mid-August and spawn almost exclusively in tributaries. Pink salmon juveniles begin migrating downstream immediately after emergence in the spring and are out of the middle river by late June.

- Arctic Grayling (***)

  Arctic grayling are most commonly associated with clearwater habitats. Spawning and major summer rearing occur in tributaries. They also rear in tributary mouth habitat. Some grayling move out of the tributaries into mainstem areas in late summer. Overwintering occurs in both tributary and mainstem habitats.

- Rainbow Trout (***)

  Rainbow trout are associated with clearwater habitats. Spawning and major rearing occur in tributary habitats. Some rainbow congregate at tributary mouths during late summer. This behavior appears to be in response to food supply (salmon eggs) provided by spawning salmon. Rainbow trout move out of the tributaries to tributary mouths during late summer and early fall and overwinter in the mainstem.

- Burbot (***)

  Burbot are found in the mainstem throughout the year. They occur mostly in turbid, low velocity, backwater areas directly influenced by mainstem flow. Spawning occurs during January. Although specific spawning sites in the middle river have not been found, evidence suggests they spawn at slough mouths and in deep, backwater areas influenced by groundwater.

- Dolly Varden (***)

  The majority of spawning and rearing by Dolly Varden occurs in tributary habitat. They move from the mainstem into tributaries by late June. The Dolly Varden move back out of the tributaries in late fall and overwinter in the mainstem.

- Conclusions Regarding Habitat Use (***)

  Several general observations can be drawn from the habitat uses summarized in Table E.2.3.3. First, tributary habitat is the habitat type used most commonly by the evaluation species. Sockeye salmon and burbot are the only species that do not use tributaries extensively for important life history phases. Secondly, the resident species make little use of side channel, side slough or upland slough habitats, whereas the anadromous species (salmon) frequently use these habitats. The most common use of the mainstem habitat is for migration and movement although resident species also overwinter in the mainstem.

Habitat requirements associated with migration and movement are less critical and restrictive than for the other life history categories. Only water depth and velocity have a major impact on movement of fish. Suitable depth and velocity conditions exist over a broad range of mainstem flows, and flow requirements to support migration and movement would not be restrictive to project operation. Flow requirements to satisfy the more critical needs of rearing and spawning/incubation will also satisfy the habitat needs for migration. Therefore, habitat requirements for rearing and spawning/incubation were emphasized for the remainder of the analysis.

The four sensitive habitat types from Table E.2.3.3, (Mainstem (MS), Side Channel (SC), Tributary Mouth (TM) and Side Slough (SS)) were selected for comparison based on their use for rearing and spawning/incubation (see Table E.2.3.4).

(MS) Mainstem habitat is used mostly for rearing, especially overwintering. Use of the mainstem by chum salmon is transient and short-term during their downstream movement to Cook Inlet. The major use of mainstem habitat by Arctic grayling, rainbow trout and Dolly Varden is for overwintering. The total area of mainstem habitat will be greater during the winter under the expected range of project flows than under natural flows. In addition, the populations of all the resident species in the middle river, including burbot, are characterized as low density.

(TM) Arctic grayling and rainbow trout use tributary mouth habitat for rearing during the ice-free seasons. Use by rainbow is transient, occurring mostly in the late summer and fall. The total area of this habitat will be greater and more stable under the lower and more stable mainstem flows during project operation (EWT&A 1985).

(SC) Side channel habitat is used by chinook salmon for rearing and chum (and sockeye) salmon for spawning. The chum salmon spawning is limited to sites with sufficient upwelling conditions and accounts for only approximately five percent of the total chum spawning in the middle river basin.

Large numbers of chinook juveniles rear in side channels through most of the summer and early fall. The use of this habitat appears to be important to chinook production in the middle river. Therefore, chinook rearing in side channels was selected as one of the critical uses of a sensitive habitat for primary consideration in developing environmental flow requirements.

(SS) Side sloughs are used by salmon species for both rearing and spawning/incubation. Based on capture data, approximately 9 percent of chinook salmon in the middle river rear in side sloughs during the ice-free season while some 23 percent rear in side channels. The remaining two thirds of the population utilize tributary habitats. Flow requirements to maintain side channel habitat would also serve chinook rearing in side sloughs. Environmental flow cases designed to protect chinook rearing in side channels also provide for overwintering in side sloughs since, for the most part, the same fish use both habitats.

Chum and sockeye salmon use side sloughs for both spawning and rearing. Sockeye use of this habitat is so similar to chum, in time and location, that their habitat needs can be provided by concentrating on the more abundant chum salmon. Both species use side sloughs for short term, initial rearing prior to outmigration to Cook Inlet or movement to another habitat type. Chum salmon utilize side sloughs extensively for spawning. This is the most intensive use of a sensitive habitat in the middle river for spawning. Therefore, chum salmon spawning in side sloughs was selected as another critical use of a sensitive habitat for development of environmental flow cases.

3.3.3 - Compatibility with Mitigation Policy (***)

The alternative flow cases had to be compatible with the mitigation policies and procedures presented in the February 1983 License Application (APA 1983d pp. E-3-3 to E-3-6 and E-3-147 to E-3-150). The flow cases had to function well with other mitigation measures to result in no-net-loss of fish production from the Susitna system. The flow cases also had to provide for habitat of sufficient quality and quantity to maintain natural reproducing populations to the greatest extent possible, consistent with other project objectives.

The environmental flow cases designed and selected for analysis emphasized the habitat needs of the evaluation species which were considered most important and most sensitive to anticipated changes from natural conditions. The flow cases were designed to mitigate potential impacts by using flow releases to maintain natural production in existing habitats.

3.4 - Detailed Discussion of Flow Cases (***)

3.4.1 - Environmental Flow Cases (***)

Environmental flow Cases E-I through E-VI, as discussed below, are based on interpretation and analysis of all the data and information available regarding Susitna River fisheries resources and their habitats. Flow constraints contained in each case are based on the physical characteristics of particular habitats and uses of habitat by particular species and life stages under natural flow conditions. The potential for new habitat with the same characteristics but at different locations under project operation flows was not considered.

Development of the flow cases emphasized maintenance of habitats most responsive to mainstem flows. Rearing habitats in mainstem backwater areas, side channels and side sloughs were given greatest emphasis. Side sloughs are the most important spawning habitat affected by mainstem flows. Flow constraints for maintenance of summer rearing habitat included two important considerations. Minimum summer flow constraints were established to preserve the desired quantity of existing habitat and summer maximums were established to prevent extensive dislocation of rearing juveniles (i.e., provide greater flow stability). Flow constraints for juvenile over-wintering habitat were chosen to provide general flow stability and to minimize mainstem over-topping of side slough berms.

Mainstem flows affect both access to, and wetted area within, side sloughs. Minimum flow constraints were chosen to provide a specific minimum level of access and wetted area within chosen critical sloughs. These flow constraints are limited to August and September when chum and sockeye salmon enter the sloughs and spawn. Several cases include spiking flows. These short duration releases of relatively high volumes of water fulfill two purposes. Spiking flows in June provide over-topping flows into side sloughs to clear debris and sediments out of spawning areas and are not required every year. Spiking flows during August and September are to augment access conditions in side sloughs.

Minimum flow constraints are generally used to maintain a specified level of habitat quantity. Maximum flow constraints are generally used to provide flow stability (habitat quality) or minimize overtopping of mainstem water into side sloughs.

The effects of project operation on the environment discussed in Exhibit E are all based on Case E-VI, the Applicant's selected case, and so it is presented in more detail than the other cases. Environmental flow requirements are defined by water week, with water week being the period October 1 through October 7. Table E.2.3.5 shows the definitions of water weeks.

(a) Case E-I (***)

(i) Management Objective (***)

Case E-I is a set of flow constraints necessary to maintain the quality and quantity of existing habitats, and represents the "no-impact" bound of the analysis. A corollary to this statement is that Case E-I achieves no net loss in productivity strictly through flow control and proper timing of flow releases. Maintenance of existing habitat and productivity does not require exact duplication of natural flow patterns and, in fact, some productivity benefits can accrue to downstream aquatic resources through increased stability by flow regulation.

(ii) Flow Constraints (***)

The E-I flow constraints are shown in Table E.2.3.6 and Figure E.2.3.3. Summer flow constraints were chosen principally to maintain existing juvenile salmon rearing habitats. These flows also provide passage conditions for upstream migration of adults. A 45,000 cfs spike is provided in June to purposely overtop sloughs and clean sediments and debris out of spawning areas. This spiking flow is not necessary in each year of operation. Flows of this magnitude may be necessary once every three to four years to achieve this purpose. Two flow spikes, 23,000 and 18,000 cfs, are provided in mid-August to allow unrestricted access by adult spawners into side sloughs. Winter minimum and maximum flows were chosen to maintain adequate over-wintering habitat and protect incubating eggs in side-slough habitats.

(iii) Project Flows (***)

Case E-I flows average 8,000 cfs at Gold Creek during the October to April period. Powerhouse discharge is increased from October to December and then decreased from December to April. December discharge can be as high as 13,000 cfs, but averages 9,800 cfs. The high minimum summer flow requirements result in low flows during the months of October, March, and April in low flow years. October flows are always greater than 4,000 cfs but 50 percent of the time, they are less than 6,000 cfs. In November, minimum flows approach 2,000 cfs. In March, minimum flows are 5,600 cfs. Lowest spring flows occur in early May and in dry years approach 4,500 cfs.

Because of the high minimum summer requirements of Case E-I, flow during May is purposely held low. Average flow during May is 7,400 cfs. During the months of June, July, August and September, project flows are the same as the minimum flow requirements 80 percent of the time. During the other 20 percent of the time, the project operation flows are usually only slightly greater than the minimum requirements. Flows would closely follow the minimum constraints during June through September, except during periods of high run off. More detailed descriptions of the flows for Case E-I are presented in Exhibit E, Chapter 2, Section 4.

(iv) Impact Assessment (***)

The flow constraints in Case E-I were chosen to maintain existing spawning and rearing habitats. No loss of production is anticipated. Certain aspects of water quality will be changed by project operation. The natural temperature and turbidity regimes will be altered. Mainstem water temperatures will be generally cooler in the summer and warmer in the winter. However, these changes are well within the known tolerances of fishes utilizing mainstem habitats and no significant change of production is anticipated (APA 1984b, APA 1984c DEIS Technical comment Nos, AQR100, AQR108, AQR119 and AQR123). Turbidity levels will be less in the summer and greater in the winter than under natural conditions. Turbidity levels in the winter will be less than natural summer levels and are within the range of tolerance for existing Susitna River stocks. The projected temperature and turbidity impacts are generally the same for all the cases and will not be repeated for each. More detailed comparison of temperatures for E-I and E-VI are described in Exhibit E, Chapter 2, Section 4.

(v) Mitigation (***)

Case E-I was designed to maintain existing habitat. Potential loss of these habitats would be minimized through timing and control of flow releases. Mitigation efforts to rectify, reduce or compensate for impacts would not be necessary. An extensive monitoring program would be conducted to measure the success of this plan in achieving the desired goal of no net loss in productivity.

(b) Case E-II (***)

(i) Management Objective (***)

Case E-II is a set of flow constraints designed to maintain 75 percent of existing chum salmon side-slough spawning habitat. Estimated numbers of chum salmon spawners in side sloughs of the middle river were less than two percent of the total escapement past Sunshine Station during the 1981-1983 seasons (ADF&G 1984f).

(ii) Flow Constraints (***)

Case E-II flow constraints are presented in Table E.2.3.7 and Figure E.2.3.4. Early summer minimum flow constraints are intended to provide for successful exit of juvenile chum from slough spawning areas and for initial downstream passage and rearing. A 35,000 cfs spike is provided in mid-June to overtop sloughs and clear spawning areas of sediments and debris. Minimum July flows of 6,000 cfs will provide for successful upstream passage of migrating adults. Maximum flow constraints are not necessary during this period to satisfy the management objective. Minimum August flows of 12,000 cfs will provide access to side sloughs by adult spawners. An 18,000 cfs spike is provided in early September to augment access to important side slough sites.

Minimum flow constraints during the winter resemble natural flow conditions and are simply to prevent unusual dewatering of spawning sites. Maximum winter flow constraints of 16,000 cfs provide a moderate level of protection to eggs incubating in side sloughs.

(iii) Project Flows (***)

Project flows for Case E-II are similar to those of Case E-V except that the October to April flows would be higher for Case E-II to reflect the fact that the July minimum flows for Case E-II are lower than for Case E-V. Flows from May to September would average 10,700 cfs and would be at the minimum flow about 55 percent of the time.

(iv) Impact Assessment (***)

Several of the Case E-II flow constraints are conservative. The June spiking flow to clean side slough spawning habitat does not have to occur every year. This spike could be provided once every several years and still achieve its purpose. The summer spiking flow may be in excess of that necessary to maintain access to 75 percent of the existing side slough spawning habitat (APA 1984c comment No. AQR072). However, a 25 percent loss of chum salmon side slough spawning habitat will be assumed for this analysis.

Sockeye salmon also spawn in the side sloughs most frequently used by chum spawning. Spawning habitat loss for sockeye salmon is expected to be similar to the losses for chum. The minimum summer flows are adequate for upstream passage and tributary access to migrant adults and since coho, chinook and pink salmon spawn almost exclusively in tributaries, no loss of spawning habitat would occur for these species.

The summer minimum flow constraints established for Case E-II would not maintain 100 percent of the existing juvenile chinook rearing habitat. The 6,000 cfs minimum flows during water weeks 39 through 43 would result in the significant loss of existing chinook rearing habitat. A 75 percent loss of existing chinook rearing habitat in the middle river is thought to be a worst case estimate and will be assumed for this evaluation.

Chum salmon juveniles also utilize mainstem affected habitats for rearing. Sampling in the middle river indicates a majority (approximately 60 percent) of the chum have left this reach prior to water week 39 so the loss of rearing habitat would not be as great for chum as for chinook. A worst case estimate for loss of rearing habitat for the chum juveniles remaining in the middle river is assumed, therefore, to be 40 percent.

(v) Mitigation (***)

Case E-II minimizes some impacts through control and timing of flow releases. Potential impacts to slough spawning chum and sockeye salmon are minimized by special flow releases timed to clean spawning substrate and provide access to spawning areas. Impacts to rearing habitats are minimized through minimum summer flow constraints and increased stability through flow control.

The remaining impacts to slough spawning habitat would be rectified by structural modification of slough mouths to provide suitable access conditions at 12,000 cfs. Similar alterations would be made within the sloughs to provide passage through critical reaches. Loss of rearing habitat within the river would be rectified through replacement habitat naturally provided at other locations on the river at lower flows. The impact assessment only considered loss of habitats utilized under natural flow conditions. The channel structure of the middle Susitna River results in comparable habitat being created at different locations when discharge changes. This is supported by studies in the literature (Mosley 1982) and by preliminary results of 1984 studies of the Susitna River. However, these studies do not suggest total replacement at flows as low as 6,000 cfs. Remaining impacts to rearing habitat that could not be rectified by flow control would be compensated by construction and operation of a propagation facility.

(c) Case E-III (***)

(i) Management Objectives (***)

Case E-III flow constraints are designed to maximize chinook salmon production (rearing) in existing habitats. Chinook do not use mainstem influenced habitats for spawning so maximization in this case does not include consideration of limitations to spawning habitat.

(ii) Flow Constraints (***)

Case E-III flow constraints are presented in Table E.2.3.8 and Figure E.2.3.5. Minimum summer flow constraints of 14,000 cfs are intended to maximize the quantity of mainstem influenced rearing habitat at sites utilized under natural conditions. These flows would also provide migrant adults with upstream passage and tributary access. Maximum summer constraints are not necessary. However, it is assumed the project would store the maximum possible quantity of water during the summer resulting in greater flow stability. Winter flow constraints provide adequate rearing habitat during the ice covered season.

(iii) Project Flows (***)

Case E-III flows during the October to April period average 7,900 cfs at Gold Creek. The Case E-III winter flows are slightly less than the 8,000 cfs average for Case E-I because of the high minimum flow requirements for Case E-III during the month of May.

From May to September the average flow for Case E-III is 12,400 cfs. Project flows are at the minimum flow requirement during the period 75 percent of the time.

(iv) Impact Assessment (***)

No loss of chinook and chum rearing habitat is expected with Case E-III flows. The flow constraints and increased stability under project operation should improve rearing habitat quality and quantity compared to natural conditions.

Case E-III flows would affect access conditions into side sloughs for chum and sockeye spawning. The

14,000 cfs flows during August would provide some improvement over the 12,000 cfs flows in Case E-II. However, some additional loss is anticipated due to elimination of spiking flows. Slough 11 would be the most affected of the major side slough spawning sites. Approximately 66 percent of the slough spawning sockeye and 17 percent of the slough spawning chum utilize Slough 11 (1981-83 average). Restricted access conditions would not completely eliminate utilization of sloughs for spawning and, as noted for Case E-II, the flow criteria used in this analysis is conservative (see APA 1984c Comment No. AQR072). However, for the purpose of this evaluation, a loss of 25 percent of existing slough spawning habitat for chum and 70 percent slough spawning habitat for sockeye will be assumed.

(v) Mitigation (***)

Potential impacts to rearing habitats, tributary access and upstream passage of adults will be avoided or minimized through timing and control of flow releases. Impacts to side-slough access will be minimized by flow release.

The remaining impacts to side-slough access for spawning will be rectified by structural modification at critical access reaches to provide successful access.

(d) Case E-IV (***)

(i) Management Objectives (***)

Case E-IV flow constraints is designed to maintain 75 percent of the existing middle river side channel rearing habitat presently utilized by juvenile chinook salmon. The constraints do not account for chum salmon spawning habitat loss which are to be mitigated through structural modification of the habitat areas used for spawning.

(ii) Flow Constraints (***)

The minimum summer flow constraint of 9,000 cfs (Table E.2.3.9 and Figure E.2.3.6) is intended to maintain approximately 75 percent of the existing middle river side channel rearing habitat utilized by juvenile chinook salmon under natural flow conditions. The maximum summer flow constraint of

35,000 cfs is intended to produce moderate flow stability and prevent severe dislocation of rearing juveniles from preferred sites.

Winter constraints are designed to maintain flow stability within reasonable boundaries. The 2,000 cfs minimum is within the range of winter flows encountered under natural conditions, while the 16,000 cfs maximum would provide for flow stability and reduce the appearance and disappearance of transient rearing sites which occurs under natural conditions.

(iii) Project Flows (***)

Case E-IV minimum summer flow requirements would result in an average flow of 9,500 cfs at Gold Creek during the October to April period. This is only slightly lower than the winter average flow for Case P-1 (9,700 cfs) [Case P-1 is a set of flow constraints designed to maximize power and energy benefits of the project (HE 1984h)]. During higher flow years, when the reservoir is filled prior to October, winter flows would be the same as for Case P-1. In lower flow years, flow at Gold Creek would be about 1,000 cfs less than for Case P-1. Minimum flows in these years would be about 5,000 cfs in October, 6,000 cfs in March, 3,000 cfs in November and about 5,000 cfs in April.

May flows for Case E-IV would average 9,000 cfs. These flows are lower than for Case P-1 in order to store as much water as possible prior to the 9,000 cfs minimum requirement which takes effect in June. June, July, and August flows are at the 9,000 cfs minimum requirement more than 50 percent of the time. Average flow for these months is 10,100 cfs. In September, project flows would be the same as the minimum flow requirement 35 percent of the time.

(iv) Impact Assessment (***)

Case E-IV would reduce the availability of existing chinook salmon side channel rearing habitat by approximately 25 percent in the middle river. Rearing habitat now used by chum salmon juveniles would be reduced in side-sloughs. The major use of side slough habitat by juvenile chum salmon occurs during May and June and habitat reduction would result from loss of over-topping flows during this period. Loss of habitat could be as great as 50 percent at the sites utilized under natural flow conditions (ADF&G 1984g). No rearing habitat loss is expected in the lower river due to the dominant effects of the Chulitna and Talkeetna rivers.

Flow constraints during August and September would significantly restrict spawning access to sloughs by adult chum and sockeye salmon. Some successful access would still occur but with significant difficulty. A worst case assumption of 100 percent loss of access is assumed for this evaluation.

(v) Mitigation (***)

Impacts on chinook and chum salmon rearing habitats would be minimized through timing and control of flow releases. A minimum summer flow constraint of 9,000 cfs would maintain a majority of the rearing habitat utilized under natural flow conditions. Increased flow stability under project operation would have an augmenting effect on over-all quality of the rearing habitats, especially for side channel sites utilized by chinook juveniles. Remaining loss of existing rearing habitat would be rectified by providing replacement habitat through control of flow releases. Flow reductions during the summer would reduce the quantity of and access to individual rearing sites utilized under natural flow conditions. However, the same flow reduction would result in new sites with the appropriate physical conditions for chinook and chum salmon rearing. This result is not unusual for rivers like the Susitna with moderately complex channel configurations. The availability of rearing habitat for chum and chinook salmon is actually expected to increase over natural conditions with operation under Case E-IV (see Section 3.4.1(h) for further discussion of Case E-VI which is similar to Case E-IV).

Loss of access to side sloughs would be rectified by structural modification of critical access reaches.

(e) Case E-IVa (***)

(i) Management Objective (***)

Case E-IVa establishes flow constraints which would maintain 75 percent of the middle river side-channel rearing habitat presently utilized by chinook salmon juveniles and provide some access to the most productive side slough spawning sites for adult chum and sockeye salmon.

(ii) Flow Constraints (***)

Case E-IVa flow constraints are presented in Table E.2.3.10 and Figure E.2.3.7. These constraints are identical to those discussed for Case E-IV above (Section 3.4.1.(d) except for the inclusion of spiking flows in water weeks 38 and 48 through 50. The purpose of the spiking flows is the same as discussed for Cases E-I and E-II (Sections 3.4.1.(a) and 3.4.1.(b). The 30,000 cfs spike in week 38 is to over-top slough berms to flush out accumulated sediments and debris. This flow would not be necessary each year of operation but would be provided at least once every three years. The spiking flows during weeks 48 through 50 are to provide access to the most productive side slough spawning sites.

(iii) Project Flows (***)

Case E-IVa flows would be similar to those of case E-IV except that during winter operation, flows would be reduced from Case E-IV during lower flow years to account for the reduced storage because of the required summer spiking flows.

Flow during June, July and August would be the same as the minimum requirements more than 55 percent of the time. Releases from the outlet works would be required to augment the powerhouse discharge during those periods when spiking is required.

(iv) Impact Assessment (***)

Impacts on rearing habitats would be the same as discussed for Case E-IV except for some momentary disturbance and dislocation caused by the spiking flows. The spiking flows would not cause a measurable effect since their magnitudes are well within the range of natural flood events and the rate of change in discharge would be limited.

Impacts on access to side slough spawning sites would be similar to Case E-II. Case E-IVa provides more spiking flows for access than E-II but the base flow would be 3-4,000 cfs less. Therefore, the expected net loss would be similar to Case E-II (i.e., a 25 percent loss of slough spawning habitat for chum and sockeye salmon).

(v) Mitigation (***)

Mitigation measures for loss of rearing habitat would be the same as discussed for Case E-IV.

Measures to rectify loss of access to slough spawning sites would be similar to those discussed for Case E-II (Section 3.4.1(b)) Some additional alteration would be necessary for Case E-IVa due to the lower base flows.

(f) Case E-IVb (***)

(i) Management Objective (***)

Case E-IVb flow constraints are designed to maintain 75 percent of the side channel rearing habitat utilized by chinook salmon juveniles under natural flow conditions and provide for some limited spawning access to the most productive side sloughs by chum salmon adults.

(ii) Flow Constraints (***)

Flow constraints for Case E-IVb (Table E.2.3.11 and Figure E.2.3.8) are identical to those discussed for Cases E-IV (Section 3.4.1(d) and E-IVa (Section 3.4.1(e)) except for the magnitude of spiking flows. Spiking flows for Case E-IVb are of the same duration as those in E-IVa, but peak at lower discharges (cfs).

(iii) Project Flows (***)

Case E-IVb has flow requirements similar to Case E-IVa except that during periods when spiking flows are provided, the magnitude of the spikes are reduced for Case E-IVb. Therefore the average winter flows with Case E-IVb would be greater than for Case E-IVa and less than for Case E-IV. However, because of the similariteis between Cases E-IV and E-IVa, winter flows with Case E-IVb operation would be the same as Case E-IV and E-IVa most of the time.

Summer flows would be almost the same as those of Case E-IVa most of the time and only slightly different at other times.

(iv) Impact Assessment (***)

Impacts on rearing habitats would be similar to those discussed for cases E-IV and E-IVa above.

Impacts on access to slough spawning sites would be greater with this case than with Cases E-II or E-IVa. Severe access problems would occur at sloughs IA and 11. Complete restriction at these sloughs would eliminate approximately 32 percent and 80 percent of the utilization of side sloughs for spawning by chum and sockeye salmon, respectively (ADF&G 1984f). Flows that range from the 9,000 cfs base flow to the 14,000 cfs spiking flows would result in a loss of access to aproximately 40 percent of the slough spawning areas (weighted for utilization: see APA 1984c Comment No. AQRO72). A worst case impact of a 50 percent loss of slough spawning habitat for chum and a 100 percent loss of slough spawning habitat for sockeye salmon is assumed for this evaluation.

(v) Mitigation (***)

Mitigation measures for loss of rearing habitat would be the same as discussed for Case E-IV.

Loss of access to sloughs for spawning chum and sockeye salmon would be rectified by structural modidification of the slough mouths and critical access reaches within the sloughs.

(g) Case E-V (***)

(i) Management Objective (***)

Case E-V flow constraints are designed to maintain 75 percent of the existing chum salmon slough spawning habitat and 75 percent of the existing chinook salmon side channel rearing habitat.

(ii) Flow Constraints (***)

Case E-V flow constraints were derived by combining Cases E-II and E-IV. The basic guideline used was to chose the maximum and minimum for each week from Cases E-II and E-IV that were most restrictive on project operation. Flows to maintain chinook rearing habitat were chosen for most of the year (Table E.2.3.12 and Figure E.2.3.9). Flows for chum spawning habitat were most important during weeks 36-38 and 44-49.

(iii) Project Flows (***)

Case E-V would result in an average flow of 8,600 cfs at Gold Creek during the October to April period. Power house discharge would increase from October to December and then decrease from December to April. December discharge would be as high as 12,000 cfs but would average 10,100 cfs. minimum flows would approach 5,000 cfs during October and March in low flow years. In these low flow years, April flows could be as low as 3,200 cfs.

During the May to September period, the flow at Gold Creek would be the same as the minimum flow requirements 55 percent of the time and, of course, higher, the remainder of the time. The average flow during this period would be 11,400 cfs.

(iv) Impact Assessment (***)

Loss of spawning habitat with Case E-V flow constraints would be similar to losses under Case E-II. Therefore, a 25 percent reduction of side slough spawning habitat for chum and sockeye salmon will be used for this evaluation.

The expected impacts on existing rearing habitat would be similar to those discussed for E-IV and E-IVa above. Case E-V flows would result in a 25 percent loss of existing chinook salmon side channel rearing habitat.

(v) Mitigation (***)

Mitigation measures for impacts on slough spawning habitat are discussed for Case E-II (Section 3.4.1(b).

Mitigation measures for loss of existing rearing habitat are discussed for Case E-IV (Section 3.4.1(d).

(h) Case E-VI (***)

Case E-VI is the Applicant's selected flow case and a more detailed description is warranted. Basically Case E-VI is a variant of E-IV with a flexible summer minimum flow constraint to achieve more economic project operation during low flow years (one in ten year low flows).

Case E-VI impact would be similar to Case E-IV and proposed mitigation measures would result in no net loss of productivity. Naturally reproducing populations would be maintained through steps to minimize and rectify project induced losses. A general improvement in the quantity and quality of rearing habitat is expected over natural conditions. The evaluation of effects of project operation on water use and quality in this Chapter and throughout Exhibit E is based on the Case E-VI flow requirements. Sensitivity analyses are provided for the Case E-I flow requirements. The effects of other flow requirements on water use and quality would be between these two bounds.

(i) Management Objective (***)

Case E-VI flow constraints are designed to maintain 75 percent of the existing chinook salmon side channel rearing habitat in all years except low flow years (defined as years with expected summer discharge less than or equal to the one in ten year low flow occurrence). Minimum summer flows are reduced to a secondary but set level during low flow years to achieve necessary but limited flexibility for project operation.

Establishment of environmental flow constraints based on the requirements of juvenile chinook salmon is a reasonable approach. Chinook salmon is one of the species of major importance to commercial and non-commercial fisheries in south-central Alaska (APA 1983d, p. E-3-1 through E-3-15). Juvenile chinook utilize habitats within or closely associated to the mainstem river for rearing during the entire year (ADF&G 1984g). The high human use value and sensitivity to potential project impacts qualifies chinook salmon as an evaluation species. Chum salmon spawning in side sloughs has been identified as the combination of species and habitat that would be most significantly affected by project operation (Woodward - Clyde 1984). However, loss of chinook mainstem rearing habitat would have to be compensated by construction and operation of artificial rearing facilities (e.g. a traditional release-return hatchery). Compensation is the least desirable option under the mitigation policies applied to the

Susitna Project (APA 1983d, pp. E-3-3 through E-3-6).

(ii) Flow Constraints (***)

Case E-VI flow constraints are shown in Table E.2.3.13 and Figure E.2.3.10. The flow constraints can be separated into three major divisions; winter flows, summer flows and transitional flows.

Maximum flows are the most important winter constraints. Normal project operation would produce the greatest discharges during the winter months (November-March). The winter maximum is intended to establish a boundary near the upper range of operational flows that would result in flow stability and provide a reasonable level of protection to over-wintering habitat. Side sloughs are especially important in this context since chinook juveniles utilize this habitat for over-wintering. The 16,000 cfs maximum flow would prevent overtopping of all the major sloughs prior to freeze-up and stabilize habitat availability during ice covered periods.

The winter minimum flow is established to prevent dewatering of rearing habitats. The 2,000 cfs minimum is chosen based on natural flows and represents a high mean natural winter flow.

Flow constraints during the winter to summer transition period (May 6 to June 2) are designed to maintain rearing habitats and provide greater flow stability. Chinook juveniles are accumulating the major portion of their freshwater growth during this period and they utilize side-channel sites that are directly affected by mainstem discharge (ADF&G 1984g). A 9,000 cfs minimum flow would maintain 75 percent of the existing habitat quantity at sites presently utilized by chinook and increased flow stability would improve habitat quality over natural conditions.

(iii) Project Flows (***)

Project operation flows for Cases E-IV and E-VI would be the same for all but the lowest flow years. Only in one year in ten would there be a significant difference. Because of this occurrence, October to April flows would average only slightly more than for Case E-IV.

May to September flows would be the same as Case E-IV, except during the one in ten year low flow when the minimum flow would be 8,000 cfs during June, July, and August. Actual flow would be the same as the minimum flow during June, July and August approximately 50 percent of the time.

(iv) Impact Assessment (***)

Case E-VI is designed to reduce impacts of project operation as compared to flow cases designed specifically for power generation However, Case E-VI does not mitigate all impacts by flow releases alone so further impact assessment and mitigation planning is necessary. This section will address significant potential impacts to each life stage of the five Pacific salmon species for habitat utilized with natural conditions. The impacts do not accout for the acquisition of other habitat areas made available as a result of the stabilized flow regime. These improvements are discussed under mitigation and show that the "no net loss" goal is achieved.

- Juvenile Rearing

  Chinook salmon juveniles rear in both clear and turbid water habitats. Substantial rearing occurs in tributaries and side channels (ADF&G 1984g). Densities generally decrease in tributaries and increase in side channel habitats through the summer. Densities in side sloughs are relatively low during the summer but increase markedly during September and October. Tributary habitat would not be impacted by altered mainstem flows. Side channel habitat would be most directly affected. Case E-VI flows would reduce the quantity of available rearing habitat at side channel sites presently used by chinook by approximately 25 percent.

  Chum salmon rearing is essentially limited to tributaries and side sloughs during the early summer (May-early June). Highest densities during late June and July occur in upland sloughs and side channels. Essentially all the juvenile chum have moved downstream, out of the middle river, by the end of July. Case E-VI flows would not impact rearing habitat in tributaries and upland sloughs. Chum salmon use of side channel sites is mostly for short-term holding and rearing during downstream migration. Case E-VI flows would decrease the availabilty of side channel sites presently used by chum by approximately the same magnitude estimated for chinook salmon. A 25 percent reduction will be assumed for this assessment. There would also be a loss of chum rearing habitat in side sloughs. Most of the loss would be due to a reduction or elimination of overtopped conditions in side sloughs during May and June under project operation. Loss of habitat could be as great as 50 percent at the sites utilized under natural flow conditions.

Sockeye juveniles rear predominantly in natal side sloughs during the early summer and then move mostly to upland sloughs by July. With project flows are not expected to affect upland slough habitats. The responses of weighted useable area for sockeye and chum are similar for side-slough rearing habitat. Therefore, loss of sockeye rearing habitat would be approximately 50 percent.

Coho salmon rear mostly in tributaries and upland sloughs. Impacts due to project operation are not expected in these habitats.

Pink salmon juveniles move rapidly from their natal tributaries to Cook Inlet. The mainstem and associated habitats are apparently used only for migration corridors so project flows would not impact pink salmon rearing.

- Downstream Migration

Downstream movement of salmon juveniles occurs throughout the summer (ADF&G 1984g). Chum, pink and age 1+ chinook salmon migrate toward Cook Inlet during the early summer and are out of the middle river reach by July. Sockeye, coho and age 0+ chinook move gradually downstream throughout the summer. Most of this movement is associated with rearing and gradual relocation into available rearing and overwintering habitat. Some of this downstream movement is influenced by discharge (ADF&G 1984g). Increasing discharge during flood flows can act as a stimulus to initiate seaward migration, especially during the early summer. Flood flows later in the summer, when juveniles are rearing or seeking alternative habitat sites, can cause dislocation from preferred rearing areas. Project operation will reduce the frequency, duration and amplitude of flood events in the middle river. This impact is not expected to affect seaward migration in a significant way. Factors other than flow, such as increasing day length, water temperature and physiological conditions, also trigger migration. Increased tributary flow and local run-off would also serve to stimulate migration.

- Upstream migration

  Adult salmon migrate up the Susitna River toward spawning areas throughout the summer. The 9,000 cfs summer minimum flows will provide sufficient conditions for upstream passage of adults.

- Spawning

  Salmon that spawn in the middle river basin are only a small proportion (less than 15 percent) of the total in the Susitna River System (ADF&G 1984f). Most of the salmon that spawn in the middle river basin use tributary habitats outside the influence of mainstem discharge. The spawning habitat most sensitive to changes in mainstem discharge are the side sloughs used by chum and sockeye salmon. Mainstem flows influence spawning success in side sloughs through affects on access past critical reaches, total useable areas within the slough and groundwater discharge. Access into the major spawning sloughs (8A, 9, 9A, 11 and 21) would be restricted under Case E-VI flows. An analysis using values of side sloughs weighted by observed spawning use provides an estimated loss of approximately 50 percent of side-slough spawning due to access restriction at 9,000 cfs (APA 1984a, Comment No. AQR072). However, considering the restricted access together with reduced area and flow within the sloughs, a worst case assumption of 100 percent loss of side-slough spawning habitat without mitigation is assumed for this evaluation.

(v) Mitigation (***)

This section will present suggested actions to mitigate potential losses due to project operation. Project operation in the absence of environmental constraints is the appropriate starting point to discuss mitigation so flow Case P-1 will be used as a standard.

Project impacts would be minimized through timing and control of flow releases by adopting the environmental flow requirements in Case E-VI. Case P-1 flows would fall below 9,000 cfs during June through August in approximately 75 percent of the years of operation. Mean monthly summer flows would be as low as 4,500 cfs in some years. This would result in the loss of most of the mainstem and side channel rearing habitat presently used by chinook and chum salmon juveniles. Case E-VI flows would minimize this impact by maintaining 75 percent of the existing side channel rearing habitat. The residual 25 percent loss of side channel habitat and the loss of chum and sockeye rearing habitat in side sloughs would be rectified by habitat replacement at the more stable, lower flows (relative to natural flows) under Case E-VI. The original rationale for design of Case E-VI and the impact assessment discussed above are based on impacts to habitat sites that are available and used under natural flow conditions. The estimates of impact relied on data and information collected at habitat sites presently utilized. The analyses and estimates did not consider the addition of new habitat sites with appropriate characteristics and qualities that would become available at lower, more stable flows. This is more fully explained in Exhibit E, Chapter 3.

Chinook salmon prefer areas of moderate depth and velocity for rearing in side channel areas. The quantity of habitat with these characteristics depends largely on channel complexity. There is relatively little of this rearing habitat available at bank full flows. The habitat quantity increases as flows drop and the flow channels become more complex. This increase will continue until a maximum is reached and habitat quantity would than decrease as discharge decreases to a level sufficiently low to restrict flow to a single thalweg channel. Comparison of channel complexity at various flows gives some indication of how habitat quantities will be impacted by project operation. Channel complexity at 9-12,000 cfs (approximate summer operational flows) is much greater than at 23,000 cfs (approximate mean summer natural flows) (see Exhibit E, Chapter 2, Section 2.2 for a discussion of natural flows). The quantity of side channel and mainstem rearing habitat for both chinook and chum salmon is expected to increase over natural conditions during project operation under Case E-VI flow requirements. Increased flow stability and decreased turbidity is expected to improve habitat quality and augment rearing potential in the middle river.

Case E-VI minimum flow constraints during late August and early September will minimize impacts of the project on chum and sockeye spawning due to operation through control of flow releases (compared to Case P-1). However, the residual impacts would be considerable and further mitigation would be necessary. Loss of side slough habitat for chum and sockeye salmon spawning would be rectified by structural modification of existing sloughs. Details of these activities are given in a report by the Applicant (Woodward-Clyde 1984) and are not repeated here.

The results of these mitigation measures are compatible with mitigation policies and objectives presented in the original License Application (APA 1983d, p. E-3-147). Habitat quantity and quality sufficient to maintain naturally reproducing populations is provided. All significant impacts would be minimized or rectified.

3.5 - Comparison of Alternative Flow Regimes (***)

The alternative flow regimes were compared, based on their performance in meeting economic and environmental objectives. The economic objective is to minimize the cost of producing energy to meet projected Railbelt system energy demands. The environmental objective (as explained in Section 3.3.2 (a) and below) is to provide sufficient habitat to maintain naturally producing populations, so called no-net-loss of habitat. The environmental objective may be achieved by providing the river flows necessary to meet the objective or by a combination of flows and other compensation such as rearing facilities. Environmental flow requirements affect Susitna energy production and may require the construction and operation of other generating facilities to meet Railbelt system energy demand. Therefore, the costs resulting from the implementation of environmental flow requirements are included in the economic evaluation of the costs to meet Railbelt energy demand. The economic and environmental objectives are combined in a single evaluation criteria which is the total cost of providing the Railbelt energy demand, including the costs of the Susitna Hydroelectric Project, other generation facilities, and the costs of mitigation measures.

3.5.1 - Economic Comparison (***)

The analysis of the economic benefits of the project is based on the objective of providing the energy required to meet the projected Railbelt energy demand. This objective is achieved by the construction and operation of the Susitna Hydroelectric Project and such other generation facilities as may be required to provide energy not provided by Susitna. This analysis is explained in more detail in Exhibit B. In addition to the Susitna cost, the cost of meeting the Railbelt (system) energy demand is a function of the environmental flow requirements since these may restrict energy generation from Susitna and require additional other generation. Economic analyses of selected flow cases, ranging from P-1 to E-VI, were performed to determine the present worth of the long term (1996-2054) production costs (costs to meet Railbelt energy demand) of each alternative. The analyses were made using the OGP model (See Exhibit D, Section 2.8). The monthly average and firm energy corresponding to each flow case were obtained from the reservoir operation program. Railbelt system expansion for the period 1996 through 2025 was analyzed with Watana Stage I coming on line in 1999, Devil Canyon Stage II in 2005 and Watana Stage III in 2012. The long-term system costs for 2026 through 2054 were estimated from the 2025 annual costs, with adjustments for fuel escalation for the 29-year period. A more detailed discussion of the economic analysis method is provided in Exhibit D, Section 2.10.

The results of the analyses are illustrated in Table E.2.3.14. They indicate that as the energy benefits of the project are increased, the cost of the associated mitigation measures is also increased. When mitigation costs are incorporated as part of the system costs, Case E-VI has the lowest cumulative present worth of net system costs.

Case E-IV ranked second in lowest cost, some $7 million greater than Case E-VI. Cases P-1 and A ranked next with a total present worth of system costs about $13 million to $15 million greater than E-VI. Case C (the proposed flow requirements presented in the July 1983 License Application), E-V, and E-I had present worth of system costs increasingly greater than Case E-VI.

The total Railbelt installed generating capacity must be increased as minimum flow requirements in the months of May through September are increased. This occurs because of the resulting decrease in available Susitna winter energy during low flow years, and the consequent requirement for additional thermal capacity to meet peak demand. Increasing installed capacity results in costs for construction of the facilities and increased costs to meet Railbelt energy demands. The installed capacity of the Susitna Project is the same for all cases, but the dependable capacity is reduced when higher summer flow requirements decrease the flow available for peak winter energy demands.

The OGP program was used to evaluate system production costs and develop the relative economic ranking of the flow cases. OGP is a long-term expansion planning model which uses daily load duration curves for system dispatch. A program using chronological hourly system dispatch may yield cost differences among the flow cases that are greater than shown in Table E.2.3.14.

3.5.2 - Environmental Comparison (***)

(a) Aquatic and Fisheries (***)

The environmental cases can be separated into three basic groups. Group 1 is designed to maintain rearing habitats and includes E-III, E-IV, and E-VI. Group 2 is designed to maintain chum spawning in side sloughs and includes only Case E-II. Case E-II is the most similar to Case C since protection of side slough spawning habitat was the primary environmental consideration in both. Group 3 is made up of cases designed to maintain both rearing and side slough spawning habitat. This group includes Cases E-I, E-IVa, E-IVb and E-V.

The two most important potential impacts of project operation are effects on mainstem influenced rearing habitats and spawning habitat in side sloughs. The environmental cases can be compared based on potential impacts and mitigation measures regarding these two categories.

The objective of mitigation planning for fisheries impacts of the proposed project is to provide sufficient habitat to maintain naturally producing populations wherever compatible with project objectives. Compensation through construction and operation of propagation facilities is a least desirable action. Group 2 flow cases (E-II, C) would require compensation for lost rearing habitat. Compensation within the Susitna Basin would likely require a propagation facility designed to replace lost chinook salmon production.

The major mitigation action (other than flow control) for Group 1 (E-III, E-IV, E-VI) and Group 3 (E-I, E-IVa, E-IVb, E-V) would involve rectifying for impacts on side-slough spawning habitat. The extent of necessary structural modification varies among the individual cases but the basic impacts and mitigation methods are the same. Group 3 flow cases would generally require less structural modification than for Group 1.

Mitigation actions described for all the environmental cases would result in no net loss of production due to project operation. However, Group 2 flow cases are the least desirable since they require actions at greatest variance from the mitigation objective. Group 3 cases are the most desirable based only on environmental consideration of potential impacts and the level of required mitigation actions.

Representative cases were chosen from each group for evaluation and comparisons based on power and economic objectives of the project. Cases E-IV and E-VI were chosen to represent Group 1, Case C to represent Group 2 and E-I and E-V to represent Group 3.

(b) Other Instream Flow Considerations (**)

(i) Downstream Water Rights (*)

Water rights in the Susitna basin are minimal (see Exhibit E, Chapter 2 Section 2.6.1). Therefore, since all flow scenarios provided more than enough flow to meet downsteam water rights, it was not a factor in minimum flow selection.

(ii) Navigation and Transportation (**)

Navigation and transportation use of the river was not considered a factor among the environmental flow requirements considered. Cases E-I, E-II, E-III, E-IV, E-V and E-VI all have minimum flow requirements exceeding 6,000 cfs at Gold Creek for the late May - late September period. As discussed in Exhibit E, Chapter 2, Section 2.6.3, this is considered adequate to ensure boating use of the river from the Talkeetna to Devil Canyon reach. Navigation use downstream of Talkeetna and in the Alexander Slough area are greatly influenced by flows from the Chulitna, Talkeetna and Yentna Rivers and the project flow regime would have less influence on navigation in these areas. The frequency of navigation difficulties in these areas would be similar to natural conditions with all the flow requirements cases considered.

(iii) Recreation (***)

Recreation on the Susitna River is closely associated with navigation and transportation and the fishery resource. Since the Susitna River below Devil Canyon will be navigable during the summer months at all minimum flow scenarios, this aspect of recreation was not a factor in the flow selection process. However, from a fishery perspective, if a fishery habitat is lost, this could reduce the recreational potential of the fishery. For flows equal to or greater than Case E-VI flows, the fishery impact can be mitigated. Hence, Case E-VI or greater flows should be selected as the minimum operation flow based on recreational considerations.

(iv) Riparian Vegetation and Wildlife Habitat (*)

Riparian vegetation is affected by one or more of the following: floods, freezeup and spring ice jams. Minimum flow selection for the cases considered is unrelated to any of these factors. Hence, riparian vegetation effects are not considered in minimum project flow selection.

Riparian vegetation is likely affected by the freezeup process, ice jams, and spring floods in the Devil Canyon to Talkeetna reach (Section 2.6.5 in Chapter 2 of Exhibit E). In the Talkeetna to Yentna and Yentna to Cook Inlet reaches, spring and summer flooding likely have the major impact on riparian vegetation. Hence, since spring floods in the Susitna River will be reduced from Watana to Cook Inlet (Section 4.1.3 in Chapter 2 of Exhibit E), it may be desirable to maintain riparian vegetation by simulating spring floods for a short period of time.

However, the spring runoff storage is a key element of the project. Large releases for even a few days would have severe economic impact on the project. Hence, no minimum flood discharges were considered.

If summer floods occur and have an effect on riparian vegetation, there would essentially be no difference between the flow cases. This is because minimum flows would not govern if the reservoir is full, inflow will be set equal to outflow up to the capacity of the release facilities.

(v) Water Quality (*)

The natural and with-project downstream summer temperatures will be similar for all cases although the lower discharges would exhibit a faster temperature response to climatic changes.

The waste assimilative capacity for all cases will be adequate at a flow of 6,000 cfs. All other water quality parameters would be similar for all flow scenarios.

(vi) Freshwater Recruitment to Cook Inlet (*)

The change in salinity in Cook Inlet will essentially be the same for all flow scenarios although higher minimum flows would cause a salinity pattern slightly closer to natural conditions. This was not considered significant in the flow selection process.

3.5.3 - Selection of Operational Instream Flow Requirements (***)

Cases E-VI and E-IV provide benchmarks to which the economics of the various flow cases can be compared. These cases yield the lowest present worth of system costs, including mitigation costs. While Cases P-1 and A are not substantially higher, it is the Applicant's policy to avoid the use of propagation facilities if habitat for naturally reproducing populations can be maintained.

As Table E.2.3.14 shows, Cases E-I and E-V have high cost penalties. The additional fishery benefits from Case E-I and E-V flow requirements do not warrant the loss of energy benefits. The same management objectives can be obtained through effective mitigation techniques at a much lower cost. Case C has a management objective to protect sloughs considered to be traditional salmon spawning areas. However, Case C does not adequately consider other management objectives which have been identified through ongoing studies. For example, it does not include flow constraints for juvenile rearing habitat.

Cases E-VI and E-IV are judged to be the superior flow cases considered. Case E-VI is selected as the preferred case because it meets the economic and environmental objectives and has the lowest cost.

3.6 - Other Constraints on Project Operation (***)

In addition to the constraints on minimum and maximum weekly flows, other considerations are required to assure the stability of flows within a week and from week to week; to provide for the safe operation of the project during floods; to provide for contingencies in case another part of the generating system is temporarily out of service; and to provide constraints on flows during filling of the three stages of the project.

3.6.1 - Flow Stability Criteria (***)

Flow stability criteria are designed to provide protection to the instream flow uses of the river in addition to that provided by weekly average minimum and maximum flow constraints. The flow stability constraints are indexed to flows from the downstream project (i.e. to Watana discharge when Watana is operating alone, and to Devil Canyon discharge when Devil Canyon is operating with Watana).

Indexing flow stability criteria to powerhouse flows rather than Gold Creek flows is necessary because of:

- The variability in flow from the intervening area between the powerhouses and Gold Creek, and
- The time required for changes in powerhouse discharge to be reflected in Gold Creek discharges.

As explained further below, the discharges from Watana in Stage I and Devil Canyon in Stages II and III will be allowed to fluctuate between 90 percent and 110 percent of the weekly average flow. This limitation was adopted:

- To avoid large water level fluctuations which may be detrimental to fish,
- To give the project some flexibility to provide reserve energy capacity to react to variations in system energy demand,

- To account for possible inaccuracies in the measurement of discharge which may be on the order of five to ten percent, and

- To account for variations in the flow from the intervening areas between the project sites, Gold Creek and fishery habitat located between Gold Creek and Talkeetna.

Stage fluctuations and variations in habitat surface area resulting from fluctuations in powerhouse discharge are described in Exhibit E, Chapter 2, Section 4.1.3(a).

(a) Watana Only Operation (***)

Watana operation will be guided by two sets of criteria. The first set will guide the long-term operation by providing weekly flows for power generation. The second will guide short-term project operation by providing hourly flows for power generation.

Long-term operation uses an operating guide to seasonally adjust flow for power generation. The operating guide assesses the amount of water available in the reservoir, the current energy demand, the season of the year and the previous week's energy generation to determine the release for power for the coming week. The development of the operating guides is explained in Exhibit B, Section 3.2.

The operating guides provide power releases as a function of the "expected" discharge for energy. The expected discharges for each week of the year are the discharges which would provide the required Susitna energies, while minimizing the cost of other facilities to meet Railbelt energy demand. To meet this goal Susitna energy production is scheduled in a manner to keep energy generation from thermal plants in the Railbelt constant at one value throughout the winter (October to mid-May) and constant at a different value throughout summer (mid-May through September). This minimizes the cost of building and operating other thermal generating units.

The relationship between the expected discharges and time is a smooth curve with high discharges in winter, low discharges in summer, and gradual changes at transitions. In the simulations, the weekly discharge during operation was set at 63, 80, 100, 120, or 140 percent of the "expected" discharge. The decision on which multiple of expected discharge to use is a function of reservoir storage, time of year, and previous week's discharge. The variation of discharge between two consecutive weeks is limited to 20 percent. However, the limitation can be violated if the discharge must be increased to maintain the Case E-VI minimum flow requirements. Thus, the weekly flow requirement would be met even when the intervening flow between Watana and Gold Creek is very low.

With a given weekly average flow obtained from the long-term operating guide, the short-term operation will be fit to the system load demand within a week given the following environmental constraints:

- The largest allowable discharge at Watana during any given week will be 110 percent of the weekly average discharge.
- The smallest allowable discharge will be 90 percent of the weekly average discharge.
- Watana discharge will be increased above 110 percent of the weekly Watana average in order to maintain the minimum weekly average flow requirements if intervening flows between Watana and Gold Creek decrease during the week and the discharge at Gold Creek is below the minimum weekly flow constraint.

If the average flow for a given week approximates or equals the minimum weekly flow requirements, there may be times during the week when the Gold Creek discharge is less than the minimum weekly flow requirements. This deviation will not exceed 800 cfs.

The following constraints on the hourly rate of change will also apply:

- The maximum allowable rate of change of discharge at Watana will be 10 percent per hour of the weekly average Watana discharge under increasing discharge conditions and 500 cfs per hour when discharge is being reduced.
- The same rates of change of discharge will apply and will be based on the weekly average discharge for the upcoming week when energy production and weekly average flows are being adjusted from one week to the next. The discharge change will occur during the early morning hours of a Sunday or a Monday. The change will be separate from, and in addition to, the 10 percent deviation from the average permitted during the remainder of the week.

(b) Watana and Devil Canyon Operation (***)

In discussion of Susitna Project operation, two time frames are considered. Short-term operation refers to hourly or daily flow variations. Long-term operation refers to weekly or montly flow variations.

In long-term operation, Watana will be used for seasonal regulation of flow whereas Devil Canyon will be kept as full as possible. The Devil Canyon water level will not be reduced below el. 1,455 unless the release from Watana for power is not enough to satisfy the minimum flow requirement at Gold Creek. Once the Watana release for power is greater than needed to satisfy downstream requirements, Devil Canyon will be refilled immediately.

In short-term operation, hourly discharges from Watana can be varied without restriction because Watana will discharge directly into the Devil Canyon Reservoir. Devil Canyon will act as a re-regulating reservoir to stabilize downstream flows.

Short-term criteria at Devil Canyon in Stages II and III will be similar to those for Watana Stage I as follows:

- o The largest allowable discharge at Devil Canyon during any given week will be 110 percent of the weekly average Devil Canyon discharge.
- o The smallest allowable discharge will be 90 percent of the average for the week.
- o The Devil Canyon discharge will be increased above the 110 percent weekly average flow fluctuation limit in order to maintain the minimum weekly average flow requirements at Gold Creek if intervening flows between Devil Canyon and Gold Creek decrease during the week and the Gold Creek discharge is below the minimum weekly flow constraint.

During a week when the Gold Creek weekly average flow is being maintained at the minimum flow requirement, there may be times when the Gold Creek discharge is less than the minimum weekly flow requirement. This deviation will not exceed 900 cfs.

The following constraint on hourly rate of change will also apply:

- o The maximum rate of change of the powerhouse discharge at Devil Canyon will be 350 cfs per hour whether discharge is being increased or decreased. At a discharge of 9,000 cfs at Gold Creek, a 350 cfs change corresponds to a 0.1 foot difference in stage at Gold Creek.

Devil Canyon powerhouse flow changes will generally be in response to changes in daily average or weekly average energy demand, not hourly demand. During the initial years of Devil Canyon operation the Railbelt system energy demand in the summer during years of high natural inflow may be met by Devil Canyon without operating Watana. It is preferable to use the Devil Canyon powerhouse during these periods to avoid outlet works discharges at Devil Canyon and resulting cooler water temperatures (See Exhibit E, Chapter 2, Section 4.2.3(c)(i)). Therefore, flow changes under these conditions may be in response to hourly demand changes.

3.6.2 - Dam Safety Criteria (***)

If the Watana Reservoir level exceeds the normal maximum operating level, dam safety criteria will supersede both weekly flow constraints and flow stability constraints. Environmental considerations are built into the dam safety criteria as discussed herein. Project operation at Watana will be similar for both Watana operating alone and Watana operating with Devil Canyon once the Watana reservoir reaches or exceeds the normal maximum operating level.

(a) Stage I - Watana Only Operation (***)

If the water level in the Watana I reservoir reaches el. 2,000.0 and continues to rise, Watana discharge will be increased by releasing water through the outlet works. Because the intake to the outlet works is approximately 80 feet below the water surface, operation of the outlet works results in reduced downstream water temperatures. In order to provide for as gradual a change in water temperature as possible, the following guidelines will apply:

- Supply as much energy as possible from the Watana powerhouse within the constraints of the system energy demand, other generation and Watana powerhouse capacity.

- Increase the outlet works discharge at the estimated minimum rate required to prevent the water level from exceeding el. 2,000.5. If the inflow to the reservoir is more than 24,000 cfs greater than the powerhouse can discharge, then the release from the outlet works will be 24,000 cfs when the water level reaches el. 2,000.5.

If the outlet works are not releasing water at full capacity and the water level rises above el. 2,000.5, the outlet works will be opened immediately to full capacity. If the full capacity of the outlet works and powerhouse flow are not sufficient to discharge all the inflow the water level will continue to rise.

If the water level exceeds el. 2,000.5 but does not reach el. 2,014.0 then the Watana discharge will remain relatively constant until the water level decreases to el. 2,000.5. If the water level starts to decrease below el. 2,000.5 then the outlet works will be closed in a gradual manner as they were opened. The rate of closure will be that estimated to cause the water level to reach el. 2,000.0 when the outlet works discharge reaches zero. The outlet works will be completely closed before the water level is allowed to decrease below el. 2,000.0.

The outlet works capacity and flood surcharge level have been planned to store and release the 50-year flood without operating the spillway. Thus, there is less than a 1 in 50 chance that in any one year the water level will continue to rise to el. 2,014.0. If the water level reaches el. 2,014.0 and continues to increase, the spillway will be opened. Since spillway operation may increase gas concentrations in the river downstream the spillway will also be opened up as gradually as possible, consistent with providing sufficient freeboard on the dam to meet safety requirements. The powerhouse and outlet works releases will continue as before, and the spillway will be opened at the estimated minimum rate required to prevent the water level from exceeding el. 2,014.3. If the water level reaches el. 2,014.3 and continues to rise, the spillway gates will be opened as much as needed to prevent the water level from increasing any further. As explained in Exhibit F Appendix F3, the spillway has the capacity to pass the 10,000 year flood at a reservoir level of el. 2014.3. Thus, there is less than a one in 10,000 chance in any year that the water level would exceed el. 2,014.3.

If the reservoir water level reaches el. 2,014.3 and the fully opened spillway, outlet works and powerhouse are insufficient to pass the inflow, the water level will increase uncontrolled. The spillway is designed to pass the Probable Maximum Flood (PMF). The water level would reach approximately el. 2,017, eight feet below the dam crest during a PMF. Watana discharge would not be controlled again until the water level decreased to el. 2,014.3. When this occurs, the spillway will be closed gradually in a manner estimated for the water level to reach el. 2,014.0 when the spillway discharge is zero. The spillway gates will be completely closed before the water level is allowed to decrease below el. 2,014.0.

(b) <u>Stage II - Watana and Devil Canyon Operation</u> (***)

Dam safety criteria at Watana with both Watana and Devil Canyon operating will be similar to Watana only operations when the water level in Watana reservoir exceeds el. 2,000.0, especially in the early years of Devil Canyon operation. However, while Watana reservoir is filling in the spring, and before the water level reaches el. 2,000.0, the Devil Canyon powerhouse will be used to generate most of the system energy demand. Watana still must generate a portion of the energy in order to meet peak energy demands. This policy was adopted for the purpose of minimizing downstream temperature effects of using the Devil Canyon outlet works. When the Watana water level reaches el. 2,000.0, it is necessary to switch energy generation from Devil Canyon to Watana in order to pass the 50 year flood through Watana without using the spillway. The change from the Devil Canyon to the Watana powerhouse would be made in a gradual manner, but in no case would the Watana water level be allowed to rise above el. 2,000.5 without the Watana powerhouse supplying available system energy demands and the Watana outlet works releasing at 24,000 cfs. After the system load is transferred from Devil Canyon to Watana the operation at Watana would be identical to that for Watana only operation.

When the Watana water level reaches el. 2,000.0 Devil Canyon reservoir will be allowed to fill while minimum flow requirements are being met. The Watana and Devil Canyon outlet works and operating policies have been planned so that while the Devil Canyon reservoir is filling, the outlet works will be opened up in a gradual manner estimated to prevent the water level from exceeding el. 1,455.0. When the water level reaches el. 1,455.0, the outlet works will be opened as much as necessary to keep the water level stable. In this period, Devil Canyon will operate as essentially a run-of-river project, passing Watana outflows and intervening flows. The rates of change of Devil Canyon discharge will be similar to those for Watana with small modifications resulting from variations in intervening flow.

Devil Canyon can pass all of the Watana outflows and all intervening flows through its outlet works without using its spillway unless the Watana spillway is operating. As noted in Exhibit E, Chapter 2, Section 4.2.3(a)(iii), the 50-year flood inflow may exceed the capacity of the Devil Canyon outlet works. Therefore, surcharge storage is provided to store the flow in excess of the outlet works capacity. During floods, the Devil Canyon water level will be maintained at el. 1,455.0 until the outlet works is discharging at full capacity. If the inflow exceeds the capacity, the water level will be allowed to increase to el. 1,456.0. In this manner the 50-year flood can be stored and released without operating the spillway. If the water level continues to rise above el 1456.0, the Devil Canyon spillway must be opened to maintain freeboard on the dam. The chance the spillway would be operated in any one year is less than 1 in 50. The spillway gates will be opened at whatever rate is necessary to keep the pool at this level. As explained in Exhibit F Appendix F3, the spillway has the capacity to pass the 10,000 year flood with the reservoir at el. 1456.0. Thus, there is less than a 1 in 10,000 chance that the Devil Canyon water level would exceed this level in any one year. If the spillway gates were opened completely and the reservoir level continued to rise, discharge from Devil Canyon would be uncontrolled. The Devil Canyon spillway is designed to pass the PMF. The maximum water level obtained during routing of the PMF is el 1465.6, which is 0.4 feet below the top of the concrete parapet and 4.4 feet below the crest of the rockfill sections of the dam. Control would not be regained until the water level receded to el. 1,455.0. When the water level decreases to el. 1,455.0 the spillway and outlet works will be closed in a manner to keep the water level at el. 1,455.0.

(c) Stage III - Watana and Devil Canyon Operation (***)

Project operation at Watana with both Watana and Devil Canyon operating in Stage III will be similar to Stage II operations. However, the normal maximum water level in Watana Reservoir will be el. 2,185 and the flood surcharge level will be el. 2,193. While Watana reservoir is filling in the spring, and before the water level reaches el. 2,185.0, the Devil Canyon powerhouse will be used to meet system energy demands. Watana must still generate a portion of the energy in order to meet peak system energy demands. This policy was adopted for the purpose of minimizing downstream temperature effects of using the Devil Canyon outlet works. When the Watana water level reaches el. 2,185.0, it is necessary to switch energy generation from Devil Canyon to Watana in order to pass the 50-year flood without using the spillway. The change from Devil Canyon to Watana would be made in a gradual manner, but in no case would the Watana water level be allowed to rise above el. 2,185.5 without the Watana powerhouse supplying all available system energy demands and the Watana outlet works releasing at 24,000 cfs. After the system load is transferred from Devil Canyon to Watana, the operation at Watana would be identical to that for Watana only operation.

When the Watana water level reaches el. 2,185, Devil Canyon reservoir will be allowed to fill while minimum flow requirements are being met. While the Devil Canyon reservoir is filling, the outlet works will be opened up in a gradual manner estimated to prevent the water level from exceeding el. 1,455.0. When the water level reaches el. 1,455.0 the outlet works will be opened as much as necessary to keep the water level stable. In this period, Devil Canyon will operate as essentially a run-of-river project, passing Watana outflows and intervening flows. The rates of change of Devil Canyon discharge will be similar to those for Watana with small modifications resulting from variations in intervening flow.

