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Water-Quality Assessment of the Cook Inlet Basin, Alaska— Environmental Setting

Water-Resources Investigations Report 99-4025

National Water-Quality Assessment Program

U.S. Department of the Interior
U.S. Geological Survey

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By Timothy P. Brabets, Gordon L. Nelson, Joseph M. Dorava, and Alexander M. Milner

U.S. GEOLOGICAL SURVEY

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National Water-Quality Assessment Program

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FOREWORD

The mission of the U.S. Geological Survey (USGS) is to assess the quantity and quality of the earth resources of the Nation and to provide information that will assist resource managers and policymakers at Federal, State, and local levels in making sound decisions. Assessment of water-quality conditions and trends is an important part of this overall mission.

One of the greatest challenges faced by water-resources scientists is acquiring reliable information that will guide the use and protection of the Nation's water resources. That challenge is being addressed by Federal, State, interstate, and local water-resource agencies and by many academic institutions. These organizations are collecting water-quality data for a host of purposes that include: compliance with permits and water-supply standards; development of remediation plans for specific contamination problems; operational decisions on industrial, wastewater, or water-supply facilities; and research on factors that affect water quality. An additional need for water-quality information is to provide a basis on which regional- and national-level policy decisions can be based. Wise decisions must be based on sound information. As a society we need to know whether certain types of water-quality problems are isolated or ubiquitous, whether there are significant differences in conditions among regions, whether the conditions are changing over time, and why these conditions change from place to place and over time. The information can be used to help determine the efficacy of existing water-quality policies and to help analysts determine the need for and likely consequences of new policies.

To address these needs, the U.S. Congress appropriated funds in 1986 for the USGS to begin a pilot program in seven project areas to develop and refine the National Water-Quality Assessment (NAWQA) Program. In 1991, the USGS began full implementation of the program. The NAWQA Program builds upon an existing base of water-quality studies of the USGS, as well as those of other Federal, State, and local agencies. The objectives of the NAWQA Program are to:

- Describe current water-quality conditions for a large part of the Nation's freshwater streams, rivers, and aquifers.
- Describe how water quality is changing over time.
- Improve understanding of the primary natural and human factors that affect water-quality conditions.

This information will help support the development and evaluation of management, regulatory, and monitoring decisions by other Federal, State, and local agencies to protect, use, and enhance water resources.

The goals of the NAWQA Program are being achieved through ongoing and proposed investigations of 59 of the Nation's most important river basins and aquifer systems, which are referred to as study units. These study units are distributed throughout the Nation and cover a diversity of hydrogeologic settings. More than two-thirds of the Nation's freshwater use occurs within the 59 study units and more than two-thirds of the people served by public water-supply systems live within their boundaries.

National synthesis of data analysis, based on aggregation of comparable information obtained from the study units, is a major component of the program. This effort focuses on selected water-quality topics using nationally consistent information. Comparative studies will explain differences and similarities in observed water-quality conditions among study areas and will identify changes and trends and their causes. The first topics addressed by the national synthesis are pesticides, nutrients, volatile organic compounds, and aquatic biology. Discussions on these and other water-quality topics will be published in periodic summaries of the quality of the Nation's ground and surface water as the information becomes available.

This report is an element of the comprehensive body of information developed as part of the NAWQA Program. The program depends heavily on the advice, cooperation, and information from many Federal, State, interstate, Tribal, and local agencies and the public. The assistance and suggestions of all are greatly appreciated.

Robert M. Hirsch

Robert M. Hirsch
Chief Hydrologist

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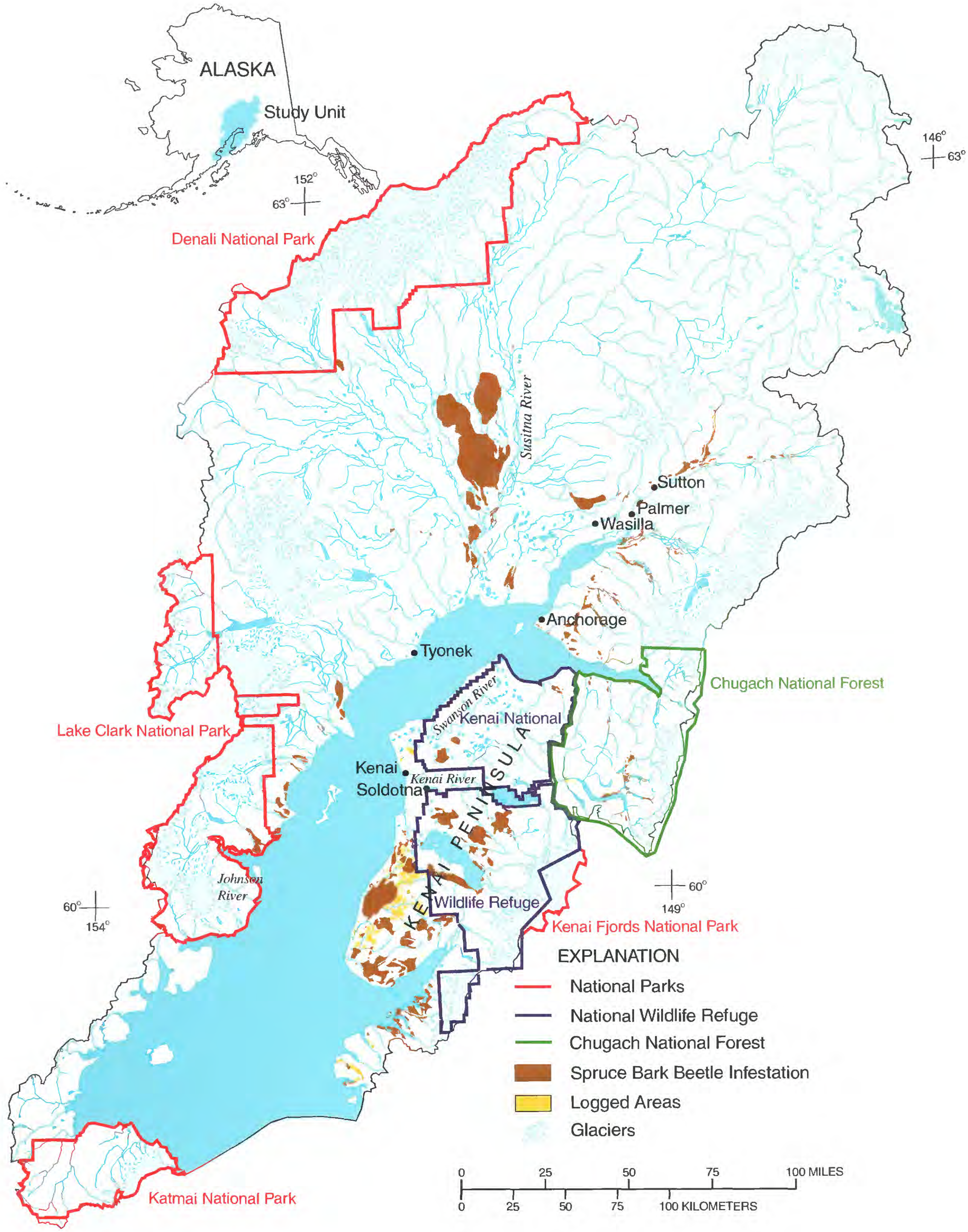

Figure 1. Location of the Cook Inlet Basin, Alaska, and major features.

CONVERSION FACTORS, VERTICAL DATUM, AND WATER-QUALITY UNITS

Multiply	by	To obtain
inch (in.)	25.4	millimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer
foot per second (ft/s)	0.3048	meter per second
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
million gallons (Mgal)	3,785	cubic meter
gallon per minute (gal/min)	0.06309	liter per second
gallon per day (gal/d)	0.003785	cubic meter per day
million gallons per day (Mgal/d)	0.04381	cubic meter per second
ton, short (2,000 lb)	0.9072	megagram
foot squared per day (ft^2/d)	0.09290	meter squared per day
degrees Fahrenheit (°F)	(°F-32)/1.8	degrees Celsius (°C)

VERTICAL DATUM

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929—A geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

WATER-QUALITY UNITS

mg/L, milligram per liter

µS/cm, microsiemen per centimeter at 25 degrees Celsius

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ABSTRACT

The Cook Inlet Basin in Alaska is one of 59 study units selected for study for water-quality assessment as part of the U.S. Geological Survey's National Water-Quality Assessment program. The Cook Inlet Basin study unit encompasses the fresh surface and ground waters in the 39,325 square-mile area that drains to Cook Inlet, but does not include the marine waters of Cook Inlet. This report describes the natural factors (climate, physiography, geology, soils, land cover) and the human factors (population, land use, water use) that affect water quality, which is the first step in designing and conducting a multidisciplinary regional water-quality assessment. The surface- and ground-water hydrology, and the aquatic ecosystems of the Cook Inlet Basin are described. The report provides an overview of existing water-quality conditions and summarizes the results of selected water-quality studies of the basin.

INTRODUCTION

Background

The U.S. Geological Survey (USGS) implemented the National Water-Quality Assessment (NAWQA) program in 1991. The purpose of the NAWQA program is to describe the status of and trends in the quality of the Nation's water resources and aquatic ecosystems, and to identify factors affecting water quality. Individual study-unit investigations are important components of the program. These study units are composed of hydrologic systems that include parts of many major river basins and aquifer systems.

Cook Inlet is located in southcentral Alaska (fig. 1). The Cook Inlet NAWQA study unit encompasses 39,325 mi^2. About 347,000 people—more than half of Alaska's population—reside in the Cook Inlet Basin. The eastern side of the basin is traversed by major highways and the Alaska Railroad (fig. 2), whereas the western side of Cook Inlet is sparsely populated and accessible only by aircraft or boat.

Both surface water and ground water are important resources in the Cook Inlet Basin. Prior to the early 1950's, the military bases and Anchorage depended primarily on surface water for their public supply. During the 1950's, ground water became recognized as a source for public supplies because it is 3° to 4° F warmer than surface water during the winter when distribution lines are subject to freezing. Ground water also exhibits less seasonal variability in quality than surface water. For example, ground water is clear throughout the year with no variation in suspended sediment, whereas the suspended sediment of a stream or river will change during the summer runoff season. Other communities in the Cook Inlet Basin utilize surface water or ground water, depending on local availability and economics of the water-distribution system.

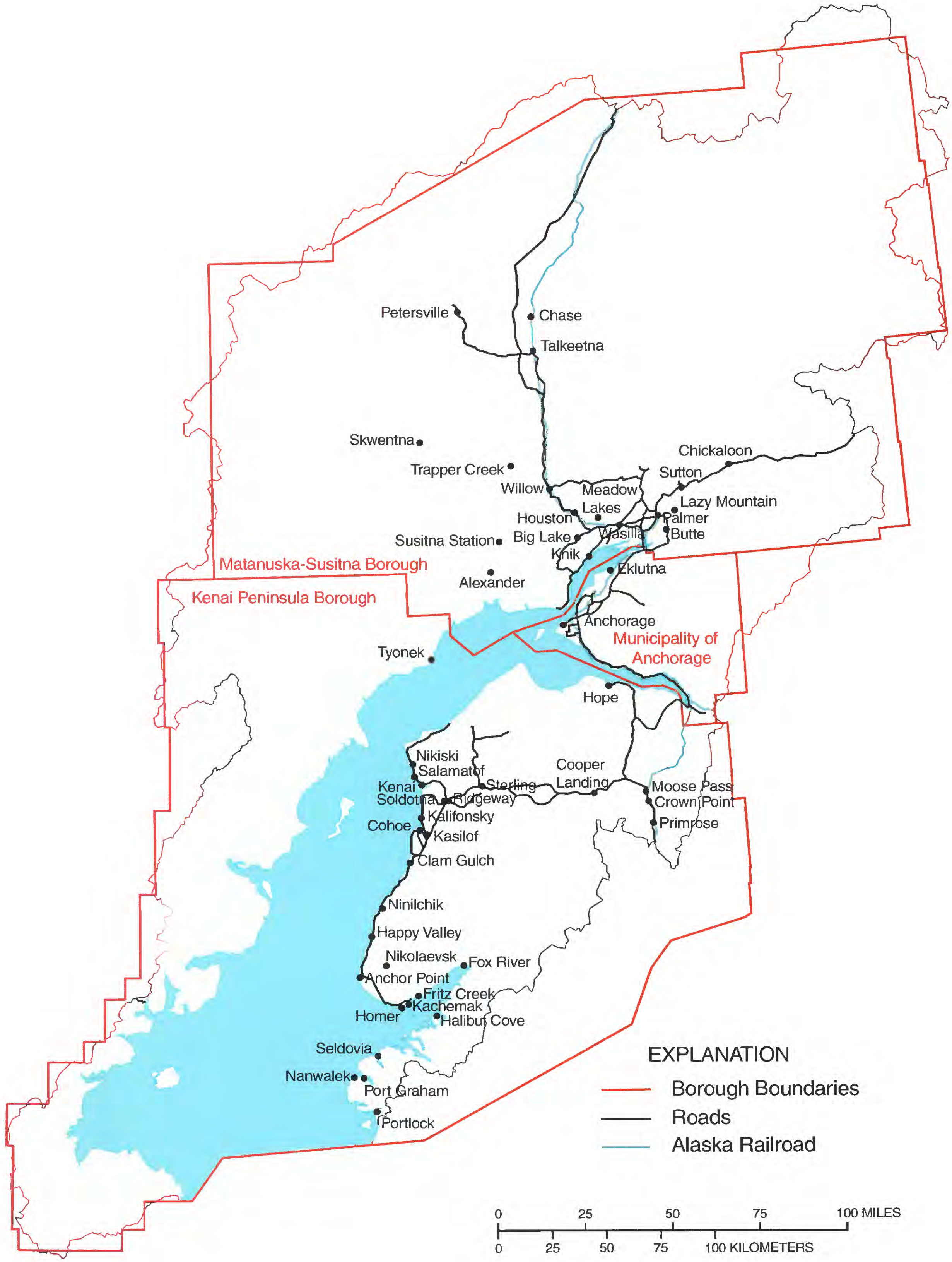


Figure 2. Towns, highways, railroad, and borough boundaries, Cook Inlet Basin, Alaska.

Purpose and Scope

The purpose of the Cook Inlet NAWQA study is to (1) describe the status of and trends in the quality of water resources within the Cook Inlet Basin and (2) provide an understanding of factors affecting water quality and aquatic ecosystems. Geographic and seasonal distribution of water quality, aquatic biota, and aquatic habitat conditions in relation to anthropogenic activities, as well as natural features will be determined. These characteristics also are important from a national perspective, because one of the primary objectives of the NAWQA program is to describe the quality of the Nation's water resources.

The purpose of this report is to describe the environmental setting of the Cook Inlet NAWQA study unit. The scope includes the physical, hydrologic, and aquatic-biological characteristics of the freshwater streams that flow into Cook Inlet, and how these characteristics affect or are affected by water quality. Major aquifers and their properties are identified. Baseline and historical information is used to describe what is currently known about the water quality of Cook Inlet. Future reports will address specific water-quality issues and processes controlling and affecting water quality in the study area. The marine waters of Cook Inlet are not considered part of the Cook Inlet NAWQA and are not discussed in this report.

The description of the environmental setting of the study unit is based on a review of currently available reports and data from Federal, State and local agencies. Many reports about various subjects specific to Cook Inlet have been written. However, it is beyond the scope of this report to detail every one; thus, only general reports and USGS reports are used. As reports dealing with specific topics of the Cook Inlet NAWQA study are written, more thorough literature searches will be undertaken to obtain all relevant information.

Water-Quality Issues

The water quality of the streams, rivers, and aquifers in the Cook Inlet Basin is determined by different combinations of natural factors and human activities. Natural factors influencing water quality include climate, geology, vegetation, soils, and physiography. Many of the rivers in the Cook Inlet Basin have their headwaters in mountainous terrain unaffected by man, and contain abundant water of high quality. Most settlement in the Cook Inlet Basin is in the lowlands along the shores of Cook Inlet and in the lower alluvial valleys, and most of the human impact on water quality occurs in these areas. Contamination of these waterways and aquifers has the potential to alter water uses and biological cycles and is of concern to affected consumers, recreationists, and resource managers.