Devil Canyon can pass all of the Watana outflows and all intervening flows through its outlet works without using its spillway unless the Watana spillway is operating. As noted in Exhibit E, Chapter 2, Section 4.3.3 (a)(iii), the 50-year flood inflow may exceed the capacity of the Devil Canyon outlet works. Therefore, a surcharge storage is provided to store the flow in excess of the outlet works capacity. During floods the Devil Canyon water level will be maintained at el. 1,455.0 until the outlet works are discharging at their full capacity. If the inflow exceeds the capacity, the water level will be allowed to increase to el. 1,456.0. In this manner the 50-year flood can be stored and released without operating the spillway.

If the water level continues to rise above el 1456.0, the Devil Canyon spillway gates must be opened to maintain freeboard on the dam. The chance the spillway would be operated in any one year is less than 1 in 50. The spillway gates will be opened at whatever rate is necessary to keep the pool at this level. As explained in Exhibit F, Appendix F3, the spillway has the capacity to pass the 10,000-year flood with the reservoir water level at el. 1456.0. Thus, there is less than a 1 in 10,000 chance that the Devil Canyon water level would exceed this level in any one year. If the spillway gates were opened completely and the reservoir level continued to rise, discharge from Devil Canyon would be uncontrolled. The Devil Canyon spillway is designed to pass the PMF. The maximum water level obtained during a routing of the PMF was el. 1,463.1 which is 2.9 feet below the crest of the concrete parapet wall and 7 feet below the top of the rockfill dam sections. Control would not be regained until the water level receded to el. 1,455.0. When the water level decreases to el. 1,455.0 the spillway and outlet works will be closed in a manner to keep the water level at el. 1,455.0.

When system energy demand increases, the operation to pass floods when the Watana reservoir reaches el. 2,185.0 would differ slightly from the early years of Devil Canyon operation. If the water level at Watana were to rise above el. 2,185.0 it would not be necessary to switch all the energy generation to Watana. Only that generation would be switched which would be necessary to keep the Watana water level from exceeding el. 2,193.0 for the 50 year flood. It is estimated that this requires a Watana powerhouse discharge of 7,000 cfs. Additionally, the increased energy demand means that Devil Canyon would have the capacity to discharge some flow from its powerhouse before it becomes necessary to open the outlet works. The additional Devil Canyon powerhouse flow would make it possible to pass the 50-year flood without surcharging the reservoir.

Overall, operation of the two dams with greater system energy demands will result in more gradual changes in discharge and less chance of outlet works or spillway operation than in the first years of Stage III operation.

3.6.3 - Emergency Situations (***)

Under normal circumstances, the minimum flow requirements at Gold Creek will be maintained at all times unless otherwise agreed to by the appropriate State and Federal agencies. In emergency situations, if powerhouse operation is not possible, outlet facilities will be operated to meet the flow requirements. Correspondingly, if another part of the energy generation system is temporarily lost, Watana and Devil Canyon may be operated to make up the deficit. The resulting discharge variation may exceed the maximum variation rate of 10 percent, and discharge may reach the maximum flow constraint. However, the discharge at Gold Creek will not be allowed to exceed the maximum weekly flow requirement and the rate of change of discharge will be constrained by the rates established in Section 3.6.1 of this Chapter.

3.6.4 - Flow Requirement During Filling (***)

The Case E-VI flow requirements will be maintained at all times during filling of the three project stages. If a dry season occurs during filling of Watana Stage I, the requirements may be reduced by 1,000 cfs in order to ensure that the water level in Watana reservoir reaches a level required for testing, commissioning and operation of the units during the winter following the summer of filling. During this winter the minimum flow requirements at Gold Creek will be natural flows rather than the Case E-VI minimum requirements.

3.7 - Power and Energy Production (***)

Based on the hydrology, reservoir operation, and Case E-VI flow requirements described above, power and energy production from the Susitna project have been estimated.

3.7.1 - Watana Stage I (***)

Table E.2.3.15 provides the estimated annual power and energy production from the initial Watana development. The Stage I Project will be operated as a base-load plant because environmental flow constraints limit the project outflow fluctuation to plus or minus ten percent of the average weekly flow. This limitation on discharge fluctuation was established:

- To avoid large water level fluctuations which may be detrimental to fish,
- To give the project some flexibility to provide reserve energy capacity and to react to variations in system energy demand,
- To account for possible inaccuracies in the measurement of discharge which may be on the order of five to ten percent, and
- To account for variations in the flow from the intervening area between the project sites, Gold Creek and fishery habitat located between Gold Creek and Talkeetna.

The Stage I power output is computed as that capacity which would provide the average monthly energy generation based on a nearly constant release rate for the week (energy = capacity x time). This effectively prevents the Watana Stage I from peaking operation and, hence, avoids undesirable flow fluctuations.

3.7.2 - Watana Stage I with Devil Canyon Stage II (***)

Table E.2.3.15 also provides the estimated annual power and energy production from Watana Stage I operating with Devil Canyon Stage II. When Devil Canyon comes on-line, the Watana project can follow load with Devil Canyon regulating any flow fluctuations. Hence, the power output from Watana can equal the capability of the turbines, which is a function of Watana Reservoir elevation. Since Devil Canyon is the downstream project, it will be operated as a base-load plant, similar to Watana

Stage I. The Devil Canyon power output is computed as described above (Section 3.7.1) for Watana operating as a base-load plant.

3.7.3 - Watana Stage III with Devil Canyon Stage II (***)

When Watana Stage III is operating with Devil Canyon Stage II, the additional storage available for flow regulation at Watana increases the energy production of both Watana and Devil Canyon (Table E.2.3.15). Also, two additional turbines are installed at Watana to take advantage of the added head and flow regulation. Watana can follow load, while Devil Canyon will be operated as a base-load plant as discussed above.

3.7.4 - Base-Load and Load-Following Operation (***)

The Applicant has estimated the cost of meeting the Railbelt energy demand utilizing the most downstream powerhouse as a base load plant. This section describes the analyses undertaken by the Applicant to estimate the difference in costs if the constraints on daily flow variation were removed. These costs represent a benefit which has been foregone to meet environmental objectives.

As described in this document, the Watana plant initially would operate as a base-load plant to maintain nearly uniform discharge from the power plant. The Watana powerhouse would also be utilized for spinning reserve, which would require that the discharge vary to some extent but within the constraint of 10 percent of the mean weekly flow. When Devil Canyon comes on line, Watana would change to a peaking operation, while Devil Canyon operates as a base-load plant similar to Watana Stage I.

The least economic cost method of meeting the Railbelt energy demand would be to provide the Susitna project the flexibility to follow loads, regulate frequency and voltage, provide spinning reserve, and react to system needs under all normal and emergency conditions. The project would be dispatched to minimize thermal plant operation and fuel costs. Consequently, the Susitna project output would vary as the system load fluctuates; on an hourly and seasonal basis. This would result in discharge and stage fluctuations downstream of the project which may be detrimental to fish.

To assess the economic impact of base-load versus load-following operation, the power and energy data for the load-following case were input to the OGP model and an economic evaluation was made. The with-Susitna plan, assuming base-load operation of the downstream project, has a 1985 present worth of system costs of $4,823 million. For the same plan, assuming load-following operation, the 1985 present worth of system costs are $4,694 million. The difference of $129 million can be considered as foregone power generation benefits or as mitigation costs for fishery enhancement.

4 - PROJECT IMPACT ON WATER QUALITY AND QUANTITY

4 - PROJECT IMPACT ON WATER QUALITY AND QUANTITY (**)

This section presents the estimated impacts of the Susitna Hydroelectric Project on water quality and quantity for construction, impoundment and operation periods of each of the three project stages as well as for the access road and transmission corridor.

The assessment is focused on the parameters most important to the aquatic and fishery resources of the Susitna River. Therefore, th most detailed analyses deal with flows, floods, river temperature, ice, suspended sediment and turbidity. Sufficiently detailed analyses are provided so that impacts to other resources, including wildlife and terrestrial habitat, cultural, socioeconomics, recreation, aesthetics, and land use, can be evaluated.

Methods Of Analyses And Coordination Between Studies (***)

The most important water use and quality parameters (flow, temperature, suspended sediment, turbidity, and ice) were evaluated using state-of-the-art computer models. The evaluations were carried out for all stages of project development, and for mean and extreme hydrological and meteorological conditions. Railbelt system energy demands representative of the period when the stages would be operating were used (Table E.2.4.2). Stages I and II are relatively short, and simulations made by the Applicant (APA 1984, Appendices IV and VI) show that the flows, temperatures and ice conditions for any one year during either stage are representative of conditions during the entire stage. Therefore, flow simulations and simulations of reservoir and river temperature and ice conditions are provided for one year in each stage. Stage III is much longer than Stages I and II since it represents the ultimate development of the project. Therefore, flow and temperature simulations are provided which bound the possible project energy generation scenarios in this stage.

To ensure that the water use and quality analyses accurately represent the expected with-project conditions, a coordinated system of studies was used. This system is diagrammed on Table E.2.4.1. The principal components are described below:

1. Hydrological studies were made to estimate the streamflows available for project use and the frequency and magnitude of floods for natural conditions. Thirty-four year sequences of monthly streamflows at the damsites were developed using a multi-site regression analysis based on available records for the Susitna River and tributaries using a program based on the FILLIN computer program (HE 1984b). Weekly flow sequences were also estimated for the damsites, Gold Creek, Sunshine and Susitna Station by transposing recorded weekly flows consistent with the estimated monthly flows. Flood frequencies were

estimated using guidelines of the United States Water Resources Council (USWRC 1981).

2. Hydrologic and morphologic studies were made to describe fish habitat. Aerial photographic mapping and field studies were made for the Susitna River at several flow rates. Different types of fishery habitat were delineated and measured on the maps, and verified in the field. Relationships between the river flow rate and the quantity of habitat of a given type were developed for input to habitat simulation studies (EWTA 1985). These are described in Chapter 3.

3. Hydrologic and hydraulic studies were made to evaluate the relationships between flow rate, velocity, depth, and water level in the river and in habitat areas. Field surveys of river cross sections and observed relationships between water level and discharge were used as input to a computer model (HEC-2) of the mainstem river (COE 1981) to estimate hydraulic parameters used in the river temperature model, the river ice model and the model for determining daily flow and stage variations. Surveyed cross sections, velocities, and depths in habitat areas were used in habitat simulation models (see Chapter 3).

4. Hydrologic studies were carried out to evaluate suspended and bedload sediment in the Susitna, Chulitna and Talkeetna Rivers. A field program was initiated to collect data which were used in studies of bed stability, habitat stability, channel morphology and in reservoir suspended sediment modeling.

5. Monthly and weekly reservoir operations studies using the RESOP computer program (see Section 3); the 34 year streamflow sequences developed previously and projected energy demands were used to estimate with project flows and reservoir water levels. The sequences of outflows were used by the habitat simulation studies, and in the river temperature and ice studies. The reservoir water levels and outflows were used in the reservoir temperature modeling.

6. The Dynamic Reservoir Simulation Model (DYRESM) was modified for use on the Susitna Hydroelectric Project by inclusion of routines for multiple level intake structures, better representation of wind induced mixing and for modeling of suspended sediment concentrations in the reservoir and in the outflow. The model was extensively tested on Eklutna Lake. Baseline streamflow, sediment and climate data as well as reservoir operations studies were used as input to the model. Output, including outflow quantity, temperature and sediment concentration, were used as input to river temperature and ice studies and in assessing the effect of the project on river turbidity. Other output including the reservoir ice cover

formation and melting dates were used in evaluations of project effects on wildlife (see Chapter 3).

7. Flood routing studies using information on reservoir water levels and powerhouse operation from the RESOP model along with baseline data on flood frequency and volume were made. These studies provided estimates of flood frequency at significant locations between the damsites and Cook Inlet. This information is used in the evaluation of project effects on channel morphology and riparian vegetation as well as providing an index of project effects on flow stability.

8. The effects of the project on stability of the mainstem channel bed, tributary mouths and side slough and side channel habitat areas were evaluated. Baseline data on streambed materials, bedload transport, flow velocity and depth and with-project information on flows and floods were used to estimate potential aggradations and degradations.

9. The effects of the project on fishery habitat were evaluated using simulation models described in Chapter 3. Input to the simulation models consisted of streamflow sequences generated by the reservoir operation model and habitat descriptions developed in field studies and from aerial photography.

10. The Stream Network Temperature model (SNTEMP) of the U.S. Fish and Wildlife Service was modified and tested for use on the Susitna River. Reservoir outflows from the RESOP study and outflow temperatures from the reservoir temperature model were input to the SNTEMP model. The physical description of the river including top widths, travel times, and depths, was from field surveys and HEC-2 results. Intervening flows downstream of the damsites were developed from hydrological studies. The output temperatures were used in an evaluation of impacts to the fishery resource (Chapter 3) and as input to the river ice study.

11. The effects of project operation on river ice conditions were evaluated using the ICECAL model. Inputs to this program include river temperatures upstream of the ice front from the SNTEMP study, river flows from the RESOP program, field surveyed river cross sections and climatogical data. The results describe the winter conditions of the river including area covered by ice, ice thickness and water level. These data were used in the analysis of project effects on fishery resources, wildlife, and riparian vegetation (Chapter 3).

12. The effect of project operation on groundwater flow to the sloughs was evaluated using relationships between the mainstem water level and groundwater flow rate and mainstem water temper-

ature and groundwater temperature. Input to this study included the sequences of with-project flows and an evaluation of the effect of project operation on mainstem water levels using results of the HEC-2 model study. An evaluation of the estimated with-project river temperatures provided the necessary data for an evaluation of with-project upwelling temperatures. The results of this analysis were used in the evaluation of effects on fishery resources (Chapter 3).

13. An evaluation of the effects of project operation on daily variations in flows and water levels was made using the National Weather Service DAMBRK dynamic flood routing model. Simulations of daily variations in flow at the powerhouses were made using results of the RESOP model modified to meet hourly variations in Railbelt energy demand subject to constraints on rate of change of discharge and maximum absolute change in discharge. The results of the analysis give the time history of discharge and stage variations and may be used to evaluate effects of discharge variations on fishery resources.

14. An evaluation of the effect of project operation on downstream gas concentrations was made. Results of the reservoir operation and with-project flood frequency studies were used to determine the reservoir surcharge levels necessary to prevent spillway operation for the 50-year flood. The effect of outlet works and cone valve operation on downstream gas concentrations was evaluated using mathematical models of jet dispersion, air entrainment and jet penetration.

The evaluations of other parameters upon which the project is expected to have smaller effects, did not require the use of computer models nor detailed information on flows and water levels. The other parameters evaluated include dissolved oxygen, nutrients, total dissolved solids, conductivity, significant ions, alkalinity, metals, total hardness, pH, free carbon dioxide, total organic carbon, chemical oxygen demand, true color, chlorophyll-a, bacteria, pesticides, uranium and gross alpha radioactivity. Project effects on lakes and streams, navigation and transportation, waste assimilative capacity and freshwater recruitment to Cook Inlet were also evaluated. Chapters 3 and 7 include evaluations of project effects on fisheries, riparian vegetation, wildlife habitat, and recreation.

All of the above described analyses, including the model studies, were based on extensive baseline data collection efforts carried out between 1981 and 1985. Detailed delineations of fish habitat, based on field studies and aerial photographic mapping, constitute the largest baseline study. These are described in Chapter 3. The collection of hydrologic (streamflow) and meteorologic (climate) data for use in reservoir operation, reservoir and river temperature and ice models, and flow stability studies, was another large baseline study.

Observations of river ice conditions were carried out for five years. Suspended and bedload sediment measurements and bed material sampling have been carried out for four years. Hydrological, meteorological, sediment and turbidity measurements, collected at Eklutna Lake for 2-1/2 years, were used to test the reservoir temperature model. Data on the temperature and quantity of surface and subsurface flows for areas of fish habitat have been collected since 1982. Mass balance measurement of glaciers in the Susitna basin were collected for three years.

Many of the analyses, including the baseline studies, have been made since the original License Application was submitted in 1983. This additional work was done largely in response to agency and public concerns and the results have been incorporated in this Amendment. Specifically, since the 1983 License Application was filed the Applicant has made:

- More than 25 simulations of the weekly operation of the project each for 32-34 years of record, using the RESOP program (Section 3). More than 15 of these were double reservoir runs.
- More than 85 simulations of daily water temperatures for Watana and Devil Canyon Reservoirs based on the reservoir operation runs. These simulations were generally for periods of one to two years.
- More than 15 simulations of the daily temperature and suspended sediment concentrations in the Watana and Devil Canyon Reservoirs. Most of these were for periods of three or four years.
- More than 50 simulations of weekly river temperatures between the dams and the Sunshine gage. Most of these were for periods of one to two years.
- More than 40 simulations of daily river ice conditions between Devil Canyon and the Chulitna-Susitna Rivers confluence, each representing six-month periods.

Many of these simulations are illustrated in this document. Most are included by specific reference to other documents which have been provided to the FERC and others.

4.1 - Watana Development (**)

For details of the physical features of the Watana development, refer to Section 1 of Exhibit A.

4.1.1 - Watana Stage I Construction (**)

Construction of Watana Stage I will begin in 1986 with expansion of the existing camp and airstrip. The initial access to the site will be constructed in 1987 and the main access in 1991. The construction camp and village will be built between 1990 and 1993. The first construction that will significantly affect the Susitna River will begin in 1992 with the construction of the diversion tunnels, and initial work on the cofferdams. The tunnels will be completed by the spring of 1994 and the river will be diverted at that time.

Filling of the reservoir is scheduled to begin in early 1998 and the water level will be high enough by mid 1998 to test the first unit. Commercial operation will begin in October 1998. Construction of the dam, powerhouse and appurtenant facilities will continue through mid 1999 when the last unit will begin commercial operation. The construction period described in this section is the period from initial construction of the access and camp to the beginning of reservoir filling.

(a) Flows and Water Levels (**)

During construction of the diversion tunnels, the flow of the mainstem Susitna will be only minimally affected. Upon completion of the diversion facilities in the spring of 1994, closure of the upstream cofferdam will be completed and flow will be diverted through the lower diversion tunnel Although flow rate will not be interrupted, a 0.6 mile section of the Susitna River will be dewatered in the construction zone. The fishery impacts resulting from this action are discussed in Chapter 3.

During the summer, both diversion tunnels will operate, although the lower tunnel will always be passing the greater portion of the flow. The upper tunnel starts to flow when the river flow exceeds about 8,000 cfs. For the mean annual flood flow of 43,500 cfs, the lower tunnel will run about 30,500 cfs and the upper tunnel 13,000 cfs. The river level immediately upstream of the project will be at el. 1496, about 20 feet above the natural river level. Water levels will be increased for a distance of about 2 miles upstream of the project. The tunnel velocities for the mean annual flood flow are about 40 ft/sec in the lower tunnel and about 30 ft/sec in the upper tunnel.

The two diversion tunnels are designed to pass the 1:50-year flood of 89,500 cfs with a maximum water surface elevation of 1,532 ft and a maximum outflow of 77,000 cfs. For flows up to the 1:50 year flood event, water levels and velocities downstream of the diversion tunnels will be almost the same as natural levels.

Floods greater than the 1:50-year event could overtop the Watana cofferdams and cause failure of the cofferdams. If a flood event of a magnitude large enough to overtop the cofferdam did occur, the only location within 80 miles downstream where damage would occur is the main dam construction site. If the main dam height is less than the cofferdam when overtopping occurs, some damage could occur. However, if the main dam is somewhat higher than the cofferdam when overtopping occurs, damage would be lessened or eliminated. Although flood related damage could occur further downstream, the relatively small volume of the head pond and the attenuation of the flood wave as it moves downstream would reduce the potential for downstream flooding.

Flows, velocities, and associated water levels upstream from the proposed Watana Stage I damsite will be unaffected in the winter. The capacity of the lower tunnel is sufficient to pass normal winter flows without significant change to the river stage upstream of the project. The tunnel gates will be full open, and the river ice conditions will be unchanged from natural conditions.

(b) River Morphology (**)

Since changes in flow will be negligible during Watana Stage I construction, impacts on morphology of the Susitna River will be confined to the dam and borrow sites. During the construction, approximately a 0.6 mile segment of the river will be blocked by cofferdams and dewatered for construction. All of the rockfill material required during Stage I construction will be obtained from excavation for powerhouse spillway and other facilities. Construction materials for filters and concrete aggregate will be from Borrow Site E on the Susitna River as shown on Figure E.2.4.1.

Borrow Site E will become a deep pool in the river. However, the site will be inundated by Devil Canyon Reservoir when it is constructed.

(c) Water Quality (**)

(i) Water Temperature (**)

Since operation of the diversion structure will essentially be run-of-river, no impact on the temperature regime will occur downstream from the tunnel exit.

(ii) Ice (**)

During freeze-up, flowing ice is naturally produced upstream of Watana in September or October. By December, the entire upper river is normally intermittently ice covered, and flowing ice is no longer present. With the Watana cofferdams in place, winter flow will be diverted through the lower tunnel uninterrupted. Little or no backwater is anticipated for the normal winter flows which are less than 5,000 cfs. Therefore, the river ice regime upstream and downstream of the construction area will be unchanged from the natural conditions.

The lower diversion tunnel is expected to convey any floating ice during freeze-up with no accumulation in the tunnel. It is possible that the higher tunnel velocities during the winter will produce some additional frazil which can accumulate in the tailrace downstream. This is not expected to produce sufficient backwater to affect the upstream river conditions.

Break-up timing and character will be similar to natural conditions. The diversion tunnels are large enough to pass the largest ice pieces which have been observed naturally during break-up in the Watana area. The diversion tunnels are designed to flow open channel up to a combined discharge of about 60,000 cfs, well beyond normal break-up flows. Therefore, flow into the tunnel will not be restricted. Ice will not accumulate substantially in the head pond even though some ponding of water will occur.

(iii) Suspended Sediments/Turbidity/Vertical Illumination (**)

During construction, suspended sediment concentrations and turbidity levels are expected to increase within the impoundment area, and for some distance downstream. This will result from the necessary construction activities within and immediately adjacent to the river, including excavation of material from Borrow Site E, construction of the diversion tunnels, placement of cofferdams, clearing the construction site of vegetation and spoil material, and selectively clearing the reservoir area of vegetation prior to impoundment.

- Diversion and Closure

During dam construction proper borrowing procedures will be used to ensure that suspended sediment and turbidity levels will not be increased. Berms will be provided to prevent sediment from the borrow areas from entering the river. Procedures are generally described below for various phases of construction and types of fill and borrow operations. Other procedures are possible and just as effective. The procedures actually used during construction will be based upon guidelines and techniques contained in the Best Management Practices Manual entitled "Erosion and Sedimentation Control" (APA 1985a). The excavation of the diversion tunnels and construction of the first diversion cofferdam may cause temporary increases in suspended sediment and turbidity. Cofferdams will be constructed upstream and downstream of the diversion tunnels to enable tunnel construction. Material excavated from the tunnels will generally be confined within the cofferdams prior to disposal. This will minimize increases in suspended sediment and turbidity. Additionally, excavated material will be disposed of in a manner based on guidelines in the Best Management Practices Manual entitled "Erosion and Sedimentation Control" (APA 1985a). The first diversion cofferdam will be located in the river. It will be constructed by dumping rock material into the river to divert flow to the diversion tunnels. During periods when rock is being placed, some sediment will be washed downstream. The amount of material introduced into the river in this manner is not expected to cause significant increases in sediment concentration since the total amount of material in the closure cofferdam is small relative to the existing river sediment load.

- Dam Construction

The primary borrow sites being considered are sites D and E. These sites are located entirely outside of streamflow limits. All borrow and quarry sites originally considered are shown in Figure E.2.4.1. The balance of the sites have been abandoned for environmental reasons, economic or engineering constraints, or are now being considered only as backup sites.

All rockfill needs for the dam will be satisfied by required excavations within the spillway, approach channel, and powerhouse intake structure areas. These structures are located within a confined construction area, and will have no effect on the condition of the river.

Borrow Site D (Figure E.2.4.2) is the selected source of impervious material for use in the cores of the main dam and cofferdams. The material in Site D consists primarily of glacial till covered with outwash materials and topsoil. The site covers approximately 1,150 acres and contains an estimated 180 million cy of alluvial and outwash materials, from which the 6.3 million cubic yards of impervious fill will be obtained. Borrow Site H is an alternative for this material; however, Site D is more desirable because of lower moisture content, less permafrost, material stratification, and its close proximity to the damsite and support facilities.

Selective excavation of the material will occur during summer (May-September) by utilizing blocks of material that have been pre-drained with lateral perimeter ditches. All runoff will be collected and directed toward settling ponds prior to discharge into Deadman Creek or the Susitna River. No work is scheduled in or immediately adjacent to Deadman Creek, and therefore, no significant erosion control problems are anticipated. However, several small lakes within the area will be drained as a result of the excavation.

The organic layer will be stripped and stockpiled prior to construction. Subsequent to disturbance, the excavated pits will be reclaimed with appropriate materials and techniques to the maximum extent possible. Portions of the site will be within the annual reservoir drawdown zone and may require stabilization to control slumping.

Borrow Site E (Figure E.2.4.3), with an areal extent of approximately 800 acres, is proposed as the primary source of material for filters and concrete aggregate. Borrow operations in Site E will be separated from the natural course of the Susitna River by either natural or man-made berms along and parallel to the river bank. This separation and disallowing of instream borrow operations will essentially prevent suspended sediment from entering the river due to the borrow operation. It is inevitable that there will be some increases in suspended sediments and turbidity, but these will be short term. Downstream from Talkeetna, turbidity and suspended sediment levels should remain essentially the same as baseline conditions. Borrow Site E will be excavated during Stage I construction below el. 1,455, which is the normal maximum Devil Canyon Stage II Reservoir operating level. A moving front excavation will begin at the downstream end of the borrow site, and possibly could extend to depths of 100 feet or more. The high groundwater level adjacent to the river will require that equipment capable of excavating below water be used. The excavation front will be advanced toward Watana Dam, in the upstream direction, with excavated material either stockpiled for future use or to drain, or transported immediately to the processing plant.

It is anticipated that Borrow Site E will be operated mainly during the summer months (May-September) with sufficient material being stockpiled from winter activities. Decreases in winter vertical illumination are expected to be commensurate with any increased suspended sediment concentrations. However, because summer vertical illumination is naturally limited by high suspended sediment concentrations, elevated levels of suspended sediments and turbidity resulting from construction activities will have essentially no effect on summer vertical illumination.

Another potential source of suspended sediments is the processing and deposition of borrow material. The primary processing operation of granular materials for dam construction could produce, over a 6 year period, as much as 5 to 7 million cubic yards of waste materials ranging in size from oversize rock to silt and clay. Most of this material will be moved from the processing plant and either used to selectively backfill portions of the borrow site, or disposed of in approved areas. Fine grained waste could be disposed of across the face of the relict channel to retard or prohibit any potential seepage infiltration.

The processing plant for concrete aggregates and filter gravels will be located at Borrow Site E. A limited amount of spoil will be produced by this aggregate processing plant which will be controlled by running the wash water into a series of settling ponds. Considerable silt will settle out immediately after discharge into settling ponds, hence control of the discharge end will be necessary to spread the material. Mud, silt and clay remaining in suspension will be settled by passing the water through additional settling ponds before discharging into the river. Control of flow between ponds will be regulated through gated culvert pipes. It is expected that much of the water will re-enter the Susitna by seeping through the granular soil in dikes between the disposal area and the river. This in itself will ensure that fine particulates are removed from the water.

It is estimated that 100,000 to 150,000 cubic yards of fine sand, silt and clay will be produced by this operation. These wastes will be completely disposed of within the excavation area in a manner that will preclude their introduction into the river.

Summer flows will be passed through the diversion tunnel with no impoundment. Hence, little settling of suspended sediments being carried naturally by the river is expected to occur. Ponding is not expected upstream of the diversion tunnels in the winter, and so normally low winter sediment and turbidity levels will not be changed.

(iv) Nutrients and Organics (*)

Increased concentrations of nutrients and organic compounds could occur as a result of the disturbance of vegetation and soil cover and the subsequent erosion of overburden and spoil materials. These potential impacts will be minimized by the careful removal of the vegetation and soil cover. They will be either burned or stockpiled to minimize their introduction into the watershed. Spoil materials will later be used to rehabilitate construction areas.

(v) Metals (o)

Increases in the concentration of trace metals will result from construction disturbances to soils and rock on the river bank and in the riverbed. As noted in Section 2.3.8(k), many metals currently exceed established criteria. As such, increases are not expected to create adverse conditions in the aquatic ecosystem.

(vi) Contamination by Petroleum Products (**)

Accidental spillage and leakage of petroleum products could contaminate surface water and ground water during construction. Proper maintenance and service of vehicles will decrease the possibility of leakage of fuel, lubricating oil, hydraulic fluid, and antifreeze. In addition, proper storage and handling techniques will be instituted to prevent accidental spills. Large quantities of petroleum products, especially diesel fuel, will be stored on site. Given the size and dynamic nature of the Susitna River, the contaminated water from small oil spills would be quickly diluted. However, specific precautions will be instituted to prevent spills in the smaller clearwater streams which could be detrimental to aquatic habitats.

To avoid or minimize storage and handling problems, the Applicant intends to incorporate into contractual documents applicable guidelines and state-of-the-art techniques contained in the Best Management Practices Manual entitled "Fuel and Hazardous Materials" (APA 1985d).

All state and federal regulations governing the prevention and reclamation of accidental spills, including the development and implementation of a Spill Prevention, Containment and Countermeasure Plan (SPCC), will be adhered to as described in Sections 6.2 and Chapter 3, Section 2.4.3(e)(ii). This plan will be developed utilizing the information contained in the Best Management Practices Manual entitled "Oil Spill Contingency Planning" (APA 1985b).

(vii) Concrete Contamination (**)

Construction of Watana Stage I could create a potential for concrete contamination of the Susitna River. To minimize the potential impacts, wastewater and waste concrete associated with the operation of the concrete batch plant will not be directly discharged into the river since this could degrade downstream water quality and potentially result in fish mortality.

Approximately 300,000 cubic yards (cy) of concrete will be placed at Watana. An efficient central batch plant will be used to minimize the potential for problems with waste concrete. It is estimated that the production of concrete for the various permanent structures will produce 7,500 cy of waste material. Approximately one-half of this quantity will be rejected concrete. It will be disposed of by hauling it directly to an approved disposal area.

The other one-half of the waste will be material washed from mixing and hauling equipment. This waste concrete will be processed through a washer/separator/classifier to provide aggregates for reuse. The wash water will be stored in an impermeable lined pond until its specific gravity drops to a point which allows its reuse as mixing water for batching new concrete. This system will minimize the waste water effluent to be returned to the river.

The wash water resulting from the cleanup of placing equipment, curing, and green cutting will be collected in sumps at concrete placement areas and pumped to a series of settling ponds to remove most of the suspended materials before the effluent is discharged into the river. Ponds will generally be lined only with sand filters to ensure removal of most waste products. Neutralization of wastewater will be conducted as required to obtain proper pH levels. It is expected that control of toxic chemicals in the effluent will be accomplished through careful selection of concrete additives, the provision of filters for effluent and the close monitoring of operations by the Construction Manager.

Airborne particulates are a second potential pollution problem related to concrete batching plants. No significant dust problems are anticipated since a modern control batch plant fully enclosed for winter operational requirements is envisioned. In addition, the transfer of materials will be through pipes, which should further contain dust.

(viii) Other (o)

No additional water quality impacts are anticipated.

(d) Groundwater Conditions (**)

During construction of the dam there will be no change in mainstem discharge or water level other than in the localized area of the project. No groundwater impacts are expected either upstream or downstream from the construction area. However, in the construction area, groundwater impacts will likely result from the construction activity.

The relict channel at Watana has previously been identified as an area of potential groundwater seepage problems after Watana Reservoir is filled (Acres 1982b). It lies within the drainage between Deadman Creek to the east, the Susitna River to the south, and Tsusena Creek to the west and northwest. Groundwater gradients in the unconsolidated sediments of the channel are principally towards Tsusena and Deadman Creeks with the diorite pluton at the damsite acting as a groundwater barrier to the south.

The groundwater regime in the relict channel is complex and poorly understood due to the presence of intermittent permafrost, aquicludes, perched water tables, and confined aquifers. Possible artesian or confined water tables exist in several of the stratigraphic units while other units appear to be unsaturated.

Permeability testing indicates the range of average permeability in the more gravelly materials is about 10^{-3} cm/sec (3 ft/day), while the tills and lacustrine deposits can be estimated at about 10^{-4} to 10^{-5} cm/sec (0.3 to 0.03 ft/day).

During Stage I, the maximum overall seepage gradient resulting from the long flow path coupled with a groundwater table in the area, will likely preclude the need for treatment in the relict channel. However, during filling of Stage I, the relict channel will be monitored with piezometers and at the outfall.

(e) Lakes and Streams (**)

Borrow Site E, at the mouth of Tsusena Creek, has the potential to create temporary turbidity and sedimentation impacts as excavated material will be hauled over the stream to the dam site. Direct impacts will be prevented by avoiding instream excavation and utilizing buffer strips.

Detailed construction practices to avoid these impacts are described in the Applicant's Best Management Practices Manual on Erosion and Sedimentation Control (APA 1985a). Appropriate sections of this manual will be incorporated into the construction specifications.

The construction, operation, and maintenance of facilities to house and support construction personnel are expected to impact the Tsusena and Deadman Creek drainage basins and some of the small lakes located between the two creeks near the damsite. For more detailed discussions of these impacts refer to Support Facilities, Section (g) below.

(f) Instream Flow Uses (**)

During construction, in all reaches of the Susitna River, except for the immediate vicinity of the Watana damsite, no impacts on navigation, transportation, recreation, fishery resources, riparian vegetation, wildlife habitat, waste load assimilation and the freshwater recruitment to Cook Inlet will occur for flows less than the 1:50-year flood event.

(i) Fishery Resources (**)

During winter, ice conditions in the river upstream and downstream of the diversion tunnels are expected to be similar to natural conditions. The diversion tunnel is planned to be completely open with no ponding upstream. Velocities in the tunnel will range from 15 ft/sec to 20 ft/sec.

During summer, the diversion gates will be fully opened. Tunnel velocities will range from 20 ft/sec to 30 ft/sec.

The impacts associated with both winter and summer diversion tunnel operation are discussed in Chapter 3.

(ii) Navigation and Transportation (**)

There will be an impact on navigation and transportation only in the immediate vicinity of Watana dam and the diversion tunnel since all flow will be diverted through the tunnels. The cofferdams will form an obstacle to navigation which will be difficult to circumvent. However, this stretch of river has limited use because of the Vee Canyon rapids upstream and Devil Canyon rapids downstream from the site. The magnitude of the impact will be minimal. Signs will be placed at the Denali Highway Bridge boat launch area to warn boats that portaging around the construction area will be necessary.

(iii) Riparian Vegetation (*)

Existing shoreline vegetation immediately upstream from the cofferdam will be inundated approximately 20 feet to el. 1,496 ft during the mean annual flood. This flooding will be confined to a one-mile reach with the depth of flooding lessening with distance upstream. Since the flooding will be infrequent and temporary in nature and since the flooded lands are within the proposed reservoir, the impact is not considered significant. Further information on the impacts to riparian vegetation can be found in Chapter 3.

(g) Support Facilities (**)

The construction of Watana will require the construction, operation, and maintenance of support facilities capable of providing the basic needs for a maximum population of approximately 3,300 people (2,300 in the construction camp and 1,000 in the village). The facilities, including roads, buildings, utilities, stores, recreation facilities, airport, etc., will be constructed in stages during the first four years (1990-1993) of the proposed ten-year construction period. The camp and village will be located approximately 0.3 miles northeast of the Watana damsite, between Deadman and Tsusena Creeks. The location and layout of the camp and village facilities are presented in Exhibit F.

(i) Water Supply (**)

Nearby Deadman Creek will be utilized as the major source of water for the community. In addition, wells may be drilled in the Deadman Creek alluvium as a backup water supply.

During construction, the required capacity of the water treatment plant has been estimated at approximately 300,000 gallons per day. Water needs for the camp and village were based on an assumed demand of 80 gallons per person per day plus the projected construction water use. The minimum flow for the lowest flow month for Deadman Creek was estimated to be 3,200 gallons per minute, or

4,600,000 gallons per day. This far exceeds the requirements.

As a result, no significant adverse impacts are anticipated from the maximum water supply withdrawal. Furthermore, the maximum withdrawal will occur during the peak summer construction season when the streamflows are much higher than the lowest flow month. The peak withdrawal in the lowest flow month in winter will be much lower, since construction personnel will be reduced by approximately two-thirds from peak summer levels.

The water supply will be treated by chemical addition, flocculation, filtration, and disinfection prior to its use. Disinfection will probably be facilitated by the use of ozone to avoid the need for later dechlorination. In addition, the water will be demineralized and aerated, if necessary.

The water rights applications for the project were submitted by the Applicant to the Alaska Department of Natural Resources (ADNR) and accepted on August 24, 1982 (ADL's 215433, 215434). In a letter to the Applicant dated December 21, 1983, the ADNR set a water rights appropriation priority date for the Alaska Power Authority of August 24, 1982. This action established the Applicant's prior right to use water from the Susitna River at both Watana and Devil's Canyon. Any applications for water use filed after August 24, 1982 will be junior to the Applicant's. Presently, water rights appropriation permit ADL 203386-P (amended) is held by the Applicant for use of 3000 gpd (11,350 liters per day) from a nearby Miller Lake for the 44-man Watana camp.

(ii) Wastewater Treatment (**)

A secondary wastewater treatment facility will treat all wastewater prior to its discharge into Deadman Creek.

Treatment will reduce the BOD and TSS concentrations to levels acceptable to the Alaska Department of Environmental Conservation (ADEC) and the U.S. Environmental Protection Agency (EPA). The levels are likely to be 30 mg/l BOD and 30 mg/l TSS. In addition, wastewater will be treated with chlorine if necessary, to ensure that fecal coliform bacteria levels meet ADEC and EPA criteria. The maximum volume of effluent would be approximately 300,000 gallons per day or 0.5 cfs which will be discharged into Deadman Creek which has a winter low flow of 4,600,000 gallons per day or 7.1 cfs. Under the worst case flow conditions (maximum effluent and low flow in Deadman Creek), this will provide a dilution factor of about 15, thereby reducing BOD and TSS concentrations to about 2 mg/l after complete mixing. Thorough mixing will occur rapidly in the creek because of its turbulence.

The effluent is not expected to cause any degradation of water quality in the 1-1/2 mile section of Deadman Creek between the wastewater discharge point and the creek's confluence with the Susitna River. Furthermore, no water quality problems are anticipated within the impoundment area or downstream on the Susitna River as a result of the input of this treated effluent.

Construction of the wastewater treatment facility is expected to be completed in the first 12 months of the Watana construction schedule. Prior to its operation, all waste will be stored in a lagoon system for treatment at a later date. No raw sewage will be discharged to any water body.

Chemical toilets located throughout the construction areas will be regularly serviced to ensure proper treatment and disposal.

The Applicant will obtain all the necessary ADEC, EPA, and ADNR permits for the water supply and wastewater discharge facilities.

(iii) Construction, Maintenance, and Operation (**)

Construction of the Watana camp, village, airstrip, etc., may cause impacts to water quality similar to those occurring for dam construction. These impacts, however, would be limited to the local drainages (i.e. Deadman Creek). Specific measures will be instituted to minimize sediment in the smaller clearwater streams, and to avoid spills of petroleum products. The Applicant intends to incorporate into contractual documents applicable guidelines and state-of-art techniques contained in the Best Management Practices Manual entitled "Fuel and Hazardous Materials" (APA 1985d).

All state and federal regulations governing the prevention and reclamation of accidental spills, including the development and implementation of a Spill Prevention, Containment and Countermeasure Plan (SPCC), will be adhered to as described in Sections 6.2 and Chapter 3, Section 2.4.3(e)(iii). This plan will be developed utilizing the information contained in the Best Management Practices Manual entitled "Oil Spill Contingency Planning" (APA 1985b).

Additional discussions on the water quality impacts associated with facilities construction, operation, and maintenance are provided in Chapter 3, Section 2.3.1(a)(ii).

4.1.2 - Impoundment of Watana Reservoir (**)

(a) Reservoir Filling Criteria (**)

The filling of Watana Stage I Reservoir, is scheduled to commence in May 1998. It will take only one summer to fill the reservoir to a level sufficient to operate the units. Unit one is planned to become operable in October 1998 and unit two in January 1999. Testing and commissioning of the units will begin during the summer of filling. During filling, downstream flow requirements will be met and a flood storage safety factor maintained.

(i) Minimum Flows (**)

The Case E-VI Flow requirements will be maintained during the summer of filling. Flow will be released from the reservoir to meet the requirements at Gold Creek. Excess water will be stored in the reservoir. If a dry year should occur during filling the E-VI flow requirements for the months of May through October will be reduced by 1,000 cfs in order to allow filling of the reservoir to a level sufficient for testing and commissioning of the first unit and commercial power operation in the winter. A dry year will be defined in the same manner as for operation (see Section 3.0 of this chapter).

During the winter after the summer of filling, the minimum flow requirement will be natural flows. This means that the Watana Reservoir water level would not be allowed to rise during the winter. Minimum requirements will be maintained by releases through the powerhouse supplemented, if necessary, by releases from the low level or mid-level outlet works depending on how high the water level is.

Minimum target flows at Gold Creek will be attained by releasing that flow necessary from the Watana impoundment which, when added to the flow contribution from the intervening drainage area between Watana and Gold Creek, will equal the minimum Gold Creek target flow. During filling, flows at Gold Creek will be monitored and the flow at Watana adjusted as necessary to provide the required Gold Creek flow.

(ii) <u>Flood Storage Protection</u> (*)

Sufficient reservoir storage will be made available during the filling sequence so that flood volumes for all floods up to the 250-year recurrence interval flood can be temporarily stored in the reservoir and discharged through the low level outlet works without endangering the main dam. When floods occur and use part of this storage capacity, discharge from the Watana Reservoir will be increased up to the maximum capacity of the outlet to lower the reservoir level.

(b) <u>Flows and Water Levels</u> (**)

(i) <u>Simulation of Reservoir Filling</u> (**)

Three reservoir filling sequences were simulated to determine the mean or likely filling sequence and probable deviations if wet or dry hydrologic sequences occurred during filling. Only one summer will be required to bring the reservoir to a level required for operation of the first two units in the winter of 1998-1999. Therefore, the wet, average and dry sequences of May through October flows were routed through the Watana Stage I Reservoir to determine average monthly flows at Gold Creek and end of summer water levels in the reservoir as discussed above in Section 4.1.2(a)(i). Synthesized monthly flow distributions at the damsite and Gold Creek were determined using the long term average monthly flows. The dry sequence of flows was computed by multiplying the long-term average monthly flows by the ratio of the mean annual 1974 flow to the long-term mean annual flow. The wet sequence of flows was computed by multiplying the long-term average monthly flows by the ratio of the mean annual 1963 flow to the long-term mean annual flow. The flows during 1963 and 1974 represent flows exceeded approximately 10 percent and 90 percent of the time. The sequences of reservoir inflows and outflows used in the filling simulation are shown in Table E.2.4.3.

The Watana Reservoir water levels would be sufficiently high at the end of the summer of filling that testing, commissioning and operation of the first two units could occur. The reservoir would not be filled to its normal maximum level until the next summer. If a dry sequence were to occur, the reservoir water level would not be high enough to operate the mid-level (cone valve) outlet works and non-power releases would be made from the low-level outlet works. If an average or wet sequence were to occur, winter non-power releases may be made through the mid-level outlet works instead of the low-level outlet works. Flow will be altered in the Talkeetna to Cook Inlet reach, but because of significant tributary contributions, the impact on summer flows will be reduced. The following table is a comparison of mean natural monthly flows and simulated monthly flows during reservoir filling at Sunshine and Susitna Station.

	Sunshine		Susitna Station	
	Mean Pre-Project	Filling	Mean Pre-Project	Filling
Month	Flow	Flow	Flow	Flow
May	27,700	19,100	57,000	48,000
June	63,300	44,300	112,000	93,000
July	64,100	52,400	127,000	115,000
August	56,100	46,600	109,000	100,000
September	32,900	26,200	68,000	61,000
October	13,800	13,000	33,000	32,000

(ii) Floods (*)

The reservoir filling criteria dictate that avail able storage volume in the reservoir must provide protection for all floods up to the 250-year recurrence interval flood. This means the reservoir must be capable of storing the flood volume of a 250-year flood less the flow which can be discharged through the outlet facilities during the flood event. The maximum discharge of the outlet facilities at Watana is 30,000 cfs. The maximum flow of 30,000 cfs represents a substantial flood peak reduction. These flood peak reductions will be maintained downstream to Cook Inlet. For example, the 1:50-year flood at Gold Creek would be reduced from approximately 100,000 cfs to approximately 50,000 cfs.

After a flood event, the outlet facility will continue to discharge at its maximum capacity until the storage volume criterion is reestablished. This will cause the flood duration to be extended beyond its normal duration although at a greatly reduced discharge.

(iii) Flow Variability (*)

Substantial changes in flow can occur daily under natural conditions. This flow variability will be reduced during the filling process. Using August 1958 as an example, Figure E.2.4.4 shows the daily flow variation that occurs naturally. The August 1958 average flow of 22,540 cfs was close to the long term average monthly August discharge of 22,000 cfs. The flow variations that would occur under filling conditions, assuming the August 1958 flow occurred during the filling process are superimposed. To obtain Curve (1), Figure E.2.4.4, it was assumed that the reservoir storage criterion was violated (i.e., 30,000 cfs discharge at Watana). The second curve was obtained assuming the reservoir was capable of accommodating the entire inflow volume. Both Gold Creek filling hydrographs have reduced flood peaks. In filling Sequence (1), Figure E.2.4.4, outflow is greater than inflow at Watana on the receding limb of the hydrograph in order to reestablish the reservoir storage volume criterion. Hence, during this time period, the Gold Creek flow is greater than the natural flow. In this example, it was assumed that ongoing construction did not permit additional storage in the reservoir. In reality, the dam height will be increasing and additional storage would be permitted, thus reducing the required outflow from Watana. This would correspondingly reduce the Gold Creek discharge.

In filling Sequence (2), the Gold Creek flow is constant at 9,000 cfs. To maintain this constant flow, the flow release at Watana during the filling sequence would only be 1,400 cfs, because flow from the drainage area between Watana and Gold Creek would contribute 7,600 cfs to the flow at Gold Creek. The natural Gold Creek flood peak without regulation was 47,800 cfs in August 1958. The Watana contribution would increase as the natural flow decreases.

Farther downstream, the daily variation in flow for both sequences will increase and be slightly less than under natural conditions. The percent change from natural flow will become less because of the added tributary inflow.

(c) Testing and Commissioning (**)

As reservoir filling nears completion and the reservoir level is above the minimum drawdown elevation (el. 1,850), testing and commissioning of the powerhouse units will commence. Testing of the first unit is scheduled to begin during July 1998. Testing of additional units may begin at three month intervals following this. The process of testing and commissioning each unit may take several months and will require a number of tests. It will be carried out in a manner to maintain downstream flow stabiltiy.

The largest fluctuations in powerhouse flow could occur during the full-load-to-off or off-to-full-load tests when the flow through the turbine being tested will be quickly reduced from approximately 3,500 cfs to 0 or increased from 0 to 3,500 cfs, respectively. This will be compensated for by opening or closing the outlet facility gates or other units which have previously been tested to stabilize flow downstream and to prevent sudden changes in downstream flows. When testing is done during summer, the Case E-VI requirements will be maintained and this will also help to stabilize the flow. The natural attenuation of flow variation with distance downstream will also serve to stabilize the flow.

If testing occurs in winter and flow is less than the test flow through the unit at Watana, flow will be gradually increased to that level over a one day period prior to the testing and maintained at that level through the testing period. If testing is temporarily halted, flow will be gradually reduced.

(d) River Morphology (**)

During filling of the Watana Reservoir, there will be trapping of sediments by the reservoir. As it begins to fill, the velocity of flow through the reservoir will decrease, and deposition of larger sediment particles will begin to occur. As the filling progresses, the flow velocity will decrease further and an increasingly larger portion of the sediment inflow will be trapped by the reservoir. At the end of the summer of filling, the reservoir water level is expected to be between el. 1,920 and el. 1,970. When the pool reaches this level almost all sediment larger than approximately 5 to 10 microns will be trapped. Thus, approximately 75 percent to 85 percent of the material will be trapped.

Filling of the reservoir will require only the relatively short time period of one summer. During this period, most flows in excess of the Case E-VI downstream requirements (Table E.2.4.3) will be stored in the reservoir. Thus, discharges from the reservoir will be small and the sediment concentration of the discharges will be smaller than under natural conditions. Therefore, the morphology of the river downstream will begin to change. For the reach between the damsite and the confluence with the Chulitna River, some degradation may occur, but it will not be significant because of the small discharge and the short period required to fill the reservoir.

For the same reach of the river, there are a number of tributaries discharging to the river. Inflow of water and sediment from these tributaries will not be affected by the reservoir. With the flow in the Susitna River reduced due to filling, there is a possibility that some aggradation would occur at the outlets of some of the tributaries. This, however, will not be significant because these tributaries are quite small compared to the Susitna River and because the period for filling the reservoir will be relatively short.

At the confluence of the Susitna, Chulitna and Talkeetna Rivers, some aggradation is expected to occur because of the large sediment discharge from the Chulitna River and the reduction in the peak flows of the Susitna River. The extent of aggradation will depend primarily on the flow of the Chulitna River and its sediment load during the period of filling the reservoir. However, the impact is expected to be small, if any, because of the short period for filling the reservoir.

Downstream from the confluence, any change in the river morphology will be insignificant during the short filling period. This is because whatever morphological changes the Susitna River may have at or above the confluence, these changes will not propagate much downstream from the confluence within the short filling period.

(e) Water Quality (**)

Beginning with the filling of the reservoir, many of the physical, chemical, and biological processes common to a lentic environment should begin to appear. Some of the more important processes include sedimentation, leaching, nutrient enrichment, stratification, and ice cover formation. These processes are expected to interact to alter the water quality conditions associated with the natural riverine conditions. A summary discussion of the processes and their interactions is provided in Peterson and Nichols (1982).

(i) Water Temperature (**)

- Watana Reservoir (**)

A simulation of reservoir temperatures during the first summer of filling the two-stage project was undertaken by the Applicant (APA 1984a Appendix IV). The schedule for filling Watana Stage I is slightly more rapid than for the first year of filling the two-stage project. The water level at the end of the summer of filling would be between el. 1,920 and el. 1,970 for Watana Stage I as opposed to approximately el. 1,860 for the two-stage project. However, the reservoir thermal structure and the outlet works operations would be similar. The simulation is shown in Figures E.2.4.5 through E.2.4.9.

Throughout the summer of filling, releases will be made through the low level outlet works. As shown in the figures, the temperatures in the reservoir will approximate natural river inflow temperatures because of the small size of the reservoir. The reservoir would become stratified within two months of the commencement of filling and temperatures near the surface will be warmer than at depth, responding to solar and atmospheric radiation. Outlet temperatures will be similar to natural, although exhibiting a lag as would occur in normal operation of the project (see Section 4.1.3(c)i). Maximum outlet temperatures of about 10°C will occur in late July.

The first unit is scheduled to begin operation in October, 1998. Withdrawals for this unit will be from the upper levels of the reservoir. As shown by Figures E.2.4.8 and E.2.4.9, reservoir temperatures in this area would be between 1°C and

2.5°C. The outlet temperatures in the winter following the first summer of filling would be in this range and would be cooler than those shown for this period on Figure E.2.4.5.

A description of the development of stratification in the reservoir is included in the Applicant's comments on the FERC's DEIS (APA 1984a Comment AQR 032).

- Watana to Talkeetna (**)

The reservoir outlet temperatures during the first summer of filling the two-stage-project Watana Reservoir were simulated to be similar to natural temperatures with short lags of about two weeks, being slightly cooler in May and June and slightly warmer in September as noted above and in the applicant's Comments on the FERC's DEIS of May 1984 (APA 1984a Appendix IV). River temperatures during the summer of filling Watana Stage I are expected to be similar to natural conditions with a similar lag time. Because river flows will be less than natural, heat exchange between the atmosphere and the river water will proceed more rapidly than under natural conditions and temperatures downstream are expected to be closer to natural than at the dam.

During the first winter after filling, the project will become operational when units one and two begin generating in October and January, respectively. Thus, outflows will be from near the surface of the reservoir, and since the reservoir will be stratified at this time (APA 1984a Comment AQR032) releases will have temperatures similar to operational conditions in later years. Since winter reservoir outflows would be 2,500 cfs to 3,500 cfs on the average, the river water will cool down toward 0°C more rapidly than when more units are operating. The winter river temperatures shown in the Applicant's comments on the FERC's DEIS (APA 1984a Appendix V, Exhibits S and U) for the first and second winters of filling the two-stage project will be similar to conditions during the first winter after filling Watana Stage I.

- Talkeetna to Cook Inlet (**)

The relative contributions of the Talkeetna and Chulitna Rivers to flow in the lower river will be much greater than the contribution from the middle reach of the Susitna River during the summer of filling. Hence, the temperature in the mainstem, downstream of Talkeetna, will reflect the temperatures of those rivers. Exhibit I of Appendix V of the Applicant's comments on the DEIS (APA 1984a) shows simulated average temperatures at Sunshine, RM 84, during the second summer of filling the two-stage project. Reservoir outflow temperatures and releases for the summer of filling Watana Stage I would be similar to or warmer than those for the second summer of filling Watana two-stage project. Thus, the simulated temperatures for the summer of filling in Stage I, are expected to be slightly warmer than shown in Exhibit I, referenced above.

The temperatures in the middle reach of the Susitna River just upstream of the confluence with the Chulitna River would be slightly warmer than natural in October. From November through April, temperatures are expected to be at 0°C. Flows in the middle Susitna River during the winter after the summer of filling will be equal to or slightly higher than natural. Therefore, immediately downstream of the Chulitna - Susitna confluence, temperatures in October may be slightly higher than natural. Further downstream, however, temperatures will be at 0°C, by late October. The influence of the Chulitna and Talkeetna River flows and the colder middle reach Susitna flows between November and May will cause temperatures in the lower river to be at natural levels during this period.

(ii) Ice (**)

- Watana Reservoir Stage I (**)

Reservoir ice development during filling of the Watana Stage I Reservoir is expected to be similar to that during the Stage I operation described in Section 4.1.3 c(ii). The expected ice cover, therefore, would typically form in late November or early December and would melt out in May or early June. Maximum ice thicknesses would typically be 3 to 5 feet.

- Watana to Talkeetna (**)

During the winter after filling of the Watana Stage I Reservoir, reservoir releases would be warmer than natural and would, therefore, delay frazil ice generation and ice cover formation, compared to natural conditions. River ice conditions during the winter after the summer of filling are expected to be similar to the filling simulations presented in the "Instream Ice Simulation Study" (HE 1984f). Frazil ice generation and border ice growth would typically begin between 5 and 40 miles downstream of the dam, varying with weather conditions; being closer to the dam during colder periods and further downstream in warmer periods. Ice cover progression upstream of Talkeetna is expected to be delayed by several weeks, compared to natural conditions. Progression of the ice cover to Gold Creek may be delayed by up to two months from natural conditions. In the reach approximately 30 miles immediately downstream of the dam, an ice cover is not expected.

River ice thicknesses and ice-induced stages would be somewhat less than those of natural conditions. Fewer sloughs and side channels are expected to be overtopped during the winter after filling the Stage I Watana reservoir than for natural conditions. Breakup of the ice cover would typically occur in May, similar in timing to natural breakup. Breakup is expected to be somwhat milder than natural, due to the warmer than natural reservoir releases which will melt and weaken the ice cover.

- Talkeetna to Cook Inlet (**)

During filling of the Watana Stage I Reservoir, ice cover formation near Cook Inlet is expected to begin in late October, as occurs naturally. Progression of the ice cover upstream to Talkeetna would be delayed by several weeks as compared to natural conditions, due to delayed ice contributions from the middle reach.

(iii) Suspended Sediments/Turbidity/Vertical Illumination (**)

- Watana Reservoir Stage I (**)

As the reservoir begins to fill, water velocities in the river will be reduced and deposition of the larger suspended sediment particles will occur. Initially, all but the larger particles will pass through the reservoir but as more water is impounded, smaller diameter particles will settle before reaching the reservoir outlet. As the reservoir approaches normal operating levels, the percentage of particles settling will be similar to that occurring during normal reservoir operation. During the summer of filling, water will be passed through the low-level outlet. As a consequence, larger particles are expected to pass through the reservoir during the summer of filling than during operation. The outflow concentration is expected to be higher than during operation. (The deposition process during reservoir operation is discussed in detail in Section 4.1.3(c) (iii)).

Reservoir turbidity will decrease in conjunction with the settling of suspended sediments during the filling process. Turbidity will be highest at the upper end of the reservoir where the Susitna River enters. Turbid overflows, interflows and underflows may occur during summer months depending on the relative densities of the reservoir and the incoming river water.

Summer turbidity levels will be less than natural. Turbidity levels will decrease after freezeup but are expected to be higher than natural.

Vertical illumination in the reservoir during the summer will vary, depending on where the incoming river water finds its equilibrium depth and also on the results of turbulent mixing. Data from glacially fed Eklutna Lake indicate that vertical illumination will be 10 feet or less during the mid-summer months (Figure E.2.4.10) (R&M 19821).

For a discussion of the potential for bank instability along the shoreline of the reservoir, see Exhibit E, Chapter 6, Section 3.3, Reservoir Slope Failures. That discussion is primarily based on Stage III conditions. Shoreline erosion in

Stage I will occur as a result of two geologic processes: beach formation and mass movement. Through the mass movement process an undetermined amount of material will be introduced into the reservoir as a consequence of skin and bimodal flows, and shallow rotational and block slides. As a result of the slope instability along the shoreline an indeterminate amount of material will become suspended in the reservoir.

The Watana Stage I Reservoir level of 2000 feet is at a lower level than Stage III and is generally within the confines of the valley. As a result, the thickness of overburden along the shoreline which could be exposed to sliding would be less than that which exists during Stage III . Additionally, the amount of reservoir shoreline is less than Stage III which would also contribute to a lesser number of slides.

Construction activities, such as the removal of timber from within the impoundment, are also expected to contribute to increased suspended sediment concentrations and turbidity levels due to erosion. The Applicant has proposed mitigation measures such as delaying vegetation removal until just prior to reservoir filling and is considering selective removal of only large trees, leaving root systems, brush and ground cover intact in order to minimize turbidity increases due to erosion (APA 1983b).

- Watana to Talkeetna (**)

Maximum suspended particle sizes passing downstream through the project area will decrease from about 500 microns during pre-project conditions to between 5 and 10 microns when the project becomes operational. Estimated suspended sediment concentrations in the river during operation are approximately 50 - 150 mg/l in the summer, reaching a maximum in July and August, then decreasing to between 10 mg/l and 40 mg/l in early May (see Section 4.1.3(c)(iii)). During the summer of filling, concentrations would be higher than this, as previously noted. During the winter following filling, concentrations would be similar to operation since units one and two will be on-line and releases will be through the multi-level intake. Maximum suspended sediment concentrations would occur during wet years with high suspended load influent to the reservoir. Minimum suspended sediment concentrations would occur during dry years with lower suspended load inflow. Because of the clear water tributary inflow in the Watana to Talkeetna reach, further dilution of the suspended sediment concentration may occur as the flow moves downstream. In general, the suspended sediment concentration in the Watana to Talkeetna reach will be reduced from natural conditions during summer and increased during winter.

During periods of high tributary flow, the same amount of suspended sediment will be added to the river by the tributaries as for natural conditions. Talus slides along the mainstem will also continue to contribute suspended sediment to the flow downstream from Watana. However, erosion of slide areas along the river should decrease due to increased flow stability and decreased flood frequencies and flows.

Downstream, summer turbidity levels will be reduced from natural levels to an estimated value of 100-300 NTU. These values will persist until December and will decrease during winter to a minimum of between 20 and 40 NTU in early May prior to breakup. Because of the reduced turbidity in summer, the vertical illumination will be enhanced. Winter vertical illumination will be reduced from natural.

- Talkeetna to Cook Inlet (**)

Suspended sediment concentration and turbidity levels in the lower river during summer will remain high because of the suspended sediment concentration of the Chulitna River and other tributaries. The Chulitna River is the major sediment contributor to the lower river.

Data collected by the USGS between 1981 and 1984 (Knott 1983, 1985) indicate that the suspended sediment load of the Chulitna River was two to three times that of the Susitna River upstream of the confluence even though the average Chulitna River flow was only approximately 85 percent of the Susitna River flow. During the same period the Talkeetna River suspended sediment load was approximately 40 percent of the Susitna River upstream of the confluence with the Chulitna. The Talkeetna River flow was approximately 40 percent of the Susitna River flow.

Approximately 60 to 65 percent of the measured suspended load on the Susitna and Chulitna Rivers was of silt-clay size. Approximately 50 percent of the suspended load on the Talkeetna River was of silt-clay size. The remaining load was sand size in all three streams. Approximately 60 to 65 percent of the suspended sediment at Sunshine was of the silt-clay size.

Measurements by the U.S.G.S at the Sunshine station, summarized below, indicate the total sediment load (suspended load plus bedload) incoming to the reach between the confluence and Sunshine was approximately equal to the load leaving the reach indicating an equilibrium condition existed.

Sediment Load (tons)

	Suspended Sediment		Bedload	
	1982[2/]	1983[2/]	1982	1983
Susitna River upstream of confluence	2,809,000	3,460,000	43,600	72,400
Chulitna River upstream of confluence	7,150,000	8,550,000	1,227,000	839,000
Talkeetna River upstream of confluence	1,350,000	1,080,000	223,000	79,300
TOTAL	11,309,000	13,090,000	1,494,000	991,000
Susitna River at Sunshine	12,620,000	13,700,000	512,000	589,000

The relative change in suspended sediment concentration downstream of the confluence can be estimated by applying the following relationship.

$$R = \frac{\dfrac{S_c + S's + S_t}{Q_c + Q's + Q_t}}{\dfrac{S_c + S_s + S_t}{Q_c + Q_s + Q_t}}$$

1/ May 1982 to September 1982

2/ October 1982 to September 1983. Contribution in October 1982 to April 1983 is less than 1 percent of total

Where:

R = the ratio of the lower river with-project sediment concentration to the natural sediment concentration

S_c = Chulitna natural suspended sediment load

S_s = Susitna natural suspended sediment load

S_t = Talkeetna natural suspended sediment load

Q_c = Chulitna natural discharge

Q_s = Susitna natural discharge

Q_t = Talkeetna natural discharge

S'_s = Susitna with-project suspended sediment load

Q'_s = Susitna with-project discharge

Based on the computed suspended sediment load of the Susitna River at Sunshine (Knott 1983, 1985) the average suspended sediment concentration for May to September (summer) was approximately 700 mg/l in 1983. When the project operates as Watana Stage I, the summer concentrations would be reduced by approximately five percent. October to April (winter) natural suspended sediment concentrations are very low. With-project suspended sediment concentrations would increase to approximately 40 to 50 mg/l, in this period, assuming an average sediment concentration in the discharge from the dam of 60 to 70 mg/l (see Section 4.1.3(c)(iii)) and no additional sediment inflow from the drainage area downstream of the dam.

During the summer of filling, suspended sediment concentrations from the dam would be higher than during operation as previously noted in this section. Thus during filling, the reduction in suspended sediment concentration at Sunshine would not be as great as during operation (described in previous paragraph). During the first winter following filling, only two units would be operational and the flows and sediment loads at Sunshine would be less than during normal operation when all four units are on line.

Summer vertical illumination in the lower river will remain less than one foot. During winter, the vertical illumination will be less than 3 feet.

(iv) Dissolved Oxygen (**)

Reservoir dissolved oxygen (D.O.) levels should approximate natural riverine conditions during the summer of filling. Stratification will begin to develop as filling progresses, but no substantial decreases in D.O. levels are anticipated. The small size of the reservoir, the volume of freshwater inflow, the effects of wind and waves, and the location of the outlet structure at the bottom are expected to minimize oxygen depletion in the reservoir water.

No significant biochemical oxygen demand (BOD) is anticipated. Large timber in the reservoir inundation zone will be cleared, thereby eliminating some of the associated oxygen demand that would be created by decomposition of vegetation. Further, the chemical oxygen demand (COD) in the Susitna River is low. COD levels measured upstream at Vee Canyon during 1980 and 1981 averaged 16 mg/l.

No significant BOD loading is expected from the construction camp and village, due to the wastewater treatment facility currently proposed.

As a result of the above factors, dissolved oxygen is expected to remain sufficiently high to support a diverse aquatic habitat.

As previously noted, the low-level outlet will be utilized for discharging water. During this time period, the reservoir D.O. level should be approximately equal to the natural riverine conditions. Thus, the levels of oxygen immediately downstream from the outlet are expected to be essentially unchanged from natural values.

(v) Total Dissolved Gas Concentration (**)

Supersaturated dissolved gas conditions currently exist in the Susitna River below the Devil Canyon rapids due to the entrainment of air and pressurization due to the plunging action as the river flows through this reach.

Supersaturated conditions are also possible below high head dams as a result of the passing of water over a spillway into a deep plunge pool or as the result of hydraulic jumps. (The mechanisms causing gas supersaturation are explained in Section 6.4.4). If the dissolved gases reach high levels (generally defined as greater than 116 percent), fish mortality may result (Turkheim 1975).

Filling will cause reduced downstream flows and result in lower summer dissolved gas concentrations below the Devil Canyon rapids. Water that is released during the filling of the reservoir to meet environmental flow requirements will pass through the low-level outlet. A flip bucket is provided on the low-level outlet works to disperse the flow and to prevent a hydraulic jump in order to minimize the potential for gas supersaturation. Gas concentrations in the river are expected to be similar to natural. Based on observed natural conditions, August flows of 12,000 cfs at Gold Creek should result in total dissolved gas saturation levels of approximately 108 percent or less immediately downstream of the Devil Canyon rapids. Equilibration with the atmosphere will reduce gas concentrations further downstream.

(vi) Nutrients (**)

Two opposing factors will affect nutrient concentrations during the filling process. First, initial inundation will likely cause an increase in nutrient concentrations due to leaching. Second, sedimentation will cause precipitation of substantial amounts of nutrients from the water column. The magnitude of net change in nutrient concentrations in the reservoir is unknown, but it is likely that nutrient concentrations will increase especially in close proximity to the reservoir floor for at least a short time during filling.

(vii) Total Dissolved Solids, Conductivity, Significant Ions, Alkalinity, and Metals (**)

Peterson and Nichols (1982) note that short-term increases in dissolved solids, conductivity, and most of the major ions could occur immediately after filling begins. Bolke and Waddell (1975) found the highest concentrations of all major ions, except magnesium, occurred immediately after dam closure.

Symons (1969), also identified similar increases of alkalinity, iron, and manganese. These findings were all attributed to the initial inundation and leaching of rocks and soils in the reservoir.

The products of leaching are not anticipated to be abundant enough to affect more than a small layer of water near the reservoir bottom (Peterson and Nichols 1982). Some leaching products may be distributed throughout the reservoir during the fall overturn following the summer of filling. However, dilution by the large reservoir volume should reduce concentrations to biologically insignificant levels. Since reservoir releases following initial operation of the first generating unit in October will be from near the reservoir surface, water released from the reservoir will not be adversely affected. As filling progresses, inorganic sediments will be deposited on the reservoir bottom and this will retard the leaching process. During the summer of filling, releases will be from the low level outlets and levels of the previously mentioned parameters could increase but are not expected to cause detrimental effects to freshwater aquatic organisms.

Further discussions of effects of the anticipated leaching process are presented in Section 4.1.3(c) (viii) and in Peterson and Nichols (1982).

(viii) Other (o)

No additional water quality impacts of any significance are anticipated.

(f) Ground Water Conditions (**)

(i) Mainstem (o)

Alluvial gravels in the river and tributary bottoms upstream from the dam will be inundated. Other than aquifers composed of the unconfined materials making up the relict channel and in the valley bottoms, no aquifers of significance are known to exist in the reservoir area.

As a result of the decreased summer flows (see Section 4.1.2(b) [i]), water levels in the mainstem of the river will be reduced between Watana and Talkeetna. This will in turn cause a reduction in adjacent ground water levels. However, the ground water level changes will be confined to the river floodplain area. The ground water level will be reduced by between 1 and 4 feet during the May to September period near the streambank with less change occurring with distance away from the river. The average change in groundwater level during this period will be a reduction of about 2 feet near the streambank.

A similar process will occur downstream from Talkeetna, but the changes in ground water levels will be less because of the decreased effect on river stages.

(ii) Sloughs and Peripheral Habitat Areas (**)

The reduced mainstem flows and associated lower Susitna River water levels will cause corresponding changes in various sloughs. The lowering of the mainstem stage generally will result in a lowering of the groundwater levels in the river bottom alluvium (see previous paragraph), and thus a dewatering of some of the seep areas in the sloughs, mainly in the higher, upper portions. Flows have been investigated in three of the sloughs and the following equations were derived from the data:

Slough	Equation
8A	Qs = -368.21 + 0.6356 W
9	Qs = -171.88 + 0.2889 W
11	Qs = -335.39 + 0.4921 W

where: Qs = flow (cfs) in the slough resulting from seepage from the mainstem
W = mainstem river stage (ft) at a cross-section just above the slough being predicted. Measured at RM 127.1, RM 129.3, RM 136.68 for 8A, 9 and 11, respectively (HE 1984d).

As can be seen from these equations, a reduction of two feet in the mainstem stage will result in a reduction of 0.6 to 1.2 cfs in the slough flows. This loss will mainly occur in the summer.

The groundwater flow from the mainstem to other slough and side channel habitat areas will be affected in the same manner.

Ice staging during the winter of filling will be similar to natural conditions and thus groundwater flow will be similar to natural.

Another aspect of slough flows is that overtopping of the berm will occur less frequently due to reduced summer flows as discussed in 4.1.2(b).

(g) Lakes and Streams (*)

Several tundra lakes will be inundated as the reservoir approaches full pool. The mouths of the tributary streams entering the reservoir will be inundated for several miles as discussed in Section 2.5.2 (see Table E.2.2.40). Bedload and suspended sediment carried by these streams will be deposited at or near the new mouths of the streams.

No significant impacts to Tsusena or Deadman Creeks are anticipated from their use as water supply and waste recipient, respectively.

(h) Instream Flow Uses (**)

(i) Fishery Resources, Riparian Vegetation, Wildlife Habitat and Recreation (**)

Impacts on fishery resources, riparian vegetation, and wildlife habitat during the filling process are discussed in Chapter 3. Impacts to recreational uses including whitewater kayaking are discussed in Chapter 7. As summer flows are reduced, fish access to slough habitats will be decreased. Since the temperature of the upwelling ground water in sloughs will be essentially unchanged and upwelling will continue to occur, impacts on the incubation of salmonid eggs are not expected to be significant.

(ii) Navigation and Transportation (**)

Once impoundment of the reservoir commences, the character of the river immediately upstream from the dam will change from a fast-flowing river with numerous rapids to a still-water reservoir. The Stage I reservoir will ultimately extend 39 miles upstream (44 miles along the river before impounding), terminating five miles downstream from the confluence with the Oshetna River, and will inundate the rapids at Vee Canyon. During average flow years, the Vee Canyon rapids, located at approximately el. 1,950, would be inundated early in

July and exposed from January through June. This will decrease the navigational hazards through Vee Canyon and increase motorized boat traffic in this reach.

Assuming boaters' portage around the construction area, the reduced summer flows released from the reservoir during filling are not expected to reduce navigation between Watana and Devil Canyon. The lower segment of this reach, from Devil Creek to Devil Canyon, will still consist of whitewater rapids.

No significant navigational difficulties are expected to occur between Devil Canyon and the confluence with the Chulitna River due to the lower summer flows. The entire reach will remain navigable from June to September. The simulated average monthly flows for dry, average, and wet years (see Section 4.1.2(b)(i)) are show in the following table, together with the Case E-VI minimum flows at Gold Creek.

Simulated Monthly Average Flows at Gold Creek During Filling of Stage I

Month	E-VI Minimum Flow at Gold Creek (cfs)	Dry Year	Average Year	Wet Year
May	4900	3900	4900	4900
June	8800	7800	8800	10800
July	9000	8000	12700	20500
August	9000	8000	12400	15500
September	6800	5800	6800	6800
October	4515	4000	5000	5000

Between June and September flows will exceed 6,800 cfs except during September in a dry year, when flows at Gold Creek would be reduced to 5,800 cfs. The only identified potential navigation problem in this reach, a channel cross-over near RM 128, has been successfully navigated by jetboat at flows of 6,300 cfs.

There are no significant impacts on navigation anticipated below the confluence with the Chulitna River from June through September except perhaps in Alexander Slough. The reduced summer flows from the Susitna River will be somewhat compensated for by the high flows from other tributaries. Minor restrictions on navigation may occur at the upstream access to Alexander Slough, but this would occur only in low streamflow years when the tributaries also have low flow. If difficulties are encountered in Alexander Slough, Powerline Slough will still be available and navigation will not be precluded (see Section 4.1.3(f)(ii)).

Since the project will be in operation after the first summer of filling, effects of impoundment on winter transportation will be similar to normal operation as discussed in Section 4.1.3(f)(i). These effects are expected to be minimal. Much of the existing winter use of the river is downstream of Talkeetna. As discussed in Section 4.1.2(e)(ii) the ice cover is expected to progress to the Chulitna confluence from Cook Inlet several weeks later than for natural conditions. Melt-out will occur several weeks earlier than under natural conditions. This will shorten the winter travel period around Talkeetna. Travel restrictions due to open leads in the ice cover which occur for natural conditions will also occur with-project.

Between Talkeetna and Devil Canyon, there will be a delay in ice cover formation, and open water will exist for a distance downstream of the project. However, winter travel in this reach is limited at present due to numerous open leads and to the use of the Alaska Railroad, which is adjacent to much of the river, as a transportation route. The effect on winter transportation patterns will be minimal in this reach.

Winter travel in the reservoir areas is expected to improve. Numerous open leads presently occur, and the river flows through a steep canyon. Once the reservoir is filled, a solid flat ice surface will exist much closer to the top of the canyon. Due to the presence of the project construction camps and villages, as well as the permanent village, winter travel on this reach of river may significantly increase over existing use patterns.

(iii) Waste Assimilative Capacity (o)

The previously noted reductions to downstream summer flows could result in a slight reduction in the waste assimilative capacity of the river. However, no adverse impacts will occur given the limited sources of waste loading to the river (see Sections 2.6.6 and 4.1.1(g) [ii]).

(iv) Freshwater Recruitment to Cook Inlet Estuary (**)

Given average hydrologic conditions, the annual Susitna River flow contribution to Cook Inlet will be reduced by its greatest proportion of approximately ten percent, during the summer (1998) of filling (See Section 4.1.2.(b)(i) for simulated flows during filling). Resource Management Associates (1983) used the previously identified computer model (Section 2.6.7) to estimate salinities during the three year filling period for the two-stage project. The reduction in flow during the summer of filling the three-stage project is similar to the reduction in flow used in the two-stage project analysis. Therefore, the results are applicable to the filling of Watana Stage I. As expected, higher salinities are present throughout the summer of filling. These increases are not substantial as explained in the following discussion.

At Node 27, near the mouth of the Susitna River (Figure E.2.2.149), the maximum increase in salinity levels of 1400 mg/l (increase from 9700 to 11,100 mg/l) are predicted to occur during June when the greatest percentage reduction in flow occurs (Figure E.2.2.150). Progressing southward down Cook Inlet away from the mouth of river, quantitative changes will be less and a slight time lag will be evident. At the center of Cook Inlet near East Foreland (Node 12) a maximum salinity increase of 600 mg/l was predicted during July and August. Simulated salinity data for filling of the two-stage project for five locations in Cook Inlet are presented in Table E.2.2.48.

These higher Cook Inlet salinities will last only until project operation, at which time a new equilibrium will be established as described in Section 4.1.3(f)(iii).

4.1.3 - Watana Stage I Operation (**)

This section describes project effects during the period between the summer of 1999, when all four powerhouse units are planned to be operational, until the construction and filling of Devil Canyon in Stage II. As noted in Section 4.2, the construction and filling periods for Devil Canyon overlap with Stage I normal operation. Since there will be limited impounding of water in Devil Canyon Reservoir until immediately before operation of Stage II, the effects on water use and quality during Devil Canyon construction and filling will be similar to those described for Stage I operation. This is explained in Sections 4.2.1 and 4.2.2 which give the impacts of Stage II construction and filling, respectively.

(a) Flows and Water Levels (**)

(i) Project Operation (**)

Watana will be operated in a storage-and-release mode, so that summer flows will be stored for release in winter. Generally, the Watana Reservoir will be at or near its normal maximum operating level of el. 2,000 feet each year at the end of September. The reservoir will then be drawn down gradually, to meet winter energy demand. The flow during this period will be governed by environmental flow constraints, the winter energy demand, the water level in the reservoir, and the powerhouse characteristics. The turbine characteristics will allow a maximum powerhouse flow of approximately 14,000 cfs at full gate. Normal powerhouse discharges are simulated to range from approximately 2,700 cfs to 12,000 cfs.

In eary May, the reservoir will reach its minimum annual level of approximately el. 1,870 ft and then begin to refill with the spring runoff. Flow in excess of both the downstream flow requirements and power needs will be stored during the summer until the reservoir reaches the normal maximum operating level of el. 2,000 ft. If the reservoir reaches el. 2,000 ft and inflows exceed environmental and energy requirements, excess flow will be released to prevent encroachment on dam satety requirements (see Section 3.6.2).

- Environmental Flow Requirement (**)

During project operation the Case E-VI environmental flow requirements will be maintained as discussed in Section 3. Mimimum requirements will be met by releases from the powerhouse and, if necessary, the outlet works.

- Weekly Reservoir Simulations (**)

Weekly simulations of reservoir operation were conducted for the 34 years of record from 1950 to 1983. Case E-VI flow requirements were used. Reservoir operation and water levels are summarized on Figures E.2.4.11 through E.2.4.14.

Additionally, to provide a sensitivity analysis for flows and temperatures, weekly reservoir simulations were made for Case E-I flow requirements (HE 1984h). Results of the reservoir simulations are presented in Figures E.2.4.15 through E.2.4.18.

Case E-I was chosen for the sensitivity testing because it has the highest minimum summer flow requirements of any of the cases considered (14,000 cfs). For comparison, Case E-VI minimum summer flow requirements are 9,000 cfs. With the information on these two extremes, it is possible to determine the effects of project operation on water use and quality for other sets of flow requirements between E-I and E-VI.

- Daily Operations (**)

Daily operation of Watana powerhouse is explained in Section 3 and the Applicant's Case E-VI Environmental Flow Regime Report (HE 1985f). As indicated in Section 3.6.1 discharge would be allowed to vary between 90 percent and 110 percent of the average weekly discharges.

Studies have been undertaken to determine water level and discharge variations in the middle reach for given daily average powerhouse releases and daily discharge variations. The results of these studies are contained on Table E.2.4.4. These studies were carried out using simulated daily demand patterns and routing the resulting discharges downstream using the DAMBRK model as described in a report by Harza-Ebasco (HE 1984g). Various levels of discharge variation ranging from a few percent to almost 50 percent were examined. Intervening flows based on historical records were added to the river discharge with distance downstream of the dam.

The results of the analysis show the following general trends with regard to fluctuations in powerhouse discharge (measured as a percent of powerhouse discharge), fluctuations in discharge at RM 130, (measured as a percent of the powerhouse discharge change), and fluctuations in water level (measured in feet).

1. As the fluctuation in powerhouse discharge increases, the fluctuation in discharge at RM 130 increases. That is, there is relatively less attenuation with distance downstream as the fluctuation in discharge at the powerhouse increases.

2. As the average daily powerhouse discharge increases, the fluctuation in discharge at RM 130, increases. That is, attenuation of discharge fluctuation decreases as average powerhouse discharge increases.

3. For a 10 percent fluctuation (5 percent ±) in discharge at the powerhouse, the fluctuation in discharge at RM 130 for a powerhouse discharge of 13,600 cfs is greater than that for a powerhouse discharge of 6,400 cfs.

4. For the normal range of powerhouse discharges of 4,000 cfs to 12,000 cfs the fluctuation in water level at RM 130 corresponding to a 10 percent (5 percent ±) fluctuation in discharge would be less than 0.3 feet.

5. For powerhouse discharges between 4,000 cfs and 7,000 cfs a 25 to 30 percent fluctuation in powerhouse discharge (12.5 percent - 15 percent ±) would change the water level at RM 130 by about 0.4 feet.

6. For a powerhouse discharge of 13,200 cfs, a 20 percent powerhouse discharge fluctuation (10 percent ±) would result in a stage fluctuations in the reach between Devil Canyon and the Susitna - Chulitna confluence of 0.3 ft to 0.9 ft.

In summary, for the normal range of powerhouse discharges during Stage I, the expected range of stage fluctuations in the middle river for a daily change in discharge of 20 percent (10 percent ±) would be from 0.2 ft to 0.7 ft.

Figures E.2.4.19 through E.2.4.24 show discharge and stage variations at RM 120.3 for three levels of discharge fluctuation defined in Table E.2.4.5 for winter average powerhouse flows of 13,200 cfs near the maximum powerhouse capacity. Figures E.2.4.25 through E.2.4.30 show discharge and stage variations at RM 132.9 for three levels of discharge fluctuation defined in Table E.2.4.5 for summer average powerhouse flows of 6,400 cfs typical of minimum summer powerhouse flows.

Figures E.2.4.31 through E.2.4.34 may be used to estimate the average stage variation from week to week resulting from changes in weekly average flow. These curves are based on steady state rating curves at the noted locations.

For example, at RM 127.1 for a weekly average flow of 10,000 cfs the maximum weekly stage fluctuation for a ±1000 cfs or ±10 percent flow variation would be 0.44 ft (±0.22 ft). The corresponding fluctuation at RM 136.68 would be 0.6 feet (±0.30 ft).

These figures have been drawn for locations near the upstream ends of Sloughs 8A, 9, 11 and 21. Examination of water surface profiles in the report "Susitna Hydroelectric Project - Middle and Lower River Water Surface Profiles and Discharge Rating Curves" (HE 1984d) indicates these are representative of the range in stage fluctuation in the Middle Reach of the Susitna River. The rating curve at the Slough 11 head appears to give near maximum stage fluctuations while those at Sloughs 8A and 21 give near minimum stage fluctuations.

Table E.2.4.6 and Figure E.2.4.35 show the surface area of the mainstem and peripheral habitat areas of the Susitna River between Devil Canyon and the Susitna-Chulitna confluence. These can be used to estimate the change in habitat surface area for a change in discharge. The change in gravel and vegetated bar area represents the areas that are either exposed or covered by water as the water level decreases or increases, respectively. The relationships were compiled from mapping of aerial photographs of the river of flows less then 25,000 cfs and from simulations of water surface profiles in the river (EWTA 1985, HE 1984d).

(ii) Mean Monthly Flows and Water Levels (**)

Weekly water levels and discharges at Watana were simulated using the weekly reservoir operation program. Maximum, minimum and average monthly reservoir water levels are shown on Figures E.2.4.11 through E.2.4.14 for Case E-VI. Maximum water levels are those that would normally be attained in wet years and minimum levels would be attained in dry years.

Figures E.2.4.11 and E.2.4.14 show that the reservoir fills to el. 2,000 in almost every year and is drawn down to between el. 1,850 and el. 1,870 by April. The effect of the 1969 and 1970 low flow years is indicated by the low reservoir level attained in September of 1969 and 1970.

The sequences of simulated monthly flows at Watana, Gold Creek, Sunshine and Susitna Station for Case E-VI are shown in Tables E.2.4.7 through E.2.4.10, respectively. Simulations were carried out for the period January 1950 through December 1983, a period of 34 years. Results are shown for the 33 complete water years, 1951 (Oct. 1950 - Sept. 1951) through 1983 (Oct. 1982 - Sept. 1983). Tables E.2.4.11 through E.2.4.14 compare natural and with-project conditions. Figures E.2.4.36 through E.2.4.40 show simulated natural and with-project flows at Gold Creek respectively for:

- o 1964 - Flood of record in June,
- o 1967 - Large flood in August,
- o 1970 - Second driest year,
- o 1981 - Wet year used in temperature simulations, and
- o 1982 - Average flow year used in temperature simulations.

In general, project operation results in higher than natural winter flows and lower than natural summer flows. Flood peaks are considerably reduced. Lowest flows occur in early May and October.

The reservoir normally is full in September. Winter energy demands are met from reservoir storage. The flows in October and May are lower than for the rest of winter since the demands in these months are less than for other winter months. The reservoir normally begins to fill in May and the reservoir operating policy is to try to fill the reservoir by early September to ensure adequate energy production in the winter. Thus, May and June releases from the reservoir are generally lower than in July and August. In average and wet years the reservoir may fill before September. Releases would then be made in excess of power and environmental requirements.

With-project mean monthly flows at Gold Creek are compared to natural flows in the following table.

Month	Natural	Project	Percent Change
January	1,500	8,100	+440
February	1,300	7,600	+480
March	1,200	5,700	+370
April	1,400	4,100	+190
May	13,500	6,400	- 50
June	27,800	13,300	- 50
July	24,400	14,500	- 40
August	21,900	18,300	- 20
September	13,500	14,200	+ 10
October	5,800	7,900	+ 40
November	2,600	7,800	+200
December	1,800	9,100	+400

Further downstream at Sunshine and Susitna Station, the differences between natural and with-project flows are reduced due to the inflows from tributaries. The following tables illustrate the differences at Sunshine and Susitna Station.

Sunshine

Month	Natural	With Project	Percent Change
January	3,700	10,000	+170
February	3,100	9,400	+200
March	2,800	7,300	+160
April	3,600	6,100	+ 70
May	28,000	21,000	- 30
June	63,000	49,000	- 20
July	64,000	54,000	- 15
August	56,000	53,000	- 5
September	33,000	34,000	+ 3
October	14,000	16,000	+ 15
November	6,200	11,000	+ 80
December	4,400	12,000	+170

Susitna Station

Month	Natural	Project	Percent Change
January	8,100	15,000	+ 80
February	7,400	14,000	+ 90
March	6,400	11,000	+ 70
April	7,700	10,000	+ 30
May	57,000	50,000	- 10
June	112,000	98,000	- 10
July	127,000	117,000	- 10
August	109,000	105,000	- 5
September	68,000	68,000	+ 0
October	33,000	35,000	+ 5
November	15,000	20,000	+ 30
December	9,300	17,000	+ 80

Mean annual flow will remain the same at all stations. However, flow will be redistributed from the summer months to the winter months to meet energy demands.

Water surface elevations based on maximum, mean, and minimum weekly flows at Gold Creek for May through September for selected mainstem locations between Portage Creek and Talkeetna are shown in Figures E.2.4.41 through E.2.4.43. The figures illustrate the water level change expected as a result of operation of Watana. In general, there is a decrease in water level from natural levels to with-project levels in the summer. As illustrated by ice simulations later in this section, there is a comparable increase in stages in winter. In general, water levels are stabilized from May through November as compared to natural conditions.

(iii) Floods (**)

Operation of the project during floods is explained in Section 3.6.2.

Flood peak frequency curves for with-project conditions were estimated for the Susitna River at Watana and Devil Canyon damsites and for USGS gaging station locations at Gold Creek, Sunshine and Susitna Station. Flood peak frequency for natural conditions was also estimated. Flood peak frequency analyses were made for the May-June and July-September periods and the annual series.

For the area upstream of the confluence of the Chulitna, Talkeetna and Susitna Rivers, the largest annual floods generally occur in June as a result of snowmelt and rainfall-runoff. Thus the natural May-June series floods are larger than for the July-September series. For the area downstream of the confluence the larger floods occur as a result of rainfall runoff in the July-September period and this series is larger than the May-June series. The project will delay flood peaks as a result of storage, until later in the year. Thus, with-project floods upstream of the confluence will be delayed. However, floods at Sunshine and Susitna Station will generally occur at about the same time as at present.

The following two procedures were used to estimate with project flood peaks at Devil Canyon and Gold Creek.

1. Flood hydrographs of selected recurrence intervals were estimated for Gold Creek, Devil Canyon and Watana Dam sites as described in Section 2.2. The differences between the hydrographs at Watana and Devil Canyon and between the hydrographs at Devil Canyon and Gold Creek were assumed to be contributions from the respective intervening areas during the occurrences of flood peaks at Watana. The Watana flood hydrograph was routed through the Watana reservoir and the routed outflow hydrograph added to the intervening flow hydrograph to determine the Devil Canyon and Gold Creek flows.

2. Flood hydrographs for the selected recurrence intervals were estimated for Gold Creek and for the intervening drainage area between Gold Creek and Watana. The difference between the two hydrographs was assumed to represent the inflow hydrograph to Watana during the flood of the given recurrence interval. This means that the flood would occur in the area downstream of the Watana reservoir and residual flow would be the inflow to the reservoir. It was determined that the flood peak from the intervening area would occur earlier than the maximum outflow from Watana. The Watana inflow hydrograph was routed through the reservoir and the outflow hydrograph was added to the intervening area flood hydrograph.

With-project peak flood flows for the two procedures were compared. For the May-June and Annual series floods, the second procedure generally results in greater peak flood flows for a given frequency because the Watana Reservoir is generally drawn down enough to store most flood flows from upstream. Flood peaks in the intervening area between Watana and Gold Creek are therefore significant. For July-September floods, both procedures give similar values. The second procedure was therefore adopted to define the with-project flood frequency.

For locations downstream of the confluence of the Chulitna, Talkeetna and Susitna Rivers (Sunshine and Susitna Station gaging stations) the intervening drainage areas are much larger than the intervening drainage area between Gold Creek and Watana as shown by the following table:

Drainage Areas at Various Sites

Location	Drainage Area (sq.mi)
Watana damsite	5,180
Devil Canyon damsite	5,810
Susitna River at	
a. Gold Creek	6,160
b. Sunshine	11,150
c. Susitna Station	19,400

Therefore, floods at these locations will be controlled by floods in the intervening areas. The intervening area flood peaks for these locations shown on Table E.2.4.15 were added to concurrent flows from Watana to determine the flood frequency at these sites.

Flood peaks computed by Method 2 at sites downstream of the project are the result of floods in the intervening area between the site and Watana and the concurrent Watana discharge. This is considered appropriate because of the large storage capacity of Watana Reservoir and its ability to regulate flood inflows. Method 1 allocates a greater amount of the peak flood flow to the area upstream of Watana than does Method 2 resulting in a smaller contribution from the area downstream of the dam.

Although Method 2 is considered appropriate for estimating the flood frequency, both methods have been considered in the design of certain features of the dams to ensure the safety of the features and to ensure that environmental criteria are met. These features are:

- The environmental 50-year flood surcharge pools at Watana and Devil Canyon, and

- The Watana and Devil Canyon construction diversion tunnels.

For the environmental 50-year flood surcharge pools at Watana and Devil Canyon, July-September with-project 50-year floods computed by Method 1 resulted in requirements for greater flood storage than Method 2 and were therefore adopted. For the Watana diversion tunnels, the 50-year natural Annual series flood computed by Method 1 resulted in a larger required tunnel diameter and was accepted for design. For the Devil Canyon diversion design, the 25-year, July-September with-project flood resulted in a larger tunnel diameter by one foot and was accepted for design.

- Spring Floods (**)

For the 34 years of weekly simulations, Watana Reservoir had sufficient storage capacity to absorb all floods. The largest flood of record, June 7, 1964, had a peak discharge of 90,700 cfs at Gold Creek, corresponding to a recurrence interval of about 40 years (annual series). This flood provided the largest mean monthly inflow on record at Gold Creek, 50,580 cfs, and contained the largest flood volume on record. For this flood, the simulated reservoir level increased from el. 1,850 ft to el. 1,980 ft. An additional 20 feet of storage was available before an outlet works release would have been necessary.

The flood volume for the May-June 1:50-year flood was determined to be 1.4 million acre-feet (HE 1984c). The 50-year May-June flood was routed through Watana Reservoir starting with the median May-June reservoir water level of el. 1,885. The average turbine discharge of 5,900 cfs was used. The flood was passed through the reservoir without raising the water level above el. 2,000, or requiring operation of the outlet works or spillway (see Sections 4.1.3(a)(v) and 6.4.4).

The following table gives the frequency of May-June floods at Watana, Gold Creek, Sunshine and Susitna Station.

May-June Flood Frequency

Return Period (Years)	Watana Natural	Watana With-Project	Gold Creek Natural	Gold Creek With-Project
2	39,000	5,900	42,500	19,800
5	51,500	5,900	56,200	26,800
10	60,000	5,900	66,300	30,600
25	73,800	5,900	80,500	33,900
50	84,400	5,900	92,100	37,900

Return Period (Years)	Sunshine Natural	Sunshine With-Project	Susitna Station Natural	Susitna Station With-Project
2	118,000	83,000	156,000	125,000
5	135,000	94,000	179,000	142,000
10	149,000	104,000	197,000	157,000
25	163,000	114,000	215,000	173,000
50	174,000	122,000	230,000	186,000

For spring floods greater than the 1:50-year event, it is possible that the Watana Reservoir would fill and inflow would be set equal to outflow. If this occurred, subsequent floods downstream would be unchanged from natural.

- Summer Floods (**)

During average flow and wet years, the Watana Reservoir will reach el.2,000 ft sometime in July or August. Design considerations were therefore established to ensure that the powerhouse and outlet facilities would have sufficient capacity to pass the 1:50-year summer flood without operation of the main spillway (see Sections 4.1.3(c)(v) and 6.4.4). A further decision criterion was established such that the reservoir would be allowed to surcharge to el. 2,014 ft during the 1:50 year flood. This is explained in Section 3.

The derivation of the July-September 1:50 year inflow hydrograph at Watana is given in a report (HE 1984c).

The 50-year July-September flood has a peak of 77,800 cfs and a volume of 1.14 x 10^6 acre feet. This flood was routed through Watana Reservoir assuming a median July-September water level of el. 1,994. The average powerhouse discharge of 9,200 cfs was also used. The maximum water level obtained did not exceed el. 2,014 and the spillway was not operated. The maximum outflow was 33,200 cfs, comprised of 24,000 cfs outlet works flow and 9,200 cfs powerhouse flow.

The following table gives the July-September flood frequency for Watana, Gold Creek, Sunshine and Susitna Stations.

July-September Flood Frequency

Return Period	Watana		Gold Creek	
(Years)	Natural	With-Project	Natural	With-Project
2	34,200	31,100	37,300	36,500
5	45,700	33,200	49,800	43,100
10	54,500	33,200	59,400	44,000
25	67,200	33,200	73,200	44,000
50	77,800	33,200	84,800	46,600

Return Period	Sunshine		Susitna Station	
(Years)	Natural	With-Project	Natural	With-Project
2	138,000	129,000	183,000	183,000
5	163,000	148,000	216,000	211,000
10	180,000	161,000	238,000	231,000
25	196,000	174,000	259,000	252,000
50	210,000	186,000	278,000	270,000

- Annual Floods (**)

Annual flood peaks at the project sites most frequently occur in June. The annual series 50-year flood was calculated to have a peak discharge of 89,500 cfs at Watana and a volume of 1.43 x 10^6 acre feet (HE 1984c). This flood was routed through the Watana Reservoir assuming a median June water surface level of el. 1919, and the average June powerhouse flow of 8,900 cfs. The maximum water level attained did not exceed el. 2,000. The maximum outflow was 8,900 cfs. Spillway operation was not required (see Sections 4.1.3(a)(v) and 6.4.4). The following table illustrates the annual series flood frequency at Watana, Gold Creek, Sunshine and Susitna Station computed in the same manner as for May-June and July-September values.

Annual Flood Frequency

Return Period (Years)	Watana		Gold Creek	
	Natural	With-Project	Natural	With-Project
2	43,500	8,900	48,000	25,600
5	57,400	8,900	63,300	33,300
10	67,000	8,900	73,700	37,700
25	79,800	8,900	87,300	41,600
50	89,500	8,900	97,700	46,200

Return Period (Years)	Sunshine		Susitna Station	
	Natural	With-Project	Natural	With-Project
2	143,000	109,000	189,000	163,000
5	166,000	125,000	220,000	189,000
10	183,000	137,000	242,000	208,000
25	200,000	151,000	264,000	229,000
50	214,000	163,000	283,000	248,000

The flood peaks for the July-September period are generally greater than for the May-June series and the Annual series at all stations and thus constitute the with-project flood frequency.

Under natural conditions the highest annual floods at Gold Creek generally occur in June. With-project the annual flood peaks will generally occur in the July-September period rather than June. At Sunshine and Susitna Stations the highest annual floods occur in the July-September period naturally and will continue to do so with project. The magnitude of the reduction in annual flood peaks will be greatest at the dam and reduced with distance downstream. The mean annual flood flows can be approximated by the 2-year return period flood (USDI 1974), for Watana, Gold Creek, Sunshine and Susitna Station as shown below.

	Mean Annual Flood 2-Year Return Period Natural Annual Series	With-Project (July-Sept Series)
Watana	43,500	31,100
Gold Creek	48,000	36,500
Sunshine	143,000	129,000
Susitna Station	189,000	183,000

Downstream of the confluence with the Chulitna and Talkeetna Rivers there is approximately a 10 percent reduction in the mean annual flood. Downstream of the Yentna River confluence, there is an approximate 3 percent reduction in the mean annual flood. The with-project flood frequencies are shown on Figures E.2.2.38, E.2.2.40 and E.2.7.41.

(iv) Flow Variability (**)

Under normal hydrologic conditions, flow from the Watana development will be totally regulated. The downstream flow will be controlled by the following criteria: downstream environmental flow requirements, minimum power demand, and reservoir operating rule curve. However, there can be significant variations in discharge from one season to the next and for the same month from one year to the next.

Flow variability under natural conditions is illustrated by the flow duration curves using daily recorded flow values shown on Figures E.2.2.44 and E.2.2.45.

As discussed in Section 3, with-project, the flow may be allowed to vary by ten percent above and below the mean weekly flow. The maximum variation in the mean weekly flow from one week to the next will be 20 percent.

Weekly reservoir operation simulations with E-VI flow requirements have been made to illustrate the variability in weekly average flows for five years. These are illustrated by Figures E.2.4.36 through E.2.4.40. There will also be variation in flows in one week from year to year. Figures E.2.4.44 through E.2.4.47 show the 6, 50 and 97 percent exceedance level flows for each week of the year for project operation with the E-VI flow requirements.

As discussed previously, sensitivity analyses were made with Case E-I flow requirement. Figures E.2.4.48 through E.2.4.51 illustrate the 6, 50, and 97 percent exceedence level flows for project operation with the E-I flow requirements (HE 1984h). Figures E.2.4.52 through E.2.4.56 illustrate the variability in weekly average flows for five years.

Additionally, in order to illustrate the variation in with-project flows as compared to natural variation, monthly flow duration curves have been prepared for Watana, Gold Creek, Sunshine and Susitna Station (Figures E.2.4.57 through E.2.4.60). These curves are based on monthly average with-project flows. The natural flow duration curves on these exhibits are also based on monthly average flows and not on daily values as in Figures E.2.2.44 and E.2.2.45.

The Watana flows show little variability because of the high degree of reservoir regulation and the relatively constant powerhouse flow. Flows at Gold Creek exhibits considerably more variation because of the variability in local inflow. The flow duration curves show a diminished natural and with-project difference with distance downstream from Watana.

(v) Operation of Watana Outlet Works and Fixed-Cone Valves (**)

The Watana outlet works discharge will be controlled by six 78-inch diameter fixed cone valves having capacities of approximately 5,000 cfs, each at the Watana Stage III normal maximum pool and 80 percent gate stroke. The capacities at the Stage I normal maximum pool are reduced by approximately 20 percent to 4,000 cfs. Thus, the total outflow capacity of the outlet works at normal maximum headwater el. 2,000 is 24,000 cfs. The purpose of the outlet works is to release flows to meet environmental requirements and to pass flood flows without using the spillway. As noted in Section 4.1.3(a) previously, floods up to the 50-year event can be discharged without using the spillway. Table E.2.4.16 gives information on outlet works operation from the weekly reservoir simulations. Included for each year of the 34 years of simulation are the week of first release, the week of maximum release, the maximum Watana release, the powerhouse flow at the time of maximum release, and the volume released.

As shown, the outlet works would operate in mid to late summer of almost every year. This occurs because the reservoir is simulated to have filled and it is necessary to pass flows to maintain freeboard on the dam.

Information on the downstream temperature impacts caused by the operation of the outlet works is discussed in Section 4.1.3(c)(i).

(b) River Morphology (**)

During operation of Watana Stage I, it is estimated that material influent to the reservoir larger than approximately 5 to 10 microns will settle. This is based on simulations of reservoir sediment behavior using DYRESM (see Section 4.1.3(c)(iii)). Approximately 80 percent to 90 percent of the incoming sediment is simulated to be trapped in the reservior. A second estimate of the sediment trapped in the reservoir using Brune's method (USDI 1974), using an average annual inflow of 8,000 cfs (HE 1985f Appendix D) and a reservoir water level of el. 2,000 was also carried out. This results in an estimated 98 percent of the influent sediment being trapped. The procedure is outlined in a similar analysis for the two-stage project (HE 1984a). The two methods of estimating settling characteristics were used to give estimates of suspended sediment concentrations in the reservoir and river downstream and to estimate the maximum possible sediment accumulation in the reservoir, to determine if storage capacity would be affected. The effects on river morphology would be the same for both estimates of trap efficiency, since all the bedload entering the reservoir would be trapped. The only sediment released from the reservoir would be so small that it would not settle in the river downstream and affect bed stability. Some five material may be deposited above the normal high water line and in backwater areas as occurs naturally.

The flows from the reservoir will have the tendency to pick up bed material and cause lowering of the streambed elevation (degradation). The reservoir operation will modify the discharges downstream from the dam by reducing flood peaks (Figures E.2.2.38, E.2.2.40, E.2.2.41, E.2.4.36 through E.2.4.40, and E.2.4.44 through E.2.4.47). This will reduce the ability of the river to transport bed material including those injected by the tributaries.

Because of the modification of flow and sediment load, the river would strive to adjust the stream channel and particle sizes of the bed material (Lane 1955). A number of studies

(Hey et al. 1982) have indicated coarsening of bed material under such conditions.

The potential morphological changes of the Susitna River have been addressed qualitatively by the the Applicant (Section 2.3.3., HE 1984a, and R&M 1982d). It is anticipated that the Susitna River between Devil Canyon and the confluence of the Susitna and Chulitna Rivers would tend to become more defined with a narrower channel. The main channel river pattern will strive for a tighter, better defined meander pattern within the existing banks. A trend of channel width reduction by encroachment of vegetation and sediment deposition near the banks would be expected. The tendency of the main channel to degrade and to be confined, may cause the channel to recede from the heads of some sloughs and side channels.

Potential degradation of the Susitna River for the reach between Devil Canyon and the confluence of the Susitna and Chulitna Rivers and the reach between the confluence and Cook Inlet has been addressed. The middle river was studied by the Applicant in general and at specific locations as described in Section 2.3.3. It is expected that for Stage I operation potential degradation would be on the order of 0.8 to 1.3 ft with larger degradation occurring closer to the Devil Canyon and decreasing with distance downstream. However, depending on many factors such as sediment discharge from the tributaries, bank erosion due to flow and ice and the magnitude, duration and frequency of high flows and floods which would occur during the project operation, the estimated degradation may take much longer to occur than the scheduled period of Stage I operation.

Because of the reduction in flood flow in the main river, tributary streams, including Portage Creek, Indian River, Gold Creek, and Fourth of July Creek, may extend their alluvial fans into the river. However, most of the tributaries will adjust to a new flow regime without detrimental effects to fish access, bridges or the railroad bed. Depending upon the hydraulic and sediment transport characteristics at the mouth of the tributaries, the adjustment may occur over a period of one wet season or a number of years (Trihey 1983, HE 1984a, R&M 1982f) (see Table E.2.2.43).

Near the confluence of the the Susitna, Chulitna and Talkeetna Rivers, some aggradation is expected to occur. Alluvial deposits at the mouth of the Chulitna River are expected to expand and probably encroach on the mainstem of the Susitna River, but this is not expected to severely reduce flow depth in the main river. This is because the flow in the river will be much more stable under with-project conditions than under natural conditions which would tend to stabilize the main channel gradually.

For the main river downstream from the confluence, sediment deposited near the confluence will gradually be transported downstream during floods, but the process will be slow and this reach of the river is not expected to exhibit significant change in its morphology during the relatively short period of Watana Stage I operation.

Overflow into most of the side channels and sloughs will be less frequent as high flows will be attenuated by the reservoir. The effects of backwater from the mainstem to the sloughs also will be less during spring and summer because water levels in the mainstem will be lower. Thus, there will likely be some encroachment of vegetation to the upstream reach and periphery of some sloughs.

(c) Water Quality (**)

(i) Water Temperature (**)

- Watana Reservoir (**)

After impoundment, the Watana Stage I Reservoir will exhibit the thermal characteristics of a deep glacial lake. Deep glacial lakes commonly show temperature stratification during both winter and summer (Mathews 1956, Gilbert 1973, Pharo and Carmack 1979, Gustavson 1975). Bradley Lake, Alaska, (Figure E.2.4.61) demonstrated a distinct thermocline in late July 1980, but was virtually isothermal by late September. A reverse thermocline was observed during the winter months COE 1982).

Similar thermal structures have been observed at Eklutna Lake, Alaska during 1982 and 1983 (Figures E.2.4.62 to E.2.4.64).

Reverse thermoclines during winter months are typical of deep reservoirs and lakes with ice covers as noted at Eklutna Lake and Williston Lake (Figure E.2.4.65). However, the depth of the thermocline under winter conditions is greatly influenced by meterological conditions at the time of ice-cover formation in addition to water withdrawals from under the ice cover.

The seasonal variation in temperature within the reservoir and for a distance downstream will change after impoundment. Bolke and Waddell (1975) noted in an impoundment study that the reservoir not only reduced the range in temperature but also changed the timing of the high and low temperatures. This will also occur in the Susitna River where pre-project temperatures generally range from 0°C to 14°C (32°F to 57°F) with the lows occurring from October through April and the highs in July or August. However, to minimize the natural to with-project temperature differences downstream, the Watana Stage I Reservoir multi-level intake structure (Figure E.2.4.66) will be operated to take advantage of the temperature stratification within the reservoir.

During summer, warmer reservoir water will be withdrawn from the surface. The intake nearest the surface generally will be used. In this way warmer waters will be passed downstream. In winter, the colder surface water will be withdrawn. This is expected to result in minimization of suspended sediment concentrations in the river and the coldest possible releases in the winter.

To provide quantitative predictions of the reservoir temperature behavior and outlet temperatures, hydrothermal studies of the originally proposed Watana Reservoir were undertaken in 1981 and 1982 (APA 1983a).

Results of the 1981 studies are presented in Appendix A4 of the Susitna Hydroelectric Project Feasibility Report (Acres 1982b). These studies were continued into 1982 and 1983 to further define the likely reservoir temperature structure and the temperature and ice regime downstream of the Watana and Devil Canyon Dams.

Detailed analyses were performed for Watana and Devil Canyon Reservoirs using a one-dimensional computer model, DYRESM. This model was tested satisfactorily, using data collected at Ekluta Lake during 1982 and 1983 (HE 1984i). A brief description of the DYRESM model follows.

. DYRESM Model (**)

Predictions of reservoir temperature stratification and outflow temperatures have been made using a numerical model developed by Imberger, et al. (1978). The dynamic reservoir simulation model, DYRESM, has been modified to include ice cover formation and outflow hydraulics associated with multiple level intake structures.

The following summary provides a concise and simplified description of how the model operates, the main physical processes incorporated therein, and its extension to include an ice cover. The discussion is completed by a brief description of the model.

In the formulation of the modelling strategy of DYRESM, the principal physical processes responsible for the mixing of heat and other water quality components have been parameterized. This contrasts with other simulation models which are largely empirically based. The modelling philosophy employed in DYRESM requires a reasonable understanding of the key processes controlling water quality, so that they may be parameterized correctly. This process related approach to modelling has the advantage that the resulting model may require less calibration and is more generally applicable than the empirically based methods. A second consideration in model formulation has been to keep the computational costs as low as is possible in order to keep the running costs within reason. This allows for a greater number of simulation runs to test the sensitivity of outflow temperatures to the major variables including intake operating policy and environmental flow requirements than if more time consuming models were used. This has necessitated the restriction of spatial variability to one dimension (in the vertical) and the adoption of a fundamental time increment of one day. Certain physical processes require time steps shorter than one day. In these cases the model allows for subdaily time intervals as small as one-quarter hour.

The following discussion demonstrates that the principal processes responsible for the mixing and which are two or even three-dimensional in character may be adequately parameterized and satisfactorily represented within a one-dimensional framework.

First, the reservoir or lake in question is subdivided into a series of horizontal slabs of varying thicknesses, volumes and cross-sectional areas in accordance with the prescribed reservoir geometry. The number of layers is allowed to vary as required to represent the vertical distribution of heat and salt to within a specified accuracy. The uppermost layer may be thought of as corresponding to the lake's surface layer or epilimnion with its base being located at the thermocline depth and its top at the lake surface. This layer is the most important as it receives the direct input of atmospheric forcing and is usually associated with the largest gradients in water quality properties. As discussed later this layer receives special attention in the model compared to other layers. Within each layer the variables are considered to be uniform. Heat in the form of solar radiation is input to each layer according to the physics of absorption of short wave radiation (Beer's Law).

The transfer of heat between all the layers (other than the upper two layers) is determined by the vertical turbulent fluxes as specified by the turbulent eddy diffusivity and the differences in properties between the layers. The value of the vertical diffusivity is not set empirically but follows the energy arguments of Ozmidov. In this way the vertical mixing process responds to changes in the level of energy available for mixing caused by storms (wind stirring) and also by the potential energy released from inflowing rivers. In addition, this internal mixing formulation includes the inhibiting effect of local stratification rates on the mixing process.

Experience has shown that it is necessary to consider the individual processes controlling the mixing in the uppermost layer, known as the upper mixed layer, in a more detailed manner than in the deeper layers. These processes are wind stirring, convective cooling, the shear across the base of the mixed layer, the stabilizing effects of the absorption of short wave radiation and the density gradient at the base of the layer. The method involves the consideration of three conservation equations within the layer: the conservation of heat, salt and turbulent kinetic energy. Solution of these equations provides an estimate of the energy available for mixing the upper layer with lower layers. One unique feature of this upper mixed layer formulation is that it allows for the influence of strong internal motions, known as seiches, on the mixing and deepening of the upper layer to be taken into account.

A brief explanation of wind generation of these internal motions or seiches provides an example of how a two and three-dimensional process occurring in a reservoir is treated within the context of a one-dimensional model. When the wind starts to blow along the longitudinal axis of the lake that is initially at rest, the shearing motion at the base of the upper layer is considered to grow at a constant rate until either the wind ceases or reverses in direction, a period of time equal to one quarter the period of the natural seiche has elapsed, or the earth undergoes a period of revolution on its axis. When any one of these limits is attained the shear is set to zero and the build-up of internal motion recommences. Not only does the shear influence the deepening of the thermocline or the upper layer thickness but also the shear may destabilize the stratification. In this latter case the temperature profile is then smoothed to the point where it remains stable with respect to shearing motion of the wind forced seiche.

Another two-dimensional process is the river inflow dynamics. If the river water is lighter than the uppermost layer of the lake it forms a new upper layer over the old one which may ultimately be amalgamated into the former upper layer. Conversely, for an underflowing river an entrainment coefficient for the incorporation of the surrounding lake water into the descending river plume is computed from the river discharge, the density constrast between lake and river water, the slope of the bottom and the geometry of the river bed. The volumes of the layers are then decremented according to the computed daily entrainment volumes at the same time as the inflowing river water is diluted by lake water until it either reaches the deepest layer or the dam. Another possibility is that the density of the plunging river plume may be reduced to that of the adjacent layer density whereupon the inflow begins to intrude into the main body of the reservoir. Whether this intrusion process is dominated by viscous-buoyancy forces or by an inertia-bouyancy balance is determined by the computation of a non-dimensional parameter depending on the discharge, the local density gradient and the mixing strength at the level of insertion. This parameter then sets the overall thickness of the inflow and therefore how the inflowing volume is subdivided among the existing layers surrounding the inflowing depth.

Similarly, outflows at a surface level and up to two subsurface levels are governed by the same parameter which determines the amounts to be withdrawn for each of the layers in the vicinity of the outflow points. To illustrate how this may work in practice, it is useful to consider two extreme cases. In one case the outflow volume is large relative to the stabilizing effect of the ambient stratification (inertia-bouyancy balance) and the outflow is withdrawn nearly uniformly from all the layers. In the second case, when a weak outflow occurs (viscous-bouyancy balance), the density gradient severely confines the vertical range of outflow layers to those in the immediate vicinity of the offtake.

The model has been extended to include the influence of ice and snow cover, and suspended ice concentration in the inflowing rivers. The conduction of heat and the penetration of solar radiation across a composite of two layers, one composed of snow and the other of ice, is computed from their physical properties, namely, thermal conductivities, extinction coefficients for solar radiation and densities, and from the energy transfers at the surface with the atmosphere. Components of the surface energy budget, as in the case of an ice-free surface, are the incoming and outgoing longwave radiation, solar radiation, the sensible heat transfer and latent heat exchanges. Several cases may be distinguished. If more heat flows upward through the ice than can be supplied by the turbulent and molecular transfers of heat from the water to the ice, ice is created and added to the existing ice cover. Conversely, the ablation of ice at the base of the ice sheet occurs when an excess of heat is present. Similarly the snow or upper surface of the ice as the case may be is melted when sufficient heat is present to elevate the surface temperature above the freezing point.

An additional physical process incorporated in the model with ice cover is an allowance for partial ice cover either during the freeze-up or break-up period. Partial ice cover accounts for the wind action in dispersing thin sheets that might be formed and is based on an assumed minimum ice thickness of 10 cm. Furthermore, the thickness of the snow cover on the ice is limited by the supporting bouyancy force associated with a given thickness and density of ice. Finally the amount of solar radiation transmitted through the snow layer depends on the thickness, age and temperature of the snow cover. Frazil ice input from the inflowing rivers is either used to cool the upper layers if an ice cover is not present or is added to the fraction of partial ice cover or to the thickness of the full ice cover.

A more detailed discussion of DYRESM is provided in Imberger and Patterson (1980).

. Testing of DYRESM model (Eklutna Lake Study) (**)

The DYRESM program has been used extensively in Australia and Canada to predict hydrothermal characteristics within lakes and reservoirs. To test DYRESM in predicting the thermal structure in glacially fed reservoirs, a data collection program was established in 1982 to obtain data on the thermal structure of Eklutna Lake located approximately 30 miles north of Anchorage, Alaska. A weather station was also established to provide the necessary meterological input to DYRESM.

Detailed daily simulations were made of Eklutna Lake from June 1 to December 31, 1982 for the 1983 License Application (APA 1983a) and from June 1, 1982 to May 31, 1983 for the studies made after submittal of the License Application (HE 1984i). These established the adequacy of the DYRESM model.

Simulated and measured vertical temperature profiles at a station in the approximate center of the lake are given in Figures E.2.4.62 through E.2.4.64 for the more recent study. In general, most profiles are modeled to within 0.5°C (1°F). This is well within the observed variation of temperature at the data collection stations throughout the lake (R&M 1982i). Deviations in measured and simulated profiles can be explained through an assessment of the meteorological variables used and the reliability of the measurement of these variables. However, even with errors due to estimating weather data from sources other than that of the station at Eklutna Lake, the temperature profiles are reasonably well modeled.

Outflow temperatures from Eklutna Lake for the period June 1982 through May 1983 are presented in Figures E.2.4.67 and E.2.4.68. In general, for the entire simulated period of June 1982 through May 1983, simulated and measured outflow temperatures show excellent agreement. Deviations of up to 2.8°C occur between measured and simulated temperatures in late June and early July, 1982. This is believed to be the combined result of the approximate nature of the initial condition specified at the beginning (June 1, 1982) of the simulation, and, possibly underestimation of wind speed.

The simulated vertical temperature profiles in the reservoir for June 18, July 14, August 11, September 9, September 21, October 14 and November 4, 1982 indicate reasonable agreement with measured profiles (Figures E.2.4.62 through E.2.4.64). This indicates that although average meteorological conditions over the entire period were suitably measured, conditions on a daily basis may be in error. Wind speed, in particular, would have the major influence since an overestimation of wind speed would result in deepening of the epilimnion which would result in warmer outflow temperatures in summer.

Field observations in the winter of 1982-1983 and 1983-1984 indicate that the ice cover formation on Eklutna Lake would begin during the latter part of November with a full ice cover formed by mid-December. In the 1982-1983 ice season, DYRESM estimated ice cover formation to begin on December 2, with a full ice cover on December 20. Measurements made on January 11 and 13, 1983 and February 18, 1983 indicate an ice cover thickness of 13 to 18 inches and 21 to 25 inches respectively. This compares favorably with a predicted ice thickness of 16.5 and 21.7 inches respectively.

The study of Eklutna Lake as described above, has demonstrated the ability of the DYRESM model to predict the hydrothermal condition of a glacial lake under Alaskan meteorological and hydrological conditions.

- Watana Stage I Reservoir Modeling (**)

Detailed daily simulations of the reservoir dynamics and thermal stratification in the Watana Stage I Reservoir were made using the DYRESM model for Case E-VI downstream flow requirements. Meteorological data collected at the Watana camp from May 1981 through October 1983 were used as input to the model as well as the river flows for the same period. The reservoir outflows used in the simulation were obtained from a weekly reservoir operation study conducted for Case E-VI environmental flow requirements. The multi-level (5-level) intake, shown in Figure E.2.4.66, was also incorporated in the simulations. Predicted temperature profiles for the first day of each month from May 1981 through October 1982 are illustrated in Figures E.2.4.69 through E.2.4.74.

- Reservoir Temperature Structure (***)

The temperature structure at Watana follows the typical pattern for reservoirs and lakes of similar size and climatic conditions. In general, stratification occurs in summer (June, July, August, and September) with a warm layer near the surface. The temperature near the surface would be about 45°F to 55°F (7°C to 13°C) the thickness of the warm surface layer would be about 80 to 210 feet depending upon weather conditions. Temporary thermoclines would also form from time to time in this layer. At times a temporary thermocline can have an appearance of an ordinary thermocline. The thickness of the underlying metalimnion would vary from about 60 to 180 feet. The approximate 39°F (4°C) hypolimnion would be located below a depth of about 200 to 300 feet.

The near isothermal condition at approximately 39°F (4°C) would occur twice a year in early November and late May. The Watana Stage I Reservoir would be dimictic in that it would mix twice a year. Mixing would occur between ice-cover meltout and the onset of the thermal stratification in late spring and between the breakdown of the thermal stratification in the fall and the onset of winter ice-cover.

The fall overturn and winter ice-cover would occur following the summer of filling. With the air temperature and insolation decreasing rapidly in October and November, mixing and further cooling would continue until the surface of the reservoir freezes. The presence of ice-cover would prevent further wind mixing and conserve the heat remaining in the reservoir. In general, for both reservoirs, the ice-cover would form in November, a total meltout would occur in May, and a total ice thickness of two to five feet can be expected.

The formation of an ice-cover in the relatively long subarctic winter would cause an inverse stratification in the reservoir to occur. The water at the contact surface with the ice would be near 0°C and the temperature would increase with depth toward a maximum of approximately 4°C at a depth of about 250 to 350 feet from the surface depending upon the weather conditions in the period between the fall overturn and the formation of ice-cover in the reservoir. The near isothermal condition of 39°F (4°C) would then be maintained in the hypolimnion.

Similar hydrothermal characteristics were also obtained in the early simulations of the originally proposed Watana Reservoir.

. Multi-Level Intake Operating Policy (***)

The Stage I multi-level intake at Watana provides the project ability to selectively withdraw water from various levels of the stratified Watana Stage I Reservoir. The Watana Stage I Reservoir can, therefore, be operated:

- To discharge water at temperatures as close to natural river temperatures as possible (i.e., maintain inflow temperatures);
- To discharge near surface water only;
- To discharge water at a pre-determined level.

For the simulations of with-project temperatures presented here, the policy of "inflowing temperature matching" was used. That is, the level of the intake being closest in water temperature to the reservoir inflow was used. This is the same policy as used in the 1983 License Application and generally means the intake level immediately below the reservoir water surface is opened. There are short periods during spring and fall when the reservoir is not strongly stratified when other levels may be used. This policy generally results in the warmest water possible being released in the summer and the coldest possible in the winter. By using the intake nearest the surface in the winter, the water having the lowest suspended sediment concentration and hence lowest turbidity is expected to be withdrawn, thus minimizing potential project effects on turbidity. As discussed later, the intake could be operated to take warmer water in the winter to minimize ice cover formation (discussed in Section 4.1.3(c)ii). However, this would result in higher downstream suspended sediment concentrations and turbidity.

. Outflow Temperatures (***)

The predicted outflow temperatures immediately downstream from the Watana Stage I Dam for the period from May 1981 to October 1982 are given in Figures E.2.4.75 and E.2.4.76.

The Stage I intake ports are located at five levels, and the discharge temperatures can be controlled to approximate the natural instream temperatures. The discharge temperatures would range from approximately 41°F (5°C) to 54°F (12°C) in the summer and approximately 33°F (0.5°C) to 37°F (3°C) in the winter depending on the meteorological condition, and energy demand level. In the summer, the inflows are more responsive to variations in the meteorological conditions than the reservoir due to the shallowness of the river. The river inflow warms up in the early summer and cools down in the late summer more rapidly than does the reservoir. Hence, the reservoir discharge water would be colder in the early summer and warmer in the early fall than the natural river conditions. However, in most of the summer months the discharge temperatures could be regulated to approximate inflow temperatures. In the winter, inflow temperatures would be near 32°F (0°C) and the temperatures in the inverse stratification zone would range from near 32°F (0°C) at the contact face with the ice-cover to approximately 39°F (4°C) at the hypolimnion. Therefore, the discharge temperatures would be slightly warmer during the winter than under natural conditions.

As shown in Figure E.2.4.75, the outlet works intake which is located near the second port level from the top was operated in August and September, 1981. The outlet works intake is closer to the water level in Stage I than in Stage III resulting in warmer outlet works discharges than for Stage III. As shown in the river temperature simulations in the following section, this results in downstream temperatures being closer to natural than in Stage III.

In June and July, 1981, the inflow temperature varies from 6°C to 12°C and the DYRESM simulation indicates that the outflow temperature can be controlled to vary from 7°C to 11°C. In August 1981, the outlet works were discharging water with a flow of up to 24,000 cfs and the powerhouse turbines were discharging at about 40% of the outlet works flow using the lowest level of the intake ports. In about two weeks starting at the beginning of August, the inflow river temperature dropped from 11°C to 5°C while the outflow temperature could be reduced from 11°C to 8°C. This clearly shows that when the outlet works are operating at high flows, powerhouse intake operation has a diminished effect on outflow temperatures. A similar conclusion can be drawn from other DYRESM simulations with other different weather and mainstem inflow conditions (APA 1984a Appendix IV).

. Sensitivity Studies (***)

Prior to the Applicant's refinement of the flow requirements and adoption of Case E-VI as its preferred alternative, sensitivity studies were carried out using the Case C flow requirements. The purpose of these studies was to provide information on the effects of multi-level intake operating policies on downstream temperatures. The conclusions from these studies are not affected by the flow regime. The study indicates that operation of the intake structure in the previous summer as well as in the winter can affect the winter release temperature. The effects of these variations in multi-level intake operating policies on open water river temperatures and ice conditions are discussed in the following sections on river temperatures and ice conditions.

An example of how summer intake operation can affect winter temperatures is the case where higher than usual releases of near surface warmer water in summer and fall may induce early formation of ice cover in winter. This may prevent wind induced mixing and further cooling of water underneath the ice cover. Thus, the winter releases may be slightly warmer than if summer releases had been less.

- Watana To Talkeetna (**)

. Mainstem (**)

The Watana outflow temperatures, which were simulated using DYRESM, were used to determine the water temperatures in the reach between Watana and Talkeetna. The discharge and outflow temperatures from Watana were input to the program SNTEMP described in other reports by the

Applicant (AEIDC 1983, 1984a, 1984b, 1984c, 1985a).

River temperatures were simulated on an average weekly basis. Daily temperatures output from DYRESM were averaged and used in the weekly simulations along with average weekly discharges output from the reservoir operation results presented in 4.1.3(a).

Temperature simulations using SNTEMP were carried out for open water reaches of the river between the dams and the Sunshine stream gaging station (RM 84). In summer, the entire reach was simulated. In winter, only the reach from the dams to the location of 0°C was simulated. For the three stage project only the period May 1981 through September 1982 was simulated. This represents a wet summer followed by an average temperature winter followed by an average flow summer. The selection of cases for simulation is discussed in the Applicant's replies to the FERC's Request for Supplemental Information of April 12, 1983 Schedule B, Exhibit E No's 2.28 and 2.41.