An adequate description of water quality includes the integration of physical, chemical, and biological components. Water-quality issues can be viewed from both national and Alaska perspectives. From the national viewpoint, Cook Inlet offers the opportunity to characterize water quality in undeveloped areas, which is not possible in most parts of the United States. From the Alaska viewpoint, many believe that development can take place without degradation of water quality. A common theme is that "Alaska is where we have the last chance to do it right the first time."

The Cook Inlet NAWQA program will focus on how the following natural factors and human activities influence water quality in general and the salmon fisheries in particular. These particular elements of the Cook Inlet NAWQA were based on internal discussions with NAWQA personnel and on external discussions with a liaison committee consisting of Federal, State, and local water-management and water-quality agencies. Cook Inlet NAWQA personnel will continue to meet with the liaison committee twice a year to present findings on various aspects of the program.

Natural Factors

The Cook Inlet Basin has moderate to high annual precipitation (Jones and Fahl, 1994). In the mountainous areas, which are unaffected by man, the water quality is controlled by factors such as the geology, soils, and vegetation. Dissolved-solids concentrations range from 33 to 185 mg/L (U.S. Geological Survey, 1959-96), which indicates that concentrations of ions, such as calcium and sulfate, are below drinking-water standards. The limited nitrogen and phosphorus data also indicated that nutrient concentrations in the natural waters are comparable with background concentrations found in water in the conterminous 48 states of the U.S. (Mueller and Helsel, 1996). Thus, the chemical quality of most surface water throughout the basin is considered good and is suitable for most uses.

Natural suspended-sediment concentrations are highly variable in Cook Inlet streams and rivers. Sediment concentration is sensitive to increases in streamflow. For example, during low-flow periods in winter, suspended-sediment concentrations commonly are less than 10 mg/L, but during high-flow periods may increase to more than 1,000 mg/L (Knott and others, 1987). If a stream or river is fed by glacial meltwater, relatively high suspended-sediment concentrations will remain for longer periods, particularly in mid- to late summer. Regardless of whether or not a stream is glacier fed, most sediment transport will occur during the open-water period, from May to September.

Large floods, including those caused by volcanic eruptions, have occurred at irregular intervals in all parts of the Cook Inlet Basin. These floods typically cause massive erosion and can deliver anomalously large loads of sediment. The effects of erosion or deposition of large amounts of sediment in streambeds can be detrimental to fish spawning. Floods throughout the Cook Inlet Basin have been caused primarily by large rainstorms occurring in August or September.

A unique characteristic of the Cook Inlet NAWQA is the large area of national parks and wildlife refuges in the basin (fig. 1). These Federal lands are unlikely to be developed, except for some Native inholdings. Collection of baseline data in these areas offers the possibility to examine trends through time and how natural conditions affect water quality.

Human Activities

Human activities can contribute contaminants to surface and ground water in the Cook Inlet Basin through both point and nonpoint source pathways. The primary human activities that have led or can lead to degradation of water quality are summarized here:

Residential development—Previous studies by Brabets and Wittenberg (1983) and Brabets (1987) documented the effects of residential development in two streams in Anchorage: Campbell Creek and Chester Creek (fig. 3). Residential development has led to increases in concentrations of suspended sediment, trace elements, fecal coliform bacteria, and dissolved constituents. Brunett (1990) documented the movement of contaminated ground water from Merrill Field landfill (fig. 3) in Anchorage. Milner and Oswood (1990) described the adverse impacts on biological communities in the lakes and streams. Petroleum hydrocarbons also have been found in the bottom materials of one lake in Anchorage. As a result, the fisheries of some of the local streams have been affected. At the present time, the Wasilla–Palmer and the Kenai–Soldotna areas (fig. 2) are the fastest growing communities in the Cook Inlet Basin. A thorough investigation of the causes and effects of residential development on water quality and fisheries will help planners minimize the effects of future residential development in the growing communities.

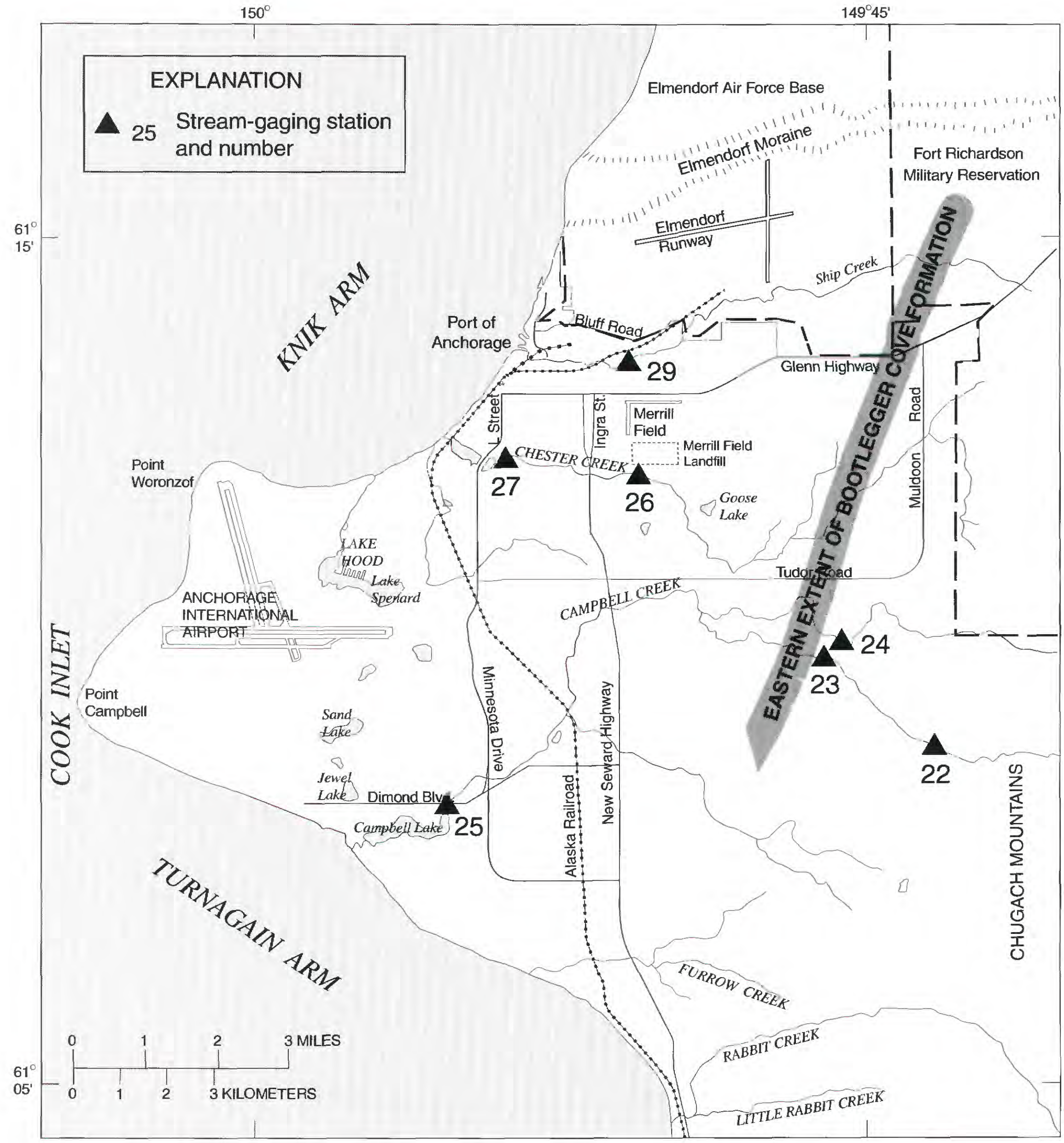


Figure 3. Major streams and land features of the Municipality of Anchorage, Alaska. (See table 2 on p. 32 for stream-gaging station names.)

Intense recreational use—The Kenai River is the most popular sportfishing river in Alaska (fig. 4). As a result of its popularity, habitat and spawning areas have been damaged. Scott (1982) concluded that as population and recreational use increase, suspended-sediment concentrations would increase through construction and bank erosion, posing a hazard to the productivity of the river. Recent studies by Dorava (1995) and Dorava and Moore (1997) have documented the effects of streamside structures and boatwakes on hydraulics and streambank erosion, which in turn have affected habitat areas for salmon spawning and rearing. Development near the river, filling of wetland areas, and construction of structures within the river itself also have affected critical habitats. Knowledge of the aquatic habitat conditions in unaffected areas, in affected areas, and in areas that have been restored serves as a guide to help protect this valuable resource.

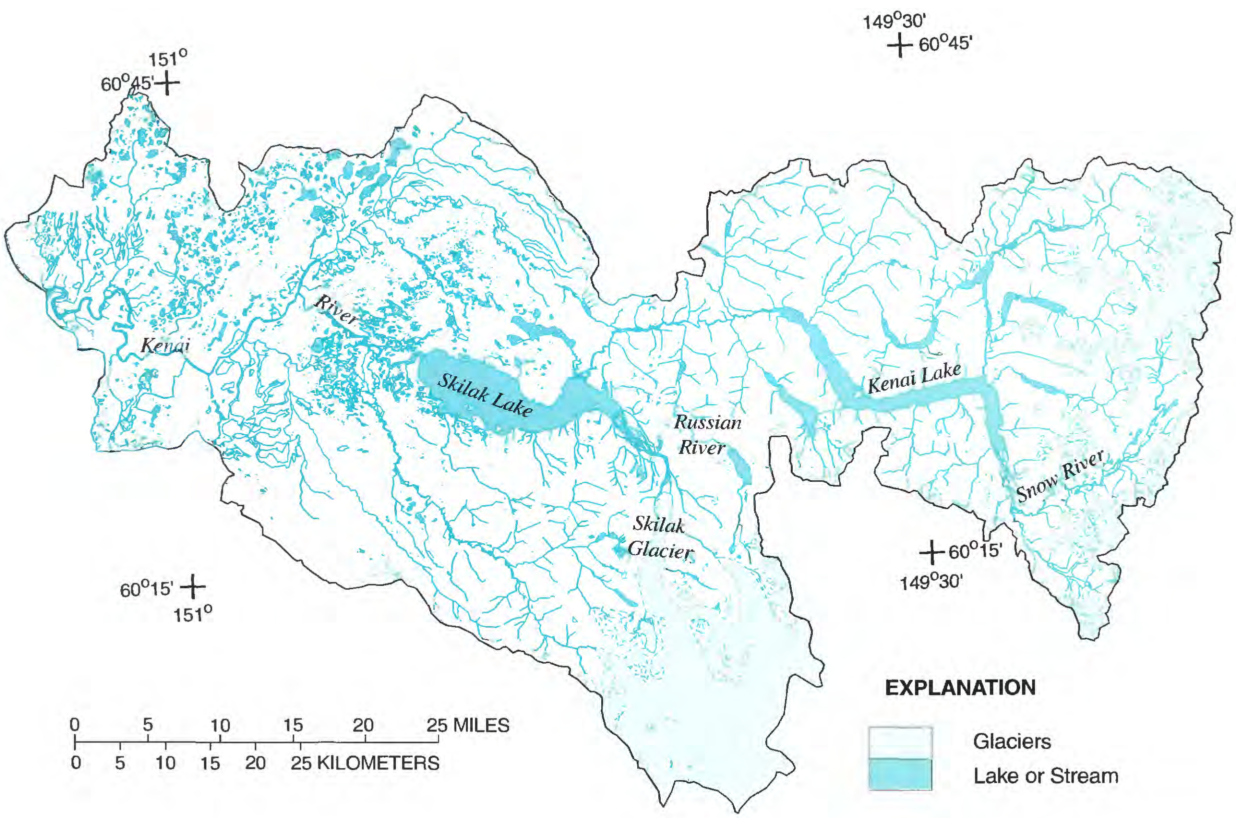


Figure 4. Kenai River watershed, Alaska.

Timber harvesting—The lower Kenai Peninsula has been extensively logged from the mid-1980's to the present (fig. 1). No studies have documented the effects of logging on the nearby streams and rivers in the Cook Inlet Basin. However, the effects of logging in other parts of the United States have been fairly well documented (Harr, 1986; Harr and Fredriksen, 1988). Possible effects are increased sediment loading to the streams, increased storm peak flows, streambank failures, and landslides. All these effects can be detrimental to salmon spawning areas. In addition, an epidemic of spruce bark beetles (fig. 1) has hit southcentral Alaska and has affected an area of more than 1,000 mi^2 to date. Salvage logging of these areas may occur. Knowledge of how current logging practices have affected stream water quality will help forest managers design or improve forest practices.

Mining—Mining has not occurred in the Cook Inlet Basin on a large scale. However, large areas exist throughout the basin for both coal (Sutton, Tyonek) and hard rock (Johnson River) (fig. 1) mining on a large scale. Mining can result in accelerated weathering of material, causing increased dissolved minerals in solution as well as increasing sediment runoff from mined areas. Knowledge of water-quality conditions before mining offers a basis for evaluating potential changes in water quality.

Petroleum and petrochemical development—Most petroleum and petrochemical development has taken place in the upper Kenai Peninsula in the Swanson River watershed (fig. 1). Wastes such as drilling muds have been buried at several sites in the area. Glass (1996) documented the degradation of ground water in this area from the presence of these waste disposal sites. Exploration, transportation, processing, and storage of petroleum could adversely affect water quality through the introduction of volatile organic compounds.

World-class salmon fishing concentrates anglers in accessible areas on the Kenai River. Stream habitat has become degraded in areas with the most intense use (photo courtesy of Gary Liepitz, Alaska Department of Fish and Game).

PHYSICAL CHARACTERISTICS OF THE COOK INLET BASIN

A discussion of the physical characteristics of the Cook Inlet Basin puts water quality in perspective with the climate, physiography, geology, and soils. The diversity in these characteristics across the study unit influences the areal distribution and flow of water and the distribution and concentrations of water-quality constituents. This description is not comprehensive, but focuses on factors that can affect water quality or aquatic biology, for the purpose of improving the understanding of environmental factors related to the quality of water in the Cook Inlet Basin.

The Cook Inlet Basin consists of four major drainage areas (fig. 5), also called "hydrologic units." They are the Susitna River Basin, the Anchorage/Matanuska area, the Kenai Peninsula, and western Cook Inlet.

Susitna River Basin (20,752 mi^2)—The northern half of the Cook Inlet Basin consists of the Susitna River Basin, the fifth largest basin in Alaska. The relief of the Susitna River Basin is a contrast of steep, rugged mountains towering above wide valley lowlands. Altitudes range from 20,320 ft at Mt. McKinley to sea level where the Susitna River empties into Cook Inlet. Tributaries to the Susitna River are commonly referred to as either glacial or nonglacial streams. The nonglacial streams are noted for their clarity compared with glacial streams which are turbid throughout most of the melt-water season (May through September). Both glacial and nonglacial streams in the Susitna River Basin are characteristically low in turbidity (less than 10 nephelometric turbidity units) during most winter months (November through March).

Anchorage/Matanuska Area (4,732 mi^2)—The Anchorage area consists of many small basins (less than 500 mi^2), but most of the population of the Cook Inlet Basin resides in this area. Two principal rivers drain the Matanuska area: the Knik River drains approximately 1,200 mi^2, and the Matanuska River drains approximately 2,100 mi^2 (fig. 5). Both river basins contain a significant percentage of glacial area.

Kenai Peninsula (6,568 mi^2)—This area is bounded on the north by Turnagain Arm, on the west by Cook Inlet, on the east and south by the Kenai Mountains (fig. 5). The Kenai Peninsula is one of the most popular destinations for recreation. World-class sports fishing is located on the Kenai and Russian Rivers (fig. 4). In addition, part of the Chugach National Forest and the entire Kenai National Wildlife Refuge are located on the peninsula (fig. 1). The Kenai and Kasilof Rivers are the two largest rivers, with drainage areas of 2,010 mi^2 and 738 mi^2 respectively.

Western Cook Inlet (7,273 mi^2)—This area is sparsely populated. Perhaps the most noted feature of this area is the presence of several active volcanoes: Mt. Spurr, Redoubt, Iliamna, and Augustine (fig. 5). Significant reserves of coal and timber in this area may be extracted depending on economic market conditions. From a recreational standpoint, a number of streams and rivers, such as the Chuitna River near Tyonek (fig. 5), are visited by fly-in sportsmen for the excellent runs of salmon these rivers produce. Recreationists also visit two popular national parks, Lake Clark and Katmai (fig. 1), for wildlife and nature viewing.

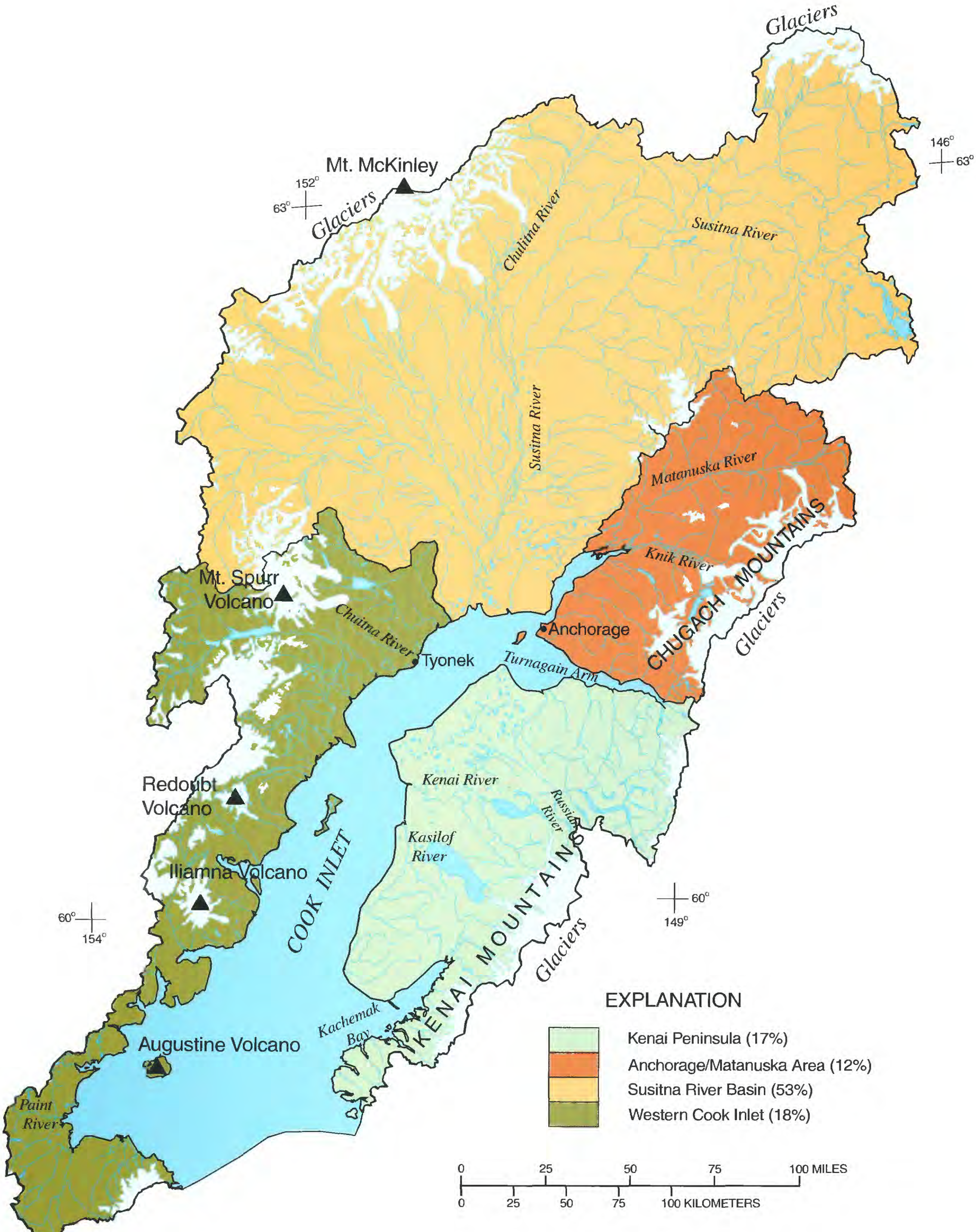


Figure 5. Major drainage areas of the Cook Inlet Basin, Alaska.

Climate

The Cook Inlet Basin has three climate zones because of its large size and range in altitude of the land surface. Climate zones have been broadly defined primarily by variations in precipitation and temperature (Searby, 1968; Hartman and Johnson, 1978). The Continental Zone (fig. 6) is characterized by an average annual precipitation of about 20 in. and an average temperature of about 22 °F. Temperature extremes are greater in the Continental Zone than in the other climatic zones. Average annual precipitation in the Transition Zone is about 30 in. and temperatures average about 27 °F. The Maritime Zone is extremely wet relative to the other climatic zones; average annual precipitation is about 70 in. and average annual temperatures are about 42 °F. This zone lacks prolonged periods of freezing weather at low altitudes and is characterized by frequent clouds and fog.

Precipitation in the Cook Inlet Basin ranges from 20 to 240 in. annually (fig. 6). Averaged over the entire basin, the annual precipitation is approximately 44 in. The amount of precipitation is directly related to topography; high rugged mountains receive the greatest amounts of precipitation and lowland areas receive the least. Much of the precipitation falls as snow from November through March. Snow may fall year-round in the high mountains, where much of it is stored for long periods in glaciers and icefields.

The relatively low temperatures, high humidity, and cloudy skies that prevail over most of the Cook Inlet Basin minimize the rate of evaporation. Short summers minimize the time during which vegetation actively grows and, thus, negligible amounts of water are returned to the atmosphere by transpiration.

Bradley River watershed near Homer. In the high mountains surrounding the Cook Inlet Basin, most of the precipitation is in the form of snow. About 6 percent of the Cook Inlet Basin is perennial snowfields.

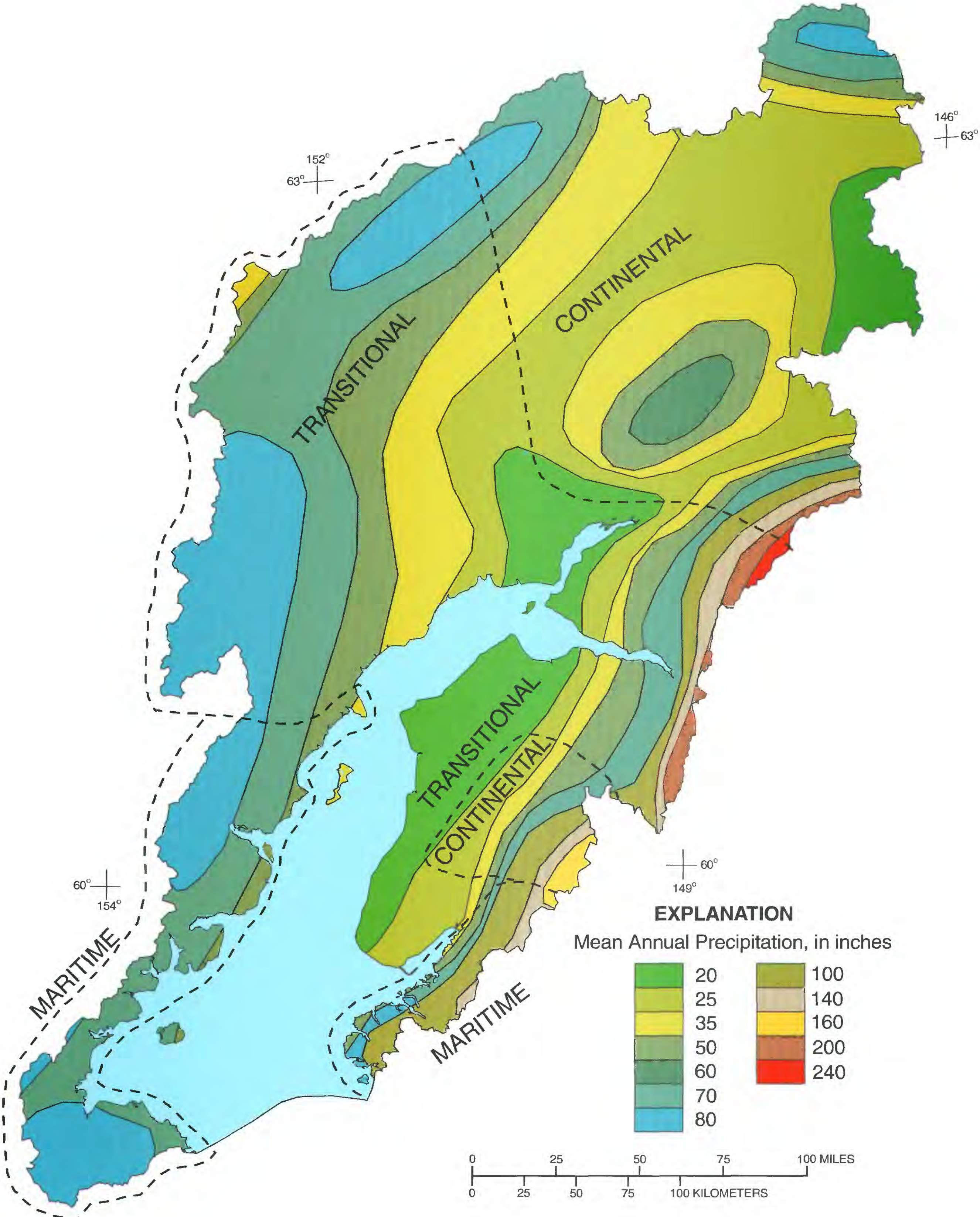


Figure 6. Climate and precipitation zones of the Cook Inlet Basin, Alaska (modified from Jones and Fahl, 1994).

Physiography

The Cook Inlet study unit is composed of five general physiographic regions (fig. 7): (1) extremely high rugged mountains (9 percent), (2) moderately high rugged mountains (49 percent), (3) low mountains, generally rolling (15 percent), (4) plateaus and highlands of rolling topography and gentle slopes (9 percent), and (5) plains and lowlands (18 percent). Specific descriptions of these regions (fig. 7) are taken from Wahrhaftig (1965).

Aleutian Range—These mountains consist of rounded east-trending ridges 1,000 to 4,000 ft in altitude, interspersed at intervals of 5–85 mi by volcanoes 4,500–8,500 ft in altitude. The drainages of the streams and rivers generally are short and steep.

Alaska Range (Southern Part)—Between Rainy Pass and Lake Chakachamna, the southern part of the Alaska Range consists of many parallel, rugged, glaciated north-trending ridges about 7,000–12,000 ft in altitude; south of Chakachamna Lake the ridges trend to the northeast and are about 4,000–6,000 ft in altitude. Between the ridges lie broad glaciated valleys that have floors less than 3,000 ft in altitude. Local relief is between 4,000 and 9,000 ft. Many spire-like mountains rise in the central part of the range. Large braided glacial streams follow the north- and northeast-trending valleys and flow eastward to the Susitna River or Cook Inlet. Extensive systems of valley glaciers originate from the higher mountains.

Alaska Range (Central and Eastern Part)—These mountains consist of two or three parallel, rugged, glaciated ridges, about 6,000–9,000 ft in altitude, interspersed by groups of extremely rugged snow-capped mountains more than 9,500 ft in altitude. The range rises abruptly from lower country on either side, and its longitudinal profile, seen from a distance, is irregular. Mount McKinley, 20,320 ft high and the highest mountain in North America, is located in this part of the Alaska Range. Streams head in glaciers and become swift and braided as they drain to the Susitna River.

Cook Inlet–Susitna Lowland—This glaciated lowland contains areas of ground moraine and stagnant ice topography, drumlin fields, eskers, and outwash plains. Most of the lowland is less than 500 ft above sea level and has a local relief of 50–250 ft. Rolling upland areas near the bordering mountain ranges rise to about 3,000 ft in altitude, and isolated mountains as high as about 4,800 ft rise from the central part of the lowland. The Cook Inlet–Susitna Lowland is the major population center of Alaska and contains most of the developed land. The lowland is drained by the Susitna River and other streams that flow into Cook Inlet. The shores of Cook Inlet are for the most part gently curving steep bluffs 50–250 ft high.

Talkeetna Mountains—These mountains are a compact group of extremely rugged radial ridges about 6,000–8,000 ft in altitude, having only a few low passes that isolate steep-walled glacier-carved U-shaped valleys. These mountains have a radial drainage of large, braided glacial streams that are tributary to the Susitna and Matanuska Rivers. The Susitna River flows westward across the Talkeetna Mountains in a narrow steep-walled gorge that is more than 1,000 ft deep in places. West-flowing streams in the southwestern Talkeetna Mountains have many long southern tributaries and few or no northern tributaries. This asymmetry probably is caused by relatively low solar elevation from the south, favoring the growth of glaciers in shaded north-facing valley heads and inhibiting their growth on sunny, south-facing slopes.

Upper Matanuska Valley—This glaciated trough, 2–5 mi wide, contains longitudinal bedrock hills about 500–1,000 ft high and has steep bounding walls several thousand feet high. Altitude of its floor ranges from 800 ft on the west to about 2,000 ft on the east. The Upper Matanuska Valley is drained entirely by

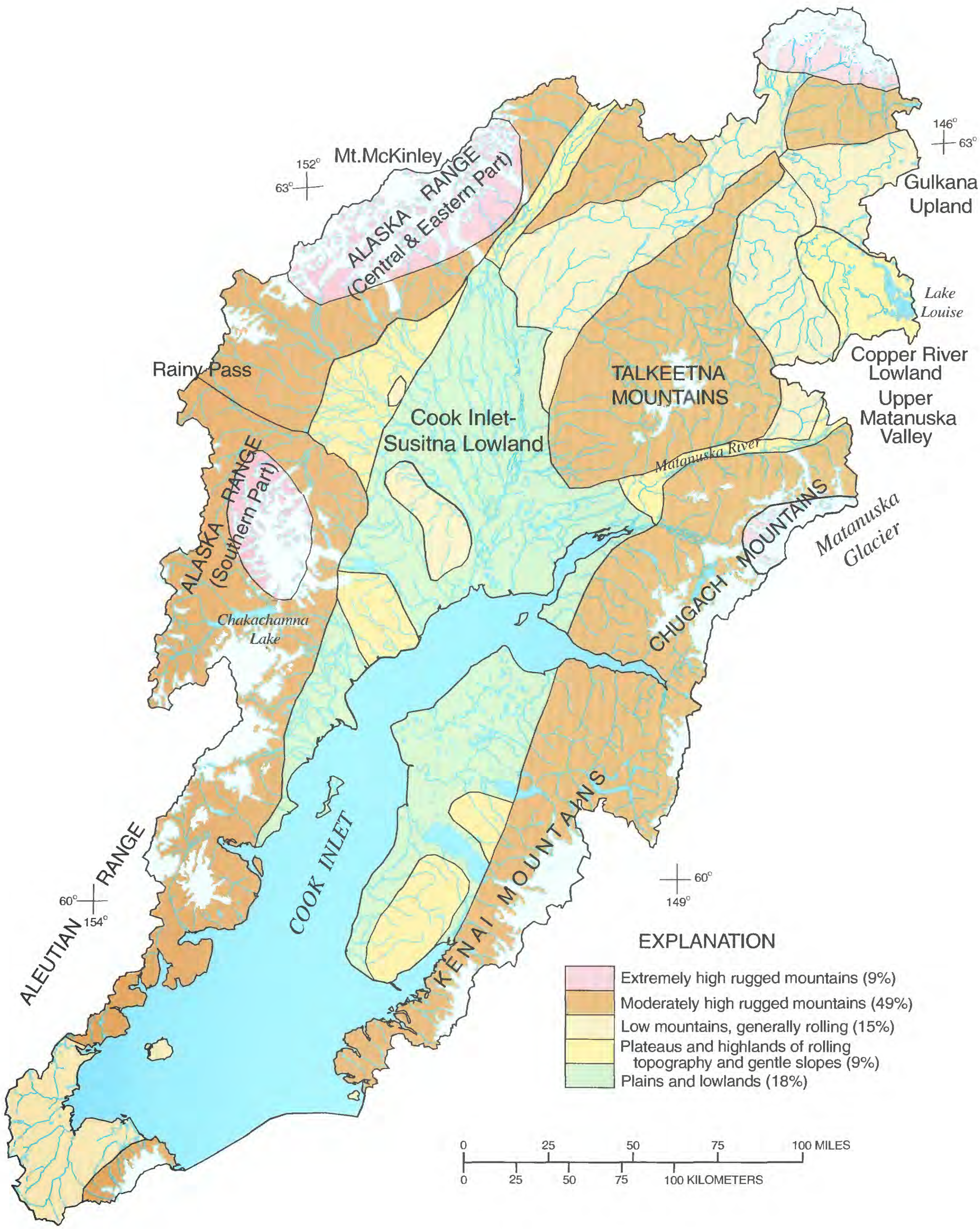


Figure 7. Physiographic regions of the Cook Inlet Basin, Alaska (modified from Wahrhaftig, 1965).

the Matanuska River, which flows westward along the trough. Matanuska Glacier is located at the east end of the trough.