Simulations for the three stage project were limited to the cases discussed above, in order to show the similarity between simulated temperatures for the original two stage and the proposed three stage project. Because the simulated temperatures for the three-stage project are similar to those for the two-stage project the simulations which have been made for the two stage project (APA 1984a Appendix V, HE 1985f Appendices H and I) may be used to determine the sensitivity of the river temperatures to various other hydrologic and meteorologic conditions. Simulations are also presented in other reports (AEIDC 1983, 1984a, 1984b, 1984c, 1985a).

The results of the simulations are presented on Figures E.2.4.77 through E.2.4.79 and on Tables E.2.4.17 and E.2.4.18. The figures indicate that the summer river temperatures for Watana Stage I at river miles 150, 130 and 100 are all similar to the temperatures for the same energy demand for the original two-stage project. Winter open water temperatures are somewhat colder and this is reflected in the ice simulations discussed later.

Summer with-project river temperatures exhibit a lag behind natural conditions of approximately 2 weeks. Simulated temperatures for natural conditions are shown on Tables E.2.4.21 and E.2.4.22. Simulated with-project temperatures at river mile 130 are generally near 4°C in early May, peak at near 10°C in late June through early August and decrease to 0°C by mid-November. In wet years the reservoir fills by early July and thus the outlet works must be operated to pass flow. Because the outlet works draw from a slightly lower elevation in the reservoir , its flows are generally cooler. This causes the drop in river temperatures in July in the 1981 simulation and the smaller drop in the 1982 simulation.

The temperature of the mainstem will remain above 0°C longer into the winter then natural because of the warmer outflows from the project. The temperature in the spring will warm up above 0°C sooner for the same reason. Between the upstream end of the ice cover and the dams the river temperature will generally be between 0°C and 2°C to 3°C, whereas the natural temperature in this reach is 0°C.

The mean annual temperature (time weighted) in the river at mile 130 has been calculated for simulations of natural conditions to be 3.7°C for the period 5/81-4/82 and 4.0°C for with-project conditions. Simulation of natural and with-project conditions for other hydrological and meteorological conditions and other environmental flow requirements confirmed that the mean annual with-project temperature is generally similar to the natural conditions.

Figures E.2.4.80 through E.2.4.83 show simulations of temperatures for other hydrological and meteorologic conditions for the two stage project (APA 1984a Appendix V). As noted previously, these are considered accurate for the three stage project.

The simulations discussed above have all been carried out using the policy of withdrawing water from the reservoir which has as close a temperature to natural as possible. This policy is known as "inflow temperature matching." Additional simulations have been carried out to determine whether other policies of multi-level intake operation would significantly affect temperatures. The policies considered were:

- o warmest water - draw warmest water from the reservoir all year using the proposed multi-level intake

- o lowest level - use lowest level of proposed intake in summer and winter

- o warmest water with other possible intakes at el. 1,636 and el. 1,800 - draw warmest water from the reservoir all year but with the addition of intakes at el. 1,636 and el. 1,800.

These simulations were carried out for the Case C flow regime and the first stage of the two stage project prior to the Applicant's development and adoption of the Case E-VI flow requirements. The purpose of these simulations was to provide an insight into operation of the multi-level intake and the results are not affected by the change in flow requirements. While the simulated temperatures may not represent expected conditions for Stage I, the differences in temperatures represent the differences which may be expected with different multi-level operating policies. Simulations were initiated by DYRESM simulations using the appropriate intake operating policy.

The "warmest water" policy with the existing intake generally means using the level of the multi-level intake immediately below the water level in the summer and fall between May and November. When the reservoir becomes isothermal in November this policy would require changing to the lowest level of the multi-level intakes to obtain the warmest water in winter. This policy would have the effect of giving the warmest possible summer temperatures and moving the ice front downstream the furthest in the winter. The incorporation of intakes at lower levels in the reservoir (i.e. el. 1,636 and el. 1,800 would allow for potentially drawing warmer water from the reservoir in the winter, however, this might have other effects on water quality downstream, such as increased suspended sediment and turbidity and decreased dissolved oxygen. Additionally, drawing warmer water from the reservoir in the winter might reduce the heat available in the reservoir for summer outflows. The "lowest level" policy is designed to withdraw the coldest water possible from the reservoir in the summer, thus preserving heat in the reservoir for winter. This would allow the warmest possible winter outflows moving the ice cover further downstream.

The results of these analyses are shown on Figures E.2.4.84 to E.2.4.86. The effect on summer river temperatures at RM 130 of the various operating policies is minimal. The policy of using the lowest level of the existing intake results in the greatest temperature differences in June and July of a wet year (1981). However, temperatures in an average year (1982) are similar to other policies. The "warmest water" policy is similar to the "inflow matching" policy in wet (1981) years and 1°C to 2°C warmer than "inflow matching" in July and August of an average year. The inclusion of intakes at el. 1,636 and el. 1,800 does not appear to affect summer temperatures. Temperatures in May and September do not seem to be very sensitive to any multi-level intake operating policy.

The 1971 simulation was included because the winter of 1971-72 was the coldest on record and was used for winter ice simulations (APA 1984a, Appendix 8). The sensitivity of ice simulations to the operating policy for this winter was also checked and is discussed in the section on ice conditions.

Additional simulations were made to determine the effect on summer river temperatures of a different environmental flow requirement. Case E-I described in a report by the Applicant (HE 1985f) was used for this simulation. The results of this simulation are presented on Figures E.2.4.87 through E.2.4.89 and on Tables E.2.4.19 and E.2.4.20. The results indicate that for Stage I the temperatures at RM 130 for both sets of flow requirements are similar. The differences between the two are generally within 0.2°C.

- Sloughs and Peripheral Habitat (**)

Slough and side channel surface water temperatures are generally dependent on the temperature of groundwater upwelling, climate conditions and the temperature of mainstem flow when the upstream berm is overtopped. Since the frequency of overtopping of the upstream berm will be reduced due to lower summer flows the slough and side channel surface water temperature will be more often solely a function of groundwater temperatures and climate. It has been determined that the temperature of the groundwater component of slough flow is generally equal to the mean annual (time weighted) temperature of the river. Since this will not change significantly, with-project, the only change in surface water temperatures in sloughs and side channels will be a function of the frequency of overtopping of the upstream berm.

When habitat areas in sloughs and side channels are not overtopped in summer their surface water temperatures are generally less than the mainstem reflecting the groundwater temperature and the climatic conditions. Therefore, a reduction in overtopping of habitat berms will generally cause slough surface water temperature in summer to be somewhat lower, on the average, than natural conditions, but higher than the groundwater temperature. The variation in surface water temperature resulting from intermittent overtopping of the berms will be reduced. Side channels will be affected less than sloughs because summer discharges with project will keep most side channel areas overtopped.

Surface water temperatures in tributary habitat areas are generally a function of tributary temperature and will not be affected by the project. The extent of the effect of the tributary temperature on the mainstem may change as a result of decreased summer mainstem flows.

Intergravel temperatures in sloughs and side channels are generally between 3°C and 5°C and appear to be related to the mean annual mainstem temperature. In some areas the intergravel temperature may be more directly related to mainstem temperature such as at a site in Lower Slough 8A. Since the mean annual mainstem temperature is not expected to change significantly, the intergravel temperature in sloughs and side channels is expected to remain the same.

- Talkeetna to Cook Inlet (**)

During summer, temperatures downstream of the confluence will reflect the temperatures of the Talkeetna and Chulitna Rivers in addition to the middle reach of the Susitna River. Since summer flows from the middle reach will be less than natural the Chulitna and Talkeetna Rivers will have a greater influence on mainstem temperatures in this reach than for natural conditions.

Because the Talkeetna and Chulitna Rivers are generally colder than the Susitna, the mainstem temperatures would be colder than natural. Simulated average weekly temperatures at Sunshine with-project can be compared to simulated natural temperatures in Exhibits Q and P of a report by the Applicant (APA 1984a, Appendix V). With project temperatures are generally between 0.5°C and 1°C less than natural in May to mid June, up to 0.5°C less than natural in July and early August and up to 0.5°C warmer than natural from mid August through September. In the fall and early winter the middle Susitna river flows will be greater than natural and will have greater influences on temperatures downstream of the confluence. This will result in downstream temperatures being slightly above natural until early to mid October. Cold climatic conditions will cause temperatures after this time to be at 0°C, the same as natural. In April and early May, warmer outflows from the reservoir may reach the confluence after the ice cover melts out. Thus, early spring temperatures may also be up to 2°C warmer than natural. This difference diminishes with time and by mid May, temperatures will be similar to natural.

(ii) Ice (**)

- Watana Reservoir Stage I (**)

As described in Section 4.1.3(c)(i), the DYRESM model was used to simulate the reservoir ice cover during operation of Watana Stage I. Based on the winter weather conditions of 1981-82 (average winter), and the Case E-VI and E-I downstream flow requirements the reservoir ice cover would form in early December and would grow to a maximum thickness of 4.5 feet by March. The ice cover would begin to melt in mid April and would be fully melted by late May. Reservoir temperature simulations presented in several other documents also include simulations of reservoir ice cover (see HE 1985f Appendices H and I, APA 1984a Appendix IV). In general, the ice cover can be expected to form in mid November to early December, grow to between 3 and 5 feet thick and melt out by early May to early June, depending on climate.

- Watana to Talkeetna (**)

River ice conditions between Watana and Talkeetna during operation of the Watana Stage I development were simulated with the ICECAL river ice model. Calibration of the ICECAL model and its application to the Susitna River upstream of Talkeetna have been documented (HE 1984e, 1984f, 1985f Appendices G, H and I). ICECAL provides a daily summary of hydraulic and ice conditions within the study reach from November 1 through April 30. The primary objective of the ICECAL model is to simulate the timing and magnitude of river stage fluctuations resulting from ice processes. Features and conditions of the model include the following:

- o Hydraulic profiles from the damsite to Talkeetna are computed daily on the basis of the Bernoulli equation and the Manning formula. Computations include the effects of river ice on water levels, where appropriate.

- o Water temperatures in the ice free reaches downstream of the reservoir are provided by the SNTEMP stream temperature model, as discussed in Section 4.1.3 c(i). Within ice covered reaches, the water temperatures are computed by ICECAL.

- Frazil ice generation is computed for reaches of 0°C open water.
- Border ice growth is computed in reaches of 0°C water based on Susitna River observations.
- Progression and thickening of a slush ice cover upstream of Talkeetna are computed based on hydraulic conditions at the ice front and the supply of frazil ice.
- Growth of solid ice within the slush ice cover is computed.
- Melting of the ice cover and retreat of the ice front are computed when relatively warm (above 0°C) water reaches the ice cover.

River ice model results during Stage I Watana operation are show in Figure E.2.4.90 based on the average winter weather conditions of 1981-82, and the Case E-VI flow requirements. For these conditions, frazil ice generation would begin where stream temperatures have cooled to 0°C, typically 35 to 65 miles downstream of the dam (RM 150 to 120) and would vary with daily weather conditions and reservoir release temperatures. Ice cover progression upstream of Talkeetna is expected to begin in mid-December, approximately 3 weeks later than for natural conditions. Progression of the ice cover would reach a maximum extent near RM 140 in late January. Maximum expected ice cover thicknesses range from 3 feet to 9 feet along the river, and are not unlike those of natural conditions. Maximum river stages within the ice-covered reach (downstream of RM 140) would often be 2 to 6 feet higher than those of natural conditions and a greater number of sloughs would be overtopped in this reach if the mitigation measure of berm construction (see Section 6.4.5) were not implemented. Upstream of the ice cover, the river would remain open with some border ice and anchor ice expected within approximately 10 miles upstream of the cover. During relatively cold periods a greater length of river would have border and anchor ice than in a warmer period. Maximum river stages upstream of the ice cover would be equivalent to or lower than those of natural conditions.

The ice cover upstream of Talkeetna is expected to substantially melt in place by the end of April. Mechanical break-up of the ice cover, which occurs during natural spring flow increases and results in ice jams and slough overtoppings, is expected to be substantially reduced or eliminated upstream of Talkeetna with Watana Stage I operating.

The effects of other winter weather conditions on simulated river ice results were examined in the Instream Ice Simulation Study (HE 1984f)and in the Case E-VI Alternative Flow Regime Report (HE 1985f Appendix I). Although these weather sensitivity simulations were not based on Watana Stage I operating, the general trends of the results are believed applicable. Therefore, with a cold winter such as that of 1971-72, the ice front progression upstream of Talkeetna is expected to begin several weeks earlier and would extend a few miles further upstream than with the average winter of 1981-82. Maximum ice cover thicknesses and river stages during the cold winter, particularly near the upstream end of the ice-covered reach, are likely to be several feet greater than those of the average winter. A very warm winter such as that of 1976-77 (HE 1985f, Appendix I) would be expected to reduce the maximum ice front by several miles relative to that of the average winter, and would typically reduce the maximum river stages and ice thicknesses by 2 to 3 feet.

The effects on river ice of alternative multi-level power intake designs and alternative power intake operating policies have also been simulated with the ICECAL model for Watana operating alone. These sensitivity simulations were not based on Stage I Watana Stage I, but the general trends of the results are believed applicable.

The alternative power intake operating policies considered include "inflow-matching" (Section 4.1.3 c[i]) "warmest water" and "lowest port". "Inflow-matching" is the policy assumed for the previously discussed ICECAL simulations and represents a year-round attempt to match the reservoir release temperatures with the natural river temperatures entering the reservoir. It also mimimizes the downstream suspended sediment and turbidity levels in the winter (See Section 6.4.7) The "warmest water" policy represents a year-round policy of releasing the warmest water available to the power intakes. The "lowest port" policy means that the lowest port of the multi-level intake is operated year-round regardless of water temperatues.

Relative to the "inflow-matching" operating policy, the "warmest water" and "lowest port" policies may tend to reduce somewhat the ice cover extent and the maximum ice thicknesses, and may result in fewer slough overtoppings during Watana operation. This trend, however, did not hold for all the sensitivity simulations and should not be counted on as a general rule for Stage I operation.

Simulations of the alternative power intake designs focused on the effects of providing an additional low level intake port (port levels are described in Section 4.1.3(c)i Water Temperature, Watana to Talkeetna, Mainstem). Results showed that provision and use of the lower ports generally tends to reduce the ice front progression and the corresponding river stages near the upstream extent of the ice cover. However, substantial reductions in river ice conditions may require lowering of the bottom intake port by several hundred feet, and other potential negative environmental effects may be associated with releases from such great depths.

To determine the sensitivity of river ice conditions to alternative flow requirements, river ice simulations of Watana Stage I operation with the Case E-I flow requirements have been performed. Results for Cases E-I and E-VI are compared in Figure E.2.4.91 based on 1981-82 weather conditions. Based on these simulation results, the ice front progression, maximum cover thicknesses, maximum river stages and slough overtoppings with Case E-I are expected to be generally similar to those discussed above for Case E-VI, although maximum river stages between RM 112 and RM 120 may be a few feet higher with Case E-I than for Case E-VI.

- Talkeetna to Cook Inlet (**)

With operation of Watana Stage I, initial ice cover formation near Cook Inlet is expected to occur with similar timing as for natural conditions. Progression of the ice cover is expected to be slower than natural due to reduced ice contributions from the middle reach, and arrival of the ice front at Talkeetna would be several weeks later than natural. With Watana Stage I operating, maximum ice-induced river stages between Talkeetna and Cook Inlet will be somewhat higher than natural conditions due to the increased flows. Project-induced stage increases in this reach are expected to be less than those upstream of Talkeetna due to the incoming flows from the Chulitna, Talkeetna and Yentna rivers which would not be affected by the project.

- Sloughs and Peripheral Habitat Areas (**)

With the staging that accompanies the natural ice formation process some sloughs are overtopped (Section 2.3.2[a]). With Watana operation, the higher discharge at freeze-up will lead to a higher stage than under natural conditions, as discussed above. Consequently, discharge will be increased through those sloughs currently overtopped if mitigation measures are not taken (See Section 6.4.5). Table E.2.4.23 summarizes information on overtopping of sloughs and side channels under natural and with-project conditions for Case E-VI flow requirements. The same information is presented in Table E.2.4.24 for Case E-I flow requirements as a sensitivity test. Results for both E-VI and E-I are similar. The tables show the occurrences of slough overtopping for natural berm elevations. Where the slough berms are elevated, overtopping would not be expected.

Increased water levels may result in flow in sloughs not currently overtopped if mitigation measures were not implemented. These higher discharges may cause scouring in the sloughs. However, because of the increased backwater at the slough mouths due to mainstem staging, velocities at the downstream ends of the sloughs should be reduced, thereby reducing the chances of scouring in the lower reaches of the sloughs. Velocities upstream of the backwater effects may be as high as

3 fps under the ice cover and may cause erosion of finer material such as sands or small gravel. The bed material in the sloughs becomes coarser with distance upstream and is more resistant to the flow.

The important salmon spawning sloughs upstream of Talkeetna will be protected by the construction of elevated berms at the upstream ends of those sloughs if ice effects are anticipated. Thus, overtopping of protected sloughs during the ice formation period will not occur. A maintenance program for the sloughs is presented in Chapter 3.

(iii) Suspended Sediments (**)

The concentration and distribution of suspended sediment in the Watana Stage I Reservoir and in the downstream river is an important water quality parameter affecting fishery resources. Two other water quality parameters, turbidity and vertical illumination, are related to the concentration and size of suspended material. Additionally, the settling of material in the reservoir may affect the storage capacity and thus, the energy production of the project. Therefore, refined analyses were made using two methods to estimate the concentration, distribution and size of material suspended in the reservoir and its outflows, and to estimate the amount of material which, over time, could settle in the reservoir. The first of these analyses was made by extending the capabiltiy of the DYRESM model (see Section 4.1.3(c)i), testing it to Eklutna Lake and applying it to Watana. The second analysis was made using generalized trap efficiency estimates.

In general, when the Susitna River enters the Watana Reservoir, the river velocity will decrease, and the larger diameter suspended sediments will settle and form a delta at the upstream end of the reservoir. The delta formation will adjust to the changing reservoir water level. Some sediment will pass through channels in the delta to be deposited further downstream in the reservoir. Depending on the relative densities of the reservoir water and the river water, the river water containing the finer unsettled suspended sediments will either enter the reservoir as an overflow, interflow, or underflow. This is further explained in Section 4.1.3(c)i in the explanation of the DYRESM model.

To estimate the maximum amount of sediment deposition in the reservoir affecting storage capacity, generalized trap efficiency envelope curves developed by Brune (1953) were used. These indicate that 90-100 percent of the incoming sediment would be trapped in a reservoir the size of Watana.

The results of the analysis using Brune's curves indicate sediment deposition will not affect the operation of Watana Stage I. A conservative assumption of a 100 percent trap efficiency was used to estimate the amount of time to fill the reservoir with sediment.

The sediment deposited over the short operating period of Watana Stage I would be about 25,000 acre-feet, or less than two percent of the dead storage volume. The results also showed the deposition of 410,000 acre-feet of sediment after 100 years (HE 1984a). The 100-year deposit is approximately 22 percent of the Stage I dead storage volume or 10 percent of the total Stage I volume.

Sedimentation studies at glacial lakes indicate that the Brune curve may overestimate sediment deposition and would thus provide a conservatively high estimate of storage lost due to deposition. These studies have shown that fine glacial sediment (flour) may pass through the reservoir. Lakes immediately below glaciers have been reported to have trap efficiencies of 70-75 percent. Kamloops Lake, British Columbia, a deep glacial lake on the Thompson River, retains an estimated 66 percent of the incoming sediment (Pharo and Carmack 1979). Kluane Lake, Yukon Territory, a deep glacial lake on the Slims River, retains an estimated 90 to 100 percent of its suspended sediment inflow (Byron 1974a, 1974b, 1974c, Fahnesstock 1974, Barnett 1974).

Because the Brune curves may overestimate suspended sediment settling in the reservoir the DYRESM model was extended. The extended model includes the simulation of suspended sediment in the reservoir in order to refine the estimates of suspended sediment concentration and turbidity. This version of the DYRESM model was tested using suspended sediment data collected at the Eklutna Lake (R&M 1985f) from November 1983 to October 1984. Good agreements on outflow suspended sediment concentration were obtained. The following sections describe the model, the testing on Eklutna Lake and the application to Watana Stage I.

- DYRESM Model (***)

  The ice-covered version of the dynamic water quality simulation model, DYRESM, was extended to include the modeling of horizontally averaged profiles of suspended sediment. A number of key processes are modeled as follows:

  - o meteorological forcing,
  - o turbulent mixing,
  - o suspended sediment induced vertical mixing, and
  - o winter ice cover and reduced vertical mixing.

  The model uses daily time steps as explained in Section 4.1.3(c)(i) and vertical settling velocities are specified externally. As with temperature and total dissolved solids, a suspended sediment profile is prescribed initially from field data or from estimation. The daily inflow values of suspended sediment concentration are also input.

  The distribution of suspended sediment in the reservoir is changed by three processes; by mixing, by convective overturn, and by settling. The convective adjustment considers the density distribution in the reservoir, including the contribution to water density of the suspended sediment. A check is made for density inversions, and unstable layers are mixed.

  A method was developed to handle the changes in suspended sediment concentration due to settling of the suspended sediment. In pre-determined time intervals, the vertical distance a sediment particle sinks at a prescribed velocity is compared to the minimum simulated layer thickness. If this distance is greater than the layer thickness, then the subdaily time step is divided by a factor of two until the distance the particle sinks in the time step is less than the thickness of the layer it has entered. In each subdaily time step, the suspended sediment entering and leaving each layer is computed and added or removed from the layer. The portion of this sediment which falls into the layer below is added to that layer.

- Eklutna Lake Modeling (***)

To test this version of the DYRESM model for its applicability to predict suspended sediment concentrations in the project reservoirs, the updated model was applied to Eklutna Lake, near Anchorage, a glacial lake hydraulically, climatologically and morphologically similar to Watana impoundment (see Section 4.1.3(c)(i)). Watana Reservoir and Eklutna Lake have similar average percentages of their drainage areas covered by glaciers, similar average residence times, similar climatological conditions, and are operated or to be operated for hydroelectric power production. The hydrological and meteorological data collection program at Eklutna, described in 4.1.3(c)(i), was continued with emphasis on suspended sediment sampling from May to November 1984.

Measured suspended sediment concentrations ranged from 0.15 to 570 mg/l in the inflow streams, from 0.1 to 200 mg/l in the lake, and from 0.56 to 36 mg/l in the outflow. Peak values in the inflow occurred in late July or early August, in the lake in about September, and in the outflow in late July to mid-August. During the winter, inflow, lake and outflow suspended sediment concentrations were on the order of 0.1 mg/l. During the summer, the average suspended sediment concentrations were substantially higher than winter values and were increased further following large rainfall events or periods of significant glacial melt. Turbidity values generally followed the trends in the suspended sediment concentration, dropping off in the winter at inflow, lake, and outflow sites and peaking in mid-to-late summer. Values observed ranged from 0.5 to 580 NTU in the inflow streams, from 1.8 to 220 NTU in the lake, and from 3.0 to 46 NTU in the outflow.

The determinations of total incoming suspended sediments to the lake were based on the total suspended sediments measured for Glacier Fork and East Fork tributaries. To simulate the suspended sediment profile in the lake, the suspended sediments were divided into three particle size groups: 0-3 microns, 3-10 microns and greater than 10 microns. Test runs indicated that particles greater than 10 microns would settle rapidly to the bottom of the lake and contribute little to the suspended sediment profiles. Therefore they were not considered further in the study.

The estimates of the total incoming suspended sediments of each group were based on the weighted particle size distributions. These distributions were determined from samples taken from East Fork and Glacier Fork (Figures E.2.4.92 and E.2.4.93) obtained during field trips made on July 20, August 28, and October 23, 1984. The daily particle size distributions were interpolated from these three basic distributions.

Application of the extended DYRESM model requires the specification of an initial distribution of suspended sediment with depth, the particle settling velocity and the density of the sediment. In the study, the settling velocity of a particle size range was determined in accordance with Stoke's Law as illustrated in Figure E.2.4.94. A settling velocity of 1.53×10^{-6} meter per second was used for the 0-3 micron sediments and 2.00×10^{-5} meter per second for the 3-10 micron sediments. A particle density of 2.60 was used in the study, to represent the measured density of from 2.50 to 3.00.

The DYRESM simulations for the 0-3 micron sediments and 3-10 micron sediments were made separately. The resulting outflow suspended sediments of these two studies were then combined to indicate give the total outflow suspended sediment concentrations (Figure E.2.4.95).

The predicted Eklutna outflow suspended sediment concentrations agree with data obtained from the powerhouse tailrace, and the model is therefore considered applicable to the Susitna Project reservoirs. On two occasions, the field data show temporary increases in tailrace suspended sediment concentrations not predicted by the DYRESM model. The temporary deviations are probably due to locally strong winds near the powerhouse intake, and, hence, more concentrated wind energy available for mixing the water and sediments near the intake. It is not possible to account for these temporary local fluctuations in the model since the weather station is located on the opposite end of the lake and can not register such local variations in winds.

- Watana Stage I Reservoir Modeling (***)

The extended DYRESM model was applied to simulate the suspended sediments in the Watana Reservoir and in the project outflows. Case E-VI flow requirements and 1970 and 1981-82 meteorological conditions were considered. Data on the suspended sediment concentration and size in the Susitna River are available for the USGS gaging stations near Cantwell and at Gold Creek. The particle size distribution of the suspended sediments at the station near Cantwell is shown on Figure E.2.4.96.

Based on the Eklutna Lake study, the suspended sediment in the Watana Stage I Reservoir outflow is expected to be comprised primarily of particles of 3-4 microns or less. Larger particles will generally settle out rapidly without significantly affecting the average suspended sediment levels in the reservoir and outflow. Therefore, settling of sediments of up to 10 microns has been studied. The incoming suspended sediments of up to 10 microns were divided into two particle size ranges and an average settling velocity was assigned to represent each size rage. The 0-3 and 3-10 micron particles were represented by average settling velocities of 1.5×10^{-6} m/sec and 2.0×10^{-5} m/sec respectively.

The total amount of sediment influent to the reservoir was estimated from the USGS observations at the gaging station near the upstream end of the reservoir. Figure E.2.4.97 shows the estimated relationship between discharge and sediment load at the USGS gaging station on the Susitna River near Cantwell. Based on this relationship the total amounts of sediment influent to the upstream end of the reservoir for 1970, 1981 and 1982, representing years of near minimum, maximum and average sediment inflow to the project were computed to be 4,200,000, 8,500,000 and 5,600,000 tons, respectively. Additional sediment load for the drainage area between the gage and the damsite was computed based on the drainage area ratio. The amount of sediment influent of each particle size range was determined from the suspended sediment particle size distribution curve of samples taken near Cantwell as shown in Figure E.2.4.96. Fifteen percent of the total sediment influent was assigned to the 0-3 micron range and 12 percent to the 3-10 micron range.

The suspended sediment concentrations in the reservoir and the outflows were simulated for the 1970, 1981 and 1982 flow conditions with Case E-VI downstream flow requirements. The outflow suspended sediment concentrations for these cases are shown in Figures E.2.4.98, E.2.4.99, and E.2.4.100 respectively. These results show that 3 to 10 micron particles will generally settle out in the reservoir. The results also indicate that the outflow suspended sediment concentration and, hence, the turbidity level, would be more uniform throughout the entire year than for natural conditions. The outflow suspended sediment concentration would reach its lowest level of about 10 to 20 mg/l in early May and increase its level toward a maximum of 100 mg/l to 200 mg/l in July or August, while the mainstem river sediment inflow may vary from about 2-180 mg/l in October to April to as much as 200 to 2,200 mg/l in July to September. These results are summarized in Table E.2.4.25.

During the winter months, because of the relatively long reservoir residence time, a large portion of the 0-3 micron sediments will remain in suspension for a relatively long period of time and continue to affect the suspended sediment level of the reservoir outflow. As shown in the results, the outflow suspended sediment concentration would approach somewhat of an equilibrium level of about 100 mg/l near the end of October, and then gradually decrease toward a minimum of about 10 to 20 mg/l in early May.

In summary, the downstream suspended sediment condition near the project site will be affected by the operation of the Watana Stage I Reservoir. The summer suspended sediment level will be decreased from about 60-2,000 mg/l to about 60-150 mg/l and, in the winter, the suspended sediment level will be increased from about 1-80 mg/l to about 20 - 100 mg/l.

- Other Sources of Sediment (***)

For a discussion of the potential for bank instability along the shoreline of the reservoir, see Exhibit E, Chapter 6, Section 3.3, Reservoir Slope Failures. Shoreline erosion will occur as a result of two geologic processes: beach formation and mass movement. Through mass movement processes, an undetermined amount of material will be introduced into the reservoir as a consequence of skin and bimodal flows, and shallow rotational and block slides. As a result of the slope instability along the shoreline, an indeterminate amount of material will become suspended in the reservoir.

The estimates of bank instability in Chapter 6 are for the Watana Stage III Reservoir, which has a normal maximum pool level of el. 2,185. The Watana Stage I Reservoir normal pool level of el. 2,000 is generally within the confines of the river valley. As a result, the overburden thickness along the shoreline which could be exposed to sliding would be less than during Stage III. Additionally, the reservoir shoreline length is less than during Stage III and would also contribute to a smaller amount of slides.

It is not possible to accurately estimate the amount of material which will become unstable or suspended in the reservoir nor the amount which will pass through the reservoir and contribute to suspended sediment in the river. The shoreline deposits are primarily glacial till comprised of silty-sands (SM) but including some sandy clays (SC). Geotechnical investigations near the dam site indicate that, of the material smaller than three inches in size, less than 15 percent is smaller the five microns. The reservoir suspended sediment modeling indicates that material of 3-4 microns or less will generally comprise the material which remains in suspension. Therefore, most of the material which may become unstable and may potentially slide, will settle out in the immediate vicinity of the slide and not contribute to reservoir sediment concentrations. Only a small portion of the material along the surface of a slide may become suspended. The bulk of the material may be expected to remain in a mass and not become entrained. Therefore, it is not believed that instability will contribute significant amounts to reservoir suspended sediment concentrations.

Although the time period during which bank instability would occur is unknown, slope failures are expected to be highest early in project operation and to decrease with time. Any resulting increase in suspended sediment concentration would follow the same pattern.

(iv) Turbidity (**)

Turbidity is a water quality parameter important to the fishery resources. It is a measure of the light transmitting characteristics of the water. Low values of turbidity indicate high light transmittance and vice-versa. Vertical illumination is related to turbidity. Turbidity is influenced by the size, concentration and minerology of material suspended in the water including sediment, dyes, and other organic and inorganic material. In the Susitna River, it is believed that, for natural conditions and with the project, the turbidity levels will be chiefly influenced by the concentration and grain size of suspended sediment. For this reason extensive studies have been made using the extended DYRESM model described in Section 4.1.3(c)(iii) to describe the suspended sediment and resulting turbidity in the Watana Reservoir and in the river downstream. Baseline studies were carried out on Eklutna Lake to describe the turbidity patterns and to develop information for comparison to and for testing of the DYRESM model. Investigations were also made to develop representative relationships between turbidity and suspended sediment concentration in lentic and lotic environments.

The studies indicate that, with the project, there will be an overall reduction in the suspended sediment load of 80 to 90 percent from natural conditions. Turbidity levels will be measurably reduced from natural conditions in the summer (May through September) and increased in the winter (October through April).

- Eklutna Lake (***)

Turbidity can have an impact on water quality and fisheries, both in the reservoir and downstream. As for suspended sediment concentrations, the expected reservoir and downstream turbidity will be a function of thermal structure, wind-mixing, re-entrainment of fine sediments along the reservoir boundaries and inflowing suspended sediment concentration. Turbidity behavior patterns observed in Eklutna Lake provide a physical model which can be used to test the DYRESM model's applicability and which can be compared to anticipated turbidity patterns within Watana Reservoir. Although it is only one-tenth the size of the Watana Reservoir, its morphometric characteristics are similar. It is seven miles long, 200 feet deep, has a surface area of 3,420 acres, and has a total storage of about 414,000 acre-feet. Bulk annual residence time is 1.77 years as compared to Watana's 1.65 years (Stage III). It also has 5.2 percent of its basin covered by glaciers, compared to 5.9 percent of Watana's drainage area.

The hydraulic and hydrologic parameters of depth divided by detention time and inflowing sediment concentration at Eklutna are less than half the Watana values. Thus, while turbidity and suspended sediment behavior patterns at the two sites would be similar, the turbidity levels and sediment concentrations at Watana are expected to be higher. These differences are taken into account in the DYRESM model and illustrated by the results discussed below.

Data collected at the approximate center of Eklutna Lake from March 1982 through June 1985 (R&M 19821, 1985f) demonstrate patterns of turbidity behavior which may be expected at Watana. In March 1982 (Figure E.2.4.101), March, April and May 1983 (Figure E.2.4.102), and March, April, May and June 1984 (Figure E.2.4.103), turbidity beneath the Eklutna Lake ice cover decreased to its annual minimum of less than 10 NTU. Shortly after the lake surface ice melted in April or May, but before significant glacial melt and runoff had commenced, turbidity was 7-10 NTU throughout the water column. Usually by June, the turbidity had begun to increase, but no distinct turbidity plume was evident. This increase in turbidity was probably due to wind-mixing and/or vernal lake turn-over, and inflowing sediment. By mid-summer, slight increases in turbidity were noted at the lake bottom near the river inlet or in the lake water column. Distinct turbidity plumes were evident as interflows, overflows, or underflows in the lake from late July through mid-September. Turbidity values had significantly decreased by the time the plume had traveled 5 miles down the lake. In late September of 1982 and 1984, a turbid layer was noted at the bottom of the lake as river water entered as underflow. By mid-October, the lake was usually either in its fall overturn period or had progressed through it, with near-uniform temperatures at approximately 7°C (44.6°F) and turbidities of less than 30-35 NTU.

- Watana Reservoir (***)

The results of the suspended sediment modeling of Watana Reservoir may be used to estimate sediment concentrations and turbidities in the upper layers of the main body of the reservoir. These simulations indicate that the reservoir will be generally uniform in suspended sediment concentration in November at a value of approximately 100 mg/l as a result of isothermal conditions and a fall overturn induced by winds. When the reservoir ice cover forms in mid to late November it minimizes wind-mixing of the upper layers of the reservoir. As clear, incoming river water enters the reservoir near the surface, and as suspended material settles, the sediment concentration near the surface will decrease. By January, concentrations near the surface will be approximately 10 mg/l. Sediment concentrations will increase with depth in the reservoir. Concentrations are simulated to be approximately 100 mg/l at about 50 feet below the surface. This pattern will be essentially unchanged throughout the ice cover period. However, concentrations near the surface may decrease to a low of 5 mg/l later in the winter, just prior to ice cover melt-out or break-up.

Beginning in May, the influx of suspended material caused by snowmelt runoff and precipitation will increase suspended sediment concentration near the surface. Flows will also enter the reservoir below the surface and concentrations may increase throughout the reservoir depth. Concentrations near the surface are simulated to increase from 70 mg/l to 110 mg/l by July 1 and to remain at these levels through early August. Concentrations are simulated to increase to a maximum of approximately 200 mg/l at a depth of approximately 100 feet. The concentration near the surface generally decreases to approximately 70 mg/l by October, and the concentration at the 100-foot depth generally decreases to 150 mg/l at the same time.

Turbidity levels in the main body of the reservoir will generally follow the same pattern as the suspended sediment concentration. As discussed later, turbidity can be related to the suspended sediment concentration by multiplying the sediment concentration, in mg/l, by two to get the turbidity in NTU. Thus, turbidities near the surface may be expected to be close to 200 NTU in November, decrease to 10-20 NTU by January, remain at that level throughout winter, increase between May and July to 200-300 NTU and remain at that level until November.

- <u>Relation between Turbidity and Suspended Sediment Concentration</u> (***)

In order to estimate the with-project turbidity levels in the river, the Applicant has carried out studies to estimate the relationship between suspended sediment concetrations in mg/l (TSS) and turbidity (NTU) in lotic (riverine) and lentic (lake) systems. Typical relationships have been developed for lotic environments in Alaska (Figures E.2.4.104 through E.2.4.107) (Peratrovich, Nottingham & Drage Inc. 1982 and Lloyd 1985). Most data from lotic glaciated environments, that do not have reservoirs or lakes acting as settling basins, appear to have NTU/TSS ratios less than 1:1. In fact, the middle reach of the Susitna River and other large Alaskan rivers draining glaciated watersheds frequently have NTU/TSS ratios of approximately 1:4 (Figures E.2.4.104 and E.2.4.105).

Investigations of a similar nature in Alaskan lentic environments draining glaciated drainages [e.g. Eklutna Lake (Figure E.2.4.108); Bradley Lake (Ott Water Engineers Inc. 1981), and Tustumena Lake

(Scott 1982] indicate NTU/TSS ratios of approximately 2:1 or greater.

Investigations in the Eklutna Lake tailrace waters (Figure E.2.4.109) gave highly variable NTU/TSS ratios, but these ratios were usually greater than or equal to 2:1. Similar investigations in relatively quiescent settling columns using Susitna River water from the Watana dam site (Tables E.2.4.26 and E.2.4.27) and from 15 separate placer mine sluice box effluents from the central Alaska mining district (R&M 19821) (Table E.2.4.28) gave NTU/TSS ratios of approximately 2:1. Very generalized NTU/TSS relationships can be derived for lotic environments (eg. NTU/TSS ratios of less than or equal to 1:1). In relatively quiescent, lentic environments NTU/TSS ratios of greater than or equal to 2:1 are found (see Figure E.2.4.109).

For the purpose of this report, a value of 2:1 is used to represent the NTU/TSS ratio. It is recognized that the actual ration of NTU/TSS may vary considerably as evidenced by the tests in other rivers and lakes. The turbidity values provided herein indicate a range of expected values for the conditions simulated, rather than precise estimates.

- Watana to Talkeetna (***)

The suspended sediment concentrations and hence the turbidity in the reach between Watana and the Susitna-Chulitna confluence will be controlled by the concentration in the reservoir release, and any contribution from the reach. The contribution from the reach is not expected to be significant since the tributaries contain generally clear water and there is very little fine sediment or glacial flour present in the streambed or on the banks which might be entrained in the flow. During summer flood periods the contribution from the intervening areas may increase concentrations in the mainstem river as a result of erosion and bank sloughing.

The suspended sediment concentration will average 100 mg/l between June and December and decrease throughout winter to a minimum of approximately 10-20 mg/l in early May prior to reservoir ice cover break-up. Average May suspended sediment concentrations will be 30-40 mg/l. Average summer suspended sediment concentrations (100 mg/l) will be less than naturally occurring levels and turbidities will therefore be measureably reduced in this period. Turbidities will average approximately 200 NTU from June through December and decrease to minimum values of 20-40 NTU by early May.

- Talkeetna to Cook Inlet (***)

  In the reach between the Susitna-Chulitna-Talkeetna Rivers confluence and Sunshine Bridge the river undergoes a mixing process. The plumes of the three rivers may often be distinguished for several miles downstream of the confluences. The Chulitna River is, under natural conditions, more turbid than the Susitna and its plume is sometimes distinguishable several miles downstream of the confluence. The plume of the Talkeetna River is less distinguishable from the Susitna.

  Summer flow from the middle reach of the Susitna will be reduced during project operation as will its average temperature, suspended sediment concentration and turbidity. The Chulitna River plume may tend to increase in size relative to natural conditions and complete mixing of the Chulitna and Susitna Rivers may occur slightly further upstream than during natural conditions. The same would generally be true of the Talkeetna River. The reduced suspended sediment concentration from the middle reach will have a minor effect on suspended sediment concentrations downstream of the complete mixing location. It is estimated that the average suspended sediment concentration downstream of Sunshine in the summer may be reduced by five percent. Turbidities related to suspended sediment concentration would not change significantly in the summer.

  In the winter the flow from the middle reach will be increased compared to natural conditions. Clear flows from the Chulitna and Talkeetna Rivers will, to some extent, dilute the middle river suspended sediment concentration. During an average October-to-May period, the middle reach suspended sediment concentration is simulated to be, with-project, approximately 60 to 70 mg/l. The average concentration downstream of the Chulitna-Susitna-Talkeetna confluence would be approximately 40 to 50 mg/l, assuming no additional input from the intervening area. Thus, turbidities in the winter would average approximately 80 to 100 NTU. Clear winter flows from the Yentna River would result in greater dilution and lesser turbidity between the Yentna River and the mouth of the Susitna River in Cook Inlet.

(v) Dissolved Oxygen (**)

Susitna River inflow to the reservoir will continue to have both high dissolved oxygen concentrations and high percentage saturations. The oxygen demand of the water entering the reservoir will be low. No man-made sources of oxygen demanding effluent exist upstream from the impoundment. Chemical oxygen demand (COD) measurements at Vee Canyon during 1980 and 1981 were low, averaging 16 mg/l. No biochemical oxygen demand values were recorded.

Wastewater from the permanent town and anticipated recreationists will not contribute an oxygen demand of any significance to the reservoir. All wastewater will be treated to avoid effluent-related problems.

The larger trees within the inundated area will be selectively cleared, avoiding the potential BOD they would have created. A layer of organic matter at the reservoir bottom will still remain and could create some localized oxygen depletion along the reservoir floor. However, the process of decomposition will be very slow because of the cold temperatures near the bottom and any waters with low dissolved oxygen will be diluted by the large volume of reservoir water with relatively high dissolved oxygen content.

The stratification that is anticipated in the reservoir may limit the oxygen replenishment in the hypolimnion. The spring turnover, with its large inflow of freshwater containing relatively high concentrations of dissolved oxygen, will cause mixing; however, the depth to which this mixing will occur is unknown. It is anticipated that the upper 200 feet of the impoundment should maintain high dissolved oxygen concentrations.

Quantitative estimates of any oxygen deficits which may occur cannot be determined. This would require knowledge of the quantity of organic matter and detritus inundated and the resultant biological and chemical oxygen demand rates as well as reservoir hydrodynamics including density currents (Grimas 1961, Grimas and Nilsson 1965, Allanson 1973, Slotta

1973, Straskraba 1973, Williams 1973, Wunderlich 1967, 1971, Wunderlich and Elder 1973, Soltero et al 1974, Cornett 1979, Duthie 1979, Hannan 1979).

Downstream from the dam, dissolved oxygen changes are not anticipated, since water will be drawn from the upper portion of the reservoir.

(vi) Total Dissolved Gas Concentration (**)

As previously noted, supersaturated dissolved gas (nitrogen) conditions can occur below high head dams as a result of flow releases (see Section 6.4.4. for an explanation of the mechanisms causing gas supersaturation). Fixed-cone valves are planned to control flow from the outlet works and will be used during project operation to discharge releases from floods with return periods of less than 50 years, in order to minimize the potential for elevatated dissolved gas concentrations downstream of the dam.

The use of the outlet works to pass flood flows and to augment power releases to meet environmental flow requirements is discussed in Section 3. Section 4.1.3(a)(v) discusses the frequency of use of the outlet works in Stage I. Table E.2.4.16 summarizes the operation of the outlet works. Information on the effectiveness of the valves for maintaining acceptable dissolved gas concentrations is available in Section 6.4.4.

Under natural conditions the mean annual flood flow, in the middle reach, of approximately 50,000 cfs would result in gas concentrations of approximately 118 percent of saturation immediately downstream of Devil Canyon. This assumes the relationship in Figure E.2.2.105 can be extrapolated from 32,500 cfs to 50,000 cfs. A more detailed discussion of gas concentrations for natural conditions is in Section 2.3.6(b).

For with-project conditions, storage of flows and regulation of floods will cause a reduction in the levels and variations of dissolved gas concentrations below Devil Canyon. Based upon data from natural conditions, mean weekly with-project summer flows (May to September) of 4,000 cfs to 20,000 cfs are expected to produce concentrations, below the Devil Canyon rapids, of approximately 107 and 111 percent, respectively. The mean annual with-project flood of approximately 37,000 cfs would result in approximately the same gas concentration downstream of Devil Canyon as the mean annual flood for natural conditions. This is based on computations indicating that this flow through the powerhouse and outlet works would result in gas concentrations of between 100 and 105 percent saturation downstream of the dam. An additional 14 percent increase in gas concentration through the Devil Canyon rapids would result in concentrations immediately downstream of the rapids of 114 to 119 percent. This is a conservatively high estimate since the amount of supersaturation in the flow downstream of Watana is expected to decrease significantly before the flow reaches Devil Canyon. Additionally, the amount of supersaturation would decrease with distance downstream of Devil Canyon as shown on Figure E.2.2.106. Gas superaturation at Gold Creek would be about half of the superaturation at Devil Canyon.

For floods in excess of the mean annual event up to the 50-year event, the release from Watana is only slightly changed (see Section 4.1.3(a)). The amount of supersaturation in the Watana release is expected to remain constant between 100 and 105 percent for all flood up to the 50-year event. The amount of supersaturation in Devil Canyon would increase so that the total gas concentration immediately downstream of Devil Canyon would be approximately 115 to 125 percent for the with-project 50-year flood. Gas concentrations have not been measured for natural conditions for flows exceeding 32,500 cfs, and a direct comparison of with-project and natural conditions is not possible for these floods. However, if the relation between flow and gas concentration developed for flows less than 32,500 cfs were extrapolated, gas concentrations for floods greater that the mean annual event for natural conditions would be higher than for with-project conditions. For example, the gas concentration for the natural 50-year flood of approximately 95,000 cfs would be approximately 130 percent.

Although no measurements of dissolved gas levels exist for the winter period for natural conditions, it is anticipated that average with-project flows (5,000 to 10,000 cfs) will cause levels of dissolved gas below Devil Canyon which exceed saturation. Concentrations are not expected to exceed the state standard value of 110 percent based upon the available natural condition measurements taken at slightly higher discharge conditions and higher ambient air temperatures.

The concentrations in the preceding discussion are all immediately downstream of Devil Canyon. As shown by Figure E.2.2.106 concentrations will be reduced with distance downstream.

(vii) Trophic Status (Nutrients and Lower Trophic Level Biology) (**)

A detailed analysis of the anticipated trophic status of the Watana Reservoir has been developed, in part, by Peterson and Nichols (1982). Information from their analysis and from more recent analyses and studies follows.

Reservoir trophic status is determined in part by the relative amounts of carbon, silicon, nitrogen, and phosphorus present in a system, as well as the quality and quantity of light penetration, reservoir morphology, hydrology, and geographic location, etc. The average 1980-1981 C:Si:N:P June ratio of 1080:-340:28:1 indicates that phosphorus will be the limiting nutrient in the Susitna impoundments. The latest estimates of Stage I, II and III reservoir suspended sediment concentrations and turbidity indicate that vertical illumination of the reservoir and downstream water columns will be substantially restricted during all seasons. The maximum euphotic zone is expected to be less than 10 feet deep during all seasons during Watana Stage I. Reservoir trophic status (Table E.2.4.29) is expected to be primarily light limited (Hecky and Guildford 1984, Planas and Hecky 1984, Hecky 1984, Hecky et al. 1984) and is expected to be classified as oligotrophic or even ultra-oligotrophic for the life of the reservoir. The standard types of empirically derived models for predicting reservoir trophic response from nutrient loading and nutrient concentration relationships (Vollenweider 1975, Dillon and Rigler 1974, Jones and Backman 1976, Larcen and Mercier 1976) are not expected to be applicable for predicting or assessing the trophic status of the project reservoir(s) (Kerekes 1982, Walker 1982, Rast and Lee 1978, Mueller 1982).

Artificial phosphorus loading of the reservoir from domestic sources was investigated by Peterson and Nichols (1982). They concluded that the maximum allowable artificial loading is equivalent to the waste from 115,800 permanent residents, if oligotrophic conditions are to be maintained and if the reservoir was expected to be clear. However, their estimate is conservative since the effects of low light penetration and the use of waste treatment have been neglected.

Reduction of riverine born suspended sediments by settling within the reservoir will result in a sediment blanket effect. Organic materials on the reservoir floor and side walls will eventually become coated and/or buried by settled (mostly inorganic) particulates. The sediment blanket effect will retard leaching and biological cycling of macro- and micro-nutrient ions, primary and secondary productivity and organic detritus oxidation (Wetzel 1975, Campbell et al 1975, Crawford and Rosenberg 1984, Wiens and Rosenberg 1984, Hecky and McCollough 1984).

Development of a small but viable phytoplankton population composed primarily of Bacillariophyceae, Chrysophaecae, Dinofyceae and Chlorophyceae with a microplankton community of photosynthetic bacteria and mostly unicellular Cyanophyceae is expected within the reservoirs. The community is expected to remain at low densities and to be primarily located within the wind mixed surface strata. Heterotrophic bacteria, fungi and actinomycetes are expected to dominate the hypolimnion biological communities. (Grimas and Nilsson 1964; Geen 1974, Wetzel 1975, Duthie 1979, Baxter and Glaude 1980, Hecky and Guildford 1984, Hecky et.al. 1984, Koenings and Kyle 1982)

Development of a limited but viable zooplankton community primarily composed of Protozoa, Rotifera, Copepoda and low densities of Cladocera and Insecta is expected in the project reservoirs. Cladocera typically exist at low densities in natural lakes heavily influenced by glacial flour in subarctic lentic environments (Wetzel 1975, Grimas and Nilsson 1965, Pinel-Alloul et al. 1982, Patalis and Salki 1984, Koenings and Kyle 1982).

A macrobenthic community with relatively low densities of Insecta, Oligochaeta, and Mollusca is expected to form immediately after impoundment. Macrobenthos densities will probably decrease after the first 5-10 years of reservoir aging (Wetzel 1975, Grimas 1961, Hutchinson 1967, Grimas and Nilsson 1965, Wiens and Rosenberg 1984, Crawford and Rosenberg 1984, Bilyj 1984, Rosenberg et al. 1984, Hecky et al).

(viii) Total Dissolved Solids, Conductivity, Significant Ions, Alkalinity, and Metals (**)

The leaching process, as previously identified in Section 4.1.2(e)(vii), is expected to result in increased levels of dissolved ions within the reservoir immediately after impoundment. The magnitude of these changes cannot be quantified, but should not be significant (Peterson and Nichols 1982). Furthermore, Baxter and Glaude (1980) have found such effects are temporary and diminish with time.

The effects of leaching will diminish for two reasons. First, the most soluble elements will dissolve into the water rather quickly and the rate of leachate production will correspondingly decrease with time. Second, much of the inorganic sediment carried by the Susitna River will settle in the Watana Reservoir. The formation of an inorganic sediment blanket on the reservoir bed will retard the leaching process (Peterson and Nichols 1982).

As discussed in Section 4.1.2(e)(vii) concentrations of leaching products will be highest near the reservoir bottom, but may be re-entrained into the upper levels during overturns. Dilution by the large reservoir volume would make the resulting concentrations biologically insignificant. Additionally, with time, a sediment layer will blanket the reservoir bottom and retard the leaching process. Since the power intakes are located in the upper levels of the reservoir, water released through the turbines should not be affected by leaching products.

During periods of evaporation, slightly higher concentrations of dissolved substances have been found at the surface of impoundments (Love 1961, Symons 1969). Because of the large surface area of the proposed impoundment, evaporation will be increased over existing conditions. The annual average evaporation rate for May through September at Watana is estimated at 10.0 inches or 0.3 percent of the reservoir volume (HE 1985e). The net evaporation, which is the difference between evaporation from the reservoir surface and evapotranspiration from the same area prior to the impoundments, will be much less, on the order of one to two inches. Given the mixing effects of wind and waves and the fact that direct precipitation exceeds annual evaporation, little measurable increase in dissolved solids is expected.

Dissolved solid concentrations are expected to increase near the surface of the impoundment during winter. Mortimer (1941,1942) noted that the formation of ice at a reservoir surface forces dissolved solids out of the freezing water, thereby increasing concentrations of these solids at the surface near the ice-water interface of the reservoir. No biologically important impacts should result either in the reservoir or downstream from the dam from this process.

In contrast to the above discussions, precipitation of metals such as iron, manganese and other trace elements have been noticed in reservoirs, resulting in reduced concentrations of these elements (Neal 1967). Oligotrophic reservoirs with high pH and high dissolved salt concentrations generally precipitate more metal than reservoirs with low pH and low dissolved salt concentrations. This is attributed to the dissolved salts reacting with the metal ions and subsequently settling out (Peterson and Nichols 1982). Average Susitna River TDS values for Vee Canyon and Gold Creek during winter are 141 and 150 mg/l, respectively. For summer they are somewhat lower, approximately 98 and 91 mg/l respectively. Average values for pH range between 6.9 and 7.6 for the two stations. Although neither of the parameters is excessively high, precipitation of metals may reduce the quantities of metals in the reservoir.

(d) Ground Water Conditions (**)

(i) Mainstem (*)

As a result of the annual water level fluctuation in the reservoir, there will be localized changes in ground water in the immediate vicinity of the reservoir. Ground water impacts downstream during summer will be similar to those described in Section 4.1.2(f)(i) and will be confined to the river area. Since powerhouse flows will generally be greater than filling flows during summer, the ground water level change from natural conditions will be slightly less than during filling. During winter, increased ice staging will occur during freeze-up (Section 4.1.3(c)[iii]) and hence ground water levels will be increased along ice covered sections of the mainstem.

(ii) Sloughs and Peripheral Habitat (**)

During winter, in the Devil Canyon to Talkeetna reach, some of the sloughs and side channels (i.e., those between Gold Creek and Talkeetna) will be adjacent to an ice-covered section of the river. In ice-covered sections, the river will have staged to form an ice cover at project operation flows of about 9,000 cfs. The associated water level will be a few feet above normal winter water levels and will cause an increase in the ground water table. This will in turn cause an increase in ground water flow.

Sloughs upstream of Gold Creek, in the vicinity of Portage Creek, may be adjacent to open water sections of the river. Because monthly average flows will be between approximately 4,000 and 9,000 cfs in winter, the associated water level will be less than water levels occurring under the natural freeze-up process. Sloughs in this area may experience a decrease in ground water flow in the winter from natural conditions. However, water levels upstream of the ice front will fluctuate less on an annual basis than during natural conditions. Thus ground water flows will be more stable all year than for natural conditions.

During summer, the mainstem-slough ground water interaction will be similar to that discussed in Section 4.1.2(f)(ii), with the exception that operational flows will be greater than the downstream flows during filling, and thus, the ground water table will be closer to the natural elevation than during filling.

During the fall, under natural conditions, flows generally decline to near 5,000 cfs before an ice cover forms. This is the period of lowest groundwater flow. With-project discharges and water levels will remain higher than natural during this period providing an increase in groundwater flow.

Overall, the stabilization of river flows and water levels as a result of project operation will result in more uniform groundwater flows to peripheral habitat areas than under natural conditions. Summer groundwater flows will be slightly reduced from natural. Fall flows will be increased as the period of minimum flows for natural conditions is eliminated. Winter flows will be increased from natural between Gold Creek and Talkeetna and decreased from natural upstream of Gold Creek.

(e) Lakes and Streams (**)

The numerous small lakes identified in Section 2.5.1 will be inundated by the Watana Reservoir during the impoundment phase. Most of them will remain below the reservoir surface at all times, but a few will become perched at low reservoir levels.

The mouths of streams flowing into the reservoir will shift upstream and downstream in response to the reservoir water level fluctuations. The position of the delta formation will likewise vary. Both bedload and suspended sediment load will be deposited wherever the stream current enters the still water of the impoundment.

The downstream tributaries described in Section 4.1.2(g) and listed in Table E.2.2.43, will begin to modify their geomorphologic regimes and either downcut their beds or remain perched above the Susitna in response to the reduced river levels during project operation. Anticipated stream impacts are listed in Table E.2.2.43.

(f) Instream Flow Uses (**)

(i) Fishery Resources, Riparian Vegetation and Wildlife Habitat, and Recreation (**)

Impacts of project operation on the fishery resources, riparian vegetation, and wildlife habitat are discussed in Chapter 3. Impacts on recreational use including whitewater kayaking are discussed in Chapter 7.

(ii) Navigation and Transportation (**)

Motorized boats that move swiftly on the reservoir will replace the present non-motorized boating when the Watana Reservoir is filled and Vee Canyon is eliminated as an obstacle.

Reservoir water craft navigation will extend to November, because of the delay in ice-cover formation. Once an ice cover forms in late November and December, the reservoir will be available for surface travel by dogsled and snow machine through April.

Assuming boaters portage around the damsite, the reduced summer flows released from Watana Reservoir during its operation are not expected to reduce navigation between Watana and Devil Canyon. However, the lower segment of this reach (from Devil Creek to Devil Canyon) will still consist of whitewater rapids. The use of the river for whitewater kayaking is discussed in Chapter 7.

Summer flows downstream of the dam will generally be reduced from natural conditions during operation of Watana, except during drought periods in late summer and fall. Flows at Gold Creek will exceed 8,000 cfs from June through early September, after which flows are gradually decreased to a minimum of 6,300 cfs by the end of September. The only identified navigation problem in the reach between Devil Canyon and the Chulitna confluence, a channel cross-over near RM 128, has been successfully navigated at flows of 6,300 cfs.

Navigation will not be significantly affected between Portage Creek and the Chulitna River confluence. In fact, several navigation benefits will occur. The navigational hazard of floating trees and debris will be reduced in most years, due to the reduction of flood flows. During dry years, project operation will improve navigability of this reach in late August and September (Table E.2.4.30).

Downstream of the Chulitna River confluence, the main channel is navigable at flows exceeding approximately 25,000 cfs (measured at the Sunshine gaging station), especially for jetboats and airboats. Below 25,000 cfs, specific areas, such as the entrance to the west channel at the head of the Delta Islands (RM 151) may be difficult to navigate for some boats. The difficulty of navigation will be dependent on the boat draft, on recent changes in channel morphology, and on tree and debris jams. Jetboats and airboats may operate with flows as low as 17,800 cfs. At least one deep water channel should exist from the main access points of Susitna Landing and Willow Creek to the main destinations of the Deshka and Yentna Rivers.

Under natural conditions minor navigational difficulties occur in this reach infrequently in late May through mid-September and become slightly more frequent in late September. This is shown by Table E.2.4.30 which indicates that a flow of 25,000 cfs is exceeded all summer long in nearly all years. That table also shows that project operation will slightly increase the frequency of navigational difficulties encountered in late May, and slightly decrease the frequency in late September. In late May, navigational difficulties may be encountered in 10 percent more years than natural, and in late September, difficulties may be encountered in about 10 percent less years than natural.

The primary destination downstream of the Yentna confluence is Alexander Creek. During high flows, boaters often use Alexander Slough. At lower flows, numerous sand bars make Alexander Slough difficult to navigate for jetboats, so boaters then either go through Powerline Slough or down the west channel to Cook Inlet, then back up the west channel. The flow rate at which jetboaters can no longer use Alexander Slough has not been precisely defined, but based on the examination of aerial photographs, it is estimated to be about 60,000 cfs as measured at Susitna Station.

Navigational difficulties occur infrequently in Alexander Slough under natural conditions between late May and early September, and become more frequent in mid- to late September. Data in Table E.2.4.30 indicate a discharge of 60,000 cfs is exceeded all summer long in nearly all years. This table also shows that project operation will slightly increase the frequency of navigational difficulties to be encountered in late May and early June. Flows exceeding 60,000 cfs will occur in 10 to 20 percent fewer years between May 27 and June 16 than during natural conditions. When navigational difficulties are encountered in Alexander Slough, Powerline Slough will still be available for use and navigation will not be precluded.

During the fall and winter, a significant reach of the river between Watana and Talkeetna will be ice free for a few weeks longer than during existing conditions. The reach between Watana and Portage Creek will not develop an ice cover. This will allow for a longer boating season, but will impede use of this river reach as a transportation corridor by snow machine or dogsled.

Downstream from Talkeetna, ice-cover formation will be delayed a few weeks and river stage during freeze-up will be increased. This will delay winter transportation across the ice.

(iii) Waste Assimilative Capacity (*)

The previously noted reductions to downstream summer flow could result in a slight reduction in the waste assimilation capacity of the Susitna River downstream of the project. However, no impacts will occur given the limited sources of waste loading to the river (see Section 2.6.6).

The winter waste assimilative capacity of the river will be at least doubled due to the increased winter flow.

The wastes generated by the population (approximately 300) at the permanent town will receive secondary treatment similar to the previously described construction camp and village wastewater treatment.

(iv) Freshwater Recruitment to Cook Inlet Estuary (**)

Salinity changes in Cook Inlet due to Watana operation were simulated using a computer model (Resource Management Associates 1983). The simulation was for the two-stage project. However, the effect on with-project flows for the three-stage project is similar to the two-stage project, and the results of the simulations are considered applicable to the three stage project. Results of the modeling indicate that the salinity in Cook Inlet will attain a dynamic equilibrium within approximately one year of reservoir operation. Winter salinities will be slightly lower and summer salinities will be slightly higher than natural conditions.

Near the mouth of the Susitna River (Node 27 - Figure E.2.2.149) natural and with-project salinity differences will be greatest during April. Salinity concentrations associated with Watana operations are estimated to be approximately 19.6 parts per thousand (ppt) or a decrease of 1.4 ppt from natural conditions. With the reduced flows during summer salinity will be increased. A maximum salinity increase of 0.7 ppt above natural salinity levels is predicted for June (Figure E.2.2.149).

At the center of Cook Inlet near East Foreland (Node 12), salinity changes will be significantly less. Concentration decreases of approximately 0.4 ppt are predicted in April. During August a salinity increase of about 0.1 ppt is estimated to occur. Additional comparisons are presented in Table E.2.2.48.

In general, salinity variations will result in a reduced with-project salinity range. The maximum reduction will be near the mouth of the Susitna River where an annual maximum to annual minimum range decrease of about 2.0 ppt can be expected.

4.2 - Devil Canyon Development (**)

This section describes the effects on water use and quality during construction, impoundment and operation of Devil Canyon Dam during Stage II. Construction is scheduled to begin in 1995 on access and in 1996 on site facilities. Diversion tunnel construction will begin in 1997 with closure of the cofferdams and diversion of the river in 1999. Construction of the main dam will begin upon river closure and is scheduled for completion in 2004. The first unit will begin operating in 2004 and commercial operation of the fourth unit will be in 2005.

The periods of construction and impoundment coincide with normal operation of Stage I, which is scheduled to begin in 1999. During construction and impoundment, the Susitna River will be diverted through a tunnel or the dam outlet works. There will be a minor amount of impoundment during the construction period. In general, the impacts on water use and quality during these two periods will be as discussed for operation of Stage I. Thus, Section 4.1.3 is referenced frequently in Sections 4.2.1 and 4.2.2. These sections describe the effects of Stage II construction and impoundment on water use and quality.