Gulkana Upland—This upland consists of rounded east-trending ridges separated by lowlands 2–10 mi wide. The ridge crests, about 3,500–5,500 ft in altitude, are 4–15 mi apart and are cut at intervals of 5–15 mi by notches and gaps that were eroded by glaciers or glacial melt water. The lowlands have floors of glacial deposits showing morainal and stagnant-ice topography and contain large esker systems. Drainage is to the southwest to the Susitna River.

Copper River Lowland—The western part of the Copper River Lowland is located in the Cook Inlet Basin and is also referred to as the "Lake Louise Plateau." It is a smooth plain about 2,200–3,500 ft in altitude, and has morainal and stagnant-ice topography. Drainage is northwest to the Susitna River.

Kenai-Chugach Mountains—These mountains form a rugged barrier along the north coast of the Gulf of Alaska. High segments of the mountains are dominated by extremely rugged east-trending ridges about 7,000–13,000 ft in altitude. Low segments consist of discrete massive mountains 5–10 mi across and about 3,000–6,000 ft in altitude. The entire range has been heavily glaciated and the topography is characterized by cirques, U-shaped valleys and passes, and rock-basin lakes. The drainage divide is generally an ice divide along the highest ridges.

Geology

Water-quality characteristics of surface water and ground water are strongly affected by surficial and bedrock geology. The geology of the Cook Inlet Basin is complex and the interpretation of the geology is based on the concept that the Cook Inlet Basin is a mosaic of geologic terranes (Silberling and others, 1994). A terrane is a body of rock of regional extent that is bounded by faults, and whose geologic history is different from that of adjacent terranes. The terranes in the Cook Inlet Basin represent blocks of the Earth's crust that have moved large or small distances relative to each other at different times in the geologic past. In the Cook

Knik Glacier near Palmer. Glaciers cover about 11 percent of the Cook Inlet Basin. Glacier-fed streams have different physical characteristics from streams that do not have glacier contributions.

Views of a clearwater river, the Deshka River near Willow (top), and a glacier-fed river, the Susitna River near Talkeetna (bottom). Glacier-fed rivers have sustained high flows during summer and are more turbid than nonglacier-fed rivers. Salmon use the glacier-fed rivers as corridors to the clearwater streams.

Inlet Basin, the four main terranes are Chugach, Peninsular, Kahiltna, and Wrangellia (fig. 8).

For the Cook Inlet Basin, the geologic materials are discussed in two categories: consolidated rocks and unconsolidated deposits (fig. 8). The rocks range in age from Paleozoic (600 million years) to Holocene (the last 10,000 years). Consolidated rocks crop out in the mountain ranges surrounding the basin and consist of sedimentary and metasedimentary rocks, as well as intrusive and volcanic rocks. Glacial drift deposited during the Pleistocene Epoch by large valley glaciers mantles mountain flanks and adjacent lowland areas in most of the mountain areas. Major deposits are as follows:

Unconsolidated deposits of Quaternary age are present in lowland areas throughout the Cook Inlet Basin. Only thick accumulations of these deposits are shown. Deposits consist primarily of alluvium and glacial deposits, but also include eolian and beach deposits. The Quaternary-age sediments in the Cook Inlet Basin are the major aquifer of ground water now being used. The thickness and grain size of these sediments are some of the principal factors controlling the ground-water potential of an area. As a general rule, the thicker the sediments and larger the grain size, the better the chances that those sediments include a water-yielding unit (Freethey and Scully, 1980).

Sedimentary rocks of Tertiary age (Cenozoic) are found in the lower Kenai Peninsula and the upper Susitna River Basin. These rocks are composed primarily of sandstone, siltstone, and shale, but also contain amounts of coal, mudstone, and conglomerate.

Intrusive igneous rocks of Tertiary age (Cenozoic) are found in the southern part of the Alaska Range and in the Talkeetna Mountains. These rocks range in composition from gabbro to granite.

Sedimentary rocks, mainly volcaniclastic, marine shelf sediments of Mesozoic age are found in the southern part of the Alaska Range, the Talkeetna Mountains, and the northern part of the Aleutian Range. These rocks are mostly shale, siltstone, and sandstone, but locally include limestone.

Volcanic rocks of Mesozoic age are present in the Talkeetna Mountains. These deposits range in composition from andesite to basalt.

Intrusive igneous rocks of Mesozoic age are found in western Cook Inlet along the southern flank of the Alaska Range, and in the Talkeetna Mountains. These rocks are mostly in upland and mountainous areas and range in composition from granite to gabbro.

Volcanic and intrusive rocks of generally low metamorphic grade of Mesozoic age underlie large parts of the Kenai-Chugach Mountains. These rocks consist of greenstone, limestone, chert, granodiorite, schist, and layered gabbro. Their contacts and extent are incompletely known because of glacial cover in many places.

Sedimentary rocks of Mississippian through Permian ages (Paleozoic) occur in the northern and eastern parts of the Alaskan Range and in the Talkeetna Mountains. These rocks are mostly limestone, shale, siltstone, and sandstone, but include beds of conglomerate, dolomite, and chert. Locally, marble, argillite, and metasedimentary and metavolcanic rocks are mapped in this category.

Sedimentary rocks of Cambrian through Devonian ages (Paleozoic) are found in the easternmost part of the Alaska Range and in the northern foothills that border that range. These rocks consist mostly of sandstone, shale, and siltstone, but also include beds of limestone, dolomite, and chert.

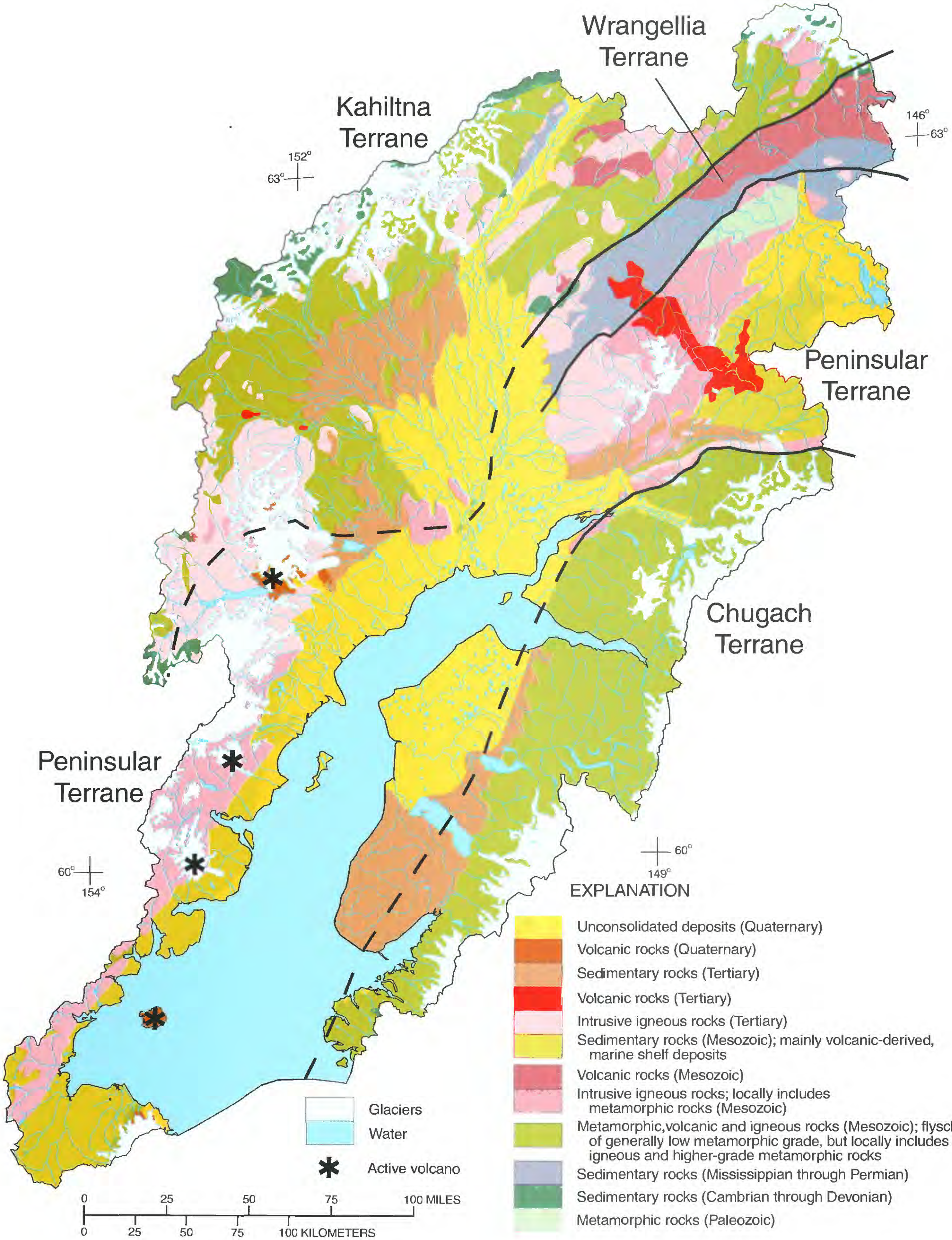


Figure 8. Geology of the Cook Inlet Basin, Alaska (modified from Silberling and others, 1994).

Soils

The formation of soils depends primarily on five factors: type of parent material, climate, relief or topography, living organisms, and time (Singer and Munns, 1987). The type of soil depends on which factor is the most dominant. In the Cook Inlet Basin, type of material, climate, and relief have been the most dominant factors in the development of soils. Soil type can affect water quality as precipitation infiltrates the soil, reacts with the minerals that are present, and then discharges into a stream. Soil type and distribution also are factors that affect the amount of soil erosion.

In the soil taxonomy of the U.S. Department of Agriculture (1975), soils were grouped at six levels or categories. The two broadest categories are the **order**, followed by the more narrowly defined category, the **suborder**. Of a possible 10 soil orders, 4 soil orders are found in the Cook Inlet Basin: Entisols, Histosols, Inceptisols, and Spodosols (fig. 9). In addition, two other areas are not classified as orders because they are largely unvegetated: **cinder lands** (areas of fresh volcanic ash and cinder flows) and **rough mountainous lands** (Rieger and others, 1979).

Entisols—These are recently formed soils with little soil horizon development and are found in areas of glacial outwash or alluvium. These areas are the basins of the Matanuska, Susitna, Yentna, and Chulitna Rivers and are also along part of western Cook Inlet. Suborders of Entisols found in the Cook Inlet Basin are aquents. Soils in this suborder are the Typic Cryaquents, which have a wide range of properties. The texture ranges from very gravelly sand to fine clay and the color from gray to grayish brown. A common property of these soils is that they are always nearly saturated.

Histosols—These are yellow-brown to dark black organic-rich soils generally formed in wetlands. They are generally found near the mouth of the Susitna River. Suborders of Histosols that are present are the Fibrists. The predominant soil is Sphagnic Borofibrists, a deep organic soil composed dominantly of sedge peat, but with one or more layers in which sphagnum moss fibers make up more than three-quarters of the peat. The soils have no permafrost but are frozen to a depth of 2 in. or more during winter.

Inceptisols—These are recently formed soils but, in contrast to Entisols, have a greater degree of soil horizon development than the Entisols. These soils are located along the Aleutian and Alaska Ranges in western Cook Inlet and along the Kenai–Chugach Mountains on the east side of Cook Inlet. Predominant suborders and soils are:

- <u>Ochrepts Suborder</u>
  Andic Cryochrepts—A layer of silty volcanic ash over soils of the typic subgroup.
- <u>Aquepts Suborder</u>
  Histic Cryaquepts—Soils with a thick accumulation of organic matter at the soil surface in a peaty mat above the mineral soil or mixed with the mineral soil.
  Pergelic Cryaquepts—Soils that have permafrost at some depth, but do not have thick peaty accumulations on the surface.
- <u>Umbrepts Suborder</u>
  Pergelic Cryumbrepts—Soils that have mean annual temperatures below freezing. These soils occur in locations with good surface drainage, in areas above treeline.

Spodosols—These consist of soils with light-colored surface horizons and organic and aluminum-rich subsurface horizons. These are the predominant soils in the Cook Inlet Basin and are located throughout the Susitna River Basin and the Kenai Peninsula. Predominant suborders and soils are (Joe Moore, Natural Resources Conservation Service, Anchorage, written commun., 1998):

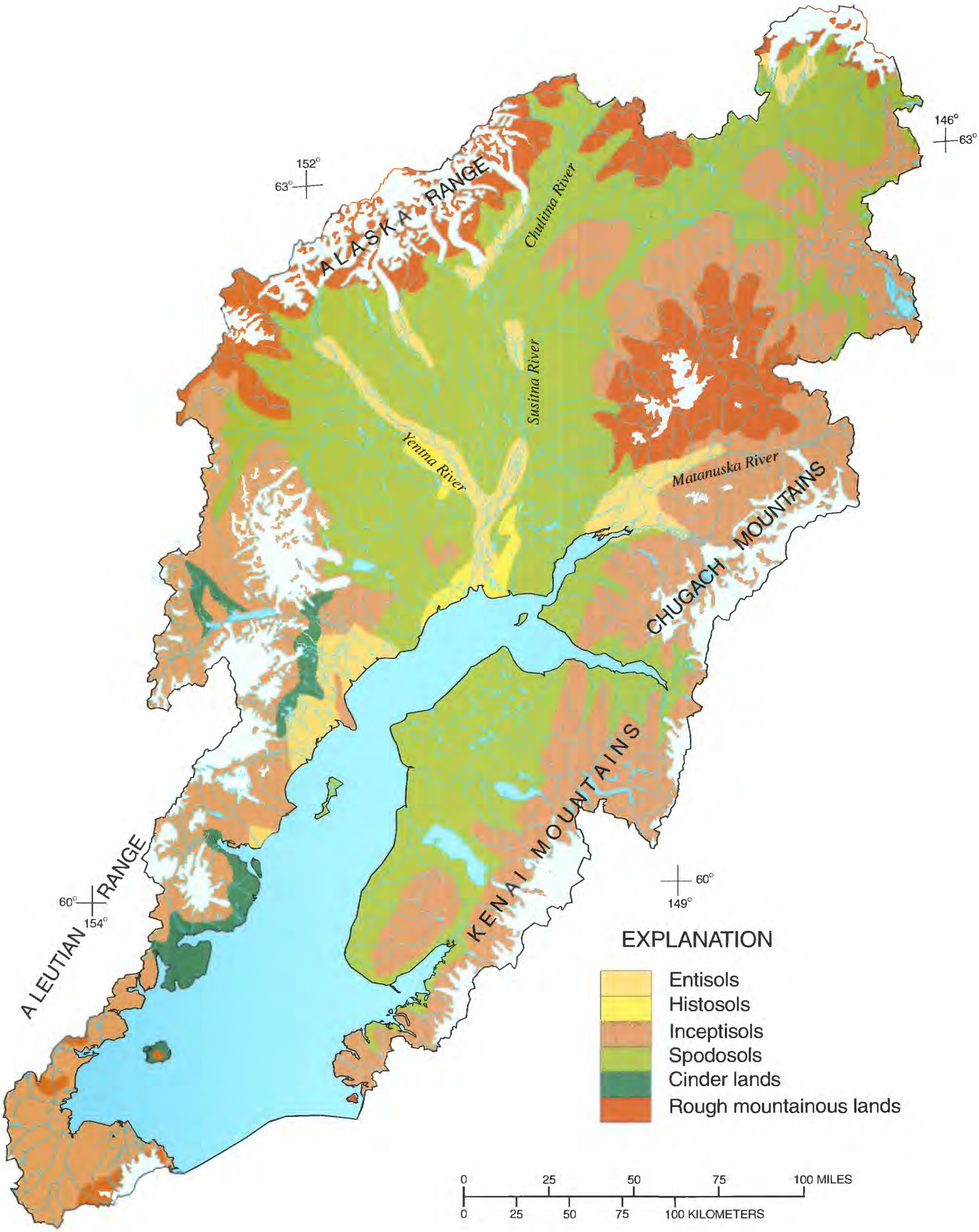


Figure 9. Soils of the Cook Inlet Basin, Alaska (modified from Rieger and others, 1979).