The period of normal operation of Stage II coincides with the construction and impoundment period of Stage III. This is described more fully in Section 4.3. Since the construction will take place at the upstream project (Watana) and normal operation of Stage II will not be affected until filling of Stage III in 2011, the impacts described herein (Section 4.2.3) are valid for this period. The effects of Stage III construction and filling are described in Sections 4.3.1 and 4.3.2. Those sections reference Section 4.2.3 (Operation of Stage II) frequently.

The Devil Canyon development when completed in 2006 will consist of a 646-foot high, concrete arch dam, outlet facilities capable of passing approximately 42,000 cfs; a flipbucket spillway which with the outlet works can pass the Probable Maximum Flood (351,000 cfs); and a 600-MW capacity underground powerhouse. Further information on the physical features of the Devil Canyon development can be found in Section 7 of Exhibit A.

4.2.1 - Watana Stage I Operation/Devil Canyon Construction (**)

The Devil Canyon diversion tunnel will be completed in 1999 and construction on the main dam will begin in that year. The tunnel is designed to pass the 1:25-year recurrence interval flood routed through Watana without endangering the diversion dam. The use of a lower recurrence interval flood for the Devil Canyon diversion design as compared to the Watana diversion design is appropriate because of the shorter period during which the Devil Canyon diversion facilities will operate. This is explained in Exhibit F.

During the Devil Canyon construction phase, most differences in the quantity and quality of the water from the existing baseline conditions will be the result of the presence and operation of the Watana facility. Therefore, the conditions described in Section 4.1.3 will, in many cases, be referred to when discussing the impacts of Devil Canyon construction.

(a) Flows and Water Levels (**)

(i) Watana Stage I Operation (**)

Operation of Watana will be unchanged during the construction of Devil Canyon. Hence, the discussion presented in Section 4.1.3(a) remains appropriate.

During construction of the diversion tunnel, the flow in the mainstem will be unaffected. Upon completion of the diversion tunnel, the upstream cofferdam will be closed and flow will be diverted through the diversion tunnel without any interruption in flow. This action will dewater approximately 1,100 feet of the Susitna River between the upstream and downstream cofferdams.

Velocites through the 35.5-foot diameter tunnel at flows of 10,000 cfs will be approximately 14 fps.

(ii) Floods (**)

As explained above the diversion tunnel is designed to pass flood flows up to the 1:25-year summer flood, routed through Watana. The flood frequency relationship for Gold Creek is given in Section 4.1.3 (a)(iii). Floods at Devil Canyon damsite would be somewhat less than at Gold Creek.

(b) River Morphology (**)

Since operation of Watana Stage I will not be affected by the construction of the Devil Canyon Dam, the morphological processes discussed in Section 4.1.3(b) will continue to occur except at the Devil Canyon damsite.

At the damsite, approximately 1,100 ft of the Susitna River between the upstream and downstream cofferdams will be blocked and dewatered for construction. No impacts to the morphology of the Susitna River are anticipated from borrowing of materials for construction because no borrow site is located within the river. Although Borrow Site G (Figure E.2.4.111) is located south of and adjacent to the Susitna River, no excavation will be undertaken in the riverbed.

(c) Water Quality (**)

(i) Water Temperature (o)

There will be no difference in water temperatures at Devil Canyon or at points downstream from the construction site from those discussed in Section 4.1.3(c)(i).

(ii) Ice (o)

Ice processes will be unchanged from those discussed in Section 4.1.3(c) (ii), Watana operation.

(iii) Suspended Sediment/Turbidity/Vertical Illumination (**)

Construction of the Devil Canyon facility is expected to have siltation and turbidity impacts similar to those anticipated at Watana, but of a smaller magnitude.

Tunnel excavation, placement of the cofferdams, excavation of construction materials, dewatering, gravel washing, and the clearing and disposal of vegetation and overburden will all provide opportunities for the introduction of sediment to the river as discussed for Watana Stage I construction (Section 4.1.1 (c) (iii). Guidelines and techniques contained in the Best Management Practices Manual entitled "Erosion and Sedimentation Control" (APA 1985a) will be followed in order to minimize impacts. Excavation of the diversion tunnels and construction of the diversion cofferdam will be carried out similarly to Watana Stage I to minimize potential increases to suspended sediment and turbidity.

The material sources required for construction are Borrow Site G and Quarry Site K (shown in Figure E.2.4.112) and previously described Borrow Site D located near Watana (Figure E.2.4.2). Borrow Site G is expected to provide approximately 2 million cubic yards (cy) of aggregate with less than five percent waste. Excavation of this material will occur in the dry. The Susitna River will form the northern boundary of the borrow area. The mouth of Cheechako Creek, however, will be diverted to the eastern boundary of the borrow site to facilitate access to all required material. The area of disturbance, located entirely within the confines of the Devil

Canyon Reservoir, is likely to exceed 40 acres, but is not expected to equal the approximate 80 acres shown in Figure E.2.4.111.

Although washing will be required, the quantities of fines should be limited since the borrow material is predominantly composed of river washed alluvial sands and gravels. All wash water will be directed to a series of settling ponds. Prior to excavation, all overburden and vegetation will either be slashed and burned, carefully stockpiled for future reclamation work, or buried.

Quarry Site K is located in an upland site that is estimated to contain total resources of 40 million cy of rock. However, only 1.5 million cy of this quantity will be needed for the saddle dam, riprap and other uses. Disposal of not more than 310,000 cy of oversized and undersized material will occur in either the existing talus pile at the base of the cliff (see Figure E.2.4.113), near the site of the saddle dam, or along the reservoir for beach material. No washing of materials will be required; and hence, no wastewater will be produced.

Overburden will be stripped and carefully stockpiled for subsequent rehabilitation of the area. No siltation problems will result from the development of this site. It is expected that 10 to 15 acres of the 30-acre primary quarry site will be disturbed.

Borrow Site D has been identified as the nearest source of impervious core material required for the saddle dam. Hauling of this material will be via the main access road between Watana and Devil Canyon. The material will be processed as required. No adverse sedimentation problems will occur due to the upland location of Borrow Site D and the use of settling ponds for runoff treatment.

In summary, the summer water clarity, resulting from the sediment trapping characteristics of the Watana Reservoir, is not expected to be adversely affected during Devil Canyon construction activities. During winter, essentially all the suspended sediment concentrations and turbidity levels released from Watana, are expected to pass downstream of the Devil Canyon construction site without significant change.

Additional information on the proposed mitigation of erosion problems is discussed in Section 6.2 and Chapter 3.

(iv) Nutrients (**)

Similar to Watana construction, increased concentrations of nutrients and organics could result from disturbances and subsequent erosion of organic soils. However, since the overburden layer near the Devil Canyon damsite is quite shallow and overburden and vegetation will be selectively cleared, safely stockpiled for future rehabilitation or buried, impacts should be insignificant.

(v) Metals (o)

As discussed in Section 4.1.1(c)(v), Watana construction, disturbances to soils, and rock adjacent to the river will increase dissolved and suspended materials in the river. Although this may result in slightly elevated metal levels within the construction area and downstream, water quality should not be significantly changed (Section 2.3.8 (k)).

(vi) Contamination by Petroleum Products (**)

All state and federal regulations governing the prevention and reclamation of accidental spills, including the development and implementation of a Spill Prevention Containment and Countermeasure Plan (SPCC), will be adhered to. Additional information on proposed mitigative measures are provided in Section 6.2 and Chapter 3. The Best Management Practices Manual entitled "Oil Spill Contingency Planning" (APA 1985b) will be utilized to develop the SPCC plan.

(vii) Concrete Contamination (**)

There is potential for concrete contamination of the Susitna River during the construction of the Devil Canyon Dam. It is estimated that 1.7 million cubic yards of concrete will be used in the construction of the dam. The wastewater and waste concrete associated with the batching of the concrete will be prevented from discharging directly into the river to prevent degrading downstream water quality and causing subsequent fish mortality. Although a modern efficient central batch plant will be utilized, approximately 20,000 cubic yards of waste material will be generated. Those materials will be disposed of in a manner that will minimize potential contamination problems using the same methods as those employed for Watana Stage I construction (see Section 4.1.1(c)(vii)).

(viii) Other Parameters (o)

No additional water quality impacts are expected.

(d) Ground Water Conditions (*)

As indicated in Section 4.2.1(a) the construction of Devil Canyon will not modify the Watana operation or flows, and the ground water impacts discussed under Watana operation (Section 4.1.3(d) will remain relevant during this period. Some local changes in ground water levels in the immediate vicinity of the damsite may occur due to dewatering of open and underground excavations.

(e) Lakes and Streams (**)

The perched lake adjacent to the Devil Canyon damsite will be eliminated by construction of the saddle dam across the low area on the south bank. The lake is just west of the downstream toe of the saddle dam and will be drained and partially filled during construction of the saddle dam.

(f) Instream Flow Uses (**)

Devil Canyon and Devil Creek rapids act as natural barriers to most upstream fish movement. However, some chinook salmon are able to reach the area upstream of Devil Canyon and construction of the diversion tunnel and cofferdams will prevent this. This will result in some loss in productivity upstream of Devil Canyon. However, this is expected to be offset by increased productivity in the reach downstream of Devil Canyon. This is more fully explained in Chapter 3. Impacts to riparian vegetation and wildlife are also discussed in Chapter 3. Navigational impacts will be the same as during Watana operation (Section 4.1.3(f)(ii)) except that the whitewater rapids at Devil Canyon will be eliminated because of construction activities. Recreational use of the river including whitewater kayaking is discussed in Chapter 7.

(g) Support Facilities (**)

The construction of Devil Canyon will require the construction, operation and maintenance of support facilities capable of providing the basic needs for a maximum population of approximately 1,900 people. The facilities, including roads, buildings, utilities, stores and recreation facilities will be constructed during the first five years (1995-1999) of the proposed eleven year construction period. The camp and village will be located approximately 2.5 miles southwest of the Devil Canyon damsite. The location and layout of the camp and village facilities are presented in Exhibit F.

(i) Water Supply and Wastewater Treatment (**)

Processes identical to those employed at Watana Stage I will be used to process the domestic water supply and treat the wastewater.

The water intake has been designed to withdraw a maximum of 775,000 gallons/day (less than 1 cfs) to provide for the needs of the support communities (Acres 1982a). Since the source of this supply is the Susitna River, no impacts on downstream flows will occur throughout the duration of the camps' existence. The water supply will be treated to conform to all state and federal regulations.

The wastewater treatment facility will be sized to handle 500,000 gallons daily. The effluent from this secondary treatment facility will not affect the waste assimilative capacity of the river and will be discharged approximately 1,000 feet downstream from the intake.

Prior to the completion of the wastewater treatment facility, all wastewater will be chemically treated and stored in lagoons for future processing by the facility. No raw sewage will be discharged to the river.

Chemical toilets will be placed throughout the construction area and will be serviced and discharged into the treatment facility.

The Applicant will obtain all the necessary state and federal permits for the water supply and waste discharge facilities.

Additional details pertaining to the proposed water supply and wastewater discharge facilities are available in The Best Management Practices Manuals entitled "Liquid and Solid Waste" (APA 1985c) and "Water Supply" (APA 1985e).

(ii) Construction, Operation, and Maintenance (*)

Similar to Watana, the construction, operation and maintenance of the camp and village could cause increases in turbidity and suspended sediments in the local drainage basins (i.e., Cheechacko Creek and Jack Long Creek). In addition, there will be a potential for accidental spillage and leakage of petroleum products and concrete wastewater contaminating ground water and local streams and lakes. Through appropriate preventative techniques (APA 1985a, 1985b), these potential impacts will be minimized. All required permits for the construction and operation of the proposed facilities will be obtained.

4.2.2 - Watana Operation/Devil Canyon Impoundment (**)

(a) Reservoir Filling Criteria (**)

Reservoir filling will be completed in two distinct stages. Upon completion of the main dam to a height sufficient to allow ponding above the outlet facilities (fixed-cone valves) which are located at el. 930 ft and el. 1,050 ft, the diversion tunnel intake gates will be partially closed to raise the upstream water level from its natural level of about el. 850 ft. The Case E-VI flow requirements described in Section 3 will be maintained during this phase of filling of Devil Canyon.

Once the level rises above the lower level discharge valves, the diversion gates will be permanently closed and flow will pass through the outlet works. The outlet works have a discharge capacity of approximately 42,000 cfs when the pool level is at el. 1,455. The capacity of the outlet works at a pool level of el. 1,135 is approximately 20,000 cfs. They are described in Section 4.2.3(a)(v).

Since the storage volume required before operation of the outlet works can commence is approximately 76,000 acre-feet, the first phase of the filling process will require from one to four weeks depending on time of year and Watana powerhouse flows when filling is begun. The reservoir will not be allowed to rise above 1,135 ft for approximately one year while the diversion tunnel is being plugged with concrete.

When the dam is completed, an additional one million acre-feet of water will be required to fill the reservoir to its normal operating level of el. 1,455 ft. Filling will be accomplished as quickly as possible. During this phase of filling of Devil Canyon Reservoir, the Case E-V1 flow requirements will also be maintained downstream of the reservoir.

(b) Flows and Water Levels (**)

Because of the two distinct filling periods, the two-stage impoundment sequence will take several years to complete, even though the actual time for filling will only be two months. As noted above, flows during the first stage of filling will be affected for only a few weeks.

Between the first stage and second stage of filling, the reservoir will not be allowed to exceed el. 1,135 ft. Thus, the Devil Canyon Reservoir will be held at a relatively constant level. Flows in the Susitna River will be unchanged from those during Watana operation (see Section 4.1.3(a)).

During the second stage of filling, 1,000,000 acre-feet of water will be added to the Devil Canyon Reservoir. The reservoir will be filled from the normal Watana releases for power generation, instream flow requirements and flood releases. During the filling period, the Watana powerhouse will be operated to supply as much of the total railbelt energy demand as possible so that Devil Canyon Reservoir can be filled in a timely manner. The rate of filling will also be dependent on the need to monitor dam and foundation performance during filling to assure a safe structure.

Filling of Devil Canyon Reservoir to el. 1,455 can be accomplished in 5 to 8 weeks depending on the amount of the Railbelt energy demand which can be supplied by the Watana powerhouse and on the occurrence of flood releases through the Watana outlet works. The flow from the Watana Reservoir that is in excess of the Case E-VI requirement will be used to fill the Devil Canyon Reservoir. Although the flow from the Watana powerhouse may be higher than the normal powerhouse flow, the impact of increased flow will be minimal in the Devil Canyon Reservoir.

Flow downstream from Devil Canyon will be reduced during this filling process. However, the filling period will be short and downstream flows will be maintained at or above the Case E-VI minimum flow requirements.

Since the filling time is short and the flood control facilities at Watana and Devil Canyon will be operational during the last stage of filling, floods are likely to be important only during the time the reservoir is at el. 1,135 ft. If a flood should occur during the time the reservoir is being held constant at el. 1,135, it may be necessary to surcharge the water level in order to store the flood while releases are being made through the outlet works.

(c) River Morphology (**)

No additional impacts on river morphology will be caused by reservoir filling other than the obvious impact of transforming the Susitna River between the Watana Dam and the Devil Canyon Dam into a reservoir. Impacts described in Section 4.1.3(b) will remain relevant.

(d) Water Quality (**)

(i) Water Temperature (*)

The outlet water temperatures from Watana will be unchanged from those that occur when Watana is operated alone. Because of the rapid filling of the Devil Canyon Reservoir, there will be minimal opportunity for changes in the outlet temperatures at Devil Canyon during both stages of filling. There will be some damping of the temperature fluctuations caused by varying meteorological conditions that occurred at the Devil Canyon site when Watana operated alone.

Between the filling stages, the larger surface area of the newly formed Devil Canyon Reservoir will offer more opportunity for atmospheric heat exchange than existed before impoundment to el. 1,135. Approximately 10 miles of river will become a reservoir. However, since the retention time will only be a few days, it is expected that, at the Devil Canyon outlet and further downstream, little change in water temperature will occur from that experienced with Watana operating alone and open water temperatures described in Section 4.1.3(c)(i) will remain relevant.

(ii) Ice (o)

An extensive ice cover is not expected to form on the Devil Canyon Reservoir during the period when the pool is maintained at el. 1,135 ft because of the warm water inflow from the Watana Reservoir. Additionally, since downstream winter temperatures will not be significantly affected by the pool, ice processes downstream from Devil Canyon described in Section 4.1.3(c) (ii) will remain relevant.

(iii) Suspended Sediments/Turbidity/Vertical Illumination (**)

As previously discussed, the Watana Reservoir will act as a sediment trap, greatly reducing the quantity of suspended sediment entering the Devil Canyon Reservoir.

Immediately prior to filling, the reservoir area will be selectively cleared of large vegetation. By delaying this activity until filling is about to commence, erosion and siltation problems prior to filling the reservoir will be minimized. During filling, however, the lack of soil stabilizing vegetative cover may cause increased erosion. These impacts are only expected to create short-term increases in turbidity and suspended sediment concentrations. In addition, suspended sediment concentration and turbidity increases may also occur within the Devil Canyon impoundment as a result of the slumping of the valley walls. However, since the Devil Canyon impoundment area is characterized by a very shallow overburden layer with numerous outcroppings of bedrock, slope instability should not significantly affect turbidity and suspended sediment concentrations. A further discussion of the slope stability can be found in the Susitna Hydroelectric Project Geotechnical Report (Acres 1982c).

As reservoir filling progresses, the Devil Canyon Reservoir will provide additional settling capability. Thus, the net result will be a slight decrease in suspended sediment and turbidity and a corresponding slight increase in vertical illumination downstream from Devil Canyon.

(iv) Dissolved Oxygen (**)

As previously discussed in Section 4.1.3(c)(v), water discharged from Watana and entering Devil Canyon will have a high dissolved oxygen concentration and low BOD.

Because of the extremely short residence time, no hypolimnetic oxygen depletion is expected to develop either during the period that the reservoir is held at el. 1,135 ft, or during the final period of reservoir filling.

Prior to filling, large standing vegetation in the reservoir area will be selectively harvested or cleared and burned, thereby eliminating some of the oxygen demand that would be caused by inundation and subsequent long-term decomposition of vegetation.

(v) Total Dissolved Gas Concentration (**)

Dissolved gas supersaturation will not be a concern during the filling of the Devil Canyon Reservoir. As the reservoir is filled, the rapids between the mouth of Devil Creek and the Devil Canyon dam site will be inundated and the turbulence that presently causes the supersaturation will thus be eliminated. Thus, dissolved gas concentrations in the reservoir area will be less than those for Stage I operation (4.1.3 (c)(vi)).

During the initial filling to el. 1,135 ft, the diversion tunnel will be utilized. Gas supersaturation in downstream waters resulting from diversion tunnel use is not expected to exceed naturally occurring levels.

After el. 1,135 ft is attained and for the balance of the filling sequence, discharge will be via the outlet works. Nitrogen supersaturation downstream from the dam will be reduced from Stage I and naturally occurring levels because of the inundation of the Devil Canyon rapids. The operation of the outlet works is discussed in further detail in the Mitigation Section 6.7.4.

(vi) Nutrients (**)

Similar to Watana Stage I, two opposing factors will affect nutrient concentrations during the filling process. First, initial inundation will likely cause an increase in nutrient concentrations due to leaching. Second, sedimentation will remove some nutrients from the water column. The magnitude of the net change in nutrient concentration is unknown, but it is likely that nutrient concentrations will increase in close proximity to the reservoir floor.

(vii) Total Dissolved Solids, Conductivity, Significant Ions, Alkalinity, and Metals (**)

Similar to the process occurring during Watana filling, increases in dissolved solids, conductivity and most of the major ions will likely result from leaching of the reservoir soils and rocks during Devil Canyon filling. The products of the leaching process will be confined to a layer of water near the bottom (Peterson and Nichols 1982).

For initial filling from el. 850 ft when the diversion tunnel is being used, no significant downstream impacts are foreseen since it will take only a few weeks to accumulate the 76,000 acre-feet of water required to fill the Devil Canyon Reservoir to el. 1,135 ft. In such a short time, insignificant leaching would occur which could be detrimental to downstream water quality.

Subsequent to this initial phase of filling and for the remainder of the filling process, the outlet works will be utilized for reservoir discharge.

The outlet works will draw water from well above the bottom of the impoundment at el. 930 ft and el. 1,050 ft. Products of the leaching process would be highly diluted prior to release and downstream water quality should not be adversely impacted.

(e) Ground Water Conditions (o)

No major ground water impacts are anticipated during the filling of the Devil Canyon Reservoir. The increased water level within the reservoir will be confined between bedrock walls. Downstream there may be a slight decrease in the ground water table caused by the reduced filling flows for the short periods when water is being impounded (see Section 2.4.4). A decrease in the ground water level in the same proportion as the decrease in mainstem stage would be expected. The change in ground water level will be confined to the alluvial deposits adjacent to the river.

(f) Lakes and Streams (*)

As the Devil Canyon pool level rises, the mouths of the tributaries entering the reservoir will be inundated (see Table E.2.2.41). As the reservoir is filled, sediment transported by these streams will be deposited at the new mouthes of the streams.

(g) Instream Flow Uses (**)

(i) Fishery Resources, Wildlife Habitat, Riparian Vegetation and Recreation (**)

As Devil Canyon Reservoir is filled, new fishery habitat will become available within the reservoir. However, adverse impacts to fish habitat may occur as tributary mouths become inundated. In addition, terrestrial habitat will be permanently lost as a consequence of reservoir filling. Detailed information on reservoir and downstream fisheries, wildlife, and botanical impacts are presented in Chapter 3. Recreational use including whitewater kayaking is discussed in Chapter 7.

(ii) Navigation and Transportation (**)

During filling, the rapids upstream from Devil Canyon will be inundated. Flatwater boating opportunities will replace the present whitewater boating. Downstream water levels may be slightly less than the normal Watana operation level during the short impoundment periods. This will not affect navigation because the E-VI minimum flows will be maintained and these provide adequate flows for navigation (Section 4.1.3 (f)(ii)).

(iii) Waste Assimilative Capacity (*)

Although flows in the river will be reduced during the two Devil Canyon Reservoir filling periods, the waste assimilative capacity of the river will not be affected.

(iv) Freshwater Recruitment to Cook Inlet Estuary (*)

Small temporary changes to the Cook Inlet salinity regime established during the operation of Watana alone are expected only during the second phase of filling Devil Canyon. This is because of the short duration of the first phase of filling and the small impoundment volume required relative to the average annual Susitna River discharge to Cook Inlet.

(h) Testing and Commissioning (***)

The first unit at Devil Canyon is scheduled to be tested and commissioned in the October 1994 to December 1994 period. Units will be added at three month intervals thereafter. The testing and commissioning of the units involves many sequences of bringing the unit on-line and taking it off-line. These will be carried out in a manner to minimize impacts to flow stability. To compensate for flow passing through the units during testing, the flow through the outlet works will be reduced by a comparable amount as discussed for the testing and commissioning of the Watana Stage I units (Section 4.1.2 (c)).

4.2.3 - Watana Stage I - Devil Canyon Operation (**)

(a) Flows and Water Levels (**)

(i) Project Operation (**)

After Devil Canyon comes on line, Watana Stage I will be operated as a peaking plant and Devil Canyon will re-regulate Watana flows. Advantage will be taken of the two-reservoir system to optimize energy production with the constraint that the Case E-VI downstream flow requirements will be met. Devil Canyon discharges may vary between 90 percent and 110 percent of the average weekly flow. A more detailed discussion of project operation is included in Section 3.

The Devil Canyon Reservoir will normally be at its maximum water level, el. 1,455, between January and May. In dry years Devil Canyon will be drawn down between May and December reaching its minimum level of el. 1,405 in August. In average flow years, the reservoir will be drawn down between June and August reaching a minimum of approximately el. 1,435 in July. Average weekly Devil Canyon powerhouse flows will be similar to Watana, but slightly higher due to additional inflow in the intervening area between the two dams.

With Devil Canyon on line, Watana will still be operated in a storage-and-release mode similar to Stage I, so that summer flows will be stored for release in winter. Generally, the Watana Reservoir will be at or near its normal maximum operating level of el. 2,000 feet each year at the end of September. The reservoir will gradually be drawn down to meet winter energy demand. The flow during this period will be governed by winter energy demand, water level in the reservoir, and powerhouse characteristics. The turbine characteristics will allow a maximum powerhouse flow of approximately 14,000 cfs at full gate. Normal Watana average weekly powerhouse discharges will range from approximately 3,000 cfs to 8,500 cfs.

In early May, the Watana Reservoir will reach its minimum annual level of approximately el. 1,870 ft and then begin to refill with the spring runoff. Flow in excess of both the downstream flow requirements and power needs will be stored during summer until the reservoir reaches the normal maximum operating level of el. 2,000 ft. If the reservoir reaches el. 2,000 ft, and inflow exceeds energy and instream flow requirements, excess flow will be released to maintain dam safety requirements (see Section 3.6.2).

- <u>Environmental Flow Requirement</u> (**)

  During project operation the Case E-VI environmental flow requirements will be maintained as discussed in Section 3. Minimum requirements will be met by releases from the powerhouse and, if necessary, the outlet works.

- <u>Weekly Reservoir Simulations</u> (**)

  Weekly simulation of reservoir operation was conducted for the 34 years of record from 1950 through 1983 for Case E-VI flow requirements. Reservoir operation and water levels are summarized on Figures E.2.4.114 through E.2.4.121.

  Additionally, to provide a sensitivity analysis for flows and temperatures, weekly reservoir simulations were made for Case E-I flow requirements (HE 1984h). Results of the reservoir simulations are presented in Figures E.2.4.122 through E.2.4.129.

  Case E-I was chosen for the sensitivity testing because it has the highest minimum summer flow requirements of any of the cases considered (14,000 cfs). For comparison, Case E-VI minimum summer flow requirements are 9,000 cfs. With the information on these two extremes it is possible to estimate the effects of project operation on water use and quality for other sets of flow requirements between E-I and E-VI.

- Daily Operations (**)

Daily operation of Watana and Devil Canyon powerhouses are explained in Section 3 and the Applicant's "Case E-VI Alternative Flow Regime Report" (HE 1985f). Watana will act as a peaking plant and Devil Canyon will re-regulate flows. The peaking of Watana will cause a water level fluctuation of less than one foot in Devil Canyon Reservoir.

Figures E.2.4.31 through E.2.4.34 may be used to estimate the average weekly stage variation resulting from changes in weekly average flow. These curves are based on steady state rating curves at the noted locations.

For example, at RM 127.1 for a weekly average flow of 10,000 cfs the maximum weekly stage fluctuation for a ±1,000 cfs or ± 10 percent flow variation would be 0.44 ft (±0.22 ft). The corresponding fluctuation at RM 136.68 would be 0.6 feet (±0.30 ft).

These figures have been drawn for locations near the upstream ends of Sloughs 8A, 9, 11 and 21. Examination of water surface profiles in the report "Susitna Hydroelectric Project - Middle and Lower River Water Surface Profiles and Discharge Rating Curves" (HE 1984d) indicates these represent the range in stage fluctuation for a given discharge fluctuation in the middle reach of the Susitna River. The rating curve at the Slough 11 head appears to give near maximum stage fluctuations while those at Sloughs 8A and 21 give near minimum stage fluctuations.

Table E.2.4.6 and Figure E.2.4.35 show the surface area of the mainstem and peripheral habitat areas of the Susitna River between Devil Canyon and the Susitna-Chulitna confluence. These can be used to estimate the change in habitat surface area for a change in discharge. The change in gravel and vegetated bar surface areas represents the area which is either exposed or covered by water as the water level decreases or increases, respectively. The relationships were compiled from mapping of aerial photographs of the river at flows less than 25,000 cfs (EWTA 1985) and from simulations of water surface profiles in the river (HE 1984d).

(ii) Mean Monthly Flows and Water Levels (**)

Weekly water levels and discharges at Watana were simulated using the weekly reservoir operation program. Maximum, minimum and average monthly reservoir water levels are shown on Figures E.2.4.114 through E.2.4.121 for Case E-VI. Maximum water levels are those which would normally be attained in wet years and minimum levels are attained in dry years.

The Watana Reservoir fills to el. 2,000 in almost every year and is drawn down to between el. 1,850 and 1,870 by April. The effects of the 1969 and 1970 low flow years are indicated by the low reservoir level attained in September of 1969 and 1970.

The Devil Canyon Reservoir fills to el. 1,455 and is stable at that level in wet years. In average flow years the reservoir may be drawn down to el. 1,435 in July but is filled by September. In dry years the reservoir may be drawn down to near minimum level between June and October.

The sequences of simulated monthly flows at Watana, Gold Creek, Sunshine and Susitna Station for Case E-VI are shown in Tables E.2.4.31 through E.2.4.35, respectively. Tables E.2.4.36 through E.2.4.39 compare natural to with-project conditions. Figures E.2.4.151 through E.2.4.155 show simulated natural and with-project flows at Gold Creek for:

- o 1964 - Flood of record in June
- o 1967 - Large flood in August
- o 1970 - Second driest year
- o 1981 - Wet year used in temperature analyses
- o 1982 - Average flow year used in temperature simulations.

In general, project operation results in higher than natural winter flows and lower than natural summer flows. Flood peaks are considerably reduced. Lowest flows occur in early May and October.

The Watana Reservoir normally is full in September. Winter energy demands are met from reservoir storage. The energy demands in October and May are less than for other winter months and the flows in these two months are correspondingly lower than for the rest of winter. Flows are generally more stable in Stage II than in Stage I from October through June, but less stable in July through September. This is a result of the increased generating capacity.

The increase in hydraulic head and generating capacity when Devil Canyon becomes operational means that winter energy demands can be met with less flow than in Stage I. This means less water is needed to meet mid-winter (December-February) demands and more water can be used in October, March, April and May. Thus, with Stage II, winter flows are more uniform than in Stage I. Additionally, because the generating capacity is greater than in Stage I, summer energy demands require less flow, thus Watana storage is filled earlier in the summer and non-power releases are necessary earlier than in Stage I. This accounts for the higher July-September flows with Stage II than for Stage I.

With-project mean monthly flows at Gold Creek are compared to natural flows in the following table.

Month	Natural	With-Project	Percent Change
January	1,500	8,000	+430
February	1,300	7,500	+480
March	1,200	6,300	+430
April	1,400	6,000	+330
May	13,500	7,100	- 50
June	27,800	9,200	- 70
July	24,400	14,900	- 40
August	21,900	20,300	- 10
September	13,500	13,600	0
October	5,800	7,600	+ 30
November	2,600	7,900	+200
December	1,800	8,600	+380

Further downstream at Sunshine and Susitna Station, the differences between natural and with-project flows are reduced, due to the inflows from tributaries. The following tables illustrates the differences at Sunshine and Susitna Stations.

Sunshine

Month	Natural	With-Project	Percent Change
January	3,700	10,200	+180
February	3,100	9,300	+200
March	2,800	7,900	+180
April	3,600	8,100	+130
May	28,000	21,000	- 20
June	63,000	45,000	- 30
July	64,000	55,000	- 15
August	56,000	55,000	0
September	33,000	33,000	0
October	14,000	16,000	+ 15
November	6,200	12,000	+ 90
December	4,400	11,000	+150

Susitna Station

Month	Natural	With-Project	Percent Change
January	8,100	15,000	+90
February	7,400	14,000	+90
March	6,400	12,000	+90
April	7,700	12,000	+60
May	57,000	50,000	-10
June	112,000	94,000	-15
July	127,000	117,000	-10
August	109,000	108,000	0
September	68,000	68,000	0
October	33,000	35,000	+ 5
November	15,000	20,000	+30
December	9,300	16,000	+70

Mean annual flow will remain the same at all stations. However, flow will be redistributed from the summer months to the winter months to meet energy demands.

Water surface elevations based on maximum, mean, and minimum monthly flows at Gold Creek for May through September for selected mainstem locations between Portage Creek and Talkeetna are illustrated in Figures E.2.4.135 through E.2.4.137. The figures illustrate the water level change expected as a result of operation of Stage II.

In general, there is a decrease in water level from natural levels to with-project levels in the summer. As illustrated by ice simulations later in this section, there is a comparable increase in stages in winter.

(iii) Floods (**)

The operation of the project during floods is explained in Section 3.6.2.

The method for estimating flood frequency is given in Section 4.1.3.(a)(iii). With Devil Canyon operational, a small amount of flood storage will be provided to prevent spillway releases during the floods with return periods of less than 50 years. This will cause the maximum outflow for these events to be less than or equal to 42,000 cfs, the outlet works capacity.

- Spring Floods (**)

For the 34 years of weekly simulations, Watana Stage I Reservoir had sufficient storage capacity to absorb all floods. The largest flood of record, June 7, 1964, had a peak discharge of 90,700 cfs at Gold Creek, corresponding to a recurrence interval of about than 40 years (annual series). This flood provided the largest mean monthly inflow on record at Gold Creek, 50,580 cfs, and contained the largest flood volume on record. For this flood, the simulated reservoir level increased from el. 1,850 ft to el. 1,994 ft. A further six feet of storage were available before an outlet works release would have been necessary.

The flood volume for the May-June 1:50-year flood was determined to be 1.4 million acre-feet (HE 1984c). The 50-year May-June flood was routed through Watana Reservoir starting with a median May-June water level of el. 1,882. The average Watana turbine discharge of 3,400 cfs was used. The flood was passed through the reservoir without raising the water level above el. 2,000, and not requiring operation of the outlet works or spillway (see Sections 4.2.3(a)v and 6.7.4).

Spring floods downstream of the project will be reduced by the discharge stored in Watana Reservoir. Devil Canyon Reservoir will generally be full during this period and will not provide any flood storage. Peak flows will generally be passed through Devil Canyon Reservoir without attenuation. Flood flows will be less than for natural conditions in the middle reach.

In the reach downstream of the confluence flood flows will be closer to natural than in the middle reach. This is because in the lower reach, the drainage area controlled by the dam is proportionally much less than in the middle reach. Additionally, under natural conditions, flood peaks in the lower reach may often result from peak flows in drainage areas not controlled by the project.

The following table gives the frequency of May-June floods at Watana, Gold Creek, Sunshine and Susitna Stations.

May-June Flood Frequency

Return Period	Watana		Gold Creek	
(Years)	Natural	With-Project	Natural	With-Project
2	39,000	3,400	42,500	17,300
5	51,500	3,400	56,200	24,300
10	60,000	3,400	66,300	28,100
25	73,800	3,400	80,500	31,400
50	84,400	3,400	92,100	35,400

Return Period	Sunshine		Susitna Station	
(Years)	Natural	With-Project	Natural	With-Project
2	118,000	80,000	156,000	122,000
5	135,000	91,000	179,000	139,000
10	149,000	102,000	197,000	154,000
25	163,000	111,000	215,000	170,000
50	174,000	119,000	230,000	183,000

The table indicates the 50-year flood peak at Gold Creek of 35,400 cfs is less than the capacity of the Devil Canyon outlet works. Thus the 50-year flood can be passed through the Devil Canyon Reservoir using only the powerhouse and outlet works and without using the spillway, thus minimizing the potential for nitrogen supersaturation (see Sections 4.2.3(a)v and 6.7.4).

For spring floods greater than the 1:50-year event, it is possible that the Watana Reservoir would fill, and inflow would be set equal to outflow. If this occurred, floods downstream would be similar to natural conditions.

- Summer Floods (**)

During average and wet years, the Watana Reservoir will reach el. 2,000 ft sometime in July or August. Design considerations were therefore established to ensure that the powerhouse and outlet facilities would have sufficient capacity to pass the 1:50-year summer flood without operation of the main spillway (see Sections 4.2.3(a)v and 6.7.4). A further decision criterion was established such that the reservoir would be allowed to surcharge to el. 2,014 ft during the 1:50 year flood. This is explained in Section 3.6.2.

The derivation of the July-September 1:50 year inflow hydrograph at Watana is given in a report by the Applicant (HE 1984c).

The 50-year July-September flood at Watana has a peak of 77,800 cfs and a volume of 1.14 x 10^6 acre feet. This flood was routed through Watana Reservoir assuming a median July-September water level of el. 2,000. The average powerhouse discharge of 10,400 cfs was also used. The maximum water level obtained did not exceed el. 2,014 and the spillway was not operated. The maximum outflow was 34,400 cfs, comprised of 24,000 cfs outlet works flow and 10,400 cfs powerhouse flow.

The following tables give the July-September flood frequency for Watana, Gold Creek, Sunshine and Susitna Stations.

July-September Flood Frequency

Return Period (Years)	Watana Natural	Watana With-Project	Gold Creek Natural	Gold Creek With-Project
2	34,200	31,100	37,300	36,500
5	45,700	34,400	49,800	43,100
10	54,500	34,400	59,400	45,000
25	67,200	34,400	73,200	45,000
50	77,800	34,400	84,800	47,000

Return Period (Years)	Devil Canyon With-Project	Sunshine Natural	Sunshine With-Project
2	34,600	138,000	129,000
5	40,900	163,000	149,000
10	41,000	180,000	162,000
25	41,000	196,000	175,000
50	42,000	210,000	187,000

Return Period (Years)	Susitna Station Natural	Susitna Station With-Project
2	183,000	183,000
5	216,000	212,000
10	238,000	232,000
25	259,000	253,000
100	278,000	271,000

These were derived in the same manner as for May-June floods.

The peak inflow to Devil Canyon Reservoir for the 50-year flood is approximately 44,000 cfs for Stage II operation. This exceeds the capacity of the outlet works by 2,000 cfs. Therefore, provision has been made in the operating policy for Devil Canyon Reservoir (Section 3.6.2) to surcharge the water level to store and release the 50-year flood without operating the spillway.

- Annual Floods (**)

Annual flood peaks of the Susitna River at the project sites most frequently occur in June. The annual series 50 year flood at Watana was calculated to have a peak discharge of 89,500 cfs and a volume of 1.43 x 10^6 acre feet (HE 1984c). This flood was routed through the Watana Reservoir assuming a median June water surface level of el. 1,920, and an average June powerhouse flow of 2,500 cfs. According to the operating policy in Section 3.6.2, the powerhouse discharge was shifted from Devil Canyon to Watana when the Watana water level reached el. 2,000 thus increasing the Watana capacity to 10,400 cfs. The maximum water level attained did not exceed el. 2,014. The maximum outflow was 23,400 cfs. The Watana discharge during the peak flow at Gold Creek was only 2,500 cfs. Spillway operation was not required and nitrogen supersaturation would be minimized (see Sections 4.1.3(a)v and 6.4.4). The following table illustrates the annual series flood frequency at Watana, Gold Creek, Sunshine and Susitna Stations computed in the same manner as for May-June and July-September values.

Annual Flood Frequency

Return Period	Watana		Gold Creek	
(Years)	Natural	With-Project	Natural	With-Project
2	43,500	2,500	48,000	19,200
5	57,400	2,500	63,300	26,900
10	67,000	2,500	73,700	31,300
25	79,800	2,500	87,300	35,200
50	89,500	2,500	97,700	39,800

Return Period	Devil Canyon	Sunshine	
(Years)	With-Project	Natural	With-Project
2	15,900	143,000	102,000
5	22,000	166,000	119,000
10	25,600	183,000	131,000
25	28,700	200,000	145,000
50	32,400	214,000	157,000

Return Period	Susitna	
(Years)	Natural	With-Project
2	189,000	157,000
5	220,000	183,000
10	242,000	202,000
25	264,000	223,000
50	283,000	252,000

The July-September, with-project flood frequency has generally greater flood peaks than the with-project annual series. Therefore with-project, the flood frequency will be as defined for the July-September series.

Under natural conditions, the highest annual floods at Gold Creek generally occur in June. With-project, the annual flood peaks will generally occur in the July-September period rather than June. At Sunshine and Susitna Stations the annual flood peaks normally occur in the July-September period and will continue to do so with-project. The magnitude of the reduction in annual flood peaks will be greatest at the dam and reduced with distance downstream. The mean annual flood flows, assuming approximately a 2-year return period (USDI 1974), for Gold Creek, Sunshine and Susitna Stations are shown below.

Mean Annual Flood Flow
2-Year Return Period

	Natural (Annual Series)	With-Project (July-Sept. Series)
Gold Creek	48,000	36,500
Sunshine	143,000	129,000
Susitna Station	189,000	183,000

Downstream of the confluence with Chulitna and Talkeetna Rivers there is approximately a 10 percent reduction in the mean annual flood. Downstream of the Yentna River confluence there is an approximate 3 percent reduction in the mean annual flood. The with-project flood frequency for Gold Creek, Sunshine and Susitna stations is shown on Figures E.2.2.38, E.2.2.40, and E.2.2.41, respectively.

(iv) Flow Variability (**)

Under normal hydrologic conditions, flow from the Stage II development will be regulated. The downstream flow will be controlled by one of the following criteria: downstream flow requirements, minimum power demand, or reservoir operating rule curve. However, there can be significant variations in discharge from one season to the next and, for the same month, from one year to the next.

Flow variability under natural conditions is illustrated by the flow duration curves using daily recorded flow values shown on Figures E.2.2.44 and E.2.2.45.

As discussed in Section 3.6.1, with-project flow from the powerhouse may be allowed to vary by 10 percent above and below the mean weekly flow. The maximum variation in the mean weekly flow from one week to the next will be 20 percent.

For Case E-VI flow requirements, weekly reservoir operations have been made to illustrate the variability in weekly average flows for five years. These are illustrated by Figures E.2.4.130 through E.2.4.134. There will also be variation in flows in one week from year to year. Figures E.2.4.138 through E.2.4.141 show the 6 percent, 50 percent and 97 percent exceedence level flows for each week of the year.

Additional simulations have been made with Case E-I flow requirements. Figures E.2.4.142 through E.2.4.145 illustrates the 6 percent, 50 percent and 97 percent exceedence level flows obtained and Figures E.2.4.146 through E.2.4.150 show the variability in weekly average flow throughout the year.

Additionally, in order to illustrate the variation in with-project flows as compared to natural variation, monthly flow duration curves have been prepared for Watana, Gold Creek, Sunshine and Susitna Stations (Figures E.2.4.151 through E.2.4.155.

These curves are based on monthly average with-project flows. The natural flow duration curves on these exhibits are based on monthly average flows and not on daily values as in Figures E.2.2.44 and E.2.2.45.

The exhibits illustrate the improvement in flow stability for with-project conditions as compared to natural conditions. The project outflows show little variability because of the high degree of reservoir regulation and the relatively constant powerhouse flow. Gold Creek exhibits more variation because of the variability in local inflow. The flow duration curves show a diminished natural and with-project difference with distance downstream from Watana.

(v) Operation of Watana and Devil Canyon Outlet Works and Fixed-Cone Valves (**)

The outlet works at Devil Canyon are controlled by the four 102-inch and three 90-inch diameter fixed cone valves which have a combined capacity of approximately 42,000 cfs at the normal maximum pool and 80 percent gate stroke. The four intakes to the 102-inch valves will draw water from el. 1,050 and discharge it approximately 120 feet above normal tailwater. The three 90-inch valves will draw water from el. 930 and discharge it about 50 ft above the normal tailwater level. The purpose of these outlet works is to release flows to meet environmental requirements and to pass flood flows without using the spillway. As noted under in Section 4.2.3(a), floods up to the 50-year event can be discharged without using the spillway. Table E.2.4.40 gives information on outlet works operation from the weekly reservoir simulations.

Included for each year of the 34 years of simulation are the week of first release, the week of maximum release, the maximum release, the powerhouse flow at the time of maximum release, and the volume released and the maximum Watana release during the period of Devil Canyon outlet works operation.

As shown, the outlet works would operate in mid to late summer of almost every year. This occurs because the reservoir has filled and it is necessary to pass flows to maintain freeboard on the dam.

Information on the downstream temperature impacts caused by the operation of the outlet works can be found in Section 4.2.3(c)(i).

(b) River Morphology (**)

When Devil Canyon comes on line, the project will be operated in a similar manner to Stage I. However, the increased generating capacity for Stage II can meet energy demands with lower average outflows than Stage I. This results in earlier filling of Watana Reservoir in Stage II than in Stage I. Excess releases in Stage II occur earlier and are somewhat greater than in Stage I. Weekly flows at Gold Creek as simulated by reservoir operation studies are shown in Figures E.2.4.138 through E.2.4.141.

These studies indicate that mean-annual maximum weekly flow at Gold Creek will be about 24,000 cfs under Stage I operation and about 28,000 cfs under Stage II operation. Using the higher values of 28,000 cfs as the dominant discharge, the potential degradation of the Susitna River in the middle river at the studied sites between Devil Canyon and the confluence will be on the order of 1.0 to 1.5 feet. This is based on an analysis of selected locations (see Section 2.3.3). The extent of degradation will gradually decrease to nearly zero at the confluence of the Susitna and Chulitna Rivers. This is because there will be some aggradation at the confluence which will prevent degradation of the channel immediately upstream.

Impacts of the Stage II project operation on the morphology of the Susitna River near the confluence and downstream from the confluence will be similar to those discussed in Section 4.1.3(c). The impact on side channels and sloughs also will be similar.

(c) Water Quality (**)

(i) Water Temperature (**)

- Watana and Devil Canyon Reservoirs (**)

The DYRESM model as described in Section 4.1.3(c)(i) was used to predict reservoir temperature profiles and outflow temperatures from both the Watana and Devil Canyon Reservoirs. The Watana inflow, the inflow temperature, and meteorological data observed at both the Watana and Devil Canyon weather stations for the period November 1980 through April 1983 were used. The Watana meteorological data used are the same as for Watana operating alone (Section 4.1.3(c)(i)), however, Watana outflow is changed due to the different mode of operating the Watana reservoir when both projects are operational.

The flows simulated for the Case E-VI downstream requirement were used as the source of inflow-outflow data for the two reservoirs.

The Watana Stage I intake structure shown on Figure E.2.4.66 was used in the Watana simulations. The two-level intake for Devil Canyon Reservoir shown on Figure E.2.4.156 was used for Devil Canyon simulations. Additional reservoir temperature runs were made to test the sensitivity of reservoir outflow temperatures to:

- o Modification of the Devil Canyon multi-level intake to include a third level of ports between the two proposed levels,
- o Modification to the allowable drawdown at Devil Canyon Reservoir to keep the water level above the upper intake port level,
- o Use of Case E-I environmental flow requirements rather than Case E-VI, and
- o Various other policies of operating the two-level intake and outlet works including the possible raising of the outlet works intake.

Watana outflow, outflow temperature, and the flow contribution from the area between the damsites are inputs to the Devil Canyon Reservoir.

The temperature of the outflow from the Watana Reservoir is more stable than the natural thermal regime. Thus, a thermally more stable than natural inflow is input to Devil Canyon. The Devil Canyon inflow temperatures are cooler in June and warmer in September than those which occur naturally. Devil Canyon Reservoir exhibits a general pattern of early summer warming, summer stratification, and fall to winter cooling through an isothermal condition to reverse stratification similar to Watana.

Stratification and outflow temperatures at Watana during Stage II under the assumed operating condition are similar to those of Watana operating alone in Stage I. Figures E.2.4.157 and E.2.4.158 show the Watana inflow temperatures and the predicted Devil Canyon Reservoir outflow temperatures for the two level outlet. The ice-cover formation and the operation of the intake structure and outlet works are also shown. Devil Canyon Reservoir outflow temperatures lag behind those of Watana by up to four weeks in summer. The lag is greater in wet years (1981) than in average years (1982). Outflow temperatures from Devil Canyon exhibit less short-term variations than those from Watana.

Figures E.2.4.159 and E.2.4.160 show the simulated Devil Canyon outlet temperatures for inclusion of a third level of ports between the proposed two levels. Figures E.2.4.161 and E.2.4.162 show the simulated outlet temperatures for a revised Devil Canyon drawdown designed to keep the water level above the upper intake port level. Figures E.2.4.163 and E.2.4.164 show the outlet temperatures for the Case E-I flow requirements. These sensitivity studies are more thoroughly discussed in the section on temperatures downstream of the dam.

Typical reservoir temperature profiles of Devil Canyon are shown in Figures E.2.4.165 through E.2.4.170 for the two level intake policy with the maximum allowable drawdown of 50-feet. These plots indicate that the Devil Canyon Reservoir would also develop thermal stratification in summer and ice-cover in winter. With a shorter residence time due to its smaller volume (about one-fourth of Watana Stage I) and lower outlet works intake facilities located 400 to 500 feet below the surface, the temperature structure in the reservoir would be more dynamic than that of Watana Reservoir especially in the hypolimnion. The outlet works would, therefore, draw mostly hypolimnetic water at a relatively constant temperature of about 4°C in early summer and increase gradually toward a higher temperature of about eight to 10°C in late summer.

The summer near surface epilimnion would be thinner with steeper thermoclines in June and July. The multi-level intake would be less effective in selectively withdrawing water for controlling outflow temperatures.

In June and July when the outlet works are not in operation, the Devil Canyon outflow temperature may vary from about five to 10°C while the Watana inflow temperatures may vary from about five to 12°C. In August, the outlet works would be operated frequently and would result in a more constant outflow temperature of about 6 to 8°C while the Watana inflow temperature may vary from 5 to 10°C. Additional studies carried out for Case C downstream requirements and various hydrological and meteorological conditions and energy demands also showed similar characteristics (APA 1984a Appendix IV).

The winter outflow temperature from the Devil Canyon Reservoir would be in the range of about 1.5°C to 3°C. In general, the period of fall total mixing or overturn at Devil Canyon would last longer than at Watana due to warmer fall inflow from the Watana Reservoir and because most of the summer outflow in excess of powerhouse flow would be passed through the outlet facilities. The temperatures in some fall overturns could approach approximately 7°C when the summer inflows are relatively high. The winter temperature structure and the timing of the ice-cover formation and meltout would be similar to Watana Reservoir. However, the maximum ice thickness of the ice-cover would be about 6 to 12 inches less than Watana Reservoir.

- <u>Devil Canyon to Talkeetna</u> (**)

  . <u>Mainstem</u> (**)

  The Devil Canyon operation outflow temperatures, which were simulated using DYRESM were used to determine the water temperatures in the reach between Devil Canyon and Talkeetna. The discharge and outflow temperatures from Watana were used as input for the program SNTEMP, described in other reports (AEIDC 1983, 1984a, 1984b, 1984c, 1985a).

  River temperatures were simulated on an average weekly basis. Output of daily temperatures from DYRESM were averaged and used in the weekly simulations along with average weekly discharges from the reservoir operation results presented in 4.2.3(a).

  Temperature simulations using SNTEMP were carried out for open water reaches of the river between the dams and the Sunshine stream gaging station (RM 84). In summer, the entire reach was simulated. In winter, only the reach from the dams downstream to the location where water temperature reached 0°C was simulated. Only the period May 1981 through September 1982 was simulated for the three-stage project. This represents a wet summer, followed by a winter of average temperatures followed by an average flow summer. The selection of cases for simulation is discussed in the Applicant's replies to the

FERC's Request for Supplemental Information of April 12, 1983 Schedule B, Exhibit E Nos. 2.28 and 2.41.

Simulations for the three-stage project were limited to the cases discussed above, in order to show the similarities and differences between simulated temperatures for the original two-stage and the proposed three-stage project. The simulations which have been made for the two-stage project (APA 1984a Appendix V, HE 1985f Appendices H and I) may be used to determine the sensitivity of the river temperatures to other hydrologic and meteorologic conditions. Simulations are also presented in other reports (AEIDC 1983, 1984a, 1984b, 1984c, 1985a).

The results of the simulations are presented on Figures E.2.4.171 through E.2.4.173 and on Tables E.2.4.41 and E.2.4.42. The figures indicate that the river temperatures for Watana Stage II at RM 150, 130 and 100 are on the average 1°C warmer between July and September than the temperatures for the same energy demand for the original two-stage project. Winter open water temperatures are somewhat colder and this is reflected in the ice simulations discussed later. With the three-stage project, temperatures are up to 2°C warmer than for the two-stage project in July through September. This is because the intake to the outlet works is located higher, relative to the surface, in Watana Stage I than in the two-stage project. Thus, outlet works discharges in this period are from warmer water than for the two-stage project.

Temperatures at RM 130 in Stage II are cooler than for Stage I in June through early August and warmer than for Stage I between mid-August and mid-April. In May the temperatures in Stages I and II are similar. This is a result of the lag in outflow temperatures introduced by Devil Canyon Reservoir, and of the fact that there is less distance between Devil Canyon Dam and RM 130 than between Watana Dam and RM 130. This means there is less opportunity for solar and atmospheric radiation to warm the outflowing water in Stage II than in Stage I.

Summer with-project river temperatures exhibit a lag behind natural conditions of approximately one month. Simulated temperatures at RM 130 are generally near 4°C in early May, peak at near 10°C in late August through late September, and decrease to 0°C by late December.

In winter, the temperature of the mainstem will remain above 0°C longer than natural because of the warmer outflows from the project. The temperature in the spring will warm up above 0°C sooner for the same reason. Between the upstream end of the ice cover and the dams the river temperature will generally be between 0°C and 2°C to 3°C, whereas the natural temperature in this reach is 0°C. This change in winter temperatures is reflected in ice simulations discussed later.

In wet years the reservoir fills by early July and thus the outlet works must be operated to pass flow. Because the outlet works draw from a lower elevation in the reservoir, its flows are generally cooler. This causes the drop in river temperatures in July in the 1981 simulation and a smaller drop in the 1982 simulation.

Based on these simulations and simulations of natural conditions, the mean annual temperature (time weighted) at RM 130 for the period May 1981 to April 1982 was calculated to be 3.7°C for natural conditions and 4.2°C for with-project conditions. Simulations of other hydrological and meteorological conditions for other flow requirements also indicated that the mean annual temperature with-project would be similar to natural conditions.

The simulated temperatures shown on Figures E.2.4.171 through E.2.4.173 are for the proposed three-stage project with a two-level intake at Devil Canyon Reservoir. The simulated operation of the project results in a drawdown of Devil Canyon Reservoir in mid-June. This drawdown may be up to 50 feet in some years. When the water level decreases below the upper of the two levels, the lower level intake is opened. This intake, being relatively deeper in the reservoir, draws colder water for a short period until the water level decreases further. Thus, there is a simulated decrease in river temperatures in mid-June to early July depending on the year simulated. The effect of this drop is most noticeable near the dam, and because of climatic conditions is not noticeable at RM 100. Two simulations were carried out with modifications to the operating policy of Devil Canyon and to the multi-level intake to attempt to improve temperatures. Because the effects of these two modifications on temperatures were minor, the Applicant maintained the Devil Canyon drawdown of 50 feet and the two level intake as discussed previously. The modifications which the Applicant considered are discussed below.

The first of these modifications was to hold the water level at Devil Canyon above the upper level intake which limits the drawdown at Devil Canyon to nine feet. This reduces project energy production somewhat since minimum flow requirements must be met from Watana storage rather than Devil Canyon. The temperature simulation is shown on Figures E.2.4.174 through E.2.4.176 and Tables E.2.4.45 and E.2.4.46. This modification generally eliminates the drop in temperatures resulting from lowered water levels. However, it also results in a noticeable increase in temperatures in mid-June and larger temperature decreases when the outlet works operate than for the 50-foot drawdown policy.

The second modification tested was to include a third level of ports between the two existing levels of ports at the Devil Canyon multi-level intake. The results of this simulation are shown on Figures E.2.4.174 through E.2.4.176 and Tables E.2.4.43 and E.2.4.44. This policy also eliminated the drop in temperatures resulting from lowered Devil Canyon water levels, and provides a smaller decrease when the outlet works operate and generally more uniform temperatures in June and July than the other two policies.

Figures E.2.4.177 and E.2.4.178 show simulations of temperatures for other hydrological and meteorologic conditions for the two stage project (APA 1984a Appendix V). As noted previously, these may be used to show the sensitivity of temperatures to various hydrologic and meteorologic conditions for the three-stage project.

The simulations discussed above have all been carried out using the policy of withdrawing water that has as close a temperature to natural as possible. This policy is known as "inflow temperature matching." Additional simulations have been carried out to determine whether other policies of multi-level intake operation would significantly affect temperatures. The policies considered were:

- o Warmest water - draw warmest water from the two reservoirs all year using proposed intake.
- o Warmest water with other possible intakes at el. 1,800 - draw warmest water from the reservoir all year, but with the addition of intakes at el. 1,800 in Watana.
- o Warmest water with an intake to the Devil Canyon outlet works near the surface of the reservoir as well as near the bottom.

These simulations were carried out using the Case C flow requirements prior to the Applicant's adoption of the Case E-VI flow requirements. The simulations are for the second stage of the two stage project which is similar to Stage III of the three stage project. The selection of a flow regime does not affect the validity of comparisons between the policies since the purpose of these simulations was to provide an insight into operation of the multi-level intake. The differences represent the variation which may be expected with different multi-level intake operating policies. Simulations were initiated by DYRESM using the appropriate intake operating policy.

The "warmest water" policy with the existing intake generally means using the uppermost intake below the water level in the summer and fall between May and November. When the reservoir becomes isothermal in November, this policy would require changing to the lowest level intake to obtain the warmest water in winter. This policy would have the effect of giving the warmest possible summer temperatures and moving the ice front downstream the furthestin the winter. The incorporation of intakes at lower levels in the Watana reservoir would allow for potentially drawing warmer water from the reservoir in the winter. However, this might have other effects on water quality downstream, such as increased suspended sediment and turbidity and decreased dissolved oxygen. Additionally, drawing warmer water from the reservoir in the winter might reduce the heat available in the reservoir for summer outflows.

The purpose of providing the high level intake to the Devil Canyon outlet works is to improve or warm temperatures during the time when the outlet works must operate.

The results of the analyses described in the previous two paragraphs are shown on Figures E.2.4.179 and E.2.4.180. The effect on summer river temperatures at RM 130 of the various operating policies is minimal. Temperatures in May and September do not seem to be very sensitive to the multi-level intake operating policy. The "warmest water" policy is similar to the "inflow matching" policy in average (1982) years and 1°C to 2°C warmer than "inflow matching" in late June and early July of a wet year. The inclusion of intakes at el. 1,800 does not appear to affect summer temperatures.

The use of a high-level intake to the Devil Canyon outlet works has a noticeable effect on river temperatures, generally increasing average temperatures during outlet works operation by 1°C to 2°C.

Additional simulations were made to determine the effect on summer river temperatures of different environmental flow requirements. Case E-I described in a report by the Applicant (HE 1985f) was used for this simulation. The results of this simulation are presented on Figures E.2.4.181 through E.2.4.183 and on Tables E.2.4.47 and E.2.4.48. The results indicate that, for Stage II, the temperatures at RM 130 for E-VI and E-I are similar except between mid-June and mid-August. During this period the temperatures with E-I average approximately 0.6°C to 0.7°C warmer than with

E-VI. The temperatures with E-I are up to 2.5°C warmer than with E-VI during this period.

Temperatures with E-I are warmer than those for E-VI during this period because the E-I flow requirements in June exceed flows required to generate energy. Approximately 250,000 acre-feet of cool hypolimnion water are released through the Devil Canyon outlet works in June for E-I and replaced by a similar amount of warmer epilimnion water from Watana. This generally increases the depth of the epilimnion at Devil Canyon for a short period and increases the outflow temperature through the powerhouse in the same period. For E-VI, June powerhouse releases are generally adequate to meet environmental requirements and excess releases from Devil Canyon are not required.

- Sloughs and Peripheral Habitat (**)

Slough and side channel surface water temperatures are generally dependent on the temperature of groundwater upwelling, climate conditions and the temperature of mainstem flow when the upstream berm is overtopped. Since the frequency of overtopping of the upstream berm will be reduced due to lower summer flows the slough and side channel surface water temperature will be more often solely a function of groundwater temperatures and climate. It has been determined that the temperature of the groundwater component of slough flow is generally equal to the mean annual temperature (time-weighted) of the river. Since the project will not alter this significantly, the only change in surface water temperatures in sloughs and side channels will be a function of the frequency of overtopping of the upstream berm.

When habitat areas in sloughs and side channels are not overtopped in summer their surface water temperatures are generally less than the mainstem reflecting the groundwater temperature and the climatic conditions. Therefore, a reduction in overtopping of habitat berms will generally cause slough surface water temperature in summer to be somewhat lower, on the average, than natural conditions, but higher than the groundwater temperature. The variation in surface water temperature resulting from intermittent overtopping of the berms will be reduced. Side channels will be affected less than sloughs because summer discharges with project will generally keep side channel areas overtopped.

Surface water temperatures in tributary habitat areas are generally a function of tributary temperature and will not be affected by the project. The extent of the effect of the tributary temperature on the mainstem may change as a result of decreased summer mainstem flows.

Intergravel temperatures in sloughs and side channels are generally between 3°C and 5°C and appear to be related to the mean annual mainstem temperature. In some areas the intergravel temperature may be more directly related to mainstem temperature such as at a site in lower Slough 8A. Since the mean annual mainstem temperature is not expected to change significantly, the intergravel temperature in sloughs and side channels is expected to remain the same.

- <u>Talkeetna to Cook Inlet</u> (**)

During summer, temperatures downstream of the confluence will reflect the temperatures of the Talkeetna and Chulitna Rivers, in addition to the Susitna River. Since the contribution to lower river flow from the middle reach of the Susitna will be lower than natural, the Chulitna and Talkeetna Rivers will have a greater influence than natural.

Because the Talkeetna and Chulitna Rivers are generally colder than the Susitna, the mainstem temperatures would be colder than natural. Simulated average weekly temperatures at Sunshine with-project can be compared to simulated natural temperatures (Tables E.2.4.21 and E.2.4.22). Stage II with-project summer temperatures are generally slightly colder than for Stage I between May and early August, similar to Stage I in August, and warmer than for Stage I in September and October. Temperature differences between Stage II and natural are generally greater than differences between than Stage I and natural; being 0.5°C to

1.5°C cooler than natural from May to July and up to 2.5°C warmer than natural in late September and October. In the fall and early winter the middle Susitna River flows will begin to have greater influences on temperatures downstream of the confluence. This will result in downstream temperatures being slightly above normal until late October to early November. Cold climatic conditions will cause temperatures after early November to be the same as under natural conditions (0°C). In April and early May, warmer outflows from the reservoir may reach the confluence after the ice cover melts out. Thus, early spring temperatures may also be up to 2°C warmer than natural. This difference diminishes with time and by mid-May temperatures will be similar to natural.

(ii) <u>Ice</u> (**)

- <u>Watana and Devil Canyon Reservoirs</u> (**)

Ice cover formation on the Watana and Devil Canyon Reservoirs, during Stage II, was simulated with the DYRESM model based on the average winter weather conditions of 1981-82, and the Case E-VI and E-I downstream flow requirements. The ice cover at Watana Reservoir during Stage II operation would be generally similar to the Stage I conditions described in Section 4.1.3 c(ii). The Watana Reservoir ice cover would form in late November and would reach a maximum thickness of 4 feet by March. The ice cover would begin to melt in mid-April and would be fully melted by late May.

An ice cover on Devil Canyon Reservoir would form at the start of December and would grow to a maximum thickness of approximately three feet by March. The ice cover would begin to melt in late March and would be fully melted by late May. Further reservoir ice simulations are included in other reports (HE 1985f Appendices H and I, APA 1984a Appendix IV).

- <u>Devil Canyon to Talkeetna</u> (**)

The ICECAL model as described in Section 4.1.3(c)(ii) was used to simulate river ice conditions between Devil Canyon and Talkeetna during Stage II operation. Results of the modeling are shown in Figure E.2.4.184 based on the winter weather conditions of 1981-82 (an average winter in terms of mean air temperature), and the Case E-VI downstream flow requirements. Frazil ice generation would be limited to the reach downstream of RM 135 and would vary with daily weather conditions and reservoir release temperatures. At times, no frazil would be produced upstream of Talkeetna.

Ice cover progression at Talkeetna is expected to begin in late December and would reach a maximum extent near RM 133 in late January. This is approximately six miles downstream of the simulated Stage I maximum ice extent. Maximum expected ice cover thicknesses would range from 2 feet to 6 feet and would be generally similar to or less than those of natural conditions. Maximum river stages within the ice covered reach would often be 1 foot to 4 feet higher than those of natural conditions and greater overtopping of sloughs would therefore be expected in this reach if the mitigation measure of berm construction (see Section 6.7.4) were not implemented. Upstream of the ice cover, the river would remain open and maximum river stages would be equivalent to or slightly less than during natural conditions.

The ice cover upstream of Talkeetna is expected to substantially melt in-place by late March. As discussed in Section 4.1.3(c)(ii), mechanical breakup and resulting ice jams and flooding events are expected to be substantially reduced compared to natural conditions.

As discussed in Section 4.1.3(c)(ii), the effects on river ice of different weather conditions were examined in the "Instream Ice Simulation Study" (HE 1984f) and the "Case E-VI Alternative Flow Regime Report" (HE 1985f, Appendix I). Although these weather sensitivity studies were not based on Stage II operation, the general trends of the results are believed applicable. For a "cold" winter such as that of 1971-72, ice front progression may occur several weeks earlier and may extend several miles further upstream than for the "average" winter of 1981-82. Maximum ice cover thicknesses and river stages with the cold winter may be 1 to 3 feet greater than those of the average winter. For a very warm winter such as that of 1976-77 (HE 1985f

Appendix I), ice front progression upstream of Talkeetna may occur several weeks later compared to that of 1981-82 "average" winter. Maximum ice cover thicknesses and river stages and the maximum upstream extent of the ice cover for the 1976-77 very warm winter may be slightly less than that of the 1981-82 average winter.

The effects on river ice of alternative designs and operating policies for the multi-level power intakes, as discussed in Section 4.1.3(c)(ii), have also been simulated with the ICECAL model for the Watana and Devil Canyon operation. Although these simulations were not based on Stage II, the general trends of the results are believed applicable.

With Stage II operating, the river ice effects of the alternative power intake designs and operating policies are expected to be less evident than those discussed for Stage I (Section 4.1.3(c)(ii)). Relative to the "inflow-matching" policy, the "warmest water" policy has essentially no effect on the simulated river ice conditions with both dams operating. Simulations for the final stage of the three stage project show that the simulated maximum extents of the ice front for both policies are within one mile of each other and maximum water levels are within one foot of each other. The similarities between ice conditions for the two policies would be the same for Stage II as Stage III. Simulations with alternative low level intake ports showed only slight reductions in simulated river ice conditions.

Stage II operation with the Case E-I flow requirements, as an alternative to Case E-VI, has also been simulated with the river ice model. Results for Case E-I and Case E-VI are compared in Figure E.2.4.185 for 1981-82 weather conditions. Based on the simulation results, the ice front progression, maximum ice cover thicknesses, maximum river stages and slough overtopping events with the Case E-I flow requirements are expected to be very similar to those with Case E-VI.

- Sloughs and Peripheral Habitat Areas (**)

For Stage II operation the maximum simulated ice thicknesses, river stages and ice front extent are substantially less than those for Stage I Watana operation (Section 4.1.3 c(ii)). Slough overtopping events during Stage II operation are therefore expected to be milder and less frequent than those of Stage I operation. Table E.2.4.23 summarizes information on winter water levels near sloughs and side channels for Case E-VI flow requirements for Stages I and II. Similar information for Case E-I flow requirements is presented in Table E.2.4.24 as a sensitivity test. Results for both flow requirements are similar. The tables show the occurrences of slough berm overtopping for natural berm elevations. Where sloughs are protected by construction of a berm, overtopping would not be expected to occur.

Mitigation measures proposed for slough protection during Stage I (Section 4.1.3(c)(ii), Section 6.4.4 and Section 6.7.4) would be adequate for Stage II.

- Talkeetna to Cook Inlet (**)

River ice conditions between Talkeetna and Cook Inlet during Stage II operation are expected to show the same general trends as discussed in Section 4.1.3(c)(ii) for Stage I operation. The initial formation of an ice cover near Cook Inlet is expected to occur at the same time as natural. Progression of the ice cover in the lower river is expected to be slightly slower than in Stage I and the ice cover is expected to arrive at Talkeetna in late December in an average year, about two weeks later than for Stage I. In the spring the ice cover in the middle reach is expected to melt out at Talkeetna about a month earlier than for Stage I. Thus, above 0°C water will reach the lower river and begin melting the lower river ice cover by early April.

(iii) Suspended Sediments/Turbidity/Vertical Illumination (**)

- Watana and Devil Canyon Reservoirs (**)

The extended DYRESM model has been applied to simulate the suspended sediment concentrations in both Watana and Devil Canyon Reservoirs and the outflows under 1982 flow conditions. As described in Section 4.1.3(c)(iii), 1982 was determined to be an average year for sediment loading. Minimum and maximum sediment years were not considered. However, the sensitivity analysis undertaken for Stage I may be used to determine the relative changes resulting from minimum or maximum loadings in Stage II. Case E-VI downstream flow requirements were used. The basic data and solution procedure used in the study are the same as that used in the Watana Stage I Reservoir study described in Section 4.1.3(c)(iii). The results are summarized in Table E.2.4.49. Figures E.2.4.186 and E.2.4.187 show the predicted outflow suspended sediment concentrations from Watana and Devil Canyon, respectively. These figures indicate that, of the suspended sediments passing through the Watana Reservoir, a small percentage is expected to settle in the Devil Canyon Reservoir. This is attributable to the small sizes of the particles (less than 4 microns in diameter) entering the reservoir from Watana and the relatively short retention time of the Devil Canyon Reservoir (2 months) in comparison to the Watana Reservoir (9 months). The suspended sediment and turbidity levels that occur within the Devil Canyon impoundment and downstream will be slightly reduced from those that exist in the outflow from Watana.

As in the case of Watana Stage I Reservoir outflows, the Devil Canyon Reservoir outflow suspended sediment concentration and turbidity levels will be more uniform throughout the entire year than under the natural river conditions. As with Watana Stage I, the average summer suspended sediments concentration (90 mg/l), and turbidity concentration, will be measurably reduced from natural conditions. The outflow suspended sediment concentration from Devil Canyon will reach its lowest level of about 20-30 mg/l in April or May and increase toward a maximum of about 130 to 150 mg/l in late July or early August. The corresponding turbidity level may vary from about 40 to 60 NTU in spring to a maximum of about 250 to 300 NTU in late July or early August.

- <u>Devil Canyon to Cook Inlet</u> (**)

During Stage II operation some of the suspended material in the Watana outflow would be trapped in the Devil Canyon Reservoir. Simulations show that during Stage II the outflow concentration of suspended sediment from Devil Canyon would be about 10-20 percent less than in the outflow from Watana. Additionally, the Devil Canyon Reservoir will tend to "smooth out" the concentrations so that the abrupt changes in concentration resulting from changing multi-level intake port operations at Watana would not be apparent downstream of Devil Canyon. With Stage II the average July-December outflow concentration would be approximately 80-100 mg/l. The maximum occurs in late July and would be about 150 mg/l, but the concentration would be relatively constant between July and December. Between January and early May the concentration generally decreases to approximately 20-30 mg/l. For Stage II, suspended sediment concentrations were only simulated for an average year (1982). Based on the results for Stage I, low sediment (1970) and high sediment (1981) years would result in concentrations approximately 10-20 percent less and 10-20 percent greater than for an average year, respectively.

The suspended sediment concentration between Devil Canyon and the Chulitna-Susitna confluence will be similar to that in the outflow from the dam. Some sediment may be injected by tributaries during floods. However, the contribution from tributaries will normally be minimal. Thus the turbidity in the Devil Canyon to Chulitna confluence reach is expected to be slightly less than in Stage I or about 160-200 NTU on the average, between July and December decreasing to a minimum of 50 NTU in May.

Downstream of the Chulitna-Susitna confluence, the summer suspended sediment concentration and turbidity will be dominated by the Chulitna River as discussed in Section 4.1.3(c)(iv). There will be little change from Stage I in this reach. In the winter, during Stage II, the suspended sediment concentration and turbidity will be slightly lower than during Stage I due to the lower reservoir outflow values.

Vertical illumination will be increased slightly from Stage I conditions between Devil Canyon and the Chulitna confluence. There will be no change in suspended sediment, turbidity, or vertical illumination in Watana Reservoir during Stage II. Downstream of the Chulitna confluence there will be very little change in vertical illumination between Stages I and II.

Within the Devil Canyon impoundment the suspended sediment and turbidity levels will be slightly reduced from Watana. The simulations show that suspended sediment concentrations near the surface will be approximately 90 mg/l in November and decrease to less than 5 mg/l in January. Concentrations will remain this low until June. In June concentrations near the surface will begin to increase, reaching levels of 30 mg/l in August, and increasing further to 70 mg/l by October. Surface turbidities will thus be less than 10 NTU in the winter, between 10 and 60 NTU in June and July, increasing to 140 NTU by October and 180 NTU by November. Vertical illumination will thus be slightly deeper in Devil Canyon than Watana.

Some slumping of the reservoir walls and resuspension of shoreline sediment will occur. This will be greatest during years when the reservoir is drawn down in the summer and fall. These processes will produce short-term, localized increases in suspended sediments. However, as noted in Acres (1982c), since the overburden layer is shallow, no significant slumping or sediment entrainment problems should arise.

(iv) Dissolved Oxygen (**)

As discussed in Section 4.1.3(c)(v), reduction of dissolved oxygen concentrations can occur in the lower levels of deep reservoirs.

Stratification and the slow biochemical decomposition of organic matter will promote lower oxygen levels near the Devil Canyon Reservoir bottom over time. However, large vegetation will have been selectively cleared and burned or buried prior to inundation, thereby reducing the potential oxygen demanding decompositon process. No estimates of the extent of oxygen depletion can be made.

Within the upper layers (epilimnion) of the reservoir, dissolved oxygen concentrations will remain high. Inflow water to the impoundment will continue to have a high dissolved oxygen content and low BOD. Since water for energy generation is drawn from the upper layers of the reservoir, no adverse effects to downstream dissolved oxygen levels are expected.

During periods of release through the Devil Canyon outlet facilities, water with somewhat reduced oxygen levels may be discharged. Given the size and dynamic nature of the river, these reduced concentrations should quickly return to saturation levels. Quantitative estimates of these reduced oxygen levels are not possible.

(v) Total Dissolved Gas Concentration (**)

Fixed cone valves have been included in the design for the Devil Canyon Dam. As explained in Section 3.6.2 and in the discussions of floods and outlet works operation in this section (Sections 4.2.3(a)(iii) and 4.2.3(a)(v), floods with return periods of less than 50-years will be passed through the project without using the spillways. This will minimize the potential for gas supersaturation to exceed naturally occurring levels. Additionally, the inundation of the Devil Canyon rapids will eliminate a natural source of gas supersaturation. A description of the effect of cone valves on gas concentrations is included in Section 6.4.4 Computations have been made to estimate the potential levels of gas concentrations downstream of Devil Canyon Dam. These show that when outlet works discharges are being made from both Watana and Devil Canyon, the expected concentration will range from approximately 102 to 107 percent of saturation. This assumes that supersaturation occurring at Watana will not be reduced in Devil Canyon Reservoir. The level of supersaturation will decrease downstream of Devil Canyon as illustrated by Figure E.2.2.106.

(vi) Trophic Status (Nutrients) (**)

The anticipated trophic status of Devil Canyon Reservoir has been assessed in a manner similar to the discussion in Section 4.1.3(c)(vii).

The analysis indicates that under natural conditions, Devil Canyon Reservoir will be ultra-oligotrophic. Estimates of permissible artificial phosphorus loading indicate that the reservoir is capable of maintaining oligotrophic status while receiving the untreated effluent of 48,300 permanent residents. This estimate is based upon Devil Canyon alone. With both reservoirs, permissible artificial phosphorus loading would be predicated on the artificial loading factor at Watana.

(vii) Total Dissolved Solids, Conductivity, Alkalinity, Significant Ions and Metals (**)

Similar to the Watana Reservoir, the leaching process in the Devil Canyon Reservoir is expected to result in increased levels of the aforementioned water quality properties near the reservoir floor. Leaching of the more soluble soils and minerals will diminish with time. These effects will not diminish as rapidly as is anticipated for Watana. The blanketing of the Devil Canyon Reservoir floor with quantities of inorganic sediment may not occur as rapidly or to the same extent as in Watana. It is anticipated that leachates will be confined to a layer of water near the impoundment floor or be substantially diluted by the reservoir water volume and although the magnitude of the increase cannot be quantified with available data, detrimental effects to aquatic organisms are not anticipated (Peterson and Nichols 1982).

During operation of the outlet works, some leaching products may be passed downstream. However, the outlet works will draw water from a large area of the reservoir thus diluting any leaching products which may be entrained in the flow. The lower set of valves at el. 930 ft will be located approximately 50 ft above the reservoir floor. The zone of degradation is expected to be close to the reservoir floor and no biologically substantial impacts are expected downstream.

Reservoir temperature modeling indicates that an ice cover will form on Devil Canyon in much the same manner as Watana (See 4.2.3(i)). There may be a small increase in dissolved solids near the reservoir surface during the winter as a result of the exclusion of solids from the freezing water.

As during Watana Stage I, concentrations of metals will be reduced by reactions with humic compounds and dissolved salts and subsequent precipitation. No quantitative estimates of these changes are available.

(d) Ground Water Conditions (**)

(i) Mainstem (***)

Effects on groundwater conditions in the impoundment zone of Devil Canyon will be as described in

Section 4.2.2(e). The Devil Canyon Reservoir is not expected to fluctuate much except in the summers of dry years when releases to meet environmental flow requirements may be made from Devil Canyon. During these periods, groundwater levels adjacent to Devil Canyon Reservoir may fluctuate up to 50 feet below el. 1,455.

Mainstem flows and water levels will generally be less stable than for Stage I in summer (June through September), but more stable the rest of the year. Groundwater levels adjacent to the mainstem would reflect these trends. The major differences being higher flows with Stage II than Stage I in late July to early September, and late February to mid May. The river ice cover will be further downstream with Stage II than Stage I and groundwater levels influenced by ice will not extend as far upstream. Ice affected water levels will also be slightly lower than for Stage I, also affecting groundwater adjacent to the mainstem.

(ii) Sloughs and Peripheral Habitat Areas (***)

Groundwater flows to sloughs and other peripheral habitat areas would reflect the flows and water levels in the mainstem, being generally less stable in the summer and more stable in the fall and winter than for Stage I. Groundwater flow during the period when natural groundwater flow is the lowest (October) will generally be higher than Stage I and higher than natural. Winter ice cover will not extend as far upstream as in Stage I nor result in as high water levels. Therefore, groundwater flow will be reduced from Stage I, but will still be higher than natural. Upstream of the ice front, the water level will be reduced from natural but will be similar to fall and spring levels, thus introducing stability to groundwater flows. In general, groundwater flows to habitat areas will be more stable than under natural conditions because of the stability in flow introduced by the Case E-VI requirements.

(e) Lakes and Streams (**)

The streams flowing into the Devil Canyon Reservoir listed in Table E.2.2.41 will be affected similar to those streams entering Watana Reservoir, described in Section 4.1.3(e). However, with the decreased drawdown of Devil Canyon Reservoir, the impacts will be less.

No lakes other than the previously described small lake at the Devil Canyon damsite will be impacted by Stage II Devil Canyon Dam.

The impacts to tributaries downstream from Devil Canyon will not change from the conditions established during Watana operation as discussed in Section 4.1.3(e).

(f) Instream Flow Uses (**)

The effects on the fishery resource, wildlife habitat, and riparian vegetation are described in Chapter 3. The effects on recreation including whitewater kayaking are described in Chapter 7.

(i) Navigation and Transportation (**)

The Devil Canyon Reservoir will inundate the Devil Creek rapids. This will replace the present whitewater boating opportunities with flat water boating opportunities.

Since the Devil Canyon facility will be operated with similar flow requirements as Watana, downstream impacts will be similar to those resulting from Watana operation (Section 4.1.3(f)(ii)).

Table E.2.4.50 shows that Stage II flows are expected to exceed levels established for navigational difficulty (Section 4.1.3(f)(ii)) with about the same frequency as for Stage I (Table E.2.4.30). Thus, the effect of Stage II project operation on navigation and transportation will be similar to Stage I, which is described in Section 4.1.3(f)(ii). During Stage II, navigational difficulties may be experienced slightly more frequently in September than for Stage I downstream of the Chulitna River and in Alexander Slough. Difficulties will be encountered about as frequently as for natural conditions.

(ii) Freshwater Recruitment to Cook Inlet Estuary (**)

Numerical modeling of Cook Inlet salinity was undertaken for the two-stage project (RMA 1983). The results are considered applicable to the three-stage project because of similarities in flows. This modeling indicates that concentrations will be essentially the same for either Watana operating alone or both Watana and Devil Canyon operating.

Table E.2.2.48 compares the expected salinities at five select locations identified in Figure E.2.2.149, assuming average hydrologic and operational conditions.

4.3 - Watana Stage III Development (***)

For details of the Watana Stage III development, refer to Section 12 of Exhibit A.

Work on raising Watana Dam to its Stage III crest level of el. 2,205 is currently scheduled to begin in 2006, following Devil Canyon Dam completion. The work will initially consist of raising the fill on the downstream side of Watana Stage I Dam. When this is complete the Watana Dam crest, spillway, intake tower and appurtenant facilities will be raised and two additional units will be added to the Watana powerhouse.

Filling of Watana Stage III will occur at the same time the dam crest level is being raised. Therefore, construction and filling of Stage III are not distinct phases. As addressed in this section, the construction phase will refer to the period between the year 2006 and the beginning of filling of Watana Stage III. This phase will end when the dam crest is high enough that the water level can be raised without adversely affecting the safety of the structure. It is currently planned that the dam crest can be raised to el. 2,100 by the year 2010. Work on raising the power intake and spillway ogee crest levels will begin in 2008 and 2010, respectively. Filling of the Stage III reservoir will begin in 2011.

The Stage III operational period refers to the period after the normal maximum water level has reached el. 2,185, which may be between two and six years after the beginning of filling, depending on the reservoir inflow and energy production.

The three periods are approximately defined by the following table:

Activity	Current Schedule	As Used in This Section
Stage III Construction	2006-2012	2006-2010
Stage III Filling	2011-2015	2011-2015
Stage III Operation	2016-life of project	2016-life of project

4.3.1 - Watana Stage III Construction/Stage II Operation (***)

This period coincides with Stage II Operation as described in Section 4.2.3. The placement of the fill on the downstream face of Watana Dam and raising of the crest level to el. 2,100 prior to filling will not affect power generation or flows and, therefore, Section 4.2.3 is generally applicable to this phase of construction.

(a) Flows and Water Levels (***)

The discussion of flows and water levels for Stage II operation, Section 4.2.3(a), is applicable to the Stage III construction period before filling starts. Case E-Vl flow requirements will be maintained.

(b) River Morphology (***)

The discussion of river morphology for Stage II operation in Section 4.2.3(b) is applicable to Stage III construction before filling commences.

(c) Water Quality (***)

(i) Water Temperature (***)

The discussion of water temperature for Stage II in Section 4.2.3(c)(i) is applicable to Stage III construction before filling commences.

(ii) Ice (***)

The discussion of ice for Stage II operation in Section 4.2.3(c)(ii) is applicable to Stage III construction before filling commences.

(iii) Suspended Sediments/Turbidity/Vertical Illumination (***)

The discussion of suspended sediments, turbidity and vertical illumination for Stage II operation (Section 4.2.3(c)(iii) would be generally applicable to Stage III construction before filling commences. The discussion for construction of Watana Stage I in Section 4.1.1(c)i also is applicable here.

(iv) Dissolved Oxygen (***)

The discussion on dissolved oxygen for Stage II operation in Section 4.2.3(c)(iv) is applicable for Stage III construction before filling commences.

(v) Total Dissolved Gas Concentration (***)

The discussion on total dissolved gas concentration for Stage II operation in Section 4.2.3(c)(v) is applicable to the construction of Stage III before filling commences.

(vi) Trophic Status (Nutrients) (***)

The discussion of trophic status for Stage II operation (Section 4.2.3(c)(vi) is applicable to Stage III construction before filling commences.

(vii) Total Dissolved Solids, Conductivity Alkalinity, Significant Ions and Metals (***)

The discussion of this subject for Stage II operation in Section 4.2.3(c)(vii) is applicable to Stage III construction before filling commences.

(viii) Contamination by Petroleum Products (***)

Impacts due to petroleum spills during this phase of the project would be similar to those expected during construction of the Watana Stage I dam (see Section 4.1.1(c)(vi)).

(ix) Concrete Contamination (***)

Significantly less concrete will be needed to complete Watana Stage III Dam than was needed during Stage I, reducing the potential for impacts due to concrete contamination. Waste concrete and wash water will be handled as discussed for Stage I in Section 4.1.1(c)(vii), further reducing the potential for aquatic impacts.

(x) Other Parameters (***)

No additional water quality impacts are expected.

(d) Groundwater Conditions (***)

The effects on groundwater conditions discussed for Stage II operation (Section 4.2.3(d)) are applicable to Stage III construction before filling commences.

(e) Lakes and Streams (***)

Additional material will be removed from Borrow Site E during Stage III construction. This material may be dredged from the lake created by Stage I gravel excavation operations, from upland portions of Borrow Site E, or from both. Turbidity and suspended sediment levels in the lake would be elevated during these operations, but would decline upon cessation of the activity. Rehabilitation will then convert the lake into productive aquatic habitat.

The operation and maintenance of housing and support facilities will cause impacts similar to those described for Stage I (Section 4.1.1(g)).

The effects on all other lakes and streams discussed for Stage II operation (Section 4.2.3(e)) are applicable to Stage III construction before filling commences.

(f) Instream Flow Uses (***)

The effects on instream flow uses described for Stage II operation (Section 4.2.3(f)) are applicable to Stage III construction before filling commences.

Since riparian vegetation in the upstream vicinity of the Watana Stage I Dam would already be inundated, no additional effects would be anticipated to these habitats during construction.

(g) Support Facilities (***)

The construction of Watana Stage III will require the operation, and maintenance of support facilities capable of providing the basic needs for a maximum population of 2,000 people (1,400 in the construction camp and 600 in the village). The facilities utilized for Watana Stage I construction, including roads, buildings, utilities, stores, recreation facilities, airport, etc., will be rehabilitated and utilized for Stage III. The camp and village will be located approximately three miles northeast of the Watana damsite, between Deadman and Tsusena Creeks. The location and layout of the camp and village facilities are presented in Exhibit F and are described in Section 4.1.1.

(i) Water Supply (***)

The water supply system utilized during Stage I construction will be utilized during Stage III. This system is described in Section 4.1.1(g).

The water requirements during Stage III construction would be less than Stage I construction and thus, as discussed in Section 4.1.1(g), no significant adverse impacts are anticipated from the maximum water supply withdrawal.

The water supply will be treated by chemical addition, flocculation, filtration, and disinfection prior to its use using facilities and methods utilized for Stage I. Disinfection will probably be facilitated by the use of ozone to avoid the need for later dechlorination. In addition, the water will be demineralized and aerated, if necessary.

(ii) Wastewater Treatment (***)

A secondary wastewater treatment facility will treat all wastewater prior to its discharge into Deadman Creek. Facilities and methods utilized for Stage I will be utilized for Stage III. Therefore the effects are expected to be similar to those discussed in Section 4.1.1(g)(ii).

The applicant will obtain all the necessary ADEC, EPA, and ADNR permits for the water supply and wastewater discharge facilities.

(iii) Construction, Maintenance, and Operation (***)

The discussion of impacts during construction maintenance and operation for Stage I (Section 4.1.1(g)(iii) is generally applicable here. However, as the Watana Stage I camp will be rehabilitated and used for Stage III construction the amount of new construction work and potential environmental disturbances will be significantly reduced from Stage I. Additional discussions on the water quality impacts associated with facilities construction, operation, and maintenance are provided in Chapter 3, Section 2.3.1(a)(ii).

4.3.2 - Watana Stage III Construction and Filling/Stage II Operation (***)

Filling of the Stage III reservoir from a normal maximum water level of el. 2,000 to a normal maximum level of el. 2,185 may take between three and seven years depending on inflow to the project, energy demands and progress in construction of the dam, powerhouse intake and spillway. The principal effects of the filling will be on flows and river temperatures. Flood flows which would normally be released through the outlet works in Stage II will be utilized to fill the reservoir. This will result in a decrease in July-September flows and a stabilization of river flows during the period of filling. River temperatures during this period will be warmer than for normal operation due to the reduction in releases through the outlet works and resulting increased warming rate in the river downstream. Filling will take place in a gradual manner and other water quality parameters will not be affected to the same degree as flow and temperature.

(a) Reservoir Filling Criteria (***)

Filling of Watana Stage III Reservoir will take place as the dam crest, spillway ogee crests and intake tower are raised. Since portions of the spillway crest will be constructed during this period, storage will be provided in the reservoir so the remaining spillway capacity will be sufficient to ensure the safety of the dam. This will be one limit on the rate that the reservoir water level can be raised. A second limit on the water level will be the amount of flow incoming to the reservoir and the power generated by the project during this period. A third constraint will be the environmental flow requirements of Case E-VI.

(b) Flows and Water Levels (***)

During normal operation of Stage II, between zero and 2,000,000 acre-feet of water will be passed through the outlet works in the July-September period every year to maintain dam freeboard requirements and ensure the safety of the structures. During filling, this water will be used to raise the normal maximum water level. Power generation will be maintained at Watana during the filling process and water levels in the reservoir will vary in the same manner as for normal operation. That is, they will reach their highest point in September and be reduced throughout the winter. Beginning in May, water levels will start to rise. Water levels will generally continue to rise through July, August, and September, provided that sufficient flood storage is available to compensate for reduced spillway capacity during spillway construction and provided the multi-level intake tower has been raised. The maximum water level attained in September will increase from year to year until the normal maximum level of el. 2,185 is reached.

Raising of the Stage III pool has been simulated assuming that the spillway, intake tower and dam crest can be raised in a manner that will not limit filling. Thirty-four year sequences of Watana excess flows (water passed through the outlet works without generating power) were developed. An analyses of these sequences indicates that the 5 million acre-feet of storage between el. 2,000 and el. 2,185 can be filled in 3 to 7 years with an average of 5 years. The water level at any one time during the year would increase by a rate of between 25 and 75 feet per year. The rate of increase would be higher in the early years of filling and reduced in the later years.

During the filling process the E-VI flow requirements will be maintained. Since excess July-September flows will be stored in Watana the flows at Gold Creek will be reduced from normal operational flows in July through September. The flows will generally be near the minimum flow requirements during the summer. Flows downstream of the confluence with the Chulitna and Talkeetna Rivers will also be reduced during this period. Flows will be similar to those described in Section 4.3.3(a) for late Stage III operation in average and dry years and slightly less than described for late Stage III for wet years. This is because the project's ability to control floods in late Stage III is similar to that during the filling period and, as a result, excess releases from the outlet works would be similar.

Flood flows downstream will also be reduced since these will be stored in the reservoir. As noted before, sufficient storage will be maintained so that the structure is not endangered by floods. The frequency of floods described in Section 4.3.3(a) for late Stage III conditions would be generally applicable to the filling period.

(c) River Morphology (***)

The impoundment of Watana Reservoir for Stage III operation may take about five years under average flow conditions.

The impoundment will reduce the frequency of discharging large floods downstream, and therefore the additional impact on downstream morphology would be negligible. The potential for additional bed degradation from that described for Stage II (Section 4.2.3(b)) will be insignificant.

(d) Water Quality (***)

(i) Water Temperature (***)

During the filling period, outlet work releases during the July-September period will be reduced.

The intake to the outlet work is located in the hypolimnion and releases through the outlet works are generally colder than those through the powerhouse. Therefore, the reduction in these releases will result in temperatures in the river downstream of the dam being warmer than normal operation. Additionally, the reduced river flow in this period will result in greater river surface area per unit discharge and more heat transfer between the river and the atmosphere causing an increased rate of warming toward natural temperatures. Therefore, during the filling period, river temperatures are expected to be closer to natural than for normal operation of the project as described for Stages II and III in Sections 4.2.3(c) and 4.3.3(c).

(ii) Ice (***)

River ice processes during filling of the Watana Stage III Reservoir are expected to be similar to those discussed in Section 4.2.3(c)(ii) for Stage II operation gradually becoming more similar to Stage III operation as filling progresses.

(iii) Suspended Sediment/Turbidity/Vertical Illumination (***)

- Watana Reservoir (***)

During the period when the Watana Reservoir water level is being raised the amount of sediment trapped in the reservoir will gradually increase from that described for Stages I and Stage II (Sections 4.1.3(c)(iii) and 4.2.3(c)(iii)) to that described later for operation of Stage III (Section 4.3.3(c)(iii)). The descriptions of reservoir suspended sediment concentration/turbidity/vertical illumination for these two stages may be used to describe the Watana Reservoir during this period.

Suspended sediment levels in Watana will be affected by sliding of bank material as described for operation of Stages I and III. As the water level in the reservoir rises, bank material at higher levels will be subject to instability.

Construction activities, such as the selective removal of timber from within the impoundment may also increase suspended sediment in the reservoir. The effects would be similar to those for Stage I and measures described for Stage I would be employed to minimize this (Section 4.1.2(e)(iii)).

- Watana to Talkeetna (***)

  The outflow concentrations of suspended sediment would gradually change from those described for Stages I and II normal operation (Sections 4.1.3(c)(iii) and 4.2.3(c)(iii) to that described for Stage III normal operation (Section 4.3.3(c)(iii)).

  Therefore, the descriptions given for those Stages for suspended sediment/turbidity/vertical illumination may be used to describe the Watana to Talkeetna reach during this period.

  River flows during this period will be less than during normal operation of the project in the July-September period because normal excess releases will be used to raise the water level. Thus, the ability of the downstream flow to pick up additional sediment will be reduced from normal operation. Additional sediment contributed by construction activities in the reservoir may affect downstream sediment concentrations, turbidity, and vertical illumination as discussed for Stage I (Section 4.1.1(c)(iii)). No dredging or borrow is planned for the river downstream during this period. Only portions of Borrow Area E (Figure E.2.4.3) Borrow Area D (Figure E.2.4.2) and Quarry A (Figure E.2.4.188 will be used. Therefore, suspended sediment, turbidity and vertical illumination would not be affected by these operations.

- Talkeetna to Cook Inlet (***)

  The same considerations apply to this reach of the river as to the Watana to Talkeetna reach. That is, subject parameters will change gradually from normal operational levels in Stage II to Stage III. During the July through September period, reservoir releases will be reduced from normal operational conditions in either Stages II or III. Thus, the dilution effect of the middle river flows and sediment concentrations in the lower river flows and sediment concentrations will be reduced.

Therefore, suspended sediment concentrations during this period will be slightly higher than during normal operation. Thus, the subject parameters will be similar to natural conditions in the summer. In the winter the same parameters will be similar to operational conditions as discussed in Sectins 4.2.3(c)(iii) and 4.3.3(c)(iii).

(iv) Dissolved Oxygen (***)

During the Stage III filling period the reservoir stratification will be similar to that described for normal operation of Stages I, II and III (Sections 4.1.3(c)i, 4.2.3(c)i and 4.3.3(d)i). Dissolved oxygen levels are expected to be similar to those described for normal operation of those stages.

A significant biochemical oxygen demand is not anticipated. The timber in the reservoir area between the Stage II clearing level and the Stage III clearing level will be selectively cleared thereby eliminating some of the associated oxygen demand that would be created by the inundation and decomposition of vegetation. Further, the chemical oxygen demand of the Susitna River is low. Levels measured upstream at Vee Canyon during 1980 and 1981 averaged 16 mg/l.

A significant BOD loading from the construction camp and village is not expected due to the planned wastewater treatment plant.

As a result of the above factors, dissolved oxygen is expected to remain sufficiently high to support a diverse aquatic habitat.

(v) Dissolved Gas (***)

During filling of Watana Stage III the water normally released through the outlet works for flood control and dam safety purposes will be stored in the reservoir to raise the water level. Therefore, Watana outlet works use will be minimized during this period. Some water may be released through the Devil Canyon outlet works to meet environmental flow requirements and as a result of floods in the area between Watana and Devil Canyon. However, there is less likelihood that the outlet works or spillway will be used during this period than at any other time during project operation. Therefore, supersaturated gas concentrations are expected to be minimized during this period. The operation of the cone valves to minimize gas concentrations is explained in Section 6.10.4.

(vi) Nutrients (***)

Two opposing factors will affect nutrient concentrations during filling of Stage III. First, initial inundation of land between el. 2,000 and el. 2,185 will likely cause an increase, in nutrient concentrations due to leaching. Second, sedimentation will strip some nutrients from the water column. The magnitude of net change in nutrient concentrations is unknown, but it is likely that nutrient concentrations will increase, especially in close proximity to the reservoir floor for at least a short time during filling.

(vii) Total Dissolved Solids, Conductivity, Significant Ions, Alkalinity and Metals (***)

The effects of dam impoundment on these parameters discussed for Stages I and II in Sections 4.1.2(e)(vii) and 4.2.3(c)(viii) are generally applicable to the raising of the Watana water level from el. 2,000 to el. 2,185. Any leaching should result in the highest concentrations of these parameters near the reservoir bottom. As the water level rises, additional bank areas may be subject to leaching. However, sediment will eventually blanket these areas and retard the leaching process. Leaching products which do not remain near the reservoir banks and bottoms will be diluted by the large reservoir volume before being drawn through the power or outlet works intakes. No adverse impacts on the water quality downstream of the project are expected.

(viii) Other (***)

No additional water quality impacts of any significance are anticipated.

(e) Groundwater Conditions (***)

Within the Watana Reservoir area, raising the water level would raise the groundwater table in a manner similar to that described for Stage I. The increase would be greatest near the reservoir banks. In the construction area, groundwater impacts will likely result from the construction activity. The relict channel at Watana has previously been identified as an area of potential groundwater seepage problems after Watana Reservoir is filled (Acres 1982b). It lies within the drainage between Deadman Creek to the east, the Susitna River to the south, and Tsusena Creek to the west and northwest. Groundwater gradients in the unconsolidated sediments of the channel are principally towards Tsusena and Deadman Creeks with the diorite pluton at the damsite acting as a groundwater barrier to the south.

The groundwater regime in the relict channel is complex and poorly understood due to the presence of intermittent permafrost, aquicludes, perched water tables, and confined aquifers. Possible artesian or confined water tables exist in several of the stratigraphic units while other units appear to be unsaturated.

Permeability testing indicates the range of average permeability in the more gravelly materials is about 10^{-3} cm/sec (2ft/day), while the tills and lacustrine deposits can be estimated at about 10^{-4} to 10^{-5} cm/sec (0.3 to 0.03 ft/day).

With the raising of the reservoir for Stage III, the overall seepage gradient between the Susitna River and Tsusena Creek will increase slightly. Although the seepage gradient will steepen, it is still considered to be low and coupled with the high groundwater table in the area, it is perceived that there is an extremely low probability of developing any significant seepage.

Since some uncertainties about seepage still exist, remedial measures for Watana Stage III have been planned. First, a long drainage gallery would be constructed in overburden across the relatively narrow relict channel exit area just upstream of Tsusena Creek. Additionally, if required, a positive seepage barrier would be built across the throat of the relict channel where the width of a potential aquifer is minimal. During raising of the reservoir the relict channel will be monitored with piezometers and at the outfall. If necessary, the outfall will be treated with a filter blanket to minimize the risk of piping.

During filling, the E-VI flow requirements will be maintained and groundwater table levels along the mainstem river downstream of the dam would be similar to normal operation of Stages II and III for most of the year. Excess flows normally released from Watana in the July-September period will be stored in the reservoir during filling.

Thus, May-November flows during filling may be more stable than during normal operation at a level slightly above the minimum requirements. Since July-September flows will be lower than normal operation, water table levels along the mainstem may be reduced by up to 2.5 feet near Gold Creek in August.

The groundwater upwelling to sloughs will follow the same general pattern as the groundwater table along the mainstem. That is, groundwater upwelling will be more stable in the May-November period during filling of Stage III as compared to normal operation. Upwelling will be less than during normal operation in the July-September period. Based on relationships obtained for Sloughs 8A, 9, and 11 groundwater upwelling during this period may be reduced by an average of 0.5 to 1.3 cfs. In the fall period upwelling will be higher than natural condition since mainstem flows will be higher than natural. Thus, the normal period of minimum upwelling will be eliminated. In the winter, ice conditions will be similar to operational and mainstem water levels will be higher than natural within ice covered reaches downstream of approximately RM 130 and lower than under natural conditions upstream of RM 130. Therefore, upwelling should be higher than natural downstream of RM 130 and lower than natural upstream of RM 130. Overall, upwelling during filling should be more stable than under natural conditions.

(f) Lakes and Streams (***)

Impoundment of waters by the Watana Stage III Dam will inundate nineteen small tundra ponds, including Sally Lake, a 63-acre lake known to contain lake trout. The impoundment will also inundate additional lotic habitat in tributaries to the Stage I reservoir (Table E.2.2.42).

(g) Instream Flow Uses (***)

(i) Fishery Resources, Riparian Vegetation, Wildlife and Recreation (***)

Impacts of the Watana Stage III impoundment on fishery resources, riparian vegetation and wildlife habitat during filling are discussed in Chapter 3. Recreation uses including whitewater kayaking are discussed in Chapter 7. Case E-VI flow constraints will be maintained through impoundment. As the reservoir level is increased, some new aquatic habitat will become available within the reservoir. However, additional tributary habitat will become inundated. In addition, approximately 18,000 acres of terrestrial habitat will be lost as a consequence of filling the reservoir from Stage I to Stage III maximum elevations.

(ii) Navigation and Transportation (***)

As previously described in this section (4.3.2.(b)) filling of the Watana Stage III Reservoir may last for approximately five years on the average. During this period, summer streamflows will be reduced to the minimum allowable level, in order to both generate power and fill the reservoir. Consequently, the downstream impacts on navigation will be the same as during Stage I filling, with the exception that Devil Canyon Reservoir will already be in place. When the water level in Watana Reservoir is being raised, the maximum upstream extent of the reservoir will reach a point eight miles downstream of the confluence with the Tyone River. Vee Canyon rapids will be permanently inundated.

(iii) Waste Assimilative Capacity (***)

Reduced summer flows due to Stage III impoundment could result in a slight reduction in the waste assimilative capacity of the river. Limited sources of waste loading to the river exist (see Section 2.6.6); therefore no adverse impacts are expected.

(iv) Freshwater Recruitment to Cook Inlet (***)

Since river flows during the July-September period will be reduced as the reservoir water level is being raised, the salinity of Cook Inlet during this period is expected to be higher than predicted for normal operation of the two stage project (RMA 1983), but similar to the salinity estimated for the filling of Stage I. Salinities during the period October through June would be similar to normal operation as flows during this period would be generally unchanged. A more detailed description of salinity change during Stage I filling is given in Section 4.1.2(h)(iv).

(h) Testing and Commissioning (***)

The fifth unit at Watana and the first unit to be installed in Stage III is scheduled to be tested and commissioned in spring of 2012. The second unit will be tested and commissioned in the summer of 2012. The testing of the units requires several sequences of bringing the units on-line and taking them off-line. These will be accomplished in a manner to minimize the effects on flow stability. This can be done in several ways, any of which may be selected. One method would be to reduce flows through the outlet works or other units by amounts comparable to the test flow through the unit. A second method would be to store the test flow at Devil Canyon Reservoir without releasing it downstream.

4.3.3 - Watana Stage III Operation/Devil Canyon Stage II Operation (***)

(a) Flows and Water Levels (***)

(i) Project Operation (***)

After Stage III comes on line, Watana will be operated as a peaking plant and Devil Canyon as a baseloaded plant subject to discharge fluctuation constraints betwen 90 percent and 110 percent of the weekly average. Advantage will be taken of the two-reservoir system to optimize energy production with the constraint that the Case E-VI downstream flow requirements will be met. A discussion of project operation is included in Section 3.

Devil Canyon Reservoir will re-regulate peak discharges from Watana. Section 3 discusses allowable weekly flow variations when Devil Canyon is on line. The Devil Canyon Reservoir will normally be at its maximum water level, el. 1,455, between November and May. In dry years Devil Canyon will be drawn down between May and November reaching its minimum level of el. 1,405 in August. In average flow years, the reservoir will be drawn down between June and August reaching a minimum of approximately el. 1,440 in July. Average weekly Devil Canyon powerhouse flows will be similar to Watana, but slightly higher due to additional inflow in the intervening area between the two dams.

Watana will still be operated in a storage-and-release mode similar to Stage II, so that summer flows will be stored for release in winter. Generally, the Watana Reservoir will be at or near its normal maximum operating level of el. 2,185 feet each year at the end of September. Gradually, the reservoir will be drawn down to meet winter energy demand. The flow during this period will be governed by winter energy demand, water level in the reservoir, and powerhouse characteristics. The turbine characteristics will allow a maximum powerhouse flow of approximately 22,000 cfs. Normal Watana Stage III average weekly powerhouse discharges are simulated to range from approximately 3,000 cfs to 9,000 cfs in early Stage III and 3,000 cfs to 13,000 cfs in late Stage III.

In early May, the Watana Reservoir will reach its minimum annual level of between approximately el. 2,080 ft and 2,130 ft, depending on energy demand and inflow, and then begin to refill with the spring runoff. Flow in excess of both the downstream flow requirements and power needs will be stored during the summer until the reservoir reaches the normal maximum operating level of el. 2,185 ft. If the reservoir reaches el. 2,185 ft, and inflow exceeds energy and environmental flow requirements, excess flow will be released and the reservoir water level will rise as the flood is being stored. This is explained in Section 3.6.2.

- <u>Environmental Flow Requirement</u> (***)

  During project operation the Case E-VI environmental flow requirements will be maintained as discussed in Section 3. Minimum requirements will be met by releases from the powerhouse and, if necessary, the outlet works.

- <u>Weekly Reservoir Simulations</u> (***)

  Weekly simulation of reservoir operation were conducted for the 34 years of record from 1950 to 1983 using Case E-VI flow requirements. Energy demands representative of conditions for early Stage III operation and a year representing near full utilization of project generating capacity were used. Reservoir operation and water levels are summarized on Figures E.2.4.189 through E.2.4.204.

  Additionally, to provide a sensitivity analysis for flows and temperatures, weekly reservoir simulations were made for Case E-I flow requirements for late Stage III energy demands (HE

1984h). Results of the reservoir simulations are presented in Figures E.2.4.205 through E.2.4.212.

Case E-I was chosen for the sensitivity testing because it has the highest minimum summer flow requirements of any of the cases considered (14,000 cfs). For comparison case E-VI minimum summer flow requirements are 9,000 cfs. With the information on these two extremes, it is possible to determine the effects of project operation on water use and quality for other sets of flow requirements between E-I and E-VI.

- Daily Operations (***)

Daily operations of Watana and Devil Canyon powerhouses are explained in Section 3 and the Applicants Case E-VI Environmental Flow Regime Report (HE 1985f). Watana will operate as a peaking plant and Devil Canyon will act as a baseloaded plant and re-regulate flows. The peaking of Watana will cause a water level fluctuation of less than one foot in Devil Canyon Reservoir.

Figures E.2.4.31 through E.2.4.34 may be used to estimate the average weekly stage variation resulting from changes in weekly average flow. These curves are based on steady state rating curves at the noted locations. For example, at RM 127.1 for a weekly average flow of 10,000 cfs the maximum weekly stage fluctuation for a ±1,000 cfs or ±10 percent flow variation would be 0.44 ft (±0.22 ft). The corresponding fluctuation at RM 136.68 would be 0.6 feet (±0.30 ft).

These figures have been drawn for locations near the upstream end of Sloughs 8A, 9, 11 and 21. Examination of water surface profiles in a report by the Applicant (HE 1984d) indicates these are representative of the range in stage fluctuation in the middle reach of the Susitna River. The rating curve at the Slough 11 head appears to give near maximum stage fluctuations while those at Sloughs 8A and 21 give near minimum stage fluctuations.

Table E.2.4.6 and Figure E.2.4.35 show the surface area of the mainstem and peripheral habitat areas of the Susitna River between Devil Canyon and the Susitna-Chulitna confluence. These can be used to estimate the change in habitat surface area for a change in discharge. The change in gravel and vegetated bar area represents the areas which are either exposed or covered by water as the water level decreases or increases, respectively. The relationships were compiled from mapping of aerial photographs of the river at flows less than 25,000 cfs (EWTA 1985) and from simulations of water surface profiles in the river (HE 1984d).

(ii) Mean Monthly Flows and Water Levels (***)

Weekly water levels and discharges at Watana were simulated using the weekly reservoir operation program. Maximum, minimum and average monthly water reservoir levels are shown on Figures E.2.4.189 through E.2.4.205 for Case E-VI. Maximum water levels are those which would normally be attained in wet years and minimum levels are attained in dry years.

The Watana Reservoir fills to el. 2,185 in almost every year and is drawn down to between el. 2,065 and 2,130 by April. The effects of the 1969 and 1970 low flow years are indicated by the low reservoir level attained in September 1969 and 1970.

The Devil Canyon Reservoir fills to el. 1,455 and is stable at that level in wet years. In average flow years the reservoir may be drawn down to el. 1,440 in July, but is filled by September. In dry years the reservoir may be drawn down to near the minimum level between June and October.

The sequences of simulated monthly flows at Watana, Devil Canyon, Gold Creek, Sunshine, and Susitna Station for Case E-VI are shown in Tables E.2.4.51 through E.2.4.60, respectively.

Tables E.2.4.61 through E.2.4.64 compare natural and with-project conditions. Figures E.2.4.213 through E.2.4.217 show simulated natural and with-project flows at Gold Creek for:

- 1964 - Flood of record in June
- 1967 - Large flood in August
- 1970 - Second driest year
- 1981 - Wet year used in temperature analysis
- 1982 - Average flow year used in temperature simulations.

Stream flow sequences for the same years using Case E-I flow requirements are shown in Figures E.2.4.218 through E.2.4.222.

In general, project operation results in higher than natural winter flows and lower than natural summer flows. Flood peaks are considerably reduced. Lowest flows occur in early May and October.

The Watana Reservoir normally is full in September. Winter energy demands are met from reservoir storage. Since the demands in October and May are less than for other winter months, the flows are lower than for the rest of winter. For the early years of Stage III, flow stability is similar to Stage II except in September and October of dry years. As energy demand increases, flow stability in Stage III improves and in average years would be very stable throughout the year. In dry years there would be decreased flows in September and October and in wet years increased flows in August and September.

The increased flow stability with increasing energy demands in Stage III is a result of the greater storage capacity made available by greater winter drawdowns at Watana. In many years the reservoir will not fill, and outlet-works releases in excess of powerhouse flows will not be required. This improves flow stability in most years. In dry years there may be a need to reduce energy production in September and October to ensure meeting winter power demands.

With-project mean monthly flows at Gold Creek are compared to natural flows in the following table.

Month	Natural	With-Project Early Stage III	With-Project Late Stage III
January	1,500	8,300	10,300
February	1,300	8,100	10,100
March	1,200	7,300	9,100
April	1,400	6,600	8,100
May	13,500	7,600	9,000
June	27,800	9,200	10,400
July	24,400	13,200	9,400
August	21,900	18,500	10,700
September	13,500	13,400	10,800
October	5,800	7,700	8,600
November	2,600	8,200	9,500
December	1,800	9,000	11,000

Further downstream at Sunshine and Susitna Stations, the differences between natural and with-project flows are reduced, due to the inflows from tributaries. The following tables illustrate the differences at Sunshine and Susitna Stations.

Month	Sunshine Natural	With-Project Early Stage III	With-Project Late Stage III
January	3,700	10,000	12,000
February	3,100	9,900	12,000
March	2,800	8,900	11,000
April	3,600	8,700	10,000
May	28,000	22,000	23,000
June	63,000	45,000	46,000
July	64,000	53,000	49,000
August	56,000	53,000	45,000
September	33,000	33,000	30,000
October	14,000	16,000	17,000
November	6,200	12,000	13,000
December	4,400	12,000	14,000

Month	Susitna Station Natural	With-Project Early Stage III	With-Project Late Stage III
January	8,100	15,000	17,000
February	7,400	14,000	16,000
March	6,400	13,000	14,000
April	7,700	13,000	14,000
May	57,000	51,000	52,000
June	112,000	94,000	95,000
July	127,000	115,000	112,000
August	109,000	106,000	98,000
September	68,000	68,000	65,000
October	33,000	35,000	36,000
November	15,000	21,000	22,000
December	9,300	16,000	18,000

The mean annual flow will remain the same at all stations. However, flow will be redistributed from the summer months to the winter months to meet energy demands.

Water surface elevations based on maximum, mean, and minimum weekly flows at Gold Creek for May through September at selected mainstem locations between Portage Creek and Talkeetna are illustrated in Figures E.2.4.223 through E.2.4.228. The figures illustrate the water level change expected as a result of operation of Stage III. In general, there is a decrease in water level from natural to with-project levels in the summer.

(iii) Floods (***)

The operation of the project during floods is explained in Section 3.6.2.

The method for estimating with-project flood flows is explained in Section 4.1.3(a)(iii).

Flood flows are given for both years representing early Stage III operation and the full use of project generating capacity.

- Spring Floods (***)

For the 34 years of weekly simulations, Watana Reservoir had sufficient storage capacity to absorb all floods. The largest flood of record on June 7, 1964 had a peak discharge of 90,700 cfs at Gold Creek, corresponding to a recurrence interval of about better than 40 years (annual series). This flood provided the largest mean monthly inflow on record at Gold Creek, 50,580 cfs, and contained the largest flood volume on record. For this flood, in early Stage III the simulated reservoir level increased from el. 2,109 to el. 2,170. A further 15 feet of storage was available before an outlet works release would have been necessary. For late Stage III the reservoir level increased from el. 2,065 to el. 2,140, leaving 45 feet of storage available before a release would be necessary.

The flood volume for the May to June 1:50-year flood was determined to be 1.4 million acre-feet (HE 1984c). The 50-year May-June flood was routed through Watana Reservoir starting with median May-June reservoir water levels of el. 2,122 and el. 2,085 for early and late Stage III simulations, respectively. The average Watana turbine discharges of 4,130 cfs and 5,900 cfs for early and late Stage III simulations, respectively, were used. The flood was passed through the reservoir without raising the water level above el. 2185, and did not require operation of the outlet works or spillway.

Spring floods downstream of the project will be reduced by the discharge stored in Watana Reservoir. Devil Canyon Reservoir will generally be full during this period and will not provide any flood storage. Peak flows will generally be passed through Devil Canyon Reservoir without attenuation. Flood flows will be less than for natural conditions in the middle reach. In the reach downstream of the confluence, flood flows will be closer to natural than in the middle reach. This is because in the lower reach, the drainage area controlled by the dam is proportionately much less than in the middle reach. Additionally, under natural conditions, flood peaks in the lower reach may often result from peak flows in drainage areas not controlled by the project.

The following table gives the frequency of May-June floods at Watana, Gold Creek, Sunshine and Susitna Station.

MAY-JUNE FLOOD FREQUENCY
NATURAL AND STAGE III

Return Period (Years)	Watana Natural	Watana With-Project Early	Watana With-Project Late	Gold Creek Natural	Gold Creek With Project Early	Gold Creek With Project Late
2	39,000	4,100	5,800	42,500	18,000	19,700
5	51,500	4,100	5,800	56,200	25,000	26,700
10	60,000	4,100	5,800	66,300	28,800	30,500
25	73,800	4,100	5,800	80,500	32,100	33,800
50	84,400	4,100	5,800	92,100	36,100	37,800

Return Period (Years)	Devil Canyon With Project Early	Devil Canyon With Project Late	Sunshine Natural	Sunshine With Project Early	Sunshine With Project Late
2	15,300	17,000	118,000	81,000	83,000
5	20,900	22,600	135,000	92,000	93,000
10	23,900	25,600	149,000	102,000	104,000
25	26,600	28,300	163,000	112,000	114,000
50	29,700	31,400	174,000	120,000	122,000

Return Period (Years)	Susitna Station Natural	Susitna Station With Project Early	Susitna Station With Project Late
2	156,000	123,000	125,000
5	179,000	140,000	142,000
10	197,000	155,000	157,000
25	215,000	171,000	173,000
50	230,000	184,000	186,000

The table above indicates that the 50-year flood peak at Devil Canyon of 31,400 cfs is less than the capacity of the Devil Canyon outlet works. Thus, the 50-year flood can be passed through the Devil Canyon Reservoir without using the spillway, minimizing the potential for nitrogen supersaturation (see Sections 4.3.3(a)(v) and 6.10.4).

For spring floods greater than the 1:50-year event, it is possible that the Watana Reservoir would fill, and inflow would be set equal to outflow. If this occurred, floods downstream would be unchanged from natural conditions.

- Summer Floods (**)

During wet years, the Watana Reservoir will reach el. 2,185 ft sometime in July or August. Design considerations were therefore established to ensure that the powerhouse and outlet facilities would have sufficient capacity to pass the 1:50-year summer flood without operation of the spillway (see Sections 4.3.3(a)(v) and 6.10.4). A further decision criterion was established that the reservoir would be allowed to surcharge to el. 2,193 ft during the 1:50 year flood. This is explained in Section 3.6.2. Derivation of the July to September 1:50 year inflow hydrograph at Watana is given in a report by Harza-Ebasco (HE 1984c).

The 50-year July to September flood at Watana has a peak of 77,800 cfs and a volume of 1.14 x 10^6 acre feet. This flood was routed through Watana Reservoir assuming median July-September water levels of el. 2,185 and el. 2,159 for early and late Stage III, respectively. The powerhouse discharge of early Stage III for the early Stage III simulation since the Watana water level was above el. 2,185 and the operating policy in Section 3.6.2 prescribes that energy demands will be met from Watana under these circumstances. For the late Stage III simulation, an average powerhouse discharge of 5,800 cfs was used when the water level was less than el. 2,185; a discharge of 12,500 cfs was used when the water level exceeded el. 2,185. The maximum water level obtained did not exceed el. 2,193, and the spillway was not operated. The maximum outflow for early Stage III of 33,900 cfs was comprised of 24,000 cfs outlet works flow and 9,900 cfs powerhouse flow. The maximum outflow for the late Stage III simulation was 5,800 cfs powerhouse flow.

The following table gives the July-September flood frequency for Watana, Gold Creek, Sunshine and Susitna Stations.

July-September Flood Frequency

Return Period (Years)	Watana Natural	Watana With-Project Early	Watana With-Project Late	Gold Creek Natural	Gold Creek With-Project Early	Gold Creek With-Project Late
2	34,200	30,100	5,800	37,300	35,500	15,700
5	45,700	33,900	5,800	49,800	43,100	21,300
10	54,500	33,900	5,800	59,400	45,000	24,000
25	67,200	33,900	5,800	73,200	45,000	26,500
50	77,800	33,900	5,800	84,800	47,300	29,500

Return Period (Years)	Devil Canyon Early	Devil Canyon Late	Sunshine Natural	Sunshine With-Project Early	Sunshine With-Project Late
2	33,600	13,700	138,000	128,000	104,000
5	40,400	18,200	163,000	149,000	121,000
10	41,000	20,400	180,000	162,000	134,000
25	41,000	22,400	196,000	175,000	147,000
50	42,000	24,800	210,000	187,000	159,000

Return Period (Years)	Susitna Station Natural	Susitna Station With-Project Early	Susitna Station With-Project Late
2	183,000	182,000	158,000
5	216,000	212,000	184,000
10	238,000	232,000	204,000
25	259,000	253,000	225,000
50	278,000	271,000	243,000

The 50-year peak inflow to Devil Canyon Reservoir for the early Stage III simulation is 42,500 cfs. This exceeds the outlet works capacity by 500 cfs. Therefore, provision has been made in the operating policy for Devil Canyon Reservoir (Section 3.6.2) to surcharge the water level and store the inflow in excess of outlet works capacity to prevent spillway operation for the 50-year flood and thus minimize potential gas concentrations downstream. The operation of the outlet works and the manner in which cone valves minimize gas concentrations are explained in Sections 4.3.3(a) and 6.10.4.

- Annual Floods (**)

Annual flood peaks of the Susitna River at the project sites most frequently occur in June. The annual series 50-year flood at Watana was calculated to have a peak discharge of 89,500 cfs and a volume of 1.43 x 10^6 acre feet (HE 1984c). This flood was routed through the Watana Reservoir assuming median June water surface levels at el. 2,141 and el. 2,104 for early and late Stage III, respectively. According to the operating policy in Section 3, the powerhouse discharge was shifted from Devil Canyon to Watana when the Watana water level reached el. 2,185, thus increasing the Watana capacities to 9,900 cfs and 12,500 cfs for early and late Stage III, respectively. The maximum water level attained did not exceed el. 2,185. The maximum outflow was 3,300 cfs for early Stage III. For late Stage III the maximum discharge was 5,400 cfs. Spillway operation was not required and nitrogen supersaturation would be minimized. The following table illustrates the annual series flood frequency at Watana, Gold Creek, Sunshine and Susitna Stations.

ANNUAL FLOOD FREQUENCY

Return Period (Years)	Watana Natural	Watana With-Project Early	Watana With-Project Late	Gold Creek Natural	Gold Creek With-Project Early	Gold Creek With-Project Late
2	43,500	3,340	5,400	48,000	20,000	22,100
5	57,400	3,340	5,400	63,300	27,700	29,800
10	67,000	3,340	5,400	73,700	32,100	34,200
25	79,800	3,340	5,400	87,300	36,000	38,100
50	89,500	3,340	5,400	97,700	40,600	42,700

Return Period (Years)	Devil Canyon Early	Devil Canyon Late	Sunshine Natural	Sunshine With Project Early	Sunshine With Project Late
2	16,700	18,800	143,000	103,000	105,000
5	22,800	24,900	166,000	119,000	121,000
10	26,400	28,500	183,000	131,000	133,000
25	29,500	31,600	200,000	145,000	147,000
50	33,200	35,300	214,000	157,000	159,000

Return Period (Years)	Susitna Station Natural	With Project Early	With Project Late
2	189,000	157,000	159,000
5	220,000	183,000	185,000
10	242,000	202,000	204,000
25	264,000	223,000	225,000
50	283,000	242,000	244,000

The 50-year peak inflow to Devil Canyon Reservoir is 33,200 cfs in early Stage III and 35,300 cfs in late Stage III. This is less than the capacity of the outlet works. Therefore, surcharging Devil Canyon Reservoir to prevent spillway operation would not be required.

Under natural conditions, the highest annual floods at Gold Creek occur in June. With the project, the annual flood peaks will occur in the July-September in early Stage III. The flood frequency for that series represents the flood frequency. As project energy generation increases over time, the Watana storage capacity in the July-September period will increase and the magnitude of the July-September floods will decrease. In late Stage III, the July-September flood peaks for Gold Creek are less than those for the May-June period and annual series. Thus, for late Stage III the flood frequency will be defined by the annual series simulation.

At Sunshine and Susitna Station the with-project flood frequency will be defined by the July-September series throughout Stage III, as for Stages I and II. The flood frequency relationship for the annual series and July-September periods at Sunshine and Susitna Station remain relatively constant from Stage I through the early years of Stage III. The simulated increase in energy demands between early and late Stage III results in additional storage available at Watana in the July-September period in late Stage III. This has an effect on the frequency of floods for this period as far downstream as Susitna Station.

Assuming a two-year return period (USDI 1974), the mean annual flood flows at Gold Creek, Sunshine and Susitna Station are shown below.

Mean Annual Flood Flows - 2-Year Return Period

	Natural	With-Project Early	With-Project Late
Gold Creek	48,000	35,500	22,100
Sunshine	143,000	128,000	105,000
Susitna Station	189,000	182,000	159,000

The reduction in the mean annual flood flow at Sunshine, downstream of the confluence with the Chulitna and Talkeetna Rivers, is less than 10 percent in early Stage III and approximately 25 percent for late Stage III. At Susitna Station, downstream of the Yentna confluence, the reductions are approximately two percent for early Stage III and approximately 15 percent for late Stage III.

(iv) Flow Variability (***)

Under normal hydrologic conditions, flow from the Stage III development will be regulated. The downstream flow will be controlled by the following criteria: downstream flow requirements, minimum power demand, and reservoir operating rule curve. However, there can be significant variations in discharge from one season to the next and for the same month from one year to the next.

Flow variability under natural conditions is illustrated by the flow duration curves using daily recorded flow values shown on Figures E.2.2.44 and E.2.2.45.

As discussed in Section 3.6.1, with-project flows from the powerhouse may be allowed to vary by 10 percent above and below the mean weekly flows. The maximum variation in the mean weekly flow from one week to the next will be 20 percent.

Weekly reservoir operation simulations were made to illustrate the variability in weekly average flows for five years. These are illustrated by Figures E.2.4.213 through E.2.4.217. There will also be variation in flows in one week from year to year. Figures E.2.4.229 through E.2.4.236 show the 6 percent, 50 percent and 97 percent exceedence level flows for each week of the year. The variability in flows for Case E-I flow requirements is shown on Figures E.2.4.237 through E.2.4.240.

Additionally, in order to illustrate the variation in with-project flows as compared to natural variation, monthly flow duration curves have been prepared for Watana, Gold Creek, Sunshine and Susitna Stations (Figures E.2.4.241 through E.2.4.250. These curves are based on monthly average with-project flows. The natural flow duration curves on these exhibits are based on monthly average flows and not on daily values as in Figures E.2.2.44 and E.2.2.45.