• Aquods Suborder

Andic Haplocryods—Well-drained soils formed in volcanic ash. These soils consist of an ashy loess layer overlying various substratum materials including glacial till, alluvium, or colluvium. Formed on stable landforms, these soils develop acidic conditions, and the acidic weathering results in leaching of iron, alumina, and organic colloids from near-surface layers and subsequent accumulation of these materials at lower depths.

Typic Haplocryods—Generally sandy soils that occur mostly in areas subject to frequent fluctuations in ground-water levels.

Andic Humicryods—These soils are similar to the Andic Haplocryods but with significant accumulation of organic carbon in the reddish subsoil zone. They are found in areas with high precipitation.

Typic Humicryods—Soils very similar to the Andic Humicryods but without the influence of volcanic ash. Either there is no loess mantle or the loess mantle is derived from glacial silts of non-volcanic origin.

Pergelic Haplocryods—The dominant feature of these soils is a temperature perennially at or below 32 °F (permafrost). The presence of permafrost restricts moisture movement through the soil as well as plant root penetration. They may or may not be stable if allowed to warm and thaw. These soils form in acidic environments and occur at higher altitudes, generally above treeline or on north-facing aspects.

• Orthods Suborder

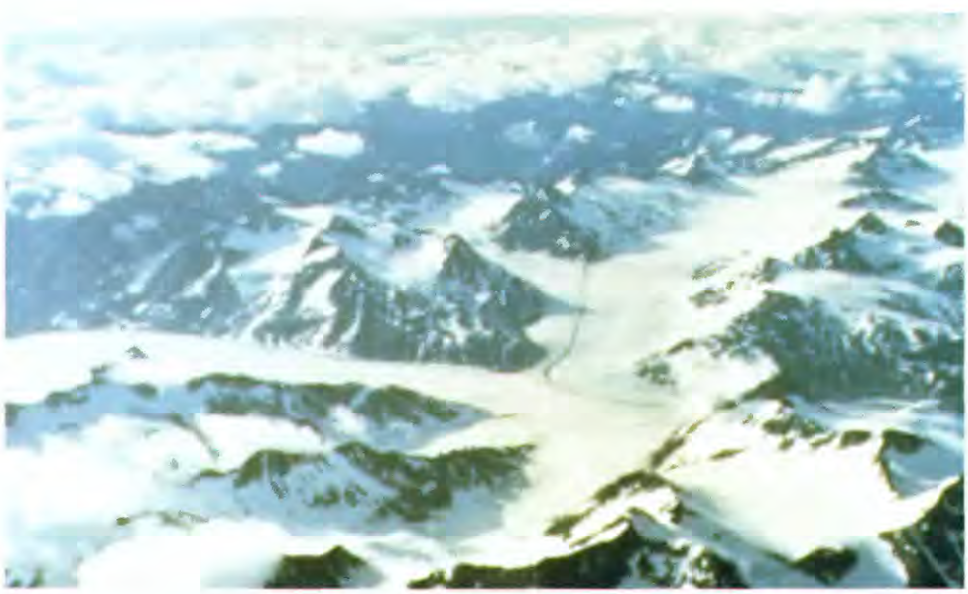
Humic Cryorthods—Well-drained soils in which organic carbon, aluminum, and iron are all present in significant quantities. These soils generally occur directly above treeline in the Cook Inlet/Susitna Lowland.

Spruce-hardwood forests of the Cook Inlet ecoregion. This ecoregion covers 28 percent of the Cook Inlet Basin, is characterized by level to rolling topography and mild climate, and has attracted most of the settlement and development in Alaska.

Land Cover

Land cover influences a number of hydrologic factors, such as snow accumulation, soil moisture depletion, surface runoff, infiltration, and erosion. These factors, in turn, can affect the water quality of a particular stream or river. For example, certain types of vegetation can prevent erosion, thus reducing the amount of sediment that enters a stream. Also, the composition of certain types of vegetation will, in turn, affect the chemistry of the water.

Water, permanent snow, and ice are present in about 19 percent of the Cook Inlet Basin (fig. 10; table 1) (Alaska Geospatial Data Clearinghouse, 1998). In the Anchorage/Matanuska area and in western Cook Inlet (fig. 10), these features account for 29 and 27 percent of their total areas respectively. Tall shrub is the dominant vegetation in the Cook Inlet Basin and accounts for about 24 percent of the total vegetation. Alpine tundra accounts for about 19 percent of the total area of Cook Inlet and is present in a large extent in the Susitna, Anchorage/Matanuska, and western Cook Inlet areas. Other distinguishing features are the amount of closed broadleaf forest found in the Susitna area (17 percent) and the amount of closed mixed forest (13 percent) and closed spruce forest (26 percent) found in the Kenai Peninsula area.



Mountains of the Alaska Range ecoregion. This ecoregion covers almost half of the Cook Inlet Basin. Extensive systems of valley glaciers are found throughout the region, which is dominated by very high steep mountains.

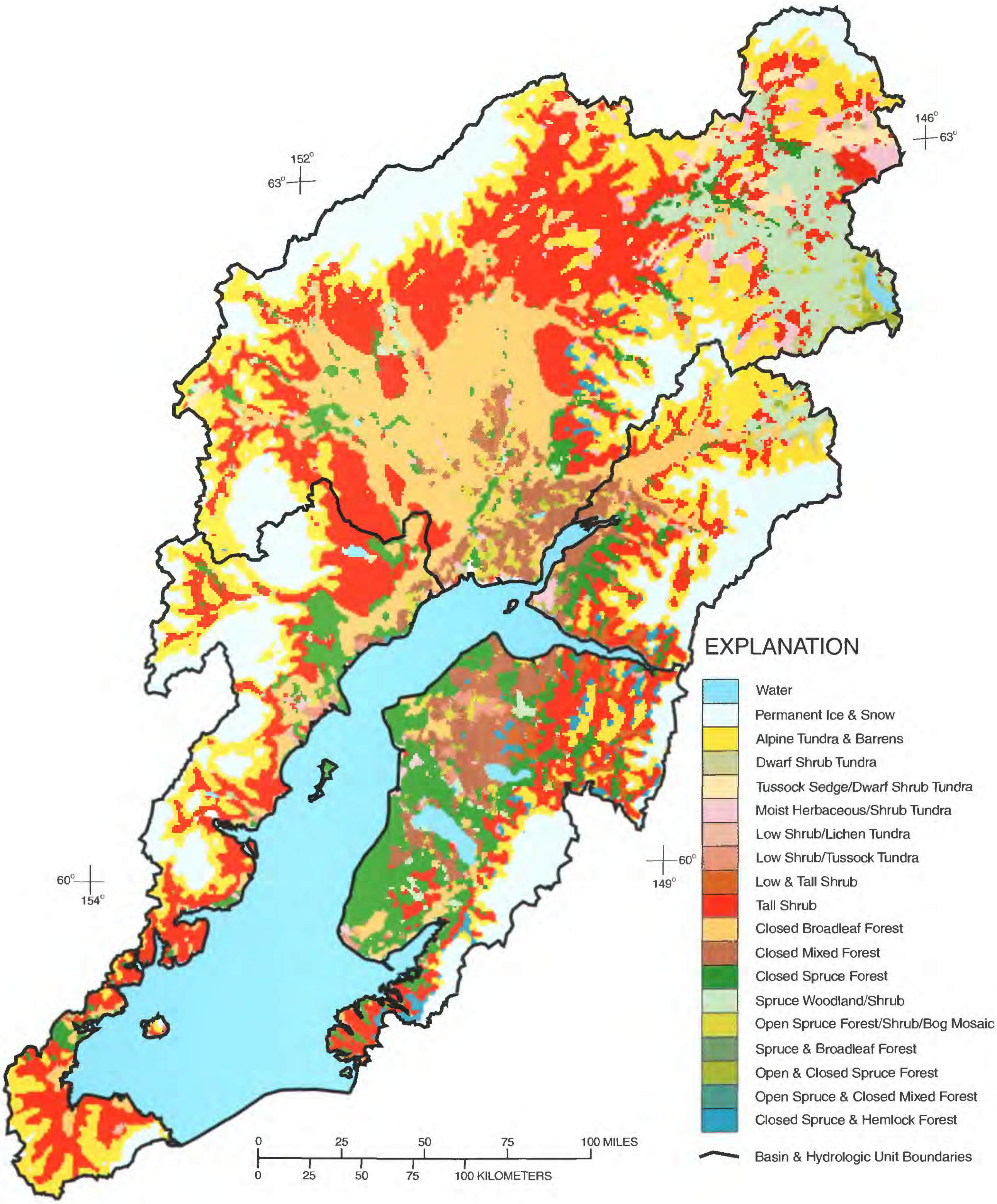


Figure 10. Land cover of the Cook Inlet Basin, Alaska (modified from Alaska Geophysical Data Clearinghouse, 1998).

Table 1. Types and amounts of land cover in the Cook Inlet Basin, Alaska
[Data from Alaska Geospatial Data Clearinghouse, 1998]

Type of land cover	Amount of area covered, in square miles and percentage									
	Susitna River Basin		Anchorage/ Matanuska Area		Kenai Peninsula		Western Cook Inlet		Total	
	Sq. miles	Per-cent	Sq. miles	Per-cent	Sq. miles	Per-cent	Sq. miles	Per-cent	Sq. miles	Per-cent
Water	246	1	46	<1	296	5	57	<1	645	2
Permanent snow and ice	2668	13	1305	28	864	13	1894	26	6731	17
Alpine tundra	3896	19	1256	26	520	8	1726	24	7398	19
Dwarf shrub tundra	160	<1	90	2	7	<1	29	<1	286	<1
Tussock sedge/dwarf shrub tundra	601	3	14	<1	0	0	12	<1	627	2
Moist herbaceous/shrub tundra	611	3	42	<1	48	<1	22	<1	723	2
Low shrub/lichen tundra	4	<1	16	<1	12	<1	34	<1	66	<1
Low shrub tussock tundra	37	<1	6	<1	151	2	48	<1	242	<1
Low and tall shrub	2	<1	71	2	250	4	8	<1	331	<1
Tall shrub	5302	26	664	14	1150	18	2168	30	9284	24
Closed broadleaf forest	3608	17	408	8	238	4	621	9	4875	12
Closed mixed forest	712	3	237	5	827	13	55	<1	1831	5
Closed spruce forest	603	3	260	5	1678	26	540	7	3081	8
Spruce woodland/shrub	1740	8	176	4	118	2	10	<1	2044	5
Open spruce forest/shrub/bog mosaic	341	2	44	<1	104	2	36	<1	525	1
Spruce and broadleaf forest	0	0	0	0	5	<1	0	0	5	<1
Open and closed spruce forest	90	<1	25	<1	10	<1	0	0	125	<1
Open spruce and closed mixed forest	2	<1	0	0	0	0	0	0	2	<1
Closed spruce and hemlock forest	98	<1	36	<1	252	4	3	<1	389	<1
Burned forest (1990 fires)	0	0	0	0	7	<1	0	0	7	<1
Burned forest (1991 fires)	31	<1	36	<1	31	<1	10	<1	108	<1
Total	20,752	100	4,732	100	6,568	100	7,273	100	39,325	100

Ecoregions

Omernik (1995) has defined ecoregions as areas with common ecological settings that have relatively homogeneous features including potential natural vegetation, geology, mineral availability from soils, physiography, and land use and land cover. The Cook Inlet Basin contains parts of six ecoregions (fig. 11): (1) Alaska Peninsula Mountains, (2) Cook Inlet, (3) Alaska Range, (4) Copper Plateau, (5) Pacific Coastal Mountains, and (6) Coastal Forest. Specific descriptions of these regions are taken from Gallant and others (1995).

Alaska Peninsula Mountains—Composed of rounded, folded, and faulted sedimentary ridges intermittently surrounded by volcanoes. The mountains were heavily glaciated during the Pleistocene Epoch (Quaternary Period). A maritime climate prevails, and the region is generally free of permafrost. Many soils formed in deposits of volcanic ash and cinder over glacial deposits and are highly erodible. Vegetation cover commonly consists of dwarf scrub communities at higher altitudes and on sites exposed to wind, and low scrub communities at lower altitudes and in more protected sites.

Cook Inlet—Located in the southcentral part of Alaska adjacent to Cook Inlet, has one of the mildest climates in the State. The climate, the level-to-rolling topography, and the coastal proximity have attracted most of the settlement and development in Alaska. The region has a variety of vegetation communities but is dominated by stands of spruce and hardwood species. The area is generally free from permafrost. Unlike many of the other nonmontane ecoregions, the Cook Inlet ecoregion was intensely glaciated during the Pleistocene Epoch.

Alaska Range—Covered by rocky slopes, icefields, and glaciers. Much of the area is barren of vegetation. Dwarf scrub communities are common at higher altitudes and on windswept sites where vegetation does exist. The Alaska Range is in the Continental Climate Zone, but because of the extreme height of many of the ridges and peaks, annual precipitation at higher altitudes is similar to that measured for some ecoregions in the Maritime Zone (fig. 6).

Copper Plateau—Occupies the site of a large lake that existed during glacial times (Pleistocene Epoch). The nearly level-to-rolling plain has many lakes and wetlands. Soils are predominantly silty or clayey, formed from glaciolacustrine sediments. Much of the region has a shallow permafrost table, and soils are poorly drained. Black spruce forests and tall scrub, interspersed with wetlands, are the major types of vegetation communities.

Pacific Coastal Mountains—Composed of steep and rugged mountains along the southeastern and southcentral coast of Alaska. This ecoregion receives more precipitation annually than the Alaska Range ecoregion. Glaciated during the Pleistocene Epoch, most of the ecoregion is still covered by glaciers and icefields. Most of the area is barren of vegetation, but where plants do occur, dwarf and low-scrub communities dominate.

Coastal Forest—Located near the southeastern part of the Cook Inlet Basin. The terrain is a result of intense erosion and deposition during late glacial advances of the Pleistocene Epoch. Evidence of the effects of glaciation are deep narrow bays, steep valley walls that expose much bedrock, thin moraine deposits on hills and in valleys, very irregular coastline, high sea cliffs, and deeply dissected glacial moraine deposits covering the lower slopes of valley walls. The region has the mildest winter temperatures in Alaska accompanied by large amounts of precipitation. Forests of western hemlock and Sitka spruce are widespread.