The project outflows show little variability because of the high degree of reservoir regulation and the relatively constant powerhouse flow. Gold Creek exhibits more variation because of the variability in local inflow. The flow duration curves show a diminished natural and with-project difference with distance downstream from Watana.

(v) Operation of Outlet Works and Fixed-Cone Valves(***)

The Watana outlet works are described in Section 4.1.3(a)(v). The maximum capacity of the Watana outlet works would be increased from 24,000 cfs in Stage I to 30,000 cfs in Stage III, as a result of the increase in hydraulic head. However, the capacity required to pass the 50-year flood without using the spillway remains at 24,000 cfs in Stage III. Passage of flows greater than 24,000 cfs may result in flows exceeding the Devil Canyon outlet works capacity of 42,000 cfs. Therefore, in Stage III the outlet works capacity at Watana will be limited to 24,000 cfs. The Devil Canyon outlet works are controlled by four 102-inch and three 90-inch diameter fixed cone valves which will have a combined capacity of approximately 42,000 cfs at the normal maximum pool and 80 percent gate stroke. The four intakes to the 102-inch valves will draw water from el. 1,050 and discharge it approximately 120 feet above the normal tailwater. The intakes to the three 90-inch valves will draw water from el. 930 and discharge it about 50 feet above the normal tailwater level. The purpose of the outlet works is to release flows to meet environmental requirements and to pass flood flows without using the spillway. As noted previously under Floods (Sec. 4.3.3(a)(iii)), those floods up to the 50-year event can be discharged without using the spillway. Tables E.2.4.65 and E.2.4.66 present data on outlet works operation from the weekly reservoir simulations.

Included for each year of the 34 years of simulation are the week of first release, the week of maximum release, the maximum release, the powerhouse flow at the time of maximum release, the volume released and the maximum Watana release during the period of Devil Canyon outlet works operation.

As shown, the outlet works would operate in middle to late summer of almost every year in early Stage III and in less than half the years for the late Stage III simulation. This occurs because the reservoir is simulated to have filled, and thus it was necessary to pass flows to maintain freeboard on the dam.

Information on the downstream temperature impacts caused by the operation of the outlet works can be found in Section 4.3.3(c)(i).

(b) River Morphology (***)

With Watana/Devil Canyon Stage III in operation, streamflows above the damsites will be regulated further (Figures E.2.4.229 through E.2.4.236) and release of large flows in excess of meeting the energy and environmental requirements will be less frequent than in Stage II. Reservoir operation studies indicate that the mean-annual maximum weekly flow at Gold Creek would be about 25,000 and 16,000 cfs for early and late Stage III respectively. These are smaller than the mean annual maximum flows during Stage II operation. If bed degradation (lowering of the bed level) has not reached its maximum expected extent in Stage II (Section 4.2.3(b)), the rate of bed degradation in Stage III will be reduced from Stage II and the maximum expected degradation would be similar to Stage I - 0.8-1.3 feet, a few inches less than in Stage II. As the projected energy production increases in Stage III, the reduction in mean annual maximum weekly flow will result in a lessened potential for further bed degradation. The stream bed is expected to stabilize early in Stage III if it has not stabilized in Stage II. If bed degradation reaches its maximum expected extent in Stage II, there would be no further degradation in Stage III and the bed will be stable.

Sediment deposition near and below the confluence of the Susitna, Chulitna, and Talkeetna Rivers will continue, but the river will gradually stabilize with a better defined, narrower channel.

Potential impacts on the side channels and sloughs will be essentially the same as those described in Section 4.1.3.(b).

(c) Water Quality (***)

(i) Water Temperature (***)

- Reservoirs (***)

The program DYRESM, described in Section 4.1.3(c)(i) was used to predict reservoir temperature profiles and outflow temperatures from both the Watana and Devil Canyon Reservoirs. The Watana inflow, the inflow temperature, and the meteorological data from Watana and Devil Canyon Stations for the period May 1981 through October 1982 were used in the simulations. These data are the same as used for Watana Stage I operation (Section 4.2.3(c)(i)), however, Watana outflow is changed due to the different mode of operating the Watana Reservoir when the project progresses from Stage I to Stage III. The simulated flows for May 1981 through October 1982 from the Case E-VI weekly reservoir simulation for early and late Stage III were used as the source of inflow and outflow data for the two reservoirs.

The four level Watana Stage III intake as shown in Figure E.2.4.251 was used in the analysis. The Watana Stage I intake was not used since the Stage I intake ports are generally below the thermocline of the Watana Stage III Reservoir. The Devil Canyon two-level intake (Section 4.2.3(c)(i)) was also used in the study.

In the DYRESM simulations, the operations of both Watana and Devil Canyon intakes were simulated to match the Watana inflow temperature as close as possible. As explained in Sections 6.10.3 and 6.10.7, this is expected to give temperatures close to natural all year and to minimize suspended sediment and turbidity in the winter.

Stratification and outflow temperatures at Watana under the assumed operating condition are similar to that of Watana operating alone. Some smoothing of peak temperatures occurs. The temperature and quantity of Watana outflow, and the flow contribution from the area between the damsites are inputs to the Devil Canyon Reservoir simulation model. The temperature of the Watana outflow is more stable and is cooler in summer and warmer in winter than for natural conditions. Devil Canyon Reservoir exhibits the general pattern of early summer warming, summer stratification, and fall to winter cooling through an isothermal condition to reverse stratification which occurs at Watana.

Figures E.2.4.252 and E.2.4.253 illustrate the Devil Canyon Reservoir outflow temperatures for May 1981 through October 1982 for late Stage III. The Watana inflow temperatures are also shown in the figures. These results indicate that, under the Stage III project operating conditions, the Devil Canyon two-level intake structure can provide reasonable control of July-August outflow temperatures when the outlet works are not in operation. With the outlet works in operation, the multi-level intake would become less effective. The outlet works would generally pass a larger volume of water from the hypoliminion and are generally operated in July through September. In September, the natural river temperature would decrease very rapidly from about 10°C to near freezing. This corresponds to the rapidly changing meteorological condition. Therefore, the September operation of the outlet works should not have a significant impact on the effectiveness of the multi-level intake operation. However, in August or July, if the outlet works are operated at larger flow rates, the effectiveness of the intake operation is expected to be affected. In general, the 1981-1982 simulation indicates that the Stage III Devil Canyon outflow temperature in June, July and August may vary from 5°C to 11°C while the Watana inflow temperature varies from 5°C to 13°C.

Temperature simulations were also made for early Stage III operation as shown on Figures E.2.4.254 and E.2.4.255 (HE 1985f, Appendix H). Reservoir outflow temperatures for energy demands between the two extremes can be estimated by interpolation in the figures.

Additionally, in order to evaluate the effects of alternative flow requirements on river temperatures, a sensitivity test was made using reservoir operations for the E-I flow requirements (HE 1984h). The outflow temperatures for this simulation are illustrated on Figures E.2.4.256 and E.2.4.257. In the wet year (1981) simulation, outflow temperatures with E-I are generally lower than for E-VI between mid-May and mid-September and higher than E-VI between mid-September and mid-November. Between December and mid-May the temperatures are generally similar. In the average year simulation the temperature differences are less. E-I outflow temperatues are generally lower than for E-VI between mid-May and early August, similar in August and September and somewhat higher in October.

Typical reservoir temperature profiles at Watana are given in Figures E.2.4.258 through E.2.4.263 for August 1981 to January 1982, respectively. The reservoir temperature profiles at Devil Canyon in Stage III would be similar to those for Stage II discussed in Section 4.2.3(c)ii. The reservoir stratification in Watana in Stage III is similar to Stages I and II as discussed in Section 4.1.3(c)ii. Devil Canyon Reservoir, because of its smaller size, is more responsive to meteorological and project operating conditions. Generally, reservoir stratification is weak in June, but builds during July and August. Typical mixed layer depths are in the order of 50 to 70 ft during the summer months.

Isothermal conditions occur in November. Cooling continues throughout the reservoir depth until maximum density is reached. Reverse stratification begins in December.

In December, the reservoir is weakly stratified. The mixed layer depth in winter is about 100 to 120 feet and is influenced by severe cold weather, mixing events, and Watana outflow and temperature.

- Devil Canyon to Talkeetna (***)

  . Mainstem (***)

  The Devil Canyon operation outflow temperatures, which were simulated using DYRESM, were used to determine the water temperatures in the reach between Devil Canyon and Talkeetna. The discharge and outflow temperatures from Devil Canyon were used as input for the program SNTEMP described in reports by the Arctic Environmental

Information and Data Center (AEIDC 1983, 1984a, 1984b, 1984c, 1985a).

River temperatures were simulated on an average weekly basis. Output of daily temperatures from DYRESM were averaged and used in the weekly simulations, along with the average weekly discharges from the reservoir operation results presented in W 4.2.3(a)

Temperature simulations using SNTEMP were carried out for open water reaches of the river between the dams and the Sunshine stream gaging station (RM 84). In summer, the entire reach was simulated. In winter, only the reach from the dams downstream to the location where water temperature reached 0°C was simulated. The period May 1981 through September 1982 was simulated for the three-stage project. This represents a wet summer followed by a winter of average temperatures followed by an average flow summer. The selection of cases for simulation is discussed in the Applicant's replies to the FERC's Request for Supplemental Information of April 12, 1983 Schedule B, Exhibit E No's 2.28 and 2.41.

Simulations for the three-stage project were limited to the cases discussed above, in order to show the similarities and differences between simulated temperatures for the original two-stage and the proposed three-stage project. The simulations which have been made for the two-stage project (APA 1984a Appendix V, HE 1985f Appendices H and I) may be used to determine the sensitivity of the river temperatures to other hydrologic and meteorologic conditions.

Simulations are also presented in other reports by the Applicant (AEIDC 1983, 1984a, 1984b, 1984c, 1985a). The results of the simulations are presented on Figures E.2.4.264 through E.2.4.266 and on Tables E.2.4.67 through E.2.4.70. The figures also contain simulated temperatures for the final stage of the original two stage project for the Case C flow requirements. They illustrate that temperatures from Case C and Case E-VI are generally similar with some small differences in the July-September period. These differences are the result of changes in the minimum flow requirements from Case C to Case E-VI. Case E-VI minimum flow requirements are higher than for Case C in June and early July. Thus more flow is released early in the summer for E-VI and the Watana Reservoir fills later. Therefore, the outlet works opens later for E-VI than for C and temperatures are higher in late July and early August. Later in the summer the outlet works must open for Case E-VI as well as Case C and the temperatures for E-VI decrease to slightly below those for Case C. The Case C temperatures are warmer in this period because the early opening of the Devil Canyon outlet works causes the replacement of cold water in the Devil Canyon hypolimnion with warm water from the Watana epilimnion.

Temperatures for late Stage III are generally warmer than Stage II temperatures in May through July or early August and cooler than Stage II temperatures from August through October. Summer Stage III simulated temperatures are closer to natural than Stage II. Open water temperatures in winter for Stage III are warmer than Stage II. This is reflected in the ice simulations discussed later.

Temperatures were also simulated for early Stage III (see Tables E.2.4.69 and E.2.4.70). A comparison between simulated temperatures for the final stage of the three stage project for early and late energy demands is shown in Figures E.2.4.296 through E.2.4.298. Temperatures for energy demands between these two extremes can be interpolated from the tables and figures.

Summer temperatures simulated for early Stage III are generally cooler than for Stage II of the three-stage project, as discussed in Section 4.2.3(c)i. Winter temperatures are somewhat warmer. Thus, when Stage III begins operating, summer temperatures may decline slightly from Stage II. Summer temperatures will probably be below those experienced during Stage III filling, since outlet works releases during Stage III filling will be minimal. Winter open water temperatures will increase gradually from Stage II operation through Stage III filling to Stage III operation. As energy demands increase, the outlet works releases will decrease and summer temperatures will increase toward levels simulated for late Stage III. In winter, the open water temperatures should not change much throughout Stage III.

In late Stage III, summer with-project river temperatures would exhibit a lag behind natural conditions of approximately one month. Simulated temperatures at RM 130 are close to 4°C in early May, peak near 10°C between July and August, and decrease to 1°C by late November. In wet years the reservoir fills by early August; thus, the outlet works must be operated to pass flow. Because the outlet works draw from a lower elevation in the reservoir, these flows are generally cooler. Outlet works releases due to a full reservoir causes the drop in river temperatures in July in the 1981 simulation and a smaller drop in the 1982 simulation.

In winter, the temperature of the mainstem will remain above 0°C longer than natural because of the warmer outflows from the project. The temperature in the spring will exceed 0°C sooner than natural for the same reason. Between the upstream end of the ice cover and the dams, the river temperature will be between 0°C and 2°C to 3°C, whereas the natural temperature in this reach is 0°C.

Based on these simulations and simulations of natural conditions, the mean annual (time weighted) temperature at RM 130 has been calculated for the period May 1981 through April 1982 to be 3.7°C for natural conditions and 4.7°C for with-project conditions. Simulations of natural and with-project conditions for other meteorological and hydrological conditions for other flow requirements also indicates that mean annual with-project temperatures may be slightly greater than natural mean annual temperatures. Mean annual temperatures in dry year with-project simulations are generally closer to natural conditions than in wet years.

The simulated temperatures shown on Figures E.2.4.264 through E.2.4.266 are for the proposed three stage project with the proposed two-level intake at Devil Canyon Reservoir. Figures

E.2.4.177 and E.2.4.178 show simulations of temperatures for other hydrological and meteorological conditions for the final stage of the two-stage project (APA 1984a) for energy demands typical of Stage II. As noted previously (Section 4.2.3(a)), these may be used to show the sensitivity of temperatures to various hydrologic and meteorologic conditions for the three-stage project. Similar sensitivity tests have been carried out for late Stage III energy demands. These are shown on Figures E.2.4.301(a) and E.2.4.301(b).

The simulations discussed above have all been carried out using the policy of withdrawing water that has as close a temperature to natural as possible. This policy is known as "inflow temperature matching." Additional simulations have been carried out to determine whether other policies of multi-level intake operation would significantly affect temperatures. The results of these studies are discussed in Section 4.2.3.(c)i.

Simulations were also made to determine the effect of different environmental flow requirements on river temperatures for late Stage III . Case E-I described in a report by the Applicant (APA 1985f) and in Section 3 was used for this simulation. The results of this simulation are presented in Figures E.2.4.270 through E.2.4.272 and in Tables E.2.4.71 and E.2.4.72. These results indicate that, for Stage III, the E-I temperatures at RM 130 are similar to E-VI between October and early to mid-June, up to 2°C colder between mid-June to mid-July, similar to E-VI between mid-July and mid-August and up to 2°C warmer between mid-August and late September. The average June-September temperatures at RM 130 for E-I and E-VI are similar, although E-VI has warmer temperatures earlier in the year. Differences between temperatures for the two cases are more pronounced at the damsite and less pronounced at RM 100 due to the effect of climate. At RM 100, temperatures for E-VI appear closer to natural than those for E-I.

Temperatures for E-VI are warmer than for E-I early in the summer primarily because the E-I environmental requirements are greater than the power demands resulting in outlet works releases. This also results in a drawdown of Devil Canyon Reservoir to el. 1,405 with E-I compared to el. 1,452 with E-VI. As a result, powerhouse flows must be drawn from the deeper port at Devil Canyon contributing to colder outflows. Removing this cold water from Devil Canyon Reservoir early in the summer raises temperatures later in the summer. The cold water removed from the Devil Canyon hypolimnion is replaced by warmer water from Watana, and outlet works releases later in the summer are warmer for E-I than E-VI.

- Sloughs and Peripheral Habitat Areas (***)

Slough and side-channel surface water temperatures are affected by the temperature of groundwater upwelling, climatic conditions, and the temperature of mainstem flow when the upstream berm is overtopped. Since the frequency of overtopping of the upstream berm will be reduced due to lower summer flows, the slough and side-channel surface water temperature will be more often solely a function of groundwater temperatures and climate. It has been determined that the temperature of the groundwater component of slough flows generally is similar to the mean annual temperature (time-weighted) of the river. Since the project will not alter this temperature significantly, the only change in surface water temperatures in sloughs and side channels will be a function of the frequency of overtopping of the upstream berm.

When habitat areas in sloughs and side channels are not overtopped in summer, their surface water temperatures are generally less than the mainstem. This reflects the influence of groundwater temperatures and climatic conditions. In summer, therefore, a reduction in overtopping of habitat upstream berms will generally cause habitat surface-water temperatures to be lower than for natural conditions, but higher than groundwater temperatures. The variation in surface-water temperature resulting from intermittent overtopping of the berms will be reduced. Side channels will be affected less than sloughs because summer discharges with-project will generally keep side channel areas overtopped.

Surface water temperatures in tributary habitats are usually a function of tributary temperature and will not be affected by the project. The extent of the effect of tributary temperatures on the mainstem may change as a result of decreased summer mainstem flows.

Intergravel temperatures in sloughs and side channels are generally between 3°C and 5°C, and appear to be related to the mean annual mainstem temperature. In some areas the intergravel temperature may be more directly related to mainstem temperature, such as at a site in Lower Slough 8A. Since the mean annual mainstem temperature is not expected to change significantly, the intergravel temperature in sloughs and side channels is expected to remain the same.

- Talkeetna to Cook Inlet (***)

During summer, temperatures downstream of the confluence will reflect the temperatures of the Talkeetna and Chulitna Rivers in addition to the middle Susitna River. Since summer flows from the middle reach will be reduced, the Chulitna and Talkeetna Rivers will have a greater effect on temperatures than for natural conditions.

Because the Talkeetna and Chulitna Rivers are generally colder than the Susitna, the mainstem temperatures would be colder than natural. Simulated average weekly with-project temperatures at Sunshine can be compared to simulated natural temperatures (Tables E.2.4.21 and E.2.4.22.) With-project summer temperatures are generally similar to those for Stage II, but are slightly colder in August and September. Stage III temperatures are slightly closer to natural than Stage II temperatures in the summer. Simulated with-project temperatures are generally between 0.5°C and 1.0°C cooler than natural between May and August, similar to natural in September, and up to 2.5° C warmer than natural in October.

In the fall and early winter, the middle Susitna River flows will begin to have greater influence on temperatures downstream of the confluence. This will result in downstream temperatures being slightly above natural until late October to early November. Cold climatic conditions will cause temperatures after early November to be the same as for natural conditions (0°C). In April, warmer outflows from the reservoir may reach the confluence after the ice cover melts. Thus, early spring temperatures may also be 2°C warmer than natural. This difference diminishes with time, and by early May temperatures will be similar to natural.

(ii) Ice (***)

- Reservoirs (***)

Ice cover formation on the Watana and Devil Canyon Reservoirs during Stage III operation was simulated with the DYRESM model based on the average winter weather conditions of 1981-82, and the Case E-VI and E-I downstream flow requirements. Simulations were made for early and late Stage III energy demands. Reservoir ice cover conditions would be similar to those of the Stage II operation. The Watana Reservoir ice cover would form in late November and would reach a maximum thickness of four feet in March. The ice cover would begin to melt in mid April and would be completely melted by late May.

The Devil Canyon Reservoir ice cover during Stage III operation would form in late November and would reach a maximum thickness of three feet by March. The ice cover would begin to melt in early April and would be completely melted by late May.

Simulations of reservoir ice cover are included in other reports for the final stage of the original two stage project. These are generally applicable to Stage III which is identical to the final stage of the two stage project (HE 1985f Appendices H and I, APA 1984a Appendix IV).

These simulations show that, depending on climatic conditions, the Watana Reservoir ice cover will generally begin to form in mid to late November and grow to between three and four feet thick before melting out between early May and early June. The Devil Canyon Reservoir ice cover will generally form a week later than at Watana and reach a thickness of approximately three feet before melting out in early to late May.

- <u>Devil Canyon to Talkeetna</u> (***)

The ICECAL model as described in Section 4.1.3c(ii) was used to simulate river ice conditions between Devil Canyon and Talkeetna during Stage III operation. Results of the modeling are shown in Figure E.2.4.273 based on the winter weather conditions of 1981-82 (an average winter in terms of mean air temperature), the Case E-VI downstream flow requirements early and late Stage III energy demands. As shown, frazil ice generation would be limited to the reach downstream of RM 126 in early Stage III. The upstream extent of frazil ie generation would gradually move downstream to near RN 115 in late Stage III. The extent of ice genration would vary with daily weather conditions and reservoir release temperatures. For much of November and December, no frazil ice would be generated upstream of Talkeetna.

Ice cover progression at Talkeetna during Stage III operation is expected to begin in early January and would reach a maximum extent near RM 126 in early Stage III and RM 114 in late Stage III. The maximum upstream extent would occur in late January. Maximum ice cover thicknesses of two to four feet are expected in early Stage III and maximum thicknesses of two feet are expected in late Stage III. Thicknesses would be several feet less than those of natural conditions. Maximum river stages within the ice-covered reach would be approximately two feet higher than those of natural conditions, causing somewhat greater than natural slough overtoppings in this reach if the mitigation measure of berm construction (Section 6.10.5) are not implemented. Upstream of the ice cover, maximum river stages would often be one to three feet lower than those of natural conditions, and fewer slough overtoppings are expected than under natural conditions.

The ice cover upstream of Talkeetna with Stage III operation is expected to be melted out by early to mid-March. As discussed for Stage I and Stage II (Section 4.1.3c(ii)), the ice cover is expected to substantially melt in place without major ice jamming or associated flooding.

The effects of differing winter weather conditions on river ice are expected to be generally similar to the trends discussed in Section 4.2.3(c)(ii). Relative to the river ice conditions for the average 1981-82 winter, ice front progression for other weather conditions may occur a few weeks earlier or later and may reach a maximum extent a few miles further upstream or downstream. Maximum ice cover thicknesses and river stages would also be expected to vary by a few feet among the various weather conditions.

The Instream Ice Simulation Study (HE 1984f) provides sensitivity studies for ice simulation and for other hydrologic and meteorologic conditions. The simulations for the final stage of the two stage project can be used to estimate the sensitivity with Stage III since Stage III is the same as the final stage of the two stage project.

The effects on Stage III river ice conditions due to alternative designs and operating policies for the multi-level power intakes is expected to be similar to that discussed for Stage II (Section 4.2.3(c)(ii)). The alternative designs and operating policies are not expected to substantially affect the river ice conditions.

Stage III operation with the Case E-I flow requirements, as an alternative to Case E-VI, has also been simulated with the river ice model. Results for Case E-I and Case E-VI are compared in Figure E.2.4.274 for 1981-82 weather conditions and for late Stage III energy demands. Based on these simulations, the maximum river stages, slough overtopping events and ice front starting and melt-out dates are expected to be similar to those discussed above for Case E-VI. Slightly greater ice thicknesses and ice front extent may occur for E-I relative to E-VI.

- Talkeetna to Cook Inlet (***)

River ice conditions between Talkeetna and Cook Inlet during Stage III operation are expected to show the same general trends as discussed for the Stage II operations. Based on the "average" 1981-82 winter, arrival of the ice front at Talkeetna is expected to occur in late December for early Stage III and early January for late Stage III, approximately four to six weeks later than for natural conditions. Maximum river stages between Talkeetna and Cook Inlet would be somewhat higher than natural due to the higher than natural flow rates.

- Sloughs and Peripheral Habitats (***)

For Stage III operation, the maximum expected ice thicknesses, river stages and ice front extent are less than those expected for Stage I or Stage II. Mitigation measures (Section 4.1.3c(ii) and Section 6.10.5) proposed for slough protection during Stage I or Stage II would, therefore, be adequate for Stage III.

Table E.2.4.23 summarizes information on winter water levels near sloughs and side channels for Stages I, II and III for Case E-VI flow requirements. Similar information for Case E-I flow requirements is provided in Table E.2.4.24. Results of the two simulations are generally similar. The tables show the occurrences of slough overtoppings for the natural berm elevations. Where berms are elevated (Section 6.10.5), overtopping would not be expected.

(iii) Suspended Sediment (***)

The extended DYRESM model has been applied to simulate the suspended sediment concentrations in both Watana and Devil Canyon Reservoirs and outflows under 1982 flow conditions. The suspended sediment load for 1982 is estimated to be similar to an average year as described for Stage I, (Section 4.1.3(c)(iii)). Case E-VI downstream flow requirements and late Stage III energy demands were incorporated. The basic data and solution procedure used in this study are the same as that used in the Stage I and Stage II studies as described in Section 4.1.3(c)(iii). Table E.2.4.73 shows the outflow suspended sediment concentration from Devil Canyon Reservoir. Figures E.2.4.275 and E.2.4.276 illustrate the predicted outflow suspended sediment concentrations from Devil Canyon. Figures E.2.4.277 and E.2.4.278 illustrate the outflow suspended sediment concentration from Watana for the same period. As indicated in the Stage II study, a small amount of the suspended sediments passing through the Watana Reservoir is expected to settle in the Devil Canyon Reservoir. This is attributable to the small sizes of the particles (less than 4 microns in diameter) entering the reservoir from Watana and the relatively short retention time of the Devil Canyon Reservoir (two months) in comparison to the Watana Reservoir (twenty months). The suspended sediment and turbidity levels that occur within the Devil Canyon impoundment and downstream will be slightly reduced from those that exist in the outflow from Watana.

As indicated in the Stage II studies, the Devil Canyon outflow suspended sediment concentration and turbidity level are expected to be more uniform throughout the entire year than the natural river condition. The outflow suspended sediment concentration of the Watana Reservoir in Stage III in July and August would be less than for the Watana Reservoir in Stages I and II. The reduction in concentration may be up to about 50 mg/l. This reduction is due to the larger and deeper Watana Reservoir formed in Stage III (retention time increases from 9 months to 20 months). The outflow suspended sediment concentration from Devil Canyon Reservoir is correspondingly less in Stage III than in Stage II.

The outflow suspended sediment concentration from Devil Canyon would reach its lowest level of about 10 to 20 mg/l in April or May and approach a maximum of about 90 to 100 mg/l in July or August. The average concentration between August and January would be about 70 mg/l.

- <u>Other Sources of Sediment</u> (***)

  As discussed in Section 4.1.3(c)(iii), and 4.3.2(d)(iii), inundation of land by the reservoir will result in the potential for bank instability and slides of the skin and bimodel flow types, shallow rotational, and assorted frozen, partially frozen and non-frozen block slides. As a result of the slope instability along the shoreline, an indeterminate amount of material will become suspended in the reservoir.

  In Stage III the potential for slope instability along the reservoir banks will be greater than for Stage I, because of the increase in shoreline length and because the shoreline at the higher water level is comprised of overburden having greater thicknesses than in Stage I. This is particularly true near the downstream end of the reservoir.

In the downstream end of the reservoir the deposits in the Stage III shoreline area are primarily glacial tills comprised primarily of silty sands (SM) but including some sandy clays (SC). Geotechnical investigations in the dam site area indicate that less than 15 percent of the material having a size less than 3 inches is smaller than 5 microns. Based on the reservoir suspended sediment modeling, material of the 3 to 4 micron size range would be expected to remain in suspension in the reservoir.

As discussed for Stage I, the time period over which bank instability and slides would occur is unknown. Slope failures would be highest early in Stage III and would decrease with time. Therefore, an increase in suspended sediment concentration due to slope failures would be highest in the early years of Stage III.

- <u>Devil Canyon to Talkeetna</u> (***)

As discussed in Section 4.1.3(c)(iv) for Stage I, suspended sediment concentrations in this reach would be similar to those in the outflow from the Devil Canyon reservoir.

- <u>Talkeetna to Cook Inlet</u> (***)

As discussed in Section 4.1.3(c)(iv) for Stage I, the reduction in suspended sediment concentration in the middle reach may result in a small reduction in summer suspended sediment concentrations downstream of the Susitna-Chulitna confluence. An increase in winter suspended sediment concentration may also be expected. During the summer, the sediment concentration will be a function of the sediment load of the Chulitna River. Mixing of the suspended sediment from the Chulitna, Susitna and Talkeetna Rivers will take place over a short length of river between Talkeetna and upstream of the bridge at Sunshine. Downstream, the fully mixed river may have a summer suspended sediment concentration of about five percent less than under natural conditions. In the winter, assuming an average sediment concentration between November and May of approximately 40-50 mg/l from the project, the average concentration downstream of the mixing area would be approximately 30-40 mg/l.

(iv) Turbidity/Vertical Illumination (***)

- Reservoirs (***)

Because of the reduced suspended sediment concentrations near the surface of the reservoirs, Stage III turbidities will be reduced from Stages I and II and vertical illumination will be increased.

In Watana Reservoir, turbidity near the surface would be approximately 170 NTU in November decreasing to less than 5 NTU by January. Turbidities would remain low throughout winter and begin to increase in May. By July the turbidity near the surface would be approximately 150 NTU and would stay between 100 NTU and 160 NTU until November when isothermal conditions in the reservoir and wind mixing cause uniform conditions in the upper portion of the reservoir.

Turbidity levels near the surface of Devil Canyon Reservoir would be less than those in Watana. Simulations of suspended sediment indicate turbidity near the surface would be close to 130 NTU in November decreasing to less than 5 NTU in December and remaining at that level throughout the winter. Turbidity would increase in March to near 20 NTU and in April and May to near 30 NTU. Simulations indicate the turbidity level would continue to increase to near 60 NTU in late June and 80 NTU in July, remaining between 60 and 80 NTU until isothermal conditions in November allow wind mixing to cause uniform conditions in the reservoir.

Vertical illumination would be greater than in Stages I or II because of the decreased turbidity.

- Devil Canyon to Talkeetna (***)

Turbidity levels in this reach would be less than Stage I and II because of the reduced suspended sediment concentrations. Turbidity in the summer would be measurably reduced from natural conditions because of the trapping of material in the reservoir. Winter turbidity levels will be higher because of the fine material which remains suspended in the reservoir and which is carried out of the reservoir with winter powerhouse flows. Summer turbidity levels are simulated to increase from values of 20-40 NTU in early May to maximums of 200 NTU in late July and to decrease to approximately 100 NTU by September. Turbidity would be relatively constant at 100-140 NTU through December and decrease to minimum levels in early May.

Vertical illumination would be greater than in Stages I or II.

- Talkeetna to Cook Inlet (***)

Summer turbidity levels in this reach would be similar to natural conditions because of the influence of the Chulitna and Talkeetna Rivers. Winter turbidity levels would be higher than natural but lower than Stages I and II and, based on suspended sediment simulations, would be approximately 60-80 NTU on the average.

Vertical illumination would be greater than in Stages I or II.

(v) Dissolved Oxygen (***)

- Watana Reservoir (***)

The discussion of dissolved oxygen for Stages I and II is applicable to Stage III. As in those stages, larger trees within the area between the Stage I and Stage III pool levels would be selectively cleared, removing the potential BOD they would have created. Some organic material will remain along the banks in the area of clearing and some localized oxygen depletion could occur.

Reservoir stratification may limit oxygen replenishment in the hypoliminion. The spring turnover, with its large inflow of freshwater, will cause mixing; however, the depth to which this mixing will occur is unknown. Dissolved oxygen is expected to be at relatively high levels in the upper portion of the reservoir (within 100 to 200 feet of the surface) and to decrease with depth. This is because most inflowing water will enter the reservoir in the upper levels. The fall turnover will tend to make dissolved oxygen levels more uniform throughout depth.

- Devil Canyon Reservoir (***)

  Dissolved oxygen in Devil Canyon Reservoir should be similar to that discussed for Stage II. Since there will be no new clearing, and since some sediment will be trapped and cover the organic layer, dissolved oxygen will increase near the bottom of the reservoir from Stage II levels. Dissolved oxygen will be highest near the surface of the reservoir, as most outflows from Watana will enter the reservoir near the surface, and outflows from Watana are expected to have relatively high dissolved oxygen concentrations.

  Mixing of the reservoir during fall and spring turnovers will replenish dissolved oxygen concentrations to an unknown depth. Operation of the outlet works may also increase dissolved oxygen levels at depth. Generally, when the outlet works operate, water from the hypolimnion is removed from Devil Canyon and replaced with water from closer to the Watana Reservoir surface. This will tend to increase dissolved oxygen concentrations in the lower levels of Devil Canyon Reservoir.

- Downstream from Devil Canyon (***)

  Dissolved oxygen levels in Stage III would be similar to Stage II. In general, dissolved oxygen is expected to be similar to natural conditions, because water will generally be withdrawn from near the reservoir surface. During periods when the Devil Canyon outlet works are operating, some water with lower than natural dissolved oxygen may be released from the reservoir. This water will be released as a diffused spray which will tend to increase its dissolved oxygen content. Additionally, exposure to the atmosphere and mixing with water released through the powerhouse will increase dissolved oxygen levels downstream. Continual operation of the Devil Canyon outlet works will cause replacement of water near the bottom of Devil Canyon Reservoir with water from near the surface of Watana. Thus, after a period of releases with potentially lower dissolved oxygen levels, the concentration in the water released through the outlet works is expected to increase.

(vi) Total Dissolved Gas Concentration (***)

As discussed for Stages I and II in Sections 4.1.3(a)(v) and 4.2.3(a)(v) and in Section 3.6.2, the project operating policy and project design are planned to minimize the potential for downstream gas concentrations to exceed naturally occurring levels. Dissolved gas concentrations in Stage III would be similar to Stage II. Fixed cone valves are provided in the outlet works to disperse releases and minimize dissolved gas concentrations downstream. Floods with recurrence intervals of less than 50 years would be released without operating the spillway (Section 4.3.3(a)(iii)). Immediately downstream of Devil Canyon Dam, dissolved gas concentrations would not exceed
105 percent to 110 percent. Further downstream, gas concentrations would be reduced. Gas concentrations are expected to be less than natural for some floods with return periods of greater than 50 years also, due to the inundation of the Devil Canyon rapids and mixing of spillway, outlet works and powerhouse flows. A description of the manner in which fixed cone valves minimize gas concentrations is given in Section 6.4.4.

(vii) Trophic Status (Nutrients) (***)

A detailed analysis of the anticipated trophic status of the Watana Reservoir has been developed by Peterson and Nichols (1982) and more recent literature studies.

Reservoir trophic status is determined in part by the relative amounts of carbon (C), silicon (Si), nitrogen (N), and phosphorus (P) present in a system, as well as the quality and quantity of light penetration. The average 1980-1981 C:Si:N:P June ratio of 1080:340:28:1 indicates that phosphorus will be the limiting nutrient in the Susitna impoundments. Nutrient loading and hydraulic residence models for large water bodies were considered to be the most reliable methods for estimating the Watana Stage III Reservoir trophic status. However, because the validity of these models are based on phosphorus data from temperate, clear-water lakes, predicting trophic status of silt-laden water bodies with reduced light conditions and high inorganic phosphorus levels may over estimate the actual trophic status (see previous discussion for Stage I Section 4.1.3(c)(vii)).

Artificial phosphorus loading of the reservoir from domestic sources was similarly investigated by Peterson and Nichols (1982). They concluded that the maximum allowable artificial loading is equivalent to the waste from 115,800 permanent residents, if oligotrophic conditions are to be maintained. However, this estimate is conservative since the effects of low light penetration and the use of waste treatment were not considered.

(viii) <u>Total Dissolved Solids, Conductivity, Significant Ions, Alkalinity, and Metals</u> (***)

The leaching process, as previously identified in Section 4.1.2(e)(vii), is expected to result in increased levels of dissolved solids within the reservoir immediately after raising the Stage III water level. The magnitude of these changes cannot be quantified, but should not be biologically significant (Peterson and Nichols 1982). Furthermore, Baxter and Glaude (1980) have found such effects are temporary and diminish with time.

The discussions of these parameters for Stage I (Section, 4.1.2.(e) and 4.1.3(c)) are generally applicable to Stage III.

(d) <u>Ground Water Conditions</u> (***)

(i) <u>Mainstem</u> (***)

As a result of the annual water level fluctuation in the reservoir, there will be localized changes in ground water in the immediate vicinity of the reservoir. Downstream ground water impacts during summer will be similar to those described in Sections 4.1.2(f)(i) and 4.1.3(d)(i) for Stage I and will be confined to the river area. During winter, ice staging will occur during freezeup (Section 4.3.3(c)(iii)) and hence, the ground water levels will increase along ice-covered sections of the mainstem. The extent of river covered with ice and with increased water levels will be reduced from Stages I and II. Mainstem stages during July and August will be higher than during filling of Stage

III because excess flows will be released rather than stored. Thus groundwater levels adjacent to the river will increase.

(ii) Sloughs and Peripheral Habitat Areas (***)

The groundwater flow to peripheral habitat areas will generally be more stable with-project than for natural conditions, reflecting the more stable with-project mainstem flows and further downstream extent of the winter ice front. During winter in the Devil Canyon to Talkeetna reach, some of the sloughs (downstream of RM 126 in early Stage III and downstream of RM 114 in late Stage III) will be adjacent to an ice-covered section of the Susitna River. The river will have staged to form an ice cover at project operation flows of about 10,000 cfs. The associated water level will be a few feet above normal winter water levels and will cause an increase in the ground water table. This will in turn cause an increase in ground water flow adjacent to the ice-covered reach of the river. In the middle reach downstream of the ice front, groundwater flow will generally be very stable all summer and increased slightly in the winter.

Sloughs upstream of RM 126 in early Stage III and RM 114 in late Stage III may be adjacent to open water sections of the Susitna River. Because flows will average approximately 10,000 cfs in winter, the associated water level will be less than water levels occurring under the natural freezeup process. Hence, the ground water table will be lower. Sloughs in this area may experience a decrease in ground water flow in the winter from natural conditions. However the flow stability for Stage III operation and the reduction in ice front extent will provide very stable water levels and upwelling all year in the middle river upstream of the ice front.

During summer, the mainstem-slough ground water interaction will be similar to that discussed in Section 4.2.2(f)(ii) and 4.1.3(d)(i).

During July and August the mainstem flow will be greater than during filling (4.3.2(c)(i)) and thus, the groundwater flow to the sloughs will be higher. During the fall, under natural conditions, flows generally decline to nearly 3,000 to 5,000 cfs before an ice cover forms. This is the period of lowest groundwater flow. With the project, discharges and water levels will remain higher than natural during this period providing an increase in groundwater flow.

(e) Lakes and Streams (***)

The numerous small lakes inundated by the Watana Stage III Reservoir will mostly remain below the reservoir surface at all times, but a few may become perched at low reservoir levels.

The mouths of reservoir tributaries will shift upstream and downstream in response to water level fluctuations in the reservoir. The position of delta formation will also vary. Bedload and suspended sediments will be deposited wherever the streams enter the still waters of the reservoir.

Reduced river levels due to project operation will cause geomorphic changes at tributary mouths downstream of Devil Canyon as described for Stages I and II.

(f) Instream Flow Uses (***)

The effects on the fishery resource, wildlife habitat, and riparian vegetation are described in Chapter 3. The effects on recreation, including whitewater kayaking, are discussed in Chapter 7.

(i) Navigation and Transportation (***)

Table E.2.4.74 shows that Stage III flows are expected to exceed levels estimated for navigation with minimum difficulty (Section 4.1.3(f)iii)) with about the same frequency as for Stages I and II (Tables E.2.4.30 and E.2.4.50). The effects of Stage III operation on navigation and transportation would thus be similar to those for Stages I and II discussed in Section 4.1.3(f)(ii) and Section 4.2.3(f)i and navigational difficulties would be similar to natural conditoins. Navigational difficulties may be encountered slightly more frequently than in Stages I and II in September downstream of the Chulitna River and in Alexander Slough. Navigational difficulties may be encountered slightly more frequently than natural in mid-September (in approximately 5 percent more years).

(ii) Freshwater Recruitment to Cook Inlet Estuary (***)

Salinity changes in Cook Inlet due to Watana operation were simulated using a computer model (Resource Management Associates 1983) for the two-stage project. The effect on flows and water levels of the three-stage project would be similar to the two-stage project and the results of the modeling of the two-stage project are considered applicable to the three-stage project. Results of the modeling indicate that the salinity in Cook Inlet will attain a dynamic equilibrium within approximately one year of reservoir operation. Winter salinities will be less and summer salinities will be greater. Results summarized in Section 4.1.3 for Stage I would be generally applicable to Stage III.

4.4 - Access Plan (**)

The Watana access road will begin with the construction of a 2.0-mile road from the Alaska Railroad at Cantwell, to the junction of the George Parks and Denali Highways. Access will then follow the existing Denali Highway for approximately 21.3 miles. Portions of this road segment will be upgraded to meet standards necessary for the anticipated construction traffic. From the Denali Highway, a 42 mile long gravel road will be constructed in a southerly direction to the Watana campsite. Access to the Devil Canyon site will be via a 37 mile road from Watana, north of the Susitna River, and a 12 mile railroad extension from Gold Creek to Devil Canyon, on the south side of the Susitna River.

Access roads will consist of unpaved 24-feet wide running surfaces with shoulder widths of 5 feet. Design speed will be 55 mph where acceptable, and 40 mph in areas of steep grades and sharp turns to avoid the need for excessively deep cuts and extensive fills.

Side borrow techniques will be the primary construction method used to develop the access roads. This will minimize disturbance to areas away from the access road by confining construction-related activities to a narrow strip on each side of the road. Careful stripping of the vegetation and organic soils, excavation, construction, backfilling and vegetative rehabilitation should be confined to an area with a maximum width of between 100 and 140 feet.

A few borrow sites of 10-20 acres will be needed along the road alignment for construction materials. These borrow sites will be located in well-drained upland areas.

Additional detail on the proposed access corridors and their construction can be found in Chapter 10 and in Exhibit A. The methodology behind the selection of these corridors is explained in Chapter 10.

4.4.1 - Flows (**)

Flow rates on streams crossed by the access road will not be changed. However, localized impacts on water levels and flow velocities could occur if crossings are improperly designed. Therefore, the Applicant has developed a manual entitled "Drainage Structure and Waterway Design Guidelines" (HE 1985d) which includes consideration of effects of bridges, culverts and other water crossings on water levels, velocities, fish passage, bed scour, and channel stability. This manual will be followed in construction of the project.

General considerations in the manual are enumerated here.

- Because they do not restrict streamflow, bridge crossings will be preferred to culverts or low-water crossings. Bridge supports will be located outside active channels, if possible.

- Improperly designed culverts can restrict upstream fish movement because of high velocities or perching of the culvert above the streambed.

- Maintenance of adequate fish passage will be ensured as per Alaska Statute 16.05-840.

- Culverts are more susceptible to ice blockage problems which can cause restricted drainage and road flooding, especially during winter snowmelt periods. Culverts will be designed to handle flood flows and icing problems.

- Low-water crossings will only be used in areas of infrequent, light traffic (for example, for construction of the transmission line). They will conform to the local streambed slope and will be constructed of materials that will allow water to flow over them instead of percolating through them.

4.4.2 - Water Quality (**)

Most water quality impacts associated with the proposed access routes will occur during construction. The principal impacts associated with construction will be temporary increases in suspended sediment and turbidity levels and the potential for accidental leakage and spillage of petroleum products. The Best Management Practices Manuals prepared by the Applicant, and the manual entitled Drainage Structure and Waterway Design Guidelines (APA 1985a, 1985b, 1985c, 1985d, 1985e, and HE 1985d), will be followed during construction of the project to minimize these potential impacts.

(a) Turbidity and Sedimentation (**)

Some of the more apparent potential sources of turbidity and sedimentation problems during access road construction include:

- Instream operation of heavy equipment;
- Location and type of permanent stream crossings (culverts vs. bridges);
- Location of borrow sites;
- Lateral stream transits;
- Vegetation clearing;
- Side hill cuts;
- Disturbances to permafrost; and
- Construction timing and schedules.

These potential sources of turbidity and sedimentation are addressed in Chapter 3, Sections 2.3 and 2.4.3. A more thorough discussion of these and other sources and of proper methods to control and minimize this impact is given in the BMP Manual "Erosion and Sedimentation Control" (APA 1985a).

(b) Contamination by Petroleum Products (**)

Contamination of water courses from accidental spills of hazardous materials, namely fuels and oils, is a major concern. During construction of the trans-Alaska oil pipeline, oil spills were a greater problem than anticipated. Most spills occurred as a result of improperly maintained machines, equipment repair, refueling, and vehicle accidents.

Water pumping for dust control, gravel processing, dewatering, and other purposes can also lead to petroleum contamination since water pumps are usually placed on the river or lake bank.

A Spill Prevention Containment and Countermeasure Plan (SPCC) will be developed and implemented prior to the start of construction to minimize petroleum contamination problems, as required by law. A Best Management Practices Manual prepared by the Applicant entitled "Oil Spill Contingency Planning" (APA 1985b) indentifies the major elements that comprise an oil spill contingency document and also describes specific techniques for spill containment, cleanup, disposal, and reclamation.

A more detailed discussion of petroleum contamination problems as they relate to fishery impacts are provided in Chapter 3, Sections 2.3 and 2.4.3.

4.5 - Transmission Corridor (*)

The transmission line consists of four segments: the Anchorage-Willow line, the Fairbanks-Healy line, the Willow-Healy Intertie, and the Gold Creek-Watana line. All Susitna transmission lines will be operated at 345 kV. A description of the segments is contained in Section 2.8. Route selection is discussed in detail in Chapter 10.

The Gold Creek-Watana segment is composed of two sections: Watana to Devil Canyon and Devil Canyon to Gold Creek. Construction of the portion from the Watana damsite to Devil Canyon will follow the same central corridor as the access road between Watana and Devil Canyon. Hence, impacts to stream flows and water quality will be confined to those streams discussed in Section 4.3. From Devil Canyon to the Intertie at Gold Creek, the transmission corridor will parallel the railroad extension from Gold Creek to Devil Canyon. This will help to minimize impacts associated with vehicular construction access.

The Willow-Healy Intertie has been built as a separate project and was completed in 1984. When Watana Stage I is completed a second line will be added parallel to the Intertie, and the operating voltage of the existing line will be increased from 138 kV to 345 kV. When Watana Stage III comes on-line, a third parallel line will be constructed from Gold Creek to Healy and from Willow to Knik Arm.

The existing access points and construction trails will be utilized to construct the additional lines. Thus, the impacts of new construction will be minimized as a result of the previous construction. The Environmental Assessment Report for the Intertie (Commonwealth Associates 1982) discusses the expected environmental impacts of transmission line construction in the Gold Creek to Willow segment.

For construction of the north (Fairbanks-Healy) and south (Anchorage-Willow) stubs, stream crossings will be required. The potential effects will be of the same type as those previously discussed in Section 4.4 and in Chapter 2, Section 2.3. However, impacts should be less than those caused by access road construction because of the limited access necessary to construct the transmission line. Short-term erosion related problems can be caused by stream crossings, vegetative clearing, siting of transmission towers, locations and methods of access and disturbances to the permafrost. With proper design and construction practices, few erosion-related problems are anticipated.

Contamination of local waters from accidental spills of fuels and oils is a second potential water quality impact. The Spill Containment and Countermeasure Plan (SPCC) to be developed and implemented will minimize the potential contamination of the watershed.

Once the transmission line has been built, there should be few impacts associated with routine inspection and maintenance of towers and lines. Some localized temporary sedimentation and turbidity problems could occur when maintenance vehicles are required to cross streams to repair damaged lines or towers. A thorough description of all transmission corridors, their development and maintenance is presented in Exhibit A, Sections 4 and 10.

5 - AGENCY CONCERNS AND RECOMMENDATIONS

5 - AGENCY CONCERNS AND RECOMMENDATIONS (**)

Numerous water quantity and quality concerns have been identified by state and federal resource agencies since 1980. These concerns were treated extensively in the Applicant's February 28, 1983 License Application, with substantial additional analysis added in the present Amendment. The principal concerns include:

- Flow regimes during filling and operation;
- Morphological stream changes expected;
- Reservoir and downstream thermal regime;
- Winter ice regime;
- Sediment and turbidity increases during construction;
- Sedimentation process and turbidity in the reservoirs and downstream;
- Dissolved oxygen levels in the reservoirs and downstream;
- Nitrogen supersaturation downstream from the dams;
- Potential contamination from accidental petroleum spills and leakage;
- Potential contamination from concrete wastewater;
- Wastewater discharge from the construction camps and villages;
- Downstream ground water impacts; and
- The effects on instream flow uses including navigation, transportation, and recreation.

The Applicant's consultation with the agencies on these and other matters is summarized in Chapter 11 of this Amendment.

6 - MITIGATION, ENHANCEMENT, AND PROTECTIVE MEASURES

6 - MITIGATION, ENHANCEMENT, AND PROTECTIVE MEASURES (**)

6.1 - Introduction (*)

Mitigation measures were developed to protect, maintain, and enhance the water quality and quantity of the Susitna River. These measures were developed primarily to avoid or minimize impacts to aquatic habitats, although all instream flow needs were given consideration.

The first step in the mitigation process was the identification of water quality and quantity impacts from construction, filling, and operation that could be mitigated through preconstruction planning, design, and scheduling. Three key mitigation measures were incorporated into the project design:

1. Flow constraints were selected to provide downstream fishery resources with adequate flows and water levels for migration, spawning, rearing, and overwintering while maintaining the economic viability of the project;

2. Multilevel intakes were added to improve downstream temperature and sediment control; and

3. Fixed cone valves were incorporated in the outlet works and flood storage pools were provided to prevent spillway operation for floods more frequent than the 50-year recurrence interval event. Regulation of flood peaks by the project, use of the outlet works and cone valves rather than the spillway, and inundation of Devil Canyon rapids will reduce with-project gas concentrations to levels below natural conditions.

The second step of the mitigation process will involve the implementation of environmentally-sound construction practices. These practices will be part of design and construction documents and, therefore, their implementation will be required. Monitoring of construction practices will be required to identify and correct problems. The process of construction monitoring and mitigation is described in detail in Exhibit E, Chapter 3, Sections 2.4 and 2.6.

Upon completion of construction, the third mitigation step will consist of operational monitoring and surveillance to identify problems and employ corrective measures as quickly and effectively as possible.

Mitigation planning, development, and refinement will continue throughout the permitting and licensing, detail design, construction, and operational phases of the project. The proposed mitigative, enhancement and protective measures are highlighted in the following sections. In some cases, the reader is referred to other chapters, especially Chapter 3, for a thorough discussion of proposed mitigation.

6.2 - Mitigation - Watana Stage I - Construction (**)

Mitigation measures during construction of all three stages are similar and are discussed in detail for Watana Stage I. This discussion is referenced in the sections on Stage II and Stage III construction.

Mitigation measures during construction of Watana Stage I will be necessary to minimize the potential of significant impacts occurring to the quality of the adjacent water resources. Techniques and guidelines contained in the Best Management Practices (BMP) manuals (APA 1985a, 1985b, 1985c, 1985d, and 1985e) and in the "Drainage Structure and Waterway Design Guidelines" report (HE 1985d) will be incorporated into contractual documents prior to the onset of construction, so that the environmental goals of the Power Authority are met.

Prior to construction, all necessary federal, state and local permits and certificates required for dam construction and instream work will be obtained.

A 401 Water Quality Certification, pursuant to Section 401 of the Federal Water Pollution Control Act, was filed with ADEC on December 9, 1982. A copy of the letter requesting this certification is attached at the end of this section. It is the Applicant's intent to renew the request for this certification upon the filing of the Amended Application.

Compliance with the terms and conditions of the various permits, certifications and licenses will mitigate many of the project-related impacts on water resources.

6.2.1 - Borrow Areas (**)

Prior to development of the borrow areas, all necessary permits for material removal will be obtained from the Bureau of Land Management (BLM), U.S. Army Corps of Engineers (COE), State of Alaska Department of Environmental Conservation (ADEC), State of Alaska Department of Natural Resources (ADNR), and the Cook Inlet Region Incorporated (CIRI). The development of Borrow Site E has been identified as a major concern because of its potential contribution to increased siltation and turbidity in the immediate area and downstream. Mitigation of these impacts primarily involves the methodology and scheduling of excavation activities and the construction and operation of settling ponds. Guidelines and techniques found in the BMP manual entitled "Erosion and Sedimentation Control" (APA 1985a) will be incorporated into contractual documents prior to the initiation of borrow activities. No instream excavation is anticipated at Borrow Site E (See Sections 4.1.1(c)iii and 4.3.2(d)iii).

The more likely water quality impacts of Watana construction are: siltation-related problems associated with development of Borrow Site E, contamination caused by concrete production waste products, contamination by petroleum products; and construction, operation, and maintenance of support facilities. Detailed discussion of additional fishery oriented mitigative measures is contained in Chapter 2 Sections 4.1.1(c), 4.2.1(c), 4.3.1(c) and 4.3.2(d) and Chapter 3.

During Stage I the waste products from the gravel processing operation will be redeposited into the excavated site to avoid their entrainment in the river flow. Washwater resulting from these operations will be discharged into bermed ponds where suspended particles will be allowed to settle.

The processing plant for concrete aggregates and filters will produce a limited amount of spoil. Potential impacts will be controlled by running the wash water into a series of settling ponds. Fines will be removed from the wash water by gravity or as it filters through the existing granular soil berms before reentering the river. These fines will be disposed of within the excavation area to preclude their entrainment in the river flow.

All waste water will be discharged into receiving waters in accordance with ADEC permit requirements (AS46.03.100).

Upon completion of mining activities, most of the borrow sites will be below the natural river level. Additional areas will be inundated by the future Devil Canyon reservoir. Selective spoil disposal will provide a diversified shoreline.

All upland borrow areas for Stage I and Stage III will be rehabilitated using the stockpiled organic layer and required erosion prevention activities will be employed.

Streams impacted by borrow activities will be reconstructed to allow natural fish movements to and from the river. Further information on material removal and erosion control is discussed in Chapter 3, Section 2.4.3.

6.2.2 - Contamination by Petroleum Products (**)

The information found in the Best Management Practice (BMP) manual entitled "Fuel and Hazardous Material" (APA 1985d) will be incorporated into contractual documents prior to the storage of fuels.

A SPCC will be developed in accordance with 40 CFR 112.7 as required by EPA. The BMP manual entitled "Oil Spill Contingency Planning" (APA 1985b) defines the elements of such a plan and describes emergency techniques. This information will be incorporated into contractual documents prior to the initiation of construction.

All oil spills will be reported to the ADEC regardless of their size as mandated in 18 AAC 70-080.

Sections 4.1.1(c)(vi), 4.2.1(c)(vi) and 4.3.1(c)(viii) of Chapter 2 and Section 2.4.3(e) of Chapter 3 describe specific measures that will be employed to minimize the potential contamination of surface water and ground water from petroleum products.

6.2.3 - Concrete Contamination (*)

The use of an efficient central batch plant will reduce the potential problems that could be caused by waste concrete and concrete wash water. Rejected concrete will be disposed of by haulage directly to an upland disposal area or dumped, allowed to harden and disposed in an excavated area.

Waste water from the washing of mixing and hauling equipment will be processed and stored in an impermeable lined pond until its specific gravity drops to a point which allows its reuse as mixing water for concrete batching. This system will minimize the wastewater effluent to be returned to the river systems.

At concrete placement areas, the wash water resulting from cleanup of placing equipment, curing and green cutting will be collected in sumps and pumped to settling ponds to remove the suspended materials before the effluent is discharged into the river. Ponds will generally be unlined with sand filters to ensure removal of most waste products. Wastewater will be neutralized to avoid elevated pH discharges. Control of toxic chemicals in the effluent will be accomplished through careful selection of concrete additives, provision of filters for the effluent, and close monitoring of operations by the Construction Manager.

All effluents will comply with ADEC and EPA effluent standards (AS 46.03.100; 18 AAC 70.020 and 18 AAC 72.010).

Airborne particulates will also be controlled with the use of a modern central batching plant. The plant will be fully enclosed to facilitate winter operation requirements and the transfer of materials will be via enclosed pipes.

Sections 4.1.1(c)(vii), 4.2.1(c)(vii) and 4.3.1(c)(ix) of Chapter 2 describe measures that will be employed to minimize potential impacts from concrete contamination in each stage of project construction.

6.2.4 - Support Facilities (**)

(a) Water Supply (**)

All required permits will be obtained and their stipulations will be complied with. Withdrawal of water for the construction camp and village will meet ADF&G criteria for the protection of fisheries resources. A water appropriation permit (AS 46.15; 11 AAC 93) will be obtained from ADNR.

An application will be filed with ADEC for approval of the proposed water supply system plan as mandated by 18 AAC 80.100.

The techniques and guidelines found in the BMP manual entitled "Water Supply" (APA 1985e) will be incorporated into contractual documents prior to the installation of the water system.

Sections 4.1.1(g)(i), 4.2.1(g)(i) and 4.3.1(g)(i) describe the water treatment requirements anticipated for all stages of project construction.

(b) Wastewater Treatment (**)

As noted in Section 4.1.1(g)(ii) all the necessary wastewater and waste disposal permits will be obtained, and complied with. These include ADEC permits 18 AAC 72.060 and 18 AAC 72 and a 401 Water Quality Certification pursuant to Section 401 of the Federal Water Pollution Control Act.

It is anticipated that compliance with all the necessary permits and certificate(s) will include the mitigation of any water quality impacts associated with the support facilities. The information found in the Best Management Practices manual entitled "Liquid and Solid Wastes" (APA 1985c) will be incorporated into contractual documents prior to the construction of the waste water treatment system, and will minimize water quality impacts.

Sections 4.1.1(g)(i), 4.2.1(g)(i) and 4.3.1(g)ii describe the water treatment requirements anticipated during the three stages of project construction.

6.2.5 - Others (o)

Additional mitigation measures are contained in Chapter 3. These measures include: stream crossings and encroachments guidelines, erosion control plans, blasting guidelines, and guidelines for clearing of vegetation.

6.3 - Mitigation - Watana Stage I Impoundment (**)

The primary concerns during filling and operation of the reservoir, as discussed in Sections 4 and 5 of this chapter and Chapter 3, include:

- o Maintenance of minimum and maximum downstream flows for fishery resources and other instream flow needs.
- o Morphological changes to the river and adjoining tributary mouths;
- o Changes in downstream sediment concentrations;
- o Maintenance of an acceptable downstream thermal regime throughout the year;
- o Ice processes;
- o Downstream gas supersaturation;
- o Eutrophication processes and trophic status; and
- o Effects on ground water levels, temperatures, and ground water upwelling rates.

Downstream flows will be provided to minimize the impact filling the reservoir could have on downstream fishery resources and other instream flow uses. Flow selection is discussed in Section 3. A minimum flow of 9,000 cfs will be provided from June through August and, in combination with the fishery mitigation measures discussed in Chapter 3, will provide for no net loss of habitat value.

Navigation problems are not anticipated with these flows (see Section 2.6.3 and Section 4.1.1(f)(ii)).

Changes in mainstem river morphology between Devil Canyon and Talkeetna may occur (see Section 4.1.2(d)), but are not expected to be significant enough to warrant mitigation, during the summer of filling, and no mitigation measures are expected to be necessary. As part of the monitoring program, access by salmon to tributaries will be monitored and if it becomes restricted, regrading of stream mouths will be undertaken where necessary to insure salmon access.

Reservoir releases will be from the low level outlet works during the summer of filling. The temperature of water released from the reservoir during filling is described in Section 4.1.2(e)(i).

Temperatures are expected to be slightly less than natural in May through July, similar to natural in August and higher than natural in September before the commercial operation of the first on-line unit. These temperature differences will be reduced with distance downstream from the project due to solar and atmospheric effects. Downstream of the Chulitna-Susitna-Talkeetna confluence the temperature differences will be further reduced. Water temperatures are expected to be within the tolerance range of the fish species present in the Susitna River and will be moderated somewhat downstream, although slight downstream thermal impacts to fish growth and migration timing may occur. No mitigation measures have been prepared to offset these below-normal downstream temperatures.

During the first winter of filling the first two powerhouse units are expected to become operational, and winter releases will be made through the multi-level powerhouse intakes. The release temperatures will generally be between 1°C and 3°C. Expected ice conditions during the winter following filling are described in Section 4.1.2(e)ii. The river is expected to become ice-covered somewhat later than under natural conditions and in the area where an ice cover forms, winter maximum water levels are expected to be similar to or less than natural. An area downstream of the dam will remain ice-free all winter, with temperatures above the normal 0°C. This is considered as being beneficial to fishery resources and therefore, no mitigation measures are proposed.

Eutrophication was determined not to be a problem and, therefore, no mitigation is required.

6.4 - Watana-Stage I Operation (**)

The primary concerns during Watana operation are identical to those identified for Watana filling.

6.4.1 - Flows (**)

Maximum and minimum flow constraints for all project stages were developed on a weekly basis for each week of the year (See Section 3). The adopted flow constraints (Case E-VI) can be separated into three major divisions: winter flows, summer flows, and transitional flows.

The most important winter flow constraints are maximum flows since normal project operation would produce discharges greater than the naturally occurring flows during the November to April period. The selected winter maximum (October-April) is intended to establish a boundary near the upper range of operational flows that would result in flow stability and provide a reasonable level of protection to over-wintering habitat for fish. The 16,000 cfs maximum flow would prevent overtopping of all the major sloughs prior to freeze-up, and stabilize habitat availability during ice-cover periods.

The winter minimum flow is established to prevent dewatering of rearing habitats. The 2,000 cfs minimum is chosen based on natural flows and represents a high mean natural winter flow.

Flow constraints during the winter to summer transition period (mid to late May) are intended to maintain flow stability and prevent rapid drops in discharge due to decreasing power demand in May and to gradually increase flow to summer levels. The minimum flow constraints are most important during this period.

Summer flow constraints are designed to maintain rearing habitats and provide greater flow stability. A 9,000 cfs minimum flow would maintain 75 percent of the existing habitat quantity at sites presently utilized by rearing chinook and increased flow stability would improve both habitat quality in existing rearing areas and increase habitat quantity in other areas over natural conditions, to ensure that the "no net loss of habitat value" criterion is maintained. This is more fully explained in Section 3 of this Chapter and Chapter 3.

Flow constraints during the summer to winter transition period (September and October) are intended to maintain flow stability and prevent rapid drops in flow prior to high winter power demands.

To provide stable downstream flows Watana will be operated primarily as a base-loaded plant until Devil Canyon is constructed. The allowable daily flow variation is discussed in Section 3. Additional details on the flow selection process are discussed in Section 3.

6.4.2 - River Morphology (**)

The mainstem Susitna River is expected to undergo a gradual degradation process (reduction in river bed elevation) between Watana and Talkeetna once the project becomes operational. This is described in Section 4.1.3(b). The maximum expected degradation is expected to average approximately one foot. This may result in somewhat lower water levels in the Watana to Talkeetna reach with-project than for the same flow under natural conditions. This may affect access conditions to sloughs, side channels and peripheral fisheries habitat, as well as affecting groundwater flow from the mainstem to the habitat areas. As part of the proposed monitoring program, these conditions will be checked and habitat modifications will be made as necessary to ensure access and adequate groundwater.