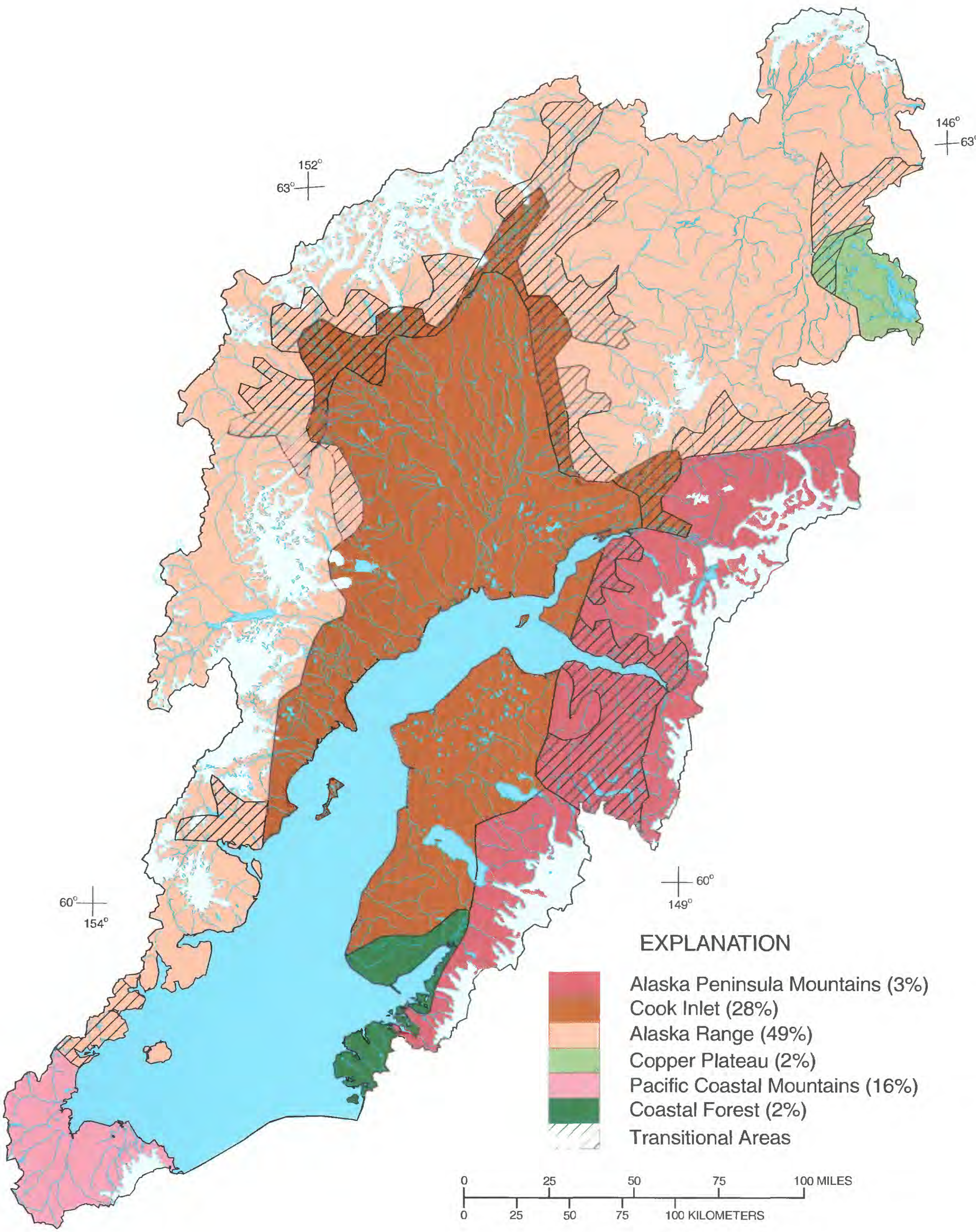


Figure 11. Ecoregions of the Cook Inlet Basin, Alaska (modified from Gallant and others, 1995).

HYDROLOGIC CHARACTERISTICS OF THE COOK INLET BASIN

Surface Water

Streamflow quantity and variability have considerable influence on the quality of surface water. The quantity of water in a stream or river influences its ability to support aquatic communities, to assimilate or dilute waste discharges, and to carry suspended sediment. Temporal variability of streamflow may, in turn, cause temporal variability of water quality. Thus, knowledge of streamflow is important to understand the water-quality and ecological dynamics of a watershed.

The Cook Inlet Basin is composed of many streams and rivers that flow into Cook Inlet (fig. 12). The watersheds of these streams range in size from numerous small ones (less than 10 mi^2) to the Susitna River watershed, which drains an area of 20,752 mi^2. Five other basins have drainage areas larger than 1,000 mi^2 and combined with the Susitna River watershed, drain 25,800 mi^2 or 66 percent of the Cook Inlet Basin. The remaining 13,525 mi^2 or 34 percent of the basin is drained by many watersheds of various sizes.

Snow and Ice

In the high, mountainous areas that surround the Cook Inlet Basin, most of the precipitation is in the form of snow. Approximately 6 percent of the Cook Inlet Basin consists of perennial snowfields. When the quantity of annual snowfall exceeds average annual snowmelt, the snow begins to change into ice or glaciers. The transformation of snow to ice is a process that is commonly long and complex (Paterson, 1994). Temperature is an important factor because snow will develop into ice much more rapidly on glaciers where periods of melting alternate with periods of freezing (Paterson, 1994).

Approximately 4,200 mi^2, or 11 percent of the Cook Inlet Basin, is covered by glaciers (fig. 12), although at one time glaciers covered most of the area (Karlstrom, 1964; Reger and others, 1996). Glaciers are presently found on the stratovolcanoes in western Cook Inlet, the Alaska Range, and the Harding Icefield. These glaciers are classified as temperate glaciers because they have a year-round ice temperature close to 32 °F.

Glaciers store an enormous quantity of water in the form of ice. This feature alone makes any drainage basin containing glaciers both unique and complex. The release of this water is highly dependent on the energy supplied by solar radiation and air temperature (Meier, 1969). A hot summer will cause rapid melting and high runoff, whereas a cool summer will have low runoff.

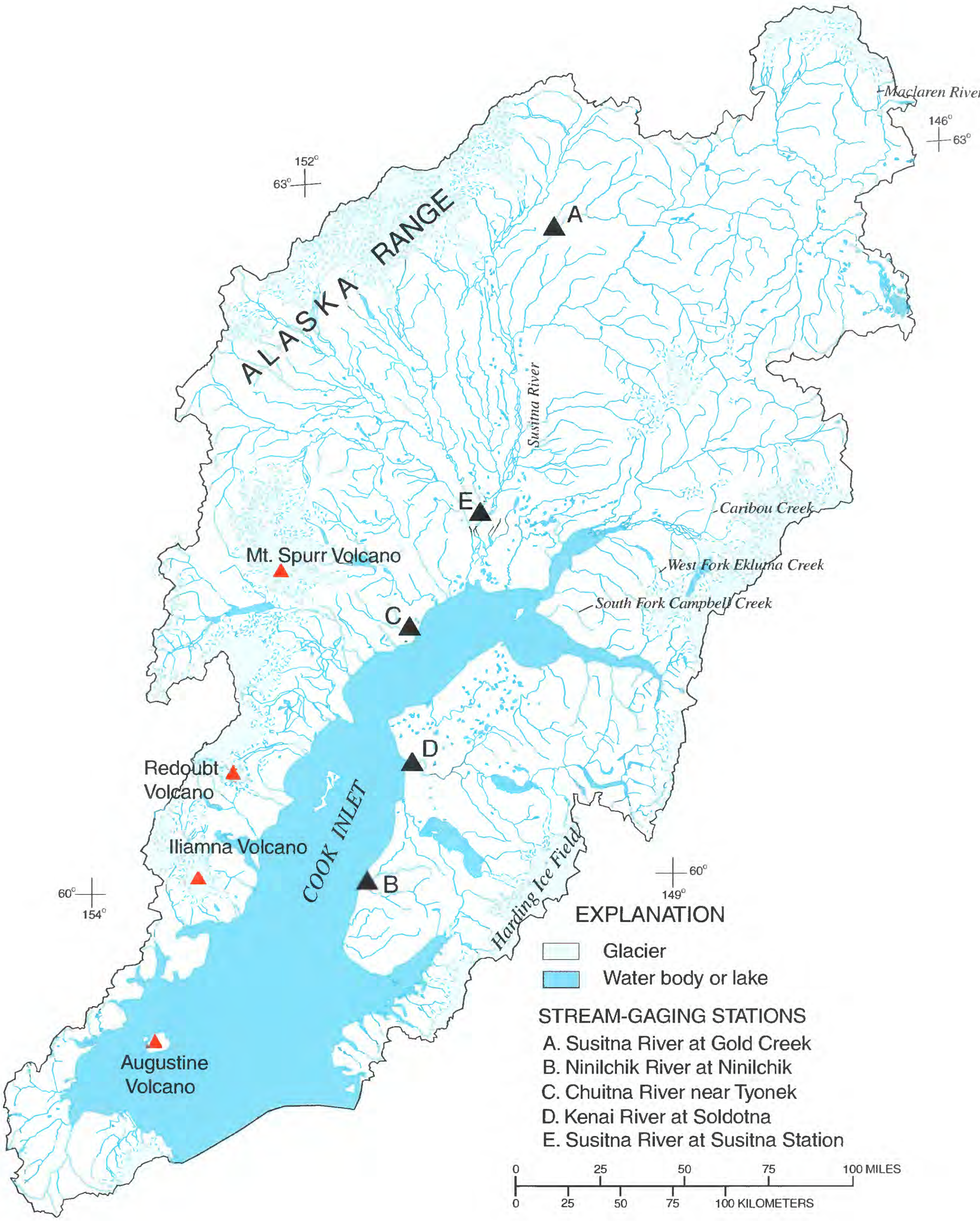


Figure 12. Selected streams, lakes, and glaciers in the Cook Inlet Basin, Alaska.

Glacial and Nonglacial Streams and Rivers

Because water quality is dependent on the quantity and timing of runoff, it is important to understand the distinction between glacial and nonglacial basins. A basin with a glacier will yield more water than an adjacent nonglacial basin, whether the glacier is growing or shrinking. Most of the meltwater from a glacier will be released during a fairly short summer season. The peak runoff from glaciers occurs later than that from lower altitude, nonglacial areas (Meier and Tangborn, 1961). Fountain and Tangborn (1985) also found that in certain years the water yield from a glacial basin was 20 to 30 percent greater than the water yield from a nonglacial basin.

Comparisons of the average daily discharge hydrographs between glacial and nonglacial streams clearly show the differences in runoff patterns (fig. 13-14). The two sets of paired watersheds represent two moderately small (less than 30 mi^2) basins, and two moderately large (about 300 mi^2) basins. In both comparisons, the glacial stream has more sustained runoff than the nonglacial stream. Discharge in the nonglacial stream has a maximum peak at the beginning of summer (mid-June), due to snowmelt. Subsequent high discharges will only occur as a result of rainfall. The glacial stream also reaches a peak discharge at the beginning of summer, but will sustain this high discharge throughout most of the summer, as glacier icemelt is added to the runoff.

Another method of comparison between glacial and nonglacial streams is the use of flow-duration curves. Flow duration can be summarized graphically as a curve derived by plotting discharge with the cumulative exceedence probability (in percent) for that discharge. The resulting flow-duration curve shows the percentage of time during which a range of flows was equaled or exceeded during the period of interest. The shape of the flow-duration curve is a function of the basin hydrological and physical characteristics. If flow-

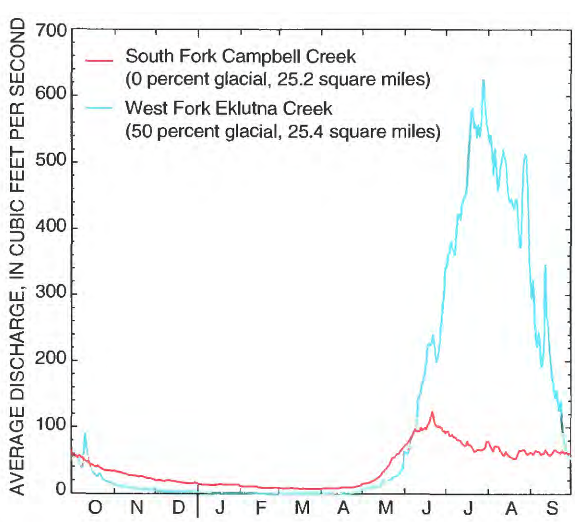


Figure 13. Comparison of discharge between glacial and non-glacial streams draining moderately small watersheds, Cook Inlet Basin, Alaska (see figure 12 for locations)

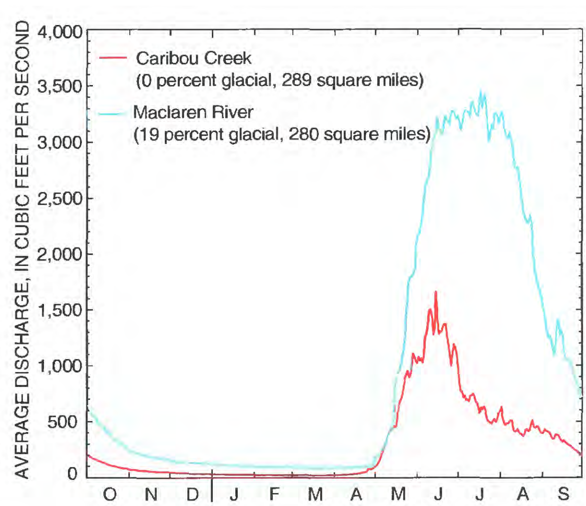


Figure 14. Comparison of discharge between glacial and non-glacial streams draining moderately large watersheds, Cook Inlet Basin, Alaska (see figure 12 for locations).

duration curves are based on representative data, the curves are useful for predicting flow distributions for water-quality assessments (Searcy, 1959).

Most of the streams and rivers in the Cook Inlet Basin are perennial and originate in the mountainous areas. Flow from these streams and rivers is primarily from snowmelt and, if glaciers are present, icemelt. Flow-duration curves from these rivers generally are flat for both high and low flows (fig. 15), illustrating the small variability in flows caused by the sustained flows snowmelt and icemelt provide. The flatness of the curve for both small and large exceedences is typical of a perennial stream with consistent high flows and sustained low flows.

Streams that originate in lowland areas of the Cook Inlet Basin and are nonglacial also are perennial. However, the slopes of their duration curves (Ninilchik River, Chuitna River; fig. 15) are not as steep as the duration curves for the glacial streams. The most likely reason for this difference is that glacier-fed streams have icemelt as an additional input. This steeper slope characteristic is found in flow-duration curves of glacial streams.

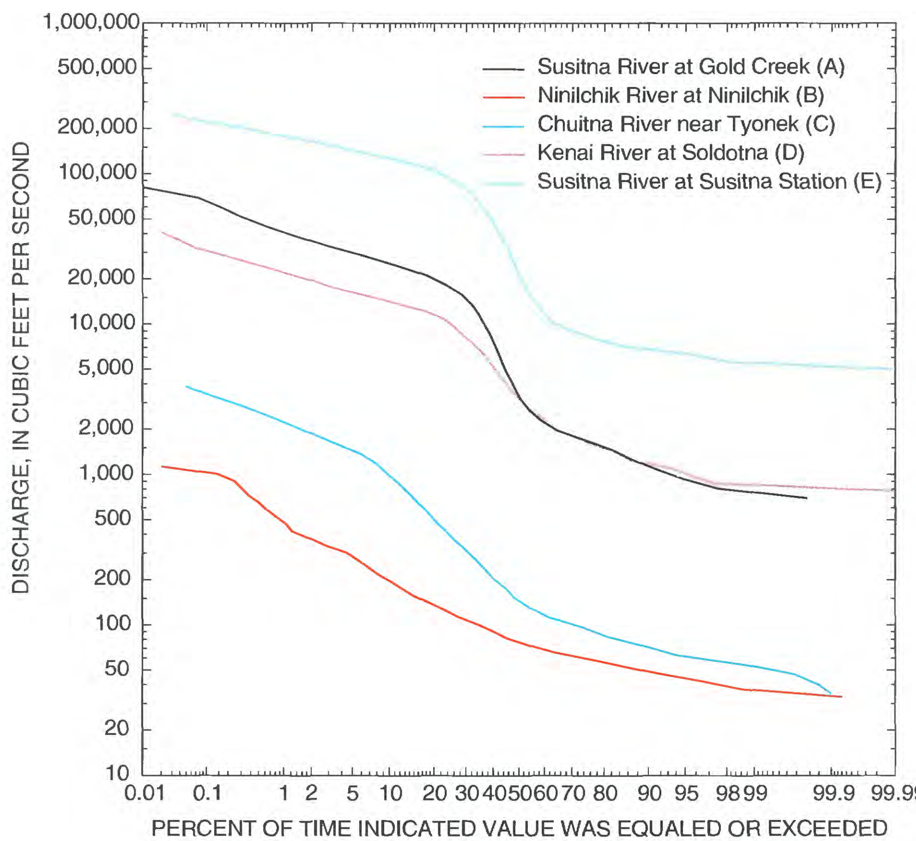


Figure 15. Flow-duration curves for several streams in the Cook Inlet Basin, Alaska (see figure 12 for locations of stream-gaging stations A–E).

Streamflow

Forty-nine streamflow-gaging stations operated by the USGS in the Cook Inlet Basin have 10 or more years of record (fig. 16; table 2). Because most of the gaging stations are located along the road system, a complete spatial coverage of streams is not available, especially in western Cook Inlet. Using the available streamflow information, the contribution to Cook Inlet from each hydrologic unit was determined (table 3). The contribution from a particular hydrologic unit was estimated by (1) calculating the average discharge for gaging stations that represented the mouth of a particular stream or river and (2) adjusting the sum of the average discharges to represent the total area of the hydrologic unit. For example, in the Susitna River Basin hydrologic unit, two stations (map Nos. 35 and 46, fig. 16) represent 94 percent of the basin (table 3). Thus, the average discharge for this hydrologic unit, 50,600 ft^3/s, was divided by 0.94 to compute the average discharge for this hydrologic unit.

The total average annual surface-water discharge into Cook Inlet is estimated to be 116,000 ft^3/s (table 3). As expected, the largest input to Cook Inlet is from the Susitna River Basin which accounts for about 47 percent of the annual total or 54,000 ft^3/s. The Anchorage/Matanuska area and the Kenai Peninsula, which account for 12 and 17 percent respectively of the area of the Cook Inlet Basin, contribute about the same percentage (14 and 16 percent) of flow. However, western Cook Inlet—which constitutes 18 percent of the total area of Cook Inlet—contributes about 22 percent of the total discharge. This higher discharge most likely is due to the presence of many glaciers in western Cook Inlet as well as the high precipitation this region receives.

A similar analysis was done for the same streamflow-gaging stations, only this time the flow contributions were analyzed by month. The purpose of this analysis was to show the relative timing of the flow (fig. 17). During the open-water period, (May through September), the average inflow to Cook Inlet is approximately 224,000 ft^3/s, almost twice the average annual inflow (116,000 ft^3/s). The lowest inflow occurs in March (18,500 ft^3/s) and the highest inflow in July (303,000 ft^3/s).

Floods

Floods are extreme hydrologic events that can degrade water quality. The largest loads of many constituents from nonpoint sources occur during flooding. Floodwaters may scour gravels and deposit fine-grained sediment, which are processes detrimental to spawning beds for some fish species. Floods also wash juvenile fish out of the river. Recent declines in sockeye salmon harvests in Cook Inlet have been attributed to the 1995 flood on the Kenai River (Paul Ruesch, Alaska Department of Fish and Game, written commun., 1998). In the Cook Inlet Basin, annual high flows occur during the summer rainy season. Nearly all major floods in the Cook Inlet Basin have occurred during the period July to early October. The floods generally result from intense, warm rains that originate in the Pacific Ocean and move to the east or northeast. Floods can occur during snowmelt season (May–June) if the snowpack in the mountains is above average. Flooding also can be caused by the release of water from glacier-dammed lakes or ice jams.

The history of flooding in the Cook Inlet Basin is virtually unknown before the establishment of a network of streamflow-gaging stations in the late 1940's and early 1950's. Since 1949, four major floods have occurred in the Cook Inlet Basin—in 1971, 1986, 1989, and 1995. These floods covered large areas of the basin and caused considerable property damage.

Flood of 1971—In May 1971, snow cover was 150 percent of average along the Alaska Range (Lamke, 1972). Below-normal air temperatures in May and June delayed

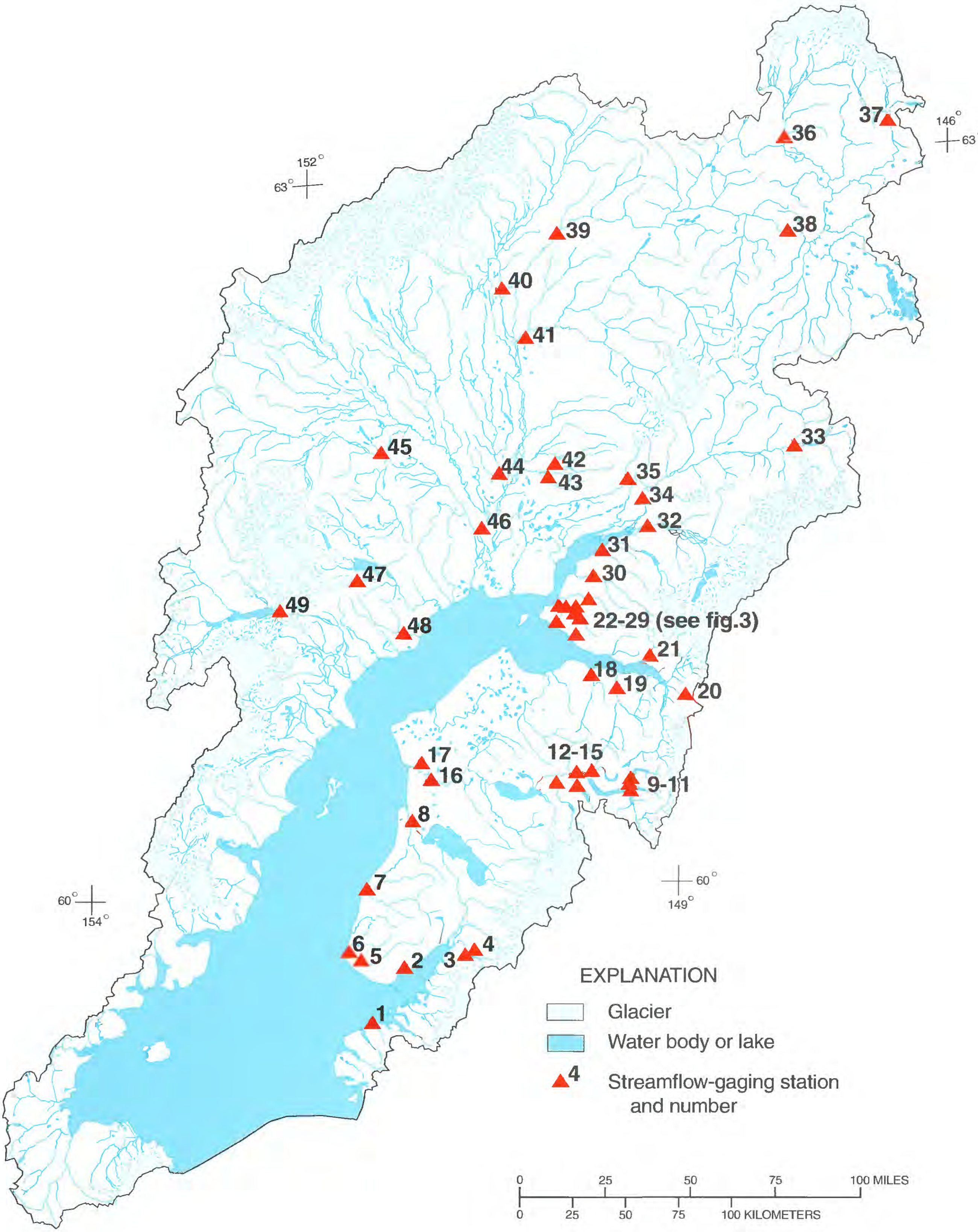


Figure 16. Location of streamflow-gaging stations with 10 or more years of record in the Cook Inlet Basin, Alaska (see table 2 for station names and additional information).

Table 2. Streamflow-gaging stations with 10 or more years of record in the Cook Inlet Basin, Alaska

[mi^2, square mile]

Map No. (fig. 16)	USGS station No.	Name	Drainage area (mi^2)	Period of record	Map No. (fig. 16)	USGS station No.	Name	Drainage area (mi^2)	Period of record
1	15238820	Barabara Creek near Seldovia	20.7	1972-92	26	15275000	Chester Creek at Anchorage	20.0	1958-76
2	15239500	Fritz Creek near Homer	10.4	1967-70 1986-92	27	15275100	Chester Creek at Arctic Boulevard at Anchorage	27.2	1966-86 1987-93
3	15239000	Bradley River near Homer	[a]54	1957-1990	28	15276000	Ship Creek near Anchorage	90.5	1946-
4	15239050	Middle Fork Bradley River near Homer	9.25	1979-	29	15276570	Ship Creek below Power Plant at Elmendorf Air Force Base	115	1971-81
5	15239900	Anchor River near Anchor Point	137	1965-73 1979-86	30	15277100	Eagle River at Eagle River	192	1966-81
6	15240000	Anchor River at Anchor Point	224	1953-66	31	15277410	Peters Creek near Birchwood	87.8	1973-83
7	15241600	Ninilchik River at Ninilchik	131	1963-85	32	15281000	Knik River near Palmer	1,180	1960-88 1992
8	15242000	Kasilof River near Kasilof	738	1949-70	33	15282000	Caribou Creek near Sutton	289	1955-78
9	15244000	Ptarmigan Creek at Lawing	32.6	1947-58	34	15284000	Matanuska River at Palmer	2,070	1949-73 1985-86
10	15246000	Grant Creek near Moose Pass	44.2	1947-58	35	15290000	Little Susitna River near Palmer	61.9	1948-
11	15248000	Trail River near Lawing	181	1947-74 1975-77	36	15291000	Susitna River near Denali	950	1957-66 1968-86
12	15254000	Crescent Creek near Cooper Landing	31.7	1949-66	37	15291200	Maclaren River near Paxson	280	1958-86
13	15258000	Kenai River at Cooper Landing	634	1947-	38	15291500	Susitna River near Cantwell	4,140	1961-72 1980-86
14	15260000	Cooper Creek near Cooper Landing	31.8	1949-59	39	15292000	Susitna River at Gold Creek	6,160	1949-96
15	15264000	Russian River near Cooper Landing	61.8	1947-54	40	15292400	Chulitna River near Talkeetna	2,570	1958-72 1980-86
16	15266300	Kenai River at Soldotna	2,010	1965-	41	15292700	Talkeetna River near Talkeetna	2,006	1964-
17	15266500	Beaver Creek near Kenai	51	1968-78	42	15294005	Willow Creek near Willow	166	1978-93
18	15267900	Resurrection Creek near Hope	149	1968-86	43	15274010	Deception Creek near Willow	48.0	1978-85
19	15271000	Sixmile Creek near Hope	234	1979-90	44	15294100	Deshka River near Willow	592	1979-86
20	15272280	Portage River at Lake Outlet near Whittier	40.5	1989-	45	15294300	Skwentna River near Skwentna	2,250	1960-82
21	15272550	Glacier Creek at Girdwood	58.2	1965-78	46	15294350	Susitna River at Susitna Station	19,400	1975-93
22	15273900	South Fork Campbell Creek at Canyon Mouth near Anchorage	25.2	1967-79	47	15294410	Capps Creek below North Capps Creek near Tyonek	10.5	1979-85
23	15274000	South Fork Campbell Creek near Anchorage	30.4	1947-71	48	15294450	Chuitna River near Tyonek	131	1976-86
24	15274300	North Fork Campbell Creek near Anchorage	13.4	1974-84	49	15294500	Chakachatna River near Tyonek	1,120	1959-72
25	15274600	Campbell Creek near Spenard	69.7	1966-93					

[a]In the summer 1990, additional water was diverted into the basin, which changed the current drainage area to about 65 mi^2.

Table 3. Relative flow contributions from hydrologic units to Cook Inlet, Alaska

[mi^2, square miles; ft^3/s; cubic feet per second]

Hydrologic unit (Drainage area)	Map No. (fig. 16)	USGS station No.	Name	Drainage area (mi^2)	Percent of hydro-logic unit	Average discharge (ft^3/s)	
						Stream	Drainage area (estimated)
Susitna River Basin (area: 20,752 mi^2)	35	15290000	Little Susitna River near Palmer	61.9	<1	206	
	46	15294350	Susitna River at Susitna Station	19,400	93	50,400	
			Total	*19,462*	*94*	*50,606*	*54,000*
Anchorage/ Matanuska Area (area: 4,732 mi^2)	20	15272280	Portage River at lake outlet near Whittier	40.5	<1	818	
	21	15272550	Glacier Creek at Girdwood	58.2	<1	265	
	27	15275100	Chester Creek at Arctic Blvd.	27.2	<1	20	
	25	15274600	Campbell Creek near Spenard	69.7	<1	68	
	28	15276000	Ship Creek near Anchorage	90.5	<1	144	
	30	15277100	Eagle River at Eagle River	192	4	528	
	31	15277100	Peters Creek near Birchwood	87.8	<1	119	
	32	15281000	Knik River near Palmer	1,180	25	6,920	
	34	15284000	Matanuska River at Palmer	2,070	43	3,810	
			Total	*3,816*	*81*	*12,692*	*16,000*
Kenai Peninsula (area: 6,568 mi^2)	1	15238820	Barabara Creek near Seldovia	20.7	<1	106	
	3	15239000	Bradley River near Homer	54	<1	443	
	6	15240000	Anchor River at Anchor Point	224	3	224	
	7	15241600	Ninilchik River at Ninilchik	131	2	107	
	8	15242000	Kasilof River near Kasilof	738	11	2,385	
	16	15266300	Kenai River at Soldotna	2,010	31	5,950	
	18	15267900	Resurrection Creek near Hope	149	2	275	
	19	15271000	Sixmile Creek near Hope	234	4	902	
			Total	*3,561*	*55*	*10,392*	*19,000*
Western Cook Inlet (area: 7,273 mi^2)	48	15294450	Chuitna River near Tyonek	131	2	359	
	49	15294500	Chakachatna River near Tyonek	1,120	15	3,640	
	(a)	15294900	Paint River near Kamishak	205	3	1,270	
			Total	*1,456*	*20*	*5,269*	*26,000*
			Total for Cook Inlet Basin				***116,000***

[a]See figure 5 for location.

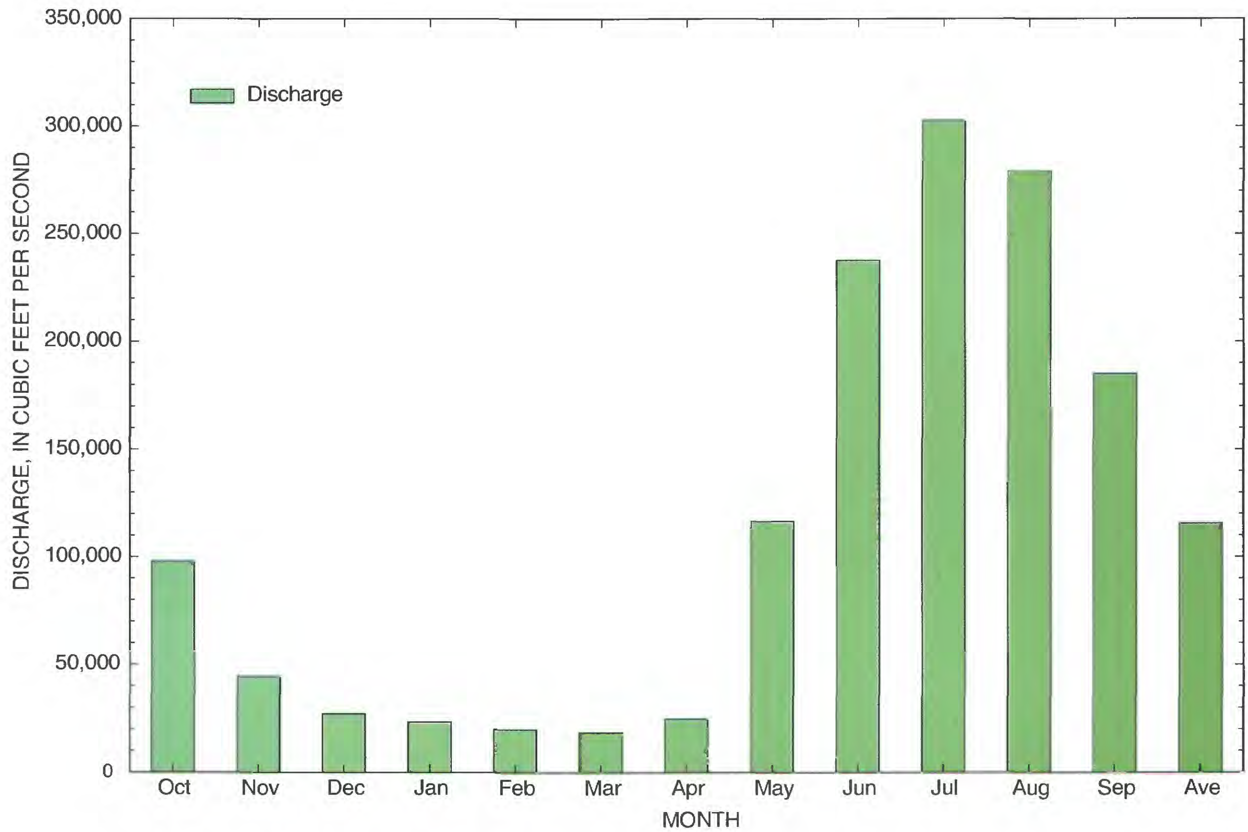


Figure 17. Monthly discharge of streams into Cook Inlet Basin, Alaska.

snowmelt until July and created antecedent conditions, such as saturated soils and above-average flows in streams, that were conducive to flooding. The flood of August 8-11, 1971, inundated areas northeast and west of Anchorage, the upper and middle Susitna River Basin, and part of the Matanuska River basin. Total damage was about $10 million, mostly to highways east of Palmer.