Additionally, it has been determined that certain tributaries of the Susitna River which support salmon may become perched (Section 4.1.3(b)) and that three streams crossed by the Alaska Railroad: Skull Creek and two unnamed creeks at RM 127.3 and 110.1, could degrade.

Perching of tributary streams is not expected to result in limiting access by fish since, over time, tributary stream flows will degrade the mouth area, and extensive mitigation is not anticipated. However, monitoring will be undertaken and should access be limited as a result of project operation, tributary mouth modification will be made to improve access.

The extent of scour in the tributaries crossed by the railroad cannot be predicted. Degradation may be limited by bedrock and the potential for endangering bridge foundations may be minimal if the foundation is sufficiently deep. If a problem becomes apparent, appropriate mitigation measures, such as placement of large riprap, will be taken to minimize possible bridge foundation problems.

The potential for aggradation in the reach between the Susitna-Chulitna confluence and the Sunshine bridge has been identified (Section 4.1.3(b)). The alluvial deposits of the Chulitna River are expected to progress toward the east and the main channel in this area is expected to become narrower and more well defined. This is not expected to restrict fish movement or other instream flow uses of this area. Therefore, no mitigation measures are proposed.

Because of the increased discharge during freeze-up, the river stage will be higher than natural in the winter. Without mitigation, this will result in increased flow through some of the sloughs which are currently overtopped during the freeze-up process. The higher stage may also cause flow through some sloughs which are presently not overtopped in winter. To minimize the impact on important salmon spawning sloughs, berms will be constructed at the heads of these sloughs to prevent overtopping during with-project river freeze-up. The spawning gravels in these sloughs will be maintained based on a monitoring program. Further information on this mitigation measure is contained in Chapter 3.

6.4.3 - Temperature (**)

As noted in Section 4.1, the impoundment of the Watana Stage I Reservoir will change the downstream temperature regime of the Susitna River. To minimize the potential change, multi-level intakes have been incorporated in the power plant intake structures so that water can be drawn from various depths. By selectively withdrawing water, an acceptable temperature for the downstream fish species can be maintained at the powerhouse outlet and downstream throughout the year. Additionally, the intake to the outlet works has been placed close to the normal maximum reservoir water level in Stage I to enable withdrawals of warmer water when the outlet works must be used.

Studies have been undertaken to determine the effect on downstream temperatures of project operation and these are described in Section 4.1.3(c). Several policies for operating the multi-level intake have been tested and are also described therein. Sensitivity studies to increased minimum summer flow requirements are also discussed.

The proposed operating policy for the outlet works (Section 3.6) is designed to minimize the potential for sudden temperature changes resulting from opening the outlet works.

6.4.4 - Total Dissolved Gas Concentration (**)

The avoidance of gas supersaturation will be achieved by the inclusion of fixed-cone valves in the outlet facilities and a flood storage pool in the reservoir.

By using the reservoir storage capacity coupled with the average summer powerhouse flow and the outlet works, floods with recurrence intervals of up to 50 years can be discharged through the outlet works and cone valves and minimize the potential for gas concentrations to exceed naturally occurring levels. As previously described in Section 4.1.3(a)(v), six 78-inch diameter valves with a design capacity of approximately 4,000 cfs each (for Stage I water levels), will be located approximately 125 feet above normal tailwater levels. These valves will discharge the flow as highly diffused jets to achieve significant energy dissipation while preventing deep penetration of an air-water mixture to depths sufficient to cause high levels of gas concentration.

Water becomes supersaturated with gas when an air-water mixture is subjected to pressures in excess of atmospheric. This causes the dissolution of nitrogen and oxygen from the entrained air into the surrounding water. The amount of dissolved gas which water can hold at saturation is directly proportional to the absolute pressure on the water. Water at a depth of 34 feet can hold 50 percent more gas than water at the surface (Johnson 1975).

A jet of water which has entrained air either in its free trajectory above the water or at the surface of the water upon impact and which reaches a depth in the tailwater of the project is likely to contain gas concentrations in excess of 100 percent saturation at atmospheric pressure. The gas concentration in the water can be minimized by reducing the entrainment of air in the jet of water, reducing the pressure to which the air-water mixture is subjected, or both. Turbine discharges, which are made below tailwater levels are not expected to contain supersaturated gas concentrations because they will not contain entrained air.

It is not possible to prevent spillway and outlet work releases from entraining air, therefore, it is necessary to prevent the water released from the structures from reaching a great enough depth to result in excessive supersaturation. The depth which the jet from either the spillway or outlet works reaches in the tailwater is dependent on the angle of impact, the flow velocity and the flow intensity (flow per unit area) at impact. The depth of jet penetration into the tailwater can be minimized by decreasing the flow intensity, decreasing the included angle between the jet and the tailwater or by decreasing the velocity at impact. Fixed cone valves were selected to be used on the outlet works because they disperse the flow and decrease the flow intensity and velocity at impact. Flip buckets, such as on the Watana and Devil Canyon spillways, also cause dispersion of flow and, depending on the velocity and depth of the flow, and the bucket lip shape, may cause the flow through the bucket to impact the tailwater over a large area. However, it is believed that the use of the cone valves will result in lesser gas concentrations than the use of the spillways to pass a given flow.

Little literature and no precedent data are available regarding the performance of fixed-cone valves in reducing or preventing supersaturated discharges. As such, a theoretical assessment of their anticipated performance was conducted based upon available studies of the aeration efficiency of similar Howell-Bunger[1/] fixed-cone valves and the physical and geometric characteris tics of diffused jets discharging freely into the atmosphere (Elder and Dougherty 1952, Allis Chalmers, Chen and Davis 1964, Falvey 1980, Johnson 1967, Johnson 1975).

The results of the assessment indicate that estimated gas concentrations that would occur as a result of a flow release are 100 to 105 percent of saturation downstream of Watana Dam. Concentrations will be within this range for up to the 50-year flood. Supersaturation will still occur in Devil Canyon, but as explained in Section 4.1.3(c)vi, with-project levels are expected

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[1/] Trademark of the Allis Chalmers Corporation to be less than naturally-occurring levels because of regulation of flood peaks by the project and the use of the outlet works cone valves. Operation of the spillway for floods less frequent than the 50-year flood would be expected to result in increased gas concentrations. However, because the dam will reduce downstream flood peaks, gas concentrations for those events may also be less than those occurring naturally for these floods.

To support these conclusions, a field test of similar valves was undertaken at the Lake Comanche Dam on the Mokelumne River in California (Ecological Analysts 1982). The results of the tests indicate that the valves prevented supersaturation and, to a limited extent, may have reduced existing nitrogen concentrations. Flows of 4,000 cfs with a dissolved nitrogen concentration of 101 percent at the intake structure were passed through four Howell-Bunger valves. Gas concentrations in the discharge were 97 percent. At 330 feet and 660 feet downstream, concentrations were 95 and 97 percent, respectively.

6.4.5 - Ice (**)

As discussed in Section 4.1.3(c)ii winter with-project water levels are expected to be a few feet above natural between the Chulitna-Susitna confluence and approximately RM 140, but varying in some years due to dimatological conditions. This may cause berms at the upstream ends of some sloughs to be overtopped with cold (0°C) water. It is believed that this could be detrimental to incubating embryos and overwintering fish. The Applicant proposes to prevent this overtopping by constructing berms above the maximum expected winter water levels at the significant habitat areas potentially affected and to maintain the habitat substrate on a regular basis as determined by a monitoring program.

Winter water levels are expected to increase slightly downstream of the Susitna-Chulitna confluence. Mitigation measures are not proposed in this reach because winter rearing habitat is expected to be the same or improved over existing conditions as a result of the higher winter flows. Only a few isolated spawning sites are found in the lower reach and these are not expected to be significantly impacted.

6.4.6 - Groundwater Flow, Temperatures and Upwelling Rates(**)

As a result of project operation summer mainstem water levels will decrease from natural, fall mainstem water levels will increase, winter mainstem water levels will increase downstream of the ice cover (RM 140±) and winter water levels will decrease upstream of the ice cover (see Figure E.2.4.45 through E.2.4.48 and Figure E.2.4.103 and E.2.4.104. In general, the stabilization of river flows in the May to November period will result in more uniform mainstem water levels during this period than under natural conditions. Since groundwater upwelling flows in sloughs and side channels are related to mainstem water levels (Section 2.4) the upwelling flows will be stabilized at levels somewhat lower than natural summer levels but higher than natural September-October values. Winter upwelling upstream of the ice cover will also be stable at levels similar to summer and fall values. Winter upwelling downstream of the ice cover will be greater than the summer-fall value.

The temperature of upwelling in peripheral habitat has been related to the mean annual mainstem temperature (Section 2.4). As pointed out in Section 4.1.3(c)i the mean annual time weighted temperature with-project will be approximately the same as natural conditions, or slightly warmer. Thus the temperature of groundwater upwelling should not be affected significantly by project operation.

Mitigation measures are not expected to be necessary. However, monitoring of habitat areas will be undertaken. If additional groundwater upwelling is required, it can be obtained, to a limited extent, by habitat modifications to increase the hydraulic gradient between the mainstem river and the habitat area such as lowering the slough bed.

6.4.7 - Suspended Sediment and Turbidity (**)

Suspended sediment concentrations and turbidity in the reach between the project and the Chulitna-Susitna confluence are expected to be decreased from natural conditions in the summer and increased in the winter. The impact of this on the biology of the fish population is discussed in Chapter 3. The winter increase is proposed to be minimized by operating the multi-level powerhouse intake in a manner to cause the lowest concentration releases downstream. This generally means using the intake port level nearest the surface in the winter. The simulations of suspended sediment concentrations discussed in Section 4.1.3(c)iii and 4.1.3(c)iv used this policy.

6.4.8 - Eutrophication Processes(**)

Eutrophication is not expected to be a problem and mitigation is not proposed.

6.5 - Mitigation - Devil Canyon Stage II - Construction (**)

Mitigation of the impacts of Devil Canyon Stage II construction activities will be achieved using the same measures described for Watana Stage I (see Section 6.2). All the appropriate permits and certifications will be obtained. Fish and wildlife mitigation measures are described in Chapter 3.

Borrow site development at Devil Canyon Stage II is not expected to cause significant increases in suspended sediment loads and turbidities. Excavation of Site G will be outside the river. Subsequently, it will be completely inundated during Devil Canyon Reservoir filling.

6.6 - Mitigation - Devil Canyon Stage II - Impoundment (**)

Other than the continuance of the Case E-VI flow constraints at Gold Creek and the use of fixed cone valves at Watana and Devil Canyon, no additional mitigation measures are planned during the Devil Canyon Stage II impoundment period.

6.7 - Mitigation - Devil Canyon/Watana Operation (**)

6.7.1 - Flows (**)

The downstream flow requirements at Gold Creek will be the same as those used during Watana Stage I operation. After Devil Canyon Stage II is on line, Watana Stage I will be operated as a peaking plant. The Watana tailrace will discharge directly into the Devil Canyon Reservoir, thus peaking at Watana Stage I will have no downstream impacts. The Devil Canyon Stage II Reservoir will provide the flow regulation required to stabilize the downstream flows.

The Devil Canyon Stage II power facilities will be operated as a base loaded plant, but with a small allowable daily flow variation (see Section 3.6.1).

6.7.2 - River Morphology (**)

As discussed in Section 4.2.3(b), effects on river morphology in Stage II are expected to be similar to Stage I. Mitigation measures and monitoring, as discussed in Section 6.4.2 for Stage I will be continued.

6.7.3 - Temperature (**)

Multi-level intakes, similar to those at Watana Stage I have been incorporated into the Devil Canyon Stage II design to regulate temperature and sediment. Only two intake levels will be needed because of the limited drawdown at Devil Canyon.

The proposed powerhouse operating policy during Stage II is also designed to minimize temperature impacts. As discussed in Section 3, during periods when flow released to meet power demands is not sufficient to meet environmental requirements, the outlet works must be operated. This results in decreased downstream temperatures because of the cool water drawn through the relatively low intakes. In order to minimize this, during periods when Watana Reservoir is filling (May, June and early July), power releases will be made from the Devil Canyon Reservoir to the extent possible and Watana powerhouse flows reduced in order to reduce Devil Canyon outlet works releases. When Watana Reservoir is filled, power generation must be shifted to Watana to aid in the passing of flood flows without using the spillway.

Additionally, as discussed in Sections 3.6 and 6.4.3, the proposed operating policy for opening the outlet works and spillways is designed to minimize abrupt changes in temperature resulting from sudden opening of the outlet works and spillway, or sudden changing of energy generation from Devil Canyon to Watana, or vice-versa.

6.7.4 - Total Dissolved Gas Concentration (**)

Fixed cone valves have been included at Devil Canyon, and a flood storage pool provided to allow storage and release of all floods up to the 50-year event without using the spillway and thus minimizing gas supersaturation downstream. The operation of the outlet works is discussed in Sections 4.2.3(a)v, 4.2.3(c)v and 6.4.4.

The Devil Canyon Dam will include seven valves at two levels with a total design capacity of 42,000 cfs. Four 102-inch diameter valves, each with a capacity of 6,300 cfs, will be located approximately 170 feet above normal tailwater. Three more valves, with diameters of 90 inches and capacities of 5,600 cfs, will be located approximately 50 feet above normal tailwater elevations. Operation of these valves is expected to result in a maximum dissolved gas concentration of between 105 and 110 percent for the 50-year flood event, immediately downstream of Devil Canyon Dam. This assumes that gas concentrations from use of the Watana cone valves of 100 to 105 percent are not dissipated in the Devil Canyon Reservoir. This is a reduction from naturally-occurring levels which would annually exceed 115 percent.

6.7.5 - Ice (**)

The with-project river ice cover is simulated to be further downstream and winter water levels are expected to be lower in Stage II than Stage I. The mitigation measures proposed for Stage I would prevent overtopping of habitat berms in Stage II. No further mitigation is proposed.

6.7.6 - Groundwater Flow, Temperature and Upwelling Rates (**)

The flow stability introduced by the Case E-VI Environmental Flow Requirements will have the same general effect on groundwater upwelling rates and temperatures as in Stage I. No further mitigation is proposed.

6.7.7 - Suspended Sediment and Turbidity (**)

The addition of Devil Canyon Reservoir will result in slight lowering of suspended sediment concentrations and turbidity from Stage I downstream of Devil Canyon. Mitigation measures proposed for Stage I would be continued.

6.7.8 - Eutrophication Processes (**)

Eutrophication is not expected to be a problem and mitigation is not proposed.

6.8 - Mitigation - Watana Stage III - Construction (***)

Mitigation of the impacts of Stage III construction activities will be achieved using the same measures described for Watana Stage I (see Section 6.1). All the appropriate permits and certifications will be obtained. Fish and wildlife mitigation measures are described in Exhibit E, Chapter 3.

Borrow site development at Watana is not expected to cause significant increases in suspended sediment loads and turbidities. As discussed in Section 4.3.1(c)(iii) and 4.3.2(d)(iii) river dredging and borrow will not be undertaken. Only portions of Borrow Site E, adjacent to the river, Borrow Site D and Quarry A are planned to be used.

Borrow Site E will be reopened for Stage III construction, but no instream borrow activities are anticipated. The lake produced by Stage I activities may be dredged, but no activity will occur in Tsusena Creek or the Susitna River. Additional upland material may also be removed from the site.

Rehabilitation of the lake at Borrow Site E will be finalized upon the completion of excavation activities.

6.9 - Mitigation - Watana Stage III Impoundment (***)

Stage III construction will continue as the reservoir is being filled. Case E-VI flow requirements will be maintained. Filling will progress as the multi-level intake ports are available to provide temperature control and as the spillway and dam crest elevation are such that dam safety is assured. The mitigation measures proposed for Stage I construction and Stage II construction will be maintained during this period.

6.10 - Mitigation - Stage III Operation (***)

6.10.1 - Flows (***)

The Case E-VI Flow Requirements will be maintained during this period as in Stages I and II. As the energy demand on the project increases with time, more water will be used to supply power requirements and less water will have to be released during the July-September period to maintain freeboard requirements. Thus, as discussed in Section 4.3.3(a), flow stability will improve with time.

Watana will continue to operate as a peaking plant to follow load changes. Devil Canyon Reservoir will act to reregulate these flows. A small daily flow fluctuation will be allowed at Devil Canyon powerhouse (see Section 3.6.1).

6.10.2 - River Morphology (***)

In the early years of Stage III operation there will still be frequent use of the outlet works during the July-September period. The middle reach channel degradation process begun in Stage I and continued in Stage II (see Sections 4.1.3(b), 4.2.3(b), and 6.4.2) will lessen and stop. Degradation will be at a reduced rate as the stream bed will be approaching its armored equilibrium position which is expected to be, on the average, approximately one foot below its natural location. As the energy demand increases the use of the outlet works in July-September will diminish and the mean annual flood flow in the middle reach will decrease. Degradation is expected to stop. The mitigation measures proposed for Stage I and II will be continued.

Measures for mitigating other morphological changes such as restricted access to tributaries by salmon will also be continued. The potential for additional streambed aggradation in the Susitna-Chulitna confluence area will diminish with time, as an equilibrium condition is reached. No mitigation is proposed.

6.10.3 - Temperatures (***)

Multi-level powerhouse intakes will be constructed and operated in Stage III. As discussed in Sections 4.3.3(c)i, 6.4.3 and 6.7.3, these will allow the withdrawal of water having temperatures as close to natural as possible and the minimization of downstream temperature impacts.

The operating policy for the Watana Stage III powerhouse and the Devil Canyon powerhouse is designed to minimize outlet works operation and resulting cool releases. As described in Sections

3.6 and 6.7.3, during periods when Watana Reservoir is filling (May, June, and early July) environmental flow requirements will be met as much as possible by using the Devil Canyon powerhouse and avoiding outlet works releases at Devil Canyon. When Watana Reservoir is full then power demands must be met by Watana first in order to ensure the ability to pass the 50-year flood without using the spillway.

6.10.4 - Total Dissolved Gas Concentration (***)

Fixed cone valves will be provided on the Watana and Devil Canyon outlet works to disperse excess releases and minimize the potential for gas supersaturation in excess of naturally occurring levels. These are described in Sections 6.4.4 and 6.7.3. The capacity of the Watana outlet works will be approximately 30,000 cfs during Stage III as compared to 24,000 cfs during Stage I because of the additional hydraulic head on the valves.

During the early years of Stage III operation the outlet works will be operated approximately as frequently in Stage III as in Stage II. However, as energy demands increase, more water will be used for power and outlet works operation will decrease. The ability of the project to control floods in excess of the 50-year event will be improved.

6.10.5 - Ice (***)

Simulated ice front progression and water levels in the winter are less with Stage III than Stages II and I. Therefore, the mitigation measures proposed in Section 6.4.5 will provide adequate protection from overtopping of habitat berms by cold mainstem water.

6.10.6 - Groundwater Flow, Temperature and Upwelling Rates (***)

The mainstem flow stability introduced by the use of the Case E-VI Environmental Flow Requirements will provide stability in groundwater upwelling in habitat areas as well. Temperatures of upwelling will generally be equal to or slightly higher than natural conditions as described in Section 6.4.6 for Watana Stage I. The with-project ice front is simulated to be further downstream in Stage III than in the other two stages so that a greater area of the river, upstream of the ice front, is expected to have stable groundwater upwelling rates all year. Downstream of the ice front, in the middle reach, winter water levels are expected to be less than in Stage I and II, introducing additional stability to groundwater upwelling rates in these areas.

6.10.7 - Suspended Sediment and Turbidity (***)

Raising of Watana normal maximum water level to its Stage III position of el. 2,185, is simulated to cause additional trapping of sediment in the reservoir and reduced downstream suspended sediment concentrations and turbidity from Stages I and II. Suspended sediment concentrations and turbidity levels will be decreased from natural in the summer and increased over natural in the winter. The mitigation measure proposed in Stages I and II will be continued in Stage III, namely, drawing water for winter powerhouse flows from as near the reservoir surface as possible, where suspended sediment concentrations are expected to be the lowest.

6.10.8 - Eutrophication (***)

Eutrophication is not expected to be a problem and mitigation measures are not proposed.

6.11 - Mitigation - Access Road and Transmission Lines (***)

The mitigation measures to be used to minimize the impacts of construction, operation, and maintenance of the access roads and transmission lines are described in Chapter 3.

STATE OF ALASKA

DEPT. OF ENVIRONMENTAL CONSERVATION

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December 21, 1982

Mr. Eric Yould
Executive Director
Alaska Power Authority
334 West 5th Avenue
Anchorage, Alaska 99501

Subject: Susitna Hydroelectric Project
401 Water Quality Certificate

Dear Mr. Yould:

This letter is to confirm that our office has received your December 9, 1982 request for Section 401 certification of the Federal Energy Regulatory Commission (FERC) license for the subject project.

As you are aware, studies are still under way to evaluate the project's potential impacts upon the environment. These studies and conclusions from others must be completed when your agency applies for the necessary Corps of Engineers construction permit(s). As this Department must also issue a 401 certificate for the Corps permit(s) and the above data, necessary for project evaluation, will then be available, we will honor your December 9, 1982 request for 401 certification at that time. Thus, a 401 certificate will be issued of the Corps of Engineer permit(s) and the FERC license at the same time.

If you have any questions concerning the above, please advise.

Sincerely,

Tim Rumfelt
Environmental Field Officer

TR/mr

7 - REFERENCES

7 - REFERENCES

Acres American Inc. 1982a. Susitna Hydroelectric Project, Feasibility Report. Hydrological Studies. Final Draft. Volume 4. Appendix A. Prepared for the Alaska Power Authority.

_____. 1982b. Susitna Hydroelectric Project, Feasibility Report. Design Development Studies. Final Draft. Volume 5. Appendix B. Prepared for the Alaska Power Authority.

_____. 1982c. Susitna Hydroelectric Project, 1980-81 Geotechnical Report. Final Draft. Volume 1. Prepared for the Alaska Power Authority.

_____. 1983. Susitna Hydroelectric Project, Slough Geohydrology Report. Unpublished.

Alaska Department of Environmental Conservation. 1978. Inventory of Water Pollution Sources and Management Actions. Maps and Tables. Division of Water Programs. Juneau, Alaska.

_____. 1979. Water Quality Standards. Juneau, Alaska.

_____. 1985. Personal communication. J. Howe, Alaska Department of Environmental Conservation to Alaska Department of Environmental Conservation.

Alaska Department of Fish and Game. 1981. Susitna Hydroelectric Project, Final Draft Report. Aquatic Habitat and Instream Flow Project. Prepared for Acres American Inc.

_____. 1982a. Susitna Hydroelectric Project, Final Draft Report. Aquatic Studies Program. Prepared for Acres American Inc.

_____. 1982b. Limnology and Fisheries Investigations at Crescent Lake 1979-1982, Part 1: Crescent Lake Limnology Data Summary. Soldotna, Alaska.

_____. 1983a. Susitna Hydro Aquatic Studies, Phase II Basic Data Report, Volume 4: Aquatic Habitat and Instream Flow Studies. Prepared for Alaska Power Authority, Anchorage, Alaska.

_____. 1983b. Susitna Hydro Aquatic Studies, Phase II Basic Data Report, Volume 4: Aquatic Habitat and Instream Flow Studies, 1982, Part I. Prepared for Alaska Power Authority, Anchorage, Alaska.

_____. 1983c. Susitna Hydro Aquatic Studies, Phase II Basic Data Report, Volume 4: Aquatic Habitat and Instream Flow Studies 1982, Part II. Prepared for Alaska Power Authority, Anchorage, Alaska.

______. 1983d. Susitna Hydro Aquatic Studies, Phase II Basic Data Report, Volume 4: Aquatic Habitat and Instream Flow Studies 1982, Appendices B and D-E. Prepared for Alaska Power Authority, Anchorage, Alaska.

______. 1983e. Susitna Hydro Aquatic Studies, Phase II Basic Data Report, Volume 4: Aquatic Habitat and Instream Flow Studies 1982, Appendices F to J. Prepared for Alaska Power Authority, Anchorage, Alaska.

______. 1983f. Dissolved Gas Studies. Prepared for Alaska Power Authority, Anchorage, Alaska.

______. 1983g. Susitna Hydro Aquatic Studies, Phase II Basic Data Report, Vol. 4: Aquatic Habitat and Instream Flow Studies. 1982 Appendices A-C. Prepared for Alaska Power Authority, Anchorage, Alaska.

______. 1984a. Susitna Hydro Aquatic Studies, Report No. 3, Aquatic Habitat and Instream Flow Investigations (May-October 1983). Part I, Chapter 1, Chapter 1 Appendices and Chapter 2. Prepared for Alaska Power Authority, Anchorage, Alaska.

______. 1984b. Susitna Hydro Aquatic Studies, Report No. 3, Aquatic Habitat and Instream Flow Investigations, Chapter 3. Prepared for Alaska Power Authority, Anchorage, Alaska.

______. 1984c. Susitna Hydro Aquatic Studies, Report No.3, Aquatic Habitat and Instream Investigations. Chapter 4: Water Quality Investivations (May-October 1983). Prepared for Alaska Power Authority, Anchorage, Alaska.

______. 1984d. Susitna Aquatic Hydro Studies, Report No. 3, Aquatic Habitat and Instream Flow Investigations, (May-October 1983). Part II, Chapter 7. Prepared for Alaska Power Authority, Anchorage, Alaska.

______. 1984e. Susitna Hydro Aquatic Studies, Continuous Water Temperature Investigation in Support of Task 32. Prepared for Alaska Power Authority, Anchorage, Alaska.

______. 1984f. Susitna Hydro Aquatic Studies Report No.1: Adult Anadromous Fish Investigations, (May-October, 1983). Prepared for Alaska Power Authority, Anchorage, Alaska.

______. 1984g. Susitna Hydro Aquatic Studies Report No. 2: Resident and Juvenile Anadromous Fish Investigations, (May-October, 1983). Prepared for Alaska Power Authority, Anchorage, Alaska.

______. 1984h. Susitna Hydro Aquatic Studies, Report No. 4, Access and Transmission Corridor Aquatic Investigations (July-October 1983). Prepared for Alaska Power Authority, Anchorage, Alaska.

______. 1984i. Susitna Hydro Aquatic Studies, Winter Aquatic Investigations, Report No. 5, Vol 2: Winter Temperature Data. Appendix F.

______. 1985a. Susitna Hydro Aquatic Studies, Report No. 7, Resident and Juvenile Anadromous Fish Investigations. Draft. Prepared for Alaska Power Authority, Anchorage, Alaska.

______. 1985b. Susitna Hydro Aquatic Studies, Report No. 5, Winter Aquatic Investigations, Volume 2. Prepared for Alaska Power Authority, Anchorage, Alaska.

______. 1985c. A Survey of Boaters Exiting at the Susitna Landing, Talkeetna Boat Launch and Airstrip, and Willow Creek During 1984. Division of Sport Fish. March, 1985.

Alaska Department of Natural Resources. 1981. State of Alaska Water Users Handbook. Alaska Department of Natural Resources, Division of Land and Water Management, Water Management Section. Anchorage, Alaska.

______. 1982. Susitna Hydroelectric Project Water Resources Analysis: A Preliminary Analysis of Potential Navigational Problems Downstream from Proposed Hydroelectric Dams on the Susitna River. Division of Land and Water Management, Water Management Section. Prepared for Acres American Inc.

______. 1984. Master Plan for the Proposed Willow Creek State Recreation Area. Division of Parks and Outdoor Recreation.

Alaska Power Authority. 1983a. Before the Federal Energy Regulatory Commission, Application for License for Major Project. Susitna Hydroelectric Project, Volume 5A. Anchorage, Alaska.

______. 1983b. Before the Federal Energy Regulatory Commission, Project No. 7114. Susitna Hydroelectric Project, Schedule B Supplemental Information, Exhibit E Chapter 2, Comments 21, 22, 23, 25, 31, 32. Anchorage, Alaska.

______. 1983c. Before the Federal Energy Regulatory Commission, Application for License for Major Project. Susitna Hydroelectric Project, Volume 5A. Anchorage, Alaska.

______. 1983d. Before the Federal Energy Regulatory Commission, Application for License for Major Project. Susitna Hydroelectric Project, Volume 5A. Anchorage, Alaska.

______. 1984a. Before the Federal Energy Regulatory Commission, Project No. 7114, Susitna Hydroelectric Project. Comments on the Federal Energy Regulatory Commission Draft Environmental Impact Statement of May, 1984. Anchorage, Alaska.

______. 1984b. Alaska Power Authority Comments on the FERC Draft Environmental Impact Statement of May 1984. Vol. 6, Appendix IV - Temperature Simulations, Watana and Devil Canyon Reservoirs.

______. 1984c. Alaska Power Authority Comments on the FERC Draft Environmental Impact Statement of May 1984. Vol. 2B, Technical Comments - Aquatic Resources.

______. 1985a. Erosion and Sedimentation Control. Best Management Practices Manual . Prepared by Frank Moolin & Associates Inc.

______. 1985b. Oil Spill Contingency Planning. Best Management Practices Manual. Prepared by Frank Moolin & Associates Inc.

______. 1985c. Liquid and Solid Waste. Best Management Practices Manual. Prepared by Frank Moolin & Associates Inc.

______. 1985d. Fuel and Hazardous Material. Best Management Practices Manual. Prepared by Frank Moolin & Associates Inc.

______. 1985e. Water Supply. Best Management Practices Manual. Prepared by Frank Moolin & Associates Inc.

Allanson, B.R. 1973. Summary: Physical Limnology of Man-Made Lakes. In: Man-Made Lakes: Their Problems and Environmental Effects. A.C. Ackerman, G.F. White and E.B. Worthington (editors). Amer. Geophys. Union, Washington, D.C.

Allis-Chalmers. No date. Howell-Bunger and Ring-Jet Valves.

Alyeska Pipeline Service Co. 1974. Environmental and Technical Stipulation Compliance Assessment Document for the Trans-Alaska Pipeline System. Volume 1. Alyeska Pipeline Service Co. Anchorage, Alaska.

Arctic Environmental Information and Data Center. 1983. Susitna Hydroelectric Project, Stream Flow and Temperature Modeling in the Susitna Basin, Alaska. Prepared for Harza/Ebasco Susitna Joint Venture.

______. 1984a. Examination of Susitna River Discharge and Temperature Changes Due to the Proposed Susitna Hydroelectric Project. Prepared for Harza/Ebasco Susitna Joint Venture.

_____. 1984b. Assessment of the Effects of the Proposed Susitna Hydroelectric Project on Instream Temperature and Fishery Resources in the Watana to Talkeetna Reach. Prepared for Harza/Ebasco Susitna Joint Venture.

_____. 1984c. Susitna Hydroelectric Project Aquatic Impact Assessment: Effects of Project-Related Changes in Temperature, Turbidity and Stream Discharge on Upper Susitna Salmon Resources During June through September. Prepared for Harza/Ebasco Joint Venture, Anchorage, Alaska.

_____. 1985a. Assessment of the Effects of the Proposed Susitna Hydroelectric Project on Instream Temperature and Fishery Resources in the Watana to Talkeetna Reach. Supplemental Report. Prepared for Harza/Ebasco Susitna Joint Venture.

_____. 1985b. Geomorphic Change in the Devil Canyon to Talkeetna Reach of the Susitna River since 1949. University of Alaska. Prepared for Harza/Ebasco Susitna Joint Venture.

Barnett, A.P. 1974. Hydrological Studies of Slims River, Yukon, June-August 1970. Icefield Ranges Research Project: Scientific Results. Vol. 4. Amer. Geographical Society - 1974. pp. 143-150.

Baxter, R.M. and P. Glaude. 1980. Environmental Effects of Dams and Impoundments in Canada: Experiences and Prospects. Canadian Bull. of Fish. and Aquat. Sci. Bull. 205. pp. 1-34.

Bilyj, B. 1984. Descriptions of Two New Species of Tanypodinae (Diptera: Chironomidae) from Southern Indian Lake, Canada. Can. J. Fish. and Aquat. Sci. 41(4): 659-681.

Bolke E.L. and K.M. Waddell. 1975. Chemical Quality and Temperature in Flaming Gorge Reservoir, Wyoming and Utah, and the Effects of the Reservoir on the Green River. U.S. Geological Survey, Water Supply Paper 2039-A.

British Columbia Hydro. 1982. Unpublished Reservoir Temperature Data. Vancouver, British Columbia.

Brune, G.M. 1953. Trap Efficiency of Reservoirs. Trans. Amer. Geophys. Union. Miscellaneous Publications 970. U.S. Department of Agriculture.

Bryan, M.L. 1974a. Sublacustrine Morphology and Deposition, Kluane Lake, Yukon Territory. Icefield Ranges Research Project: Scientific Results. Vol. 4. Amer. Geographical Society - 1974. pp. 171-187.

_____. 1974b. Sedimentation in Kluane Lake. Icefield Ranges Research Project: Scientific Results. Vol. 4. Amer. Geographical Society - 1974. pp. 151-154.

_____. 1974c. Water Masses in Southern Kluane Lake. Icefield Ranges Research Project: Scientific Results. Vol. 4. Amer. Geographical Society - 1974. pp. 163-169.

Campbell, P.G., B. Bobee, A. Caille, M.J. Demalsy, J.L. Sasseville and S.A. Visser. 1975. Pre-Impoundment Site Preparation: A Study of the Effects of Topsoil Stripping on Reservoir Water Quality. Verh. Internat. Verein. Limnol. 19: 1768-1777.

Chen, T.F. and J.R. Davis. 1964. Disintegration of a Turbulent Water Jet. Journal of the Hydraulics Division, American Society of Civil Engineers. HY1.

Chow, V.T. 1964. Handbook of Applied Hydrology. McGraw-Hill.

Clarke, T.S. 1985. Glacier Runoff Balance and Dynamics in the Upper Susitna River Basin, Alaska. A thesis presented to the University of Alaska, Fairbanks in partial fulfillment of the requirements for the degree of Master of Science draft.

Cole, G.A. 1975. Textbook of Limnology. Department of Zoology, Arizona State University. C.V. Mosby Co., St. Louis.

Commonwealth Associates Inc. 1982. Anchorage - Fairbanks Transmission Intertie. Prepared for the Alaska Power Authority.

Cornett, R.J. and F.H. Rigler. 1979. Hypolimnetic Oxygen Deficits: Their Prediction and Interpretation. Science 205: 580-581.

Crawford, P.J. and D.M. Rosenberg. 1984. Breakdown of Conifer Needle Debris in a New Northern Reservoir, Southern Indian Lake, Manitoba. Can. J. Fish. and Aquat. Sci. 41(4): 649-658.

Dillion, P.J. and F.H. Rigler. 1974. A Test of a Simple Nutrient Budget for Predicting Phosphorus Concentration in Lake Water. J. Fish. Res. Bd. Can. 31(11): 1771-1778.

Duthie, H.C. 1979. Limnology of Subarctic Canadian Lakes and Some Effects of Impoundment. Arctic and Alpine Research. 11(2): 145-158.

Dwight, L.P. 1981. Susitna Hydroelectric Project, Review of Existing Water Rights in the Susitna River Basin. Prepared for Acres American Inc.

_____. 1982. Transmission Corridor Water Quality Literature Search. Unpublished letter/report.

E.W. Trihey & Associates. 1984a. Response of Aquatic Habitat Surface Areas to Mainstem Discharge in the Talkeetna to Devil Canyon Reach of the Susitna River, Alaska. Prepared for Harza/Ebasco Joint Venture, Anchorage, Alaska.

______. 1984b, Preliminary Analysis of the Relationship Between Turbidity and Light Penetration in the Susitna River, Alaska, Prepared for the Harza-Ebasco Susitna Joint Venture.

______. 1985. Susitna Hydroelectric Project, Response of Aquatic Habitat Surface Areas to Mainstem Discharge in the Talkeetna to Devil Canyon Reach of the Susitna River, Alaska. Prepared for Harza/Ebasco Susitna Joint Venture, Anchorage, Alaska.

Ecological Analysts Inc. 1982. Lake Comanche Dissolved Nitrogen Study, Concord California. Prepared for Milo Bell.

Elder, R.A. and G.B. Dougherty. 1952. Characteristics of Fixed Dispersion Cone Valves. Transactions of the American Society of Civil Engineers. Paper No. 2567.

Fahnesstock, R.K. 1974. Morphology of Slims River. Icefield Ranges Research Project: Scientific Results. Vol. 4. Amer. Geographical Society - 1974. pp. 161-1 72.

Falvey, H.T. 1980. Air-Water Flow in Hydraulic Structures. U.S. Department of the Interior, Bureau of Reclamation. Engineering Monograph No. 41.

Freethey, G.W. and D.R. Scully. 1980. Water Resources of the Cook Inlet Basin, Alaska. USGS Hydrological Investigations Atlas. HA-620.

Geen, G.H. 1974. Effects of Hydroelectric Development in Western Canada on Aquatic Ecosystems. J. Fish. Res. Bd. Can. 31: 913-927.

General Electric Co. 1979. Optimized Generation Planning Program (OGP). General Electric Co., Electric Utility Systems Engineering Department. Schenectady, New York.

Gilbert, R. 1973. Processes of Underflow and Sediment Transport in a British Columbia Lake. Proceedings of the 9th Hydrology Symposium. University of Alberta. Edmonton, Canada. 493-507.

Grimas, U. 1961. The Bottom Fauna of Natural and Impounded Lakes in Northern Sweden (Ankarvattnet and Blasjon). Rep. Institute of Freshwater Research, Drottningholm. 42: 183-237.

Grimas, U. and N.A. Nilsson. 1965. On the Food Chain in Some North Swedish River Reservoirs. Rep. Institute of Freshwater Research, Drottningholm. 46: 31-48.

Gustavson, T.C. 1975. Bathymetry and Sediment Distribution in Proglacial Malaspina Lake, Alaska. Journal of Sedimentary Petrology. 450:461.

Hannan, H.H. 1979. Chemical Modifications in Reservoirs - Regulated Streams. In: The Ecology of Regulated Streams. J.V. Ward and J.A. Stanford (editors). Plenum Press, New York. pp. 75-94.

Harrison, W.D. 1985. Susitna Hydroelectric Project, Glacier Mass Balance and Runoff Study. University of Alaska, Fairbanks, Geophysical Institute. Prepared for Harza/Ebasco Susitna Joint Venture.

Harza/Ebasco Susitna Joint Venture. 1984a. Susitna Hydroelectric Project, Reservoir and River Sedimentation. Prepared for Alaska Power Authority, Anchorage, Alaska.

_____. 1984b. Weekly Flow Duration Curves and Observed and Filled Weekly Flows for the Susitna River Basin. Prepared for Alaska Power Authority, Anchorage, Alaska.

_____. 1984c. Susitna Hydroelectric Project, Flood Frequency Analysis. Prepared for Alaska Power Authority, Anchorage, Alaska.

_____. 1984d. Susitna Hydroelectric Project, Middle and Lower Susitna River, Water Surface Profiles and Discharge Rating Curves. Prepared for Alaska Power Authority, Anchorage, Alaska.

_____. 1984e. Susitna Hydroelectric Project, Instream Ice Calibration of Computer Model. Prepared for Alaska Power Authority, Anchorage, Alaska.

_____. 1984f. Susitna Hydroelectric Project, Instream Ice Simulation Study. Prepared for Alaska Power Authority, Anchorage, Alaska.

_____. 1984g. Watana Development, River Stage Fluctuations Resulting from Alternative Operations. Prepared for Alaska Power Authority, Anchorage, Alaska.

_____. 1984h. Evaluation of Alternative Flow Requirements. Final Report. Prepared for Alaska Power Authority, Anchorage, Alaska. 55 pp.

_____. 1984i. Susitna Hydroelectric Project, Eklutna Lake Temperature and Ice Study with Six Month Simulation for Watana Reservoir. Prepared for Alaska Power Authority, Anchorage, Alaska.

_____. 1985a. Case E-VI Alternative Flow Regime. Appendix E - Stream Flows and Flow Duration Curves at Watana, Gold Creek, Sunshine and Susitna Stations for Watana Only Operation in 1996 and 2001. Final Report. Prepared for Alaska Power Authority, Anchorage, Alaska.

_____. 1985b. Case E-VI Alternative Flow Regime. Appendix F - Stream Flow and Flow Duration Curves at Devil Canyon, Gold Creek, Sunshine and Susitna Stations for Devil Canyon/Watana Operation in 2002 and 2020. Prepared for Alaska Power Authority, Anchorage, Alaska.

_____. 1985c. Susitna Hydroelectric Project, Watana Support Facilities Master Plan (Draft Report). Prepared for Alaska Power Authority, Anchorage, Alaska.

_____. 1985d. Drainage Structure and Waterway Design Guidelines. Final Report. Prepared for Alaska Power Authority, Anchorage, Alaska.

_____. 1985e. Case E-VI Alternative Flow Regime, Appendix D - Streamflow Time Series. Anchorage, Alaska.

_____. 1985f. Case E-VI, Alternative Flow Regime. Anchorage, Alaska.

Hawley, B. 1984. Personal communication. Owner, Susitna Landing. Interview with B. Ashton, R & M Consultants Inc., August 22, 1984.

Hecky, R.E. 1984. Thermal and Optical Characteristics of Southern Indian Lake Before, During and After Impoundment and Churchill River Diversion. Can. J. Fish. Aquat. Sci. 41(4): 579-590.

Hecky, R.E. and G.K. McCullough. 1984. Effects of Impoundment and Diversion on the Sediment Budget and Nearshore Sedimentation of Southern Indian Lake. Canadian J. Fish. Aquat. Sci. 41: 567-578.

Hecky, R.E. and S.J. Guildford. 1984. Primary Productivity of Southern Indian Lake, Before, During and After Impoundment and Churhill River Diversion. Can. J. Fish. and Aquat. Sci. 41(4): 591-604.

Hecky, R.E., R.W. Newbury, R.A. Bodaly, K. Patalas and D.M.Rosenberg. 1984. Environmental Impact Prediction and Assessment: The Southern Indian Lake Experience. Can. J. Fish. and Aquat. Sci. 41(4): 720-732.

Hey, R.D., J.C. Bathurst and C.R. Thorne (editors). 1982. Gravel-Bed Rivers Fluvial Processes, Engineering and Management. John Wiley and Sons, New York.

Hutchinson, G.E. 1967. A Treatise on Limnology, II. Introduction to Lake Biology and the Limnoplankton. John Wiley and Sons, New York. 1115 pp.

Imberger, J. and J.C. Patterson. 1980. A Dynamic Reservoir Simulation Model - DYRESM:5. Proc. Symposium on Predictive Ability of Surface Water Flow and Transport Models. Berkeley, California.

Imberger, J., J. Patterson, B. Hebbert and I. Loh. 1978. Dynamics of Reservoirs of Medium Size. Jour. Hydraulic Dev., Proc. American Society of Civil Engineers. 104(No. HY5) 725-743.

Johnson, G. 1967. The Effect of Entrained Air on the Scouring Capacity of Water Jets. Proceedings of the 12th Congress of the International Association for Hydraulic Research, Fort Collins, CO. Vol. 3.

Johnson, P.L. 1975. Prediction of Dissolved Gas at Hydraulic Stuctures. U.S. Department of the Interior, Bureau of Reclamation. Report No. GR-8-75.

Jones, J.R. and R.W. Bachman. 1976. Prediction of Phosphorus and Chlorophyll Levels in Lakes. J. Wat. Poll. Control Fed. 48(9): 2176-2186.

Kerekes, J.J. 1982. The Application of Phosphorus Load-Trophic Response Relationships to Reservoirs. Can. Wat. Res. J. 7(1): p.349.

Knott, J.M. and S.W. Lipscomb. 1983. Sediment Discharge Data for Selected Sites in the Susitna River Basin, Alaska, 1981-1982. U.S. Geological Survey. Open File Report 83-870.

_____. 1985. Sediment Discharge Data for Selected Sites in the Susitna River Basin, Alaska. October, 1982 to February, 1984. U.S. Geological Survey. Open File Report 85-157.

Koenigs, J.P. and G.B. Kyle. 1982. Limnology and Fisheries Investigations at Crescent Lake (1979-1982). Alaska Department of Fish and Game, Fisheries Rehabilitation, Enhancement and Development, Soldotna, Alaska.

Lamke, R.D. 1970. Flood Characteristics of Alaskan Streams. USGS, Water Resources Investigation. 78-129.

Lane, E.W. 1955. The Importance of Fluvial Morphology in Hydraulic Engineering. Proc. ASCE. Volume 21 No. 745, 17pp.

Lane, E.W. and E.J. Carlson. 1953. Some Factors Affecting the Stability of Canals Constructed in Coarse Granular Materials. Proceedings of the Minnesota International Hydraulics Convention, Joint Meeting of IAHR and Hydraulics Division, ASCE.

Larcen, D.P. and H.T. Mercier. 1976. Phosphorus Retention Capacity of Lakes. J. Fish. Res. Bd. Can. 33: 1742-1750.

Leopold, L.B. and T. Maddock. 1953. The Hydraulic Geometry of Stream Channels and Some Physiographic Implications. USGS Prof. Paper 252. 57pp.

Lloyd, D.S. 1985. Turbidity in Freshwater Habitats of Alaska. A Review of Published and Unpublished Literature Relavent to the Use of Turbidity as a Water Quality Standard. Alaska Department of Fish and Game. Report No. 85-1. Juneau, Alaska. 100 pp.

Love, K.S. 1961. Relationship of Impoundment to Water Quality. JAWWA. 53:.

Mahay, S. 1984. Personal communication. Owner and Operator, Mahay's Riverboat Service. Interview with S. Vaissiere, Harza/Ebasco Susitna Joint Venture, August 27, 1984.

Mathews, W.H. 1956. Physical Limnology and Sedimentation in a Glacial Lake. Bulletin of the Geological Society of America. Volume 67.

Mavis, F.T. and L.M. Laushey. 1984. A Reappraisal of the Beginning of Bed-Movement Competent Velocity. International Association for Hydraulic Research, Second Meeting, Stockholm.

McNeely, R.N., V.P. Neimanism and K. Dwyer. 1979. Water Quality Sourcebook -- A Guide to Water Quality Parameters. Environment Canada, Inland Water Directorate, Water Quality Branch. Ottawa, Canada.

Mortimer, C.H. 1941. The Exchange of Dissolved Substaces Between Mud and Water in Lakes, Parts 1 and 2. Journal of Ecology. 29: 280-329.

_____. 1942. The Exchange of Dissolved Substances Between Mud and Water in Lakes, Parts 3 and 4. Journal of Ecology. 30: 147-201.

Mosley, M.P. 1982. Analysis of the Effect of Changing Discharge on Channel Morphology and Instream Uses in a Braided River, Ohau River, New Zealand. Water Resources Research. 18(4): 800-812.

Mueller, D.K. 1982. Mass Balance Model Estimation of Phosphorus Concentrations in Reservoirs. Water Resources Bull. 18(3): 377-382.

Neal, J.K. 1967. Reservoir Eutrophication and Dystrophication Following Impoundment. Reservoir Fish Resources Symposium. Georgia University. Athens, Georgia.

Nilsson, B. 1976. The Influence of Man's Activities in Rivers on Sediment Transport. Nordic Hydrology. 7: 145-160.

Ott Water Engineers Inc. 1981. Bradley Lake Water Quality Report. Prepared for U.S. Army Corps of Engineers, Alaska District, Anchorage, Alaska. September, 1981.

Patalas, K. and A. Salki. 1984. Effects of Impoundment and Diversion on the Crust acean Plankton of Southern Indian Lake. Can. J. Fish. and Aquat. Sci. 41: 6 13-637.

Peratrovich, Nottingham and Drage Inc. 1982. Susitna Reservoir Sedimentation and Water Clarity Study. Prepared for Acres American Inc.

Peterson, L.A. and G. Nichols. 1982. Water Quality Effects Resulting from Impoundment of the Susitna River. Prepared for Acres American Inc.

Pharo, C.H. and E.D. Carmack. 1979. Sedimentation Processes in a Short Residence Time - Intermontane Lake, Kamloops Lake, British Columbia. Sedimentology. 26:.

Pinel-Alloul, B., E.Magmin, G. Codin-Blumer and P. Ross. 1982. Zooplankton Population Dynamics During and After Impoundment in a Small Reservoir (James Bay, Quebec). Can. Wat. Res. J. 7(1): 168-188.

Planas, D. and R.E. Hecky. 1984. Comparison of Phosphorus Turnover Times in Northern Manitoba Reservoirs with Lakes of the Experimental Lakes Area. Can. J. Fish. and Aquat. Sci. 41: 605-612.

R & M Consultants Inc. 1981a. Horizontal and Vertical Control Surveys. Prepared for Acres American Inc.

_____. 1981b. Susitna Hydroelectric Project, Glacier Studies. Prepared for Acres American Inc.

_____. 1981c. Devil Canyon Reservoir Mapping, Flight 5(6-8). Manuscript 2. Prepared for Acres American Inc.

_____. 1981d. 1981 Field Data Index. Prepared for Acres American Inc.

_____. 1981e. Susitna Hydroelectric Project, Ice Observations 1980-81. Prepared for Acres American Inc.

_____. 1981f. Susitna Hydroelectric Project, Regional Flood Studies. Prepared for Acres American Inc.

_____. 1981g. Susitna Hydroelectric Project, River Mile Index. Prepared for Acres American Inc.

_____. 1981h. Susitna Hydroelectric Project, Water Quality. Annual Report 1980. Prepared for Acres American Inc.

_____. 1981i. Susitna Hydroelectric Project, Water Quality. Annual Report. Prepared for Acres American Inc.

______. 1982a. Susitna Hydroelectric Project, 1982 Susitna Basin Glacier Studies. Prepared for Acres American Inc.

______. 1982b. Susitna Hydroelectric Project, Hydraulic and Ice Studies. Prepared for Acres American Inc.

______. 1982c. Aerial Photography, Photogrammetric Mapping and Photogrammetric Ground Control Surveys. Prepared for Acres American Inc.

______. 1982d. Susitna Hydroelectric Project, River Morphology. Prepared for Acres American Inc.

______. 1982e. Susitna Hydroelectric Project, Slough Hydrology. Interim Report. Prepared for Acres American Inc.

______. 1982f. Susitna Hydroelectric Project, Tributary Stability Analysis. Prepared for Acres American Inc.

______. 1982g. Susitna Hydroelectric Project, Winter 1981-1982 Ice Observations Report. Prepared for Acres American Inc.

______. 1982h. Susitna Hydroelectric Project, Hydrographic Surveys Report. Prepared for Acres American Inc.

______. 1982i. Susitna Hydroelectric Project, Field Data, Collection and Processing. Volume 3. Prepared for Acres American Inc.

______. 1982j. Low Water Boat Navigation, Susitna River at Mile 128. Memo. November, 1982.

______. 1982k. Placer Mining Waste Water Settling Pond Demonstration Project Report. Prepared for Alaska Department of Environmental Conservation, Juneau, Alaska.

______. 1982l. Glacial Lake Studies. Prepared for Acres American Inc.

______. 1982m. Water Quality Annual Report - 1982. Prepared for Acres American Inc.

______. 1983. Susitna Hydroelectric Project, 1982-1983 Susitna River Ice Study. Prepared for Harza/Ebasco Susitna Joint Venture.

______. 1984. Susitna Hydroelectric Project, 1983-84 Susitna River Ice Study. Prepared for Harza/Ebasco Susitna Joint Venture.

______. 1985a. Susitna Hydroelectric Project, Susitna River Ice Study: 1984 Freeze up. Prepared for Harza/Ebasco Susitna Joint Venture.

______. 1985b. Susitna Hydroelectric Project, Lower Susitna River Aggradation Study: Field Data. Prepared for Harza/Ebasco Susitna Joint Venture.

______. 1985c. Susitna Hydroelectric Project, Assessment of Access by Spawning Salmon into Tributaries of the Lower Susitna River. Prepared for Harza/Ebasco Susitna Joint Venture.

______. 1985d. Susitna Hydroelectric Project, Water Balance Studies of Middle Susitna Sloughs. Prepared for Harza/Ebasco Susitna Joint Venture.

______. 1985e. Effects on Navigation, Susitna Hydroelectric Project. Prepared for Harza/Ebasco Susitna Joint Venture

______. 1985f. Glacial Lake Physical Limnology Studies, Eklutna Lake, Alaska. Draft Report. Prepared for Harza/Ebasco Susitna Joint Venture, Anchorage, Alaska .

______. 1985g. Suspended Sediment and Turbidity Settling Column Study. Prepared for Harza/Ebasco Susitna Joint Venture and Alaska Power Authority.

R & M Consultants Inc. and L.A. Peterson & Associates. 1982. Water Quality Interpretation - 1981. Prepared for Acres American Inc.

Rast, W. and G.F. Lee. 1978. Summary Analysis of the North American (U.S. Portion) OECD Eutrophication Project: Nutrient Loading-Lake Response Relationships and Trophic State Indices. EPA-600/3-78-008. 455 pp.

Resource Management Associates. 1983. Susitna Hydroelectric Project, Salinity Model. Prepared for Acres American Inc.

Rosenberg, D.M., B. Bilyj and A.P. Wiens. 1984. Chironimidae (Diptera) Emerging from the Littoral Zone of Reservoirs, With Special Reference to Southern Indian Lake, Manitoba. Can. J. Fish. Aquat. Sci. 41(4): 672-681.

Santos-Cayudo, J. and D.B. Simons. 1972. River Response. In: H.W. Shen (editor). Environmental Impacts on Rivers. Water Resources Publications. Fort Collins, Colorado.

Schmidt, D. 1981. Summary of Key Findings of 1981 Dissolved Gas Investigation of the Susitna River in the Devil Canyon Vicinity. Unpublished report.

Schumm, S.A. 1971. Fluvial Geomorphology In: H.W. Shen (editor). The Historical Perspective, River Mechanics. Water Resources Publications, Fort Collins, Colorado.

Scott, K.M. 1982. Erosion and Sedimentation in the Kenai River, Alaska. USGS Professional Paper No. 1235. 35 pp.

Scott, W.B. and E.J. Crossman. 1973. Freshwater Fishes of Canada. Fisheries Research Board of Canada. Bull. No. 184. Ottawa, Canada.

Simons, Li & Associates. 1982. Engineering Analysis of Fluvial Systems. Fort Collins, Colorado.

Sittig, M. 1981. Handbook of Toxic and Hazardous Chemicals. Noyes Publications. Park Ridge, New Jersey.

Slotta, L.S. 1973. Stratified Reservoir Density Flows Influenced by Entering Stream Flows. In: Man-Made Lakes: Their Problems and Environmental Effects. W.C. Ackerman, G.F. White and E.B. Worthington (editors). Amer. Geophys. Union, Washington, D.C.

Soltero, R.A., A.F. Gasperino and W.G. Grahm. 1974. Chemical and Physical Characteristics of a Eutrophic Reservoir and Its Tributaries, Long Lake, Washington. Water Research. 8: 419-431.

St. John, B.E., E.C. Carmack, R.J. Daley, C.B.J. Gray and C.H. Pharo. 1976. The Limnology of Kamloops Lake, B.C. Department of Environment. Vancouver, B.C. 176 pp.

Straskraba, M. 1973. Limnological Basis for Modeling Reservoir Ecosystems. In: Man-Made Lakes: Their Problems and Environmental Effects. W.C. Ackerman, G.F. White and E.B. Worthington (editors). Amer. Geophys. Union, Washington, D.C.

Stuart, T.J. 1983. The Effects of Freshet Turbidity on Selected Aspects of the Biogeochemistry and the Trophic Status of Flathead Lake, Montana, USA. Ph. D. dissertation, North Texas State University. 229 pp.

Symons, J.M. 1969. Water Quality Behavior in Reservoirs: A Compilation of Published Research Papers. U.S. Department of Heal h, Education and Welfard, Public Health Service, Environmental Control Administration, Cincinnati, Ohio. Public Health Service No. 1930. 616 pp.

Terrestrial Environmental Specialists Inc. 1982. Land Use Analysis Report. Prepared for Alaska Power Authority, Anchorage, Alaska.

Tetra Tech Inc. 1977. User's Guide for the Estuary Hydrodynamic and Water Quality Models. Prepared for U.S. Department of the Army Corps of Engineers, Alaska District.

Trihey. E.W. 1983. Preliminary Assessment of Access by Spawning Salmon into Portage Creek and Indian River. Prepared for Alaska Power Authority, Anchorage, Alaska.

Turkheim, R.A. 1975. Biophysical Impacts of Arctic Hydroelectric Development. In: J.C. Day (editor). Impacts of Hydroelectric Projects and Associated Developments on Arctic Renewable Resources and the Inuit. University of Western Ontario, Ontario, Canada.

U.S. Army Corps of Engineers. 1975. Program Description and User Manual for Streamflow Synthesis and Reservoir Regulation (SSARR). U.S. Army Corps of Engineers, North Pacific Division. Portland, Oregon.

_____. 1978. Topographical Maps - Watana Sheets 6 and 11 of 26.

_____. 1981. HEC-2 Water Surface Profiles User's Manual.

_____. 1982. Bradley Lake Hydroelectric Project. Design Memorandum No. 2, Appendix E.

U.S. Department of the Interior, Bureau of Reclamation. 1974. Design of Small Dams, A Water Resources Technical Publication. Second Edition, revised reprint.

U.S. Environmental Protection Agency. 1976. Quality Criteria for Water. U.S. Environmental Protection Agency. Wash., D.C.

_____. 1980. Water Quality Criteria Documents: Availability, Environmental Protection Agency.

U.S. Geological Survey. 1965-1982. Water Resources Data for Alaska.

_____. 1949-1964. Surface Water Records for Alaska.

_____. 1960. Water Supply Paper No. 1500.

_____. 1981. 1982 Water Quality Laboratory Services Catalog. USGS Open-File Report 81-1016.

U.S. Water Resources Council. 1981. Guidelines for Determining Flood Frequency. Bulletin 17B. Wash., D.C.

Vollenweider, R.A. 1975. Input-Output Models, With Special Reference to the Phosphorus Loading Concept in Limnology. Schweizz. Hydrol. 37: 53-84.

Walker, W.W. 1982. An Emperical Analysis of Phosphorus, Nitrogen and Turbidity Effects on Reservoir Chlorophyll-a Levels. Can. Wat. Res. J. 7(1): 88-107.

Wetzel, R.G. 1975. Limnology. W.B. Saunders Co., Philadelphia, PA. 743 pp.

Wiens, A.P. and D.M. Rosenberg. 1984. Effect of Impoundment and River Diversion on Profundal Macrobenthos of Southern Indian Lake. Can. J. Fish. and Aquat. Sci. 41(4): 638-648.

Williams, W.D. 1973. Man-Made Lakes and Changing Limnological Environment in Australia. In: Man-Made Lakes: Their Problems and Environmental Effects. W.C. Ackerman, G.F. White and E.B. Worthington (editors). Amer. Geophys. Union, Washington, D.C.

Woodward-Clyde Consultants Inc. 1984. Fish Mitigation Plan. Prepared for Harza/Ebasco Susitna Joint Venture, Anchorage, Alaska.

Wunderlich, W.O. 1967. The Mechanics of Stratified Flow in Reservoirs. In: Reservoir Fishery Resources Symposium. Amer. Fish. Soc., Wash., D.C.

_____. 1971. The Dynamics of Density-Stratified Reservoir. In: G.E. Hall (ed). Reservoir Fisheries and Limnology. Special Publication No. 8. Amer. Fish. Soc., Wash., D.C.

Wunderlich, W.O. and R.A. Elder. 1973. Mechanics of Flow Through Man-Made Lakes. In: Man-Made Lakes: Their Problems and Environmental Effects. W.C. Ackerman, G.F. White and E.B. Worthington (editors). Amer. Geophys. Union, Washington, D.C.

8 - GLOSSARY

Accretion - the gradual addition of material by the deposition of sediment carried by the water of a stream.

Alluvium - a general term for all detrital deposits resulting from the operations of modern rivers, thus including the sediments laid down in riverbeds, floodplains, lakes, fans at the foot of mountain slopes and estuaries; stream deposits of relatively recent age.

Aquiclude - a formation that will not transmit water fast enough to furnish an appreciable supply for a well or spring.

Aquifer - stratum or zone below the surface of the earth capable of producing water, as from a well.

Aufeis - an ice feature that is formed by water overflowing onto a surface, such as river ice or gravel deposits, and freezing, with subsequent layers formed by water again overflowing onto the ice surface and freezing.

Bankfull stage - the river stage (height above a known elevation) which results in a water level that just fills the banks of a stream at a given location without encroaching on the floodplain or overbank area.

Bifurcate - forked as in a Y-shape.

Candle ice - elongate, prismatic crystals of ice arranged perpendicular to the surface and in a weakened state.

Colluvial - consisting of alluvium in part and also containing angular fragments of the original rocks; rock detritus and soil accumulated at the foot of a slope.

Diel - a chronological day (24 hours) or distinct from the daylight portion of varying duration.

Epilimnion - an upper stratum of more or less uniformly warm, circulating and fairly turbulent water, usually overlying a deep, cold, and relatively unturbulent hypolimnion.

Eutrophication - the process by which a body of water becomes overly rich in nutrients and deficient in dissolved oxygen.

Floodplain - that portion of a river valley, adjacent to the river channel, which is built of sediments during the present regimen of the stream, and which is covered with water when the river overflows its banks at flood stages.

Fluvial - of or pertaining to rivers; produced by river action.

Frazil ice - ice formed in turbulent, supercooled water in rivers and lakes.

Glacial flour - finely ground rock particles, chiefly clay size, resulting from glacial abrasion.

Hypolimnion - a relatively deep, cold undisturbed, non-turbulent layer of water usually underlying a relatively warm, freely circulating, turbulent epilimnion.

Ice pan - a large, flat piece of ice.

Lacustrine - pertaining to, produced by, or formed in a lake or lakes.

Lithology - the study of the physical characteristics of rock.

Meltstream - water resulting from the melting of snow or of glacier ice.

Outwash - drift deposited by meltwater streams beyond active glacier ice.

Periglacial - of, or pertaining to the outer perimeter of a glacier, particularly to the fringe areas immediately surrounding the continental glaciers of the geologic ice ages, with respect to environment, topography, areas, processes, and conditions influenced by the low temperature of ice.

Stratigraphic unit - unit consisting of stratified sedimentary rocks grouped for description.

Thalweg - the line connecting the lowest or deepest points of a stream bed, valley, or reservoir, whether underwater or not.

Thermocline - the horizontal plane in a thermally stratified lake located at the depth where temperature decreases most rapidly with depth.

Till - nonsorted material deposited by glaciation, usually composed of a wide range of particle sizes; and nonstratified drift

Water year - as defined by the U.S. Geological Survey, the period from October 1 of a given year to September 30 of the next year is defined as the water year of the next year.