Flood of 1986—During the period October 9-11, 1986, a large North Pacific storm system moved onshore over southcentral Alaska, where it caused record-setting rainfall that led to widespread flooding (Lamke and Bigelow, 1988). In the Cook Inlet Basin, the hardest hit area was the lower Susitna River Valley—west of Talkeetna, southward from Talkeetna to Willow, and then southwest toward Tyonek. Peak discharges at several streams in this area (table 4) had recurrence intervals greater than 100 years. Total damage from the storm was estimated at $20 million.

Table 4. Summary of flood discharges for the flood of October 10-12, 1986, Cook Inlet Basin, Alaska

[ft^3/s, cubic feet per second: >, greater than; data from U.S. Geological Survey, 1988; --, not shown on map]

Map No. (fig. 16)	USGS station No.	Name	Peak discharge (ft^3/s)	Recurrence interval (years)
41	15292700	Talkeetna River near Talkeetna	75,700	40
--	15292800	Montana Creek near Montana	15,300	>100
42	15294005	Willow Creek near Willow	12,000	50
--	15294025	Moose Creek near Talkeetna	5,790	100
44	15294100	Deshka River near Willow	48,000	>100
45	15294300	Skwentna River near Skwentna	69,000	100
46	15294350	Susitna River at Susitna Station	312,000	40
47	15294410	Capps Creek below North Capps Creek near Tyonek	>1,200	>100
48	15294450	Chuitna River near Tyonek	>10,000	>100

Flood of 1989—Major flooding occurred in southcentral Alaska in 1989. A new 24-hour rainfall record of 4.12 in. was set at the National Weather Service station at Anchorage International Airport for the period ending at 10:00 a.m. on August 26; nearly 6 in. of rain was measured in the storm period of August 25-27 (Larry Rundquist, National Weather Service, oral commun., 1998). Two streams in the Anchorage area, Campbell Creek and Chester Creek (fig. 3), had peak discharges 3.2 and 2.4 times, respectively, as large as their prior record peak discharges. Although the true recurrence interval of the peak discharges at these two sites is unknown because of ongoing development in their respective drainages, most likely the recurrence interval was greater than 100 years. Additionally, Ship Creek (fig. 3), another undeveloped Anchorage stream had a recurrence interval of 100 years. Outside Anchorage, the Knik River (fig. 5) had a peak discharge of 84,000 ft^3/s, approximately a 100-year recurrence. Damage was estimated at $10 million, mostly from inundation of residences.

Flood of 1995—Remnants of Tropical Storm Oscar struck southcentral Alaska on September 19-21, 1995. Flood damage was reported along the Skwentna River in Skwentna (map No. 45, fig. 16), along the Knik River (map No. 32) and several of its tributaries, along the Kenai River in Soldotna (fig. 4), and along Glacier Creeks in Girdwood (map No. 21). Eagle River (map No. 30), Peters Creek (map No. 31), Knik River (map No. 32), and Matanuska River (map No. 34) flow into Knik Arm of Cook Inlet. Peak flows for these streams were estimated to have been greater than the 100-year flood (table 5), yet streams in Anchorage did not overtop their banks. Damage estimates from the Kenai River flooding exceeded $10 million.

Other floods have occurred in the Cook Inlet Basin from ice jams and glacier-dammed breakouts. On August 11, 1971, the Chakachatna River near Tyonek (map No. 49, fig. 16) peaked at 470,000 ft^3/s. This peak was the result of the lateral erosion of a channel constriction at the outlet of Chakachamna Lake (fig. 7) formed by the leading edge of Barrier Glacier. After the flood, the lake level, which has a surface area of about 26 mi^2, dropped 14 ft. In the Kenai River Basin, a flood was caused by an outburst from Skilak Glacier at the head of Skilak Lake (fig. 4) and by subsequent ice jams downstream from the lake on January 18, 1969. The Kenai River also is subject to flooding from a glacier-dammed lake at the headwaters of the Snow River (fig. 4), which fails every 2 to 3 years (Post and Mayo, 1971). Nearly every year until 1966, the Knik River near Palmer (map No. 32, fig. 16) reached flood stage when glacier-dammed Lake George failed, causing an outburst flood.

Table 5. Summary of flood discharges during floods in September 1995, Cook Inlet Basin, Alaska

[ft^3/s, cubic feet per second; <, less than; >, greater than; data from U.S. Geological Survey, 1996; --, not shown on map]

Map No. (fig. 16)	USGS station No.	Name	Peak discharge (ft^3/s)	Recurrence interval (years)
4	15239050	Middle Fork Bradley River near Homer	1,470	100
16	15266300	Kenai River at Soldotna	42,200	100
--	15272530	California Creek at Girdwood	106	50
--	15276000	Ship Creek near Anchorage	1,890	50
30	15277100	Eagle River at Eagle River	14,000	>100
31	15277410	Peters Creek near Birchwood	5,000	>100
32	15281000	Knik River near Palmer	152,000	>100
34	15284000	Matanuska River at Palmer	46,000	<100

Droughts

Like floods, droughts also are extreme hydrologic events that can degrade water quality. Droughts or deficit streamflow in Alaska primarily affect anadromous fish, which may not have sufficient streamflow to migrate upstream to spawn, or affect the eggs after spawning, which may not survive if they are exposed by decreasing stream levels. During low flows, water temperatures of streams tend to increase and concentrations of dissolved oxygen tend to decrease. Long periods of deficit rainfall commonly lead to declines in ground-water levels, which, in turn, decrease baseflow of streams, decrease available supply from small-yield wells, and lower water levels in recreational lakes.

In the Cook Inlet Basin, annual low flow occurs during the winter when there is no surface runoff and inflow is primarily from ground water. During the runoff season, discharge is higher than in the winter period even if snowfall and rainfall are below average. In addition, glacier-fed streams add icemelt as input to a stream. Thus, assigning a time period as a drought is somewhat subjective. An approach used by Lamke (1991), which analyzes the departure of the annual discharge from the long-term mean, provides a good indication of the trend of streamflow. By analyzing the streamflow at four long-term gaging stations, three droughts or periods of deficit flow were identified in the Cook Inlet Basin since 1949: 1968–71, 1972–76, and 1995–96.

Drought of 1968 to 1971—This drought resulted from severe deficits in streamflow in the Cook Inlet Basin outside the Maritime Climate Zone (fig. 6). A more severe short-term drought in 1969 is included in this drought period. The drought ended in 1971 when high flows began in July 1971 and by the flood of August 8-11, 1971 (fig. 18).

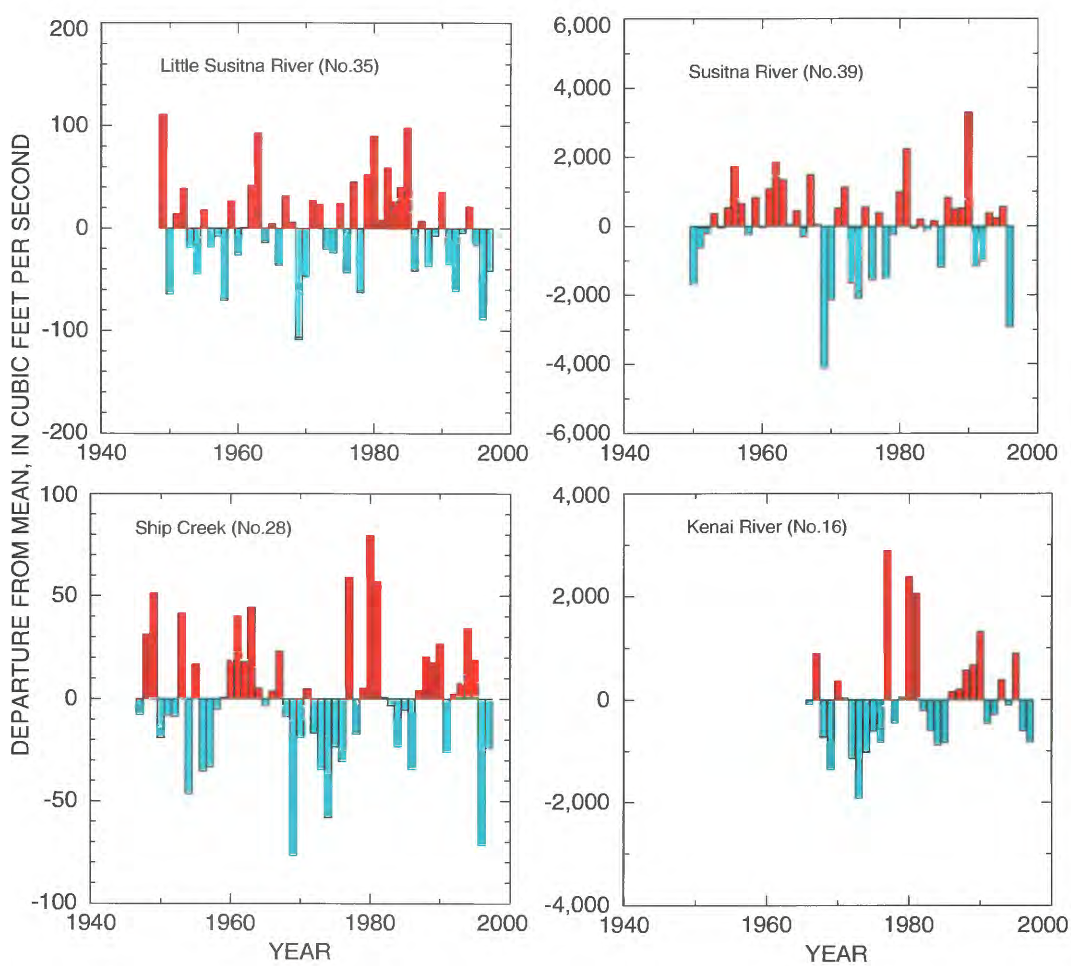


Figure 18. Departure from average discharge for several long-term streamflow-gaging stations in the Cook Inlet Basin, Alaska (see figure 16 for locations).

Drought of 1972 to 1976—This drought resulted from severe flow deficits in southcentral Alaska streams in the high-altitude areas of the Kenai Peninsula and the Anchorage vicinity. Deficits in the most affected streams ranged from 60 to 88 percent of average flow.

Drought of 1995 to 1996—The winter of 1995-96 was one of the lowest snowfall years; the snowpack at the end of March ranged from 37 percent to 70 percent of normal. The average streamflow for June 1996 at many streams was the lowest for their period of record. The Miller's Reach fire near Big Lake in 1996 spread quickly and became the worst fire in terms of monetary damage in Alaska history. This probably happened because of the extremely dry antecedent conditions. For the year, the flow deficits at most of the sites were only second to the deficits of 1969. Flow deficits continued through water year 1997, which may indicate another prolonged drought period.

Effects from Volcanic Eruptions

Volcanic eruptions disturb watersheds primarily by depositing rock, debris, and ash on land or directly in the water and by substantially increasing the water flow and temperature in local rivers and lakes. Deposits of material in the watershed can accumulate in streams and impede movement of fish or create high concentrations of suspended sediment that can be lethal to fish. Increases in streamflow generated by melting of snow and ice on a volcano can scour streambeds where salmon have placed their eggs, or debris moving in the stream can be deposited over the spawning areas and incubating eggs can suffocate. Subsequent high-flow velocities greater than about 6 ft/s can wash juvenile salmonids downstream before they have developed sufficiently. Extreme temperature increases resulting from hot volcanic material entering a stream can kill incubating eggs, developing fry, or mature fish.

Four volcanoes are located in the Cook Inlet Basin: Mt. Spurr, Redoubt, Iliamna, and Augustine (fig. 5). These volcanoes are part of an arc of volcanoes that extends from upper Cook Inlet along the Aleutian Islands. Coastal streams that are found along the volcanoes and drain into Cook Inlet support one of the most productive salmon fisheries in the world. Although marine survival and commercial harvest are the primary factors most often considered as threats to fisheries, the cumulative loss of spawning and rearing habitats resulting from volcanic activity could also threaten this resource.

The two most recent eruptive periods occurred in 1989–90 when Redoubt was active and in 1992 when Mt. Spurr was active. For these two eruptions, flow estimates of the affected rivers were made. Comparing the estimated flows of the Drift River and Chakachatna River to the estimated 100-year flood (table 6) indicates the magnitude of floods caused by volcanic eruptions. Although no fishery data are available to determine the magnitude of losses in these two rivers, most likely all fish present in the rivers or in spawning beds were substantially affected. Although eruptions may be infrequent when compared with the frequency of floods and droughts, the time required for a watershed to recover from the effects of a volcanic eruption may be quite lengthy (50–100 years). Thus, even when eruptions in the Cook Inlet Basin are separated by many years, recovery periods will likely overlap.

Table 6. Magnitude of floods from eruptions of Redoubt and Mt. Spurr Volcanoes, Alaska

[ft^3/s, cubic feet per second; data from Dorava and Meyer (1994) and Meyer and Trabant (1995)]

River (and volcano) (fig. 5)	100-year flood estimate (ft^3/s)	Date of eruption	Estimated peak discharge (ft^3/s)
Drift River (Redoubt)	19,100	12-15-89	640,000 to 800,000
		01-02-90	420,000 to 2,100,000
		02-15-90	350,000 to 880,000
		03-14-90	88,000
		04-15-90	35,300
Chakachatna River (Mt. Spurr)	26,500	06-27-92	70,600

Water Quality

The quality of surface water in rivers and streams of the Cook Inlet Basin is affected by both natural and anthropogenic factors. Natural factors that affect stream-water quality include climate, ecology, physiography, geology, and soil type. Anthropogenic factors in the Cook Inlet Basin include runoff from urban areas, timber-harvested areas, mining, and accelerated bank erosion from intense recreational use. The present discussion is limited to suspended sediment, alkalinity, dissolved solids, and the nutrient phosphorus.

Suspended sediment—Suspended sediment in streams and rivers is the result of erosion, which can occur naturally, or can be accelerated by land-cover disturbances such as mining and logging. Elevated suspended-sediment concentrations can adversely affect aquatic life by covering fish spawning sites or altering habitat of benthic organisms. Suspended sediment in urban runoff also is likely to have contaminants adsorbed onto it.

Concentrations of suspended sediment from various streams and rivers in the Cook Inlet Basin show considerable variation (fig. 19). Much of this variation can be attributed to (1) the presence or absence of glaciers in the basin, (2) the presence of lakes that can act as sediment traps, and (3) the relatively low concentrations during winter or low-flow conditions. The Susitna, Knik, and Matanuska Rivers all have glaciers in their basins and have the highest median values and the largest variability of suspended-sediment concentration. The Chakachatna, Kasilof, and Kenai Rivers all have large lakes in their basins (fig. 16) that trap much of the suspended sediment. Thus, median suspended-sediment concentrations for these three rivers are low compared with concentrations for glacier-fed rivers without lakes. Chester Creek, a small urbanized stream in the Anchorage area, does exhibit higher suspended-sediment concentrations than the river basins that contain lakes. This increase in suspended sediment may be due to the effects of residential development in the basin (Brabets, 1987).

Annual sediment loads for the Susitna River (Knott and others, 1987), Knik River, and Matanuska River (U.S. Geological Survey, 1954-98) have been determined. In addition, suspended-sediment samples have been collected at three other major inflows into Cook Inlet (Kenai, Kasilof, and Chakachatna Rivers). A method described by Colby (1956) was used to compute the annual suspended-sediment loads for these three rivers. This method requires defining a relation between instantaneous sediment discharge and water discharge and applying this relation to daily discharge. This computation indicates that the annual suspended-sediment load to Cook Inlet is more than 44 million tons (table 7). The largest load is from the Susitna River, followed by the Knik and Matanuska Rivers. Because the correlation between suspended-sediment discharge and water discharge is high, most of the load is transported during the high runoff period, May through September (fig. 20).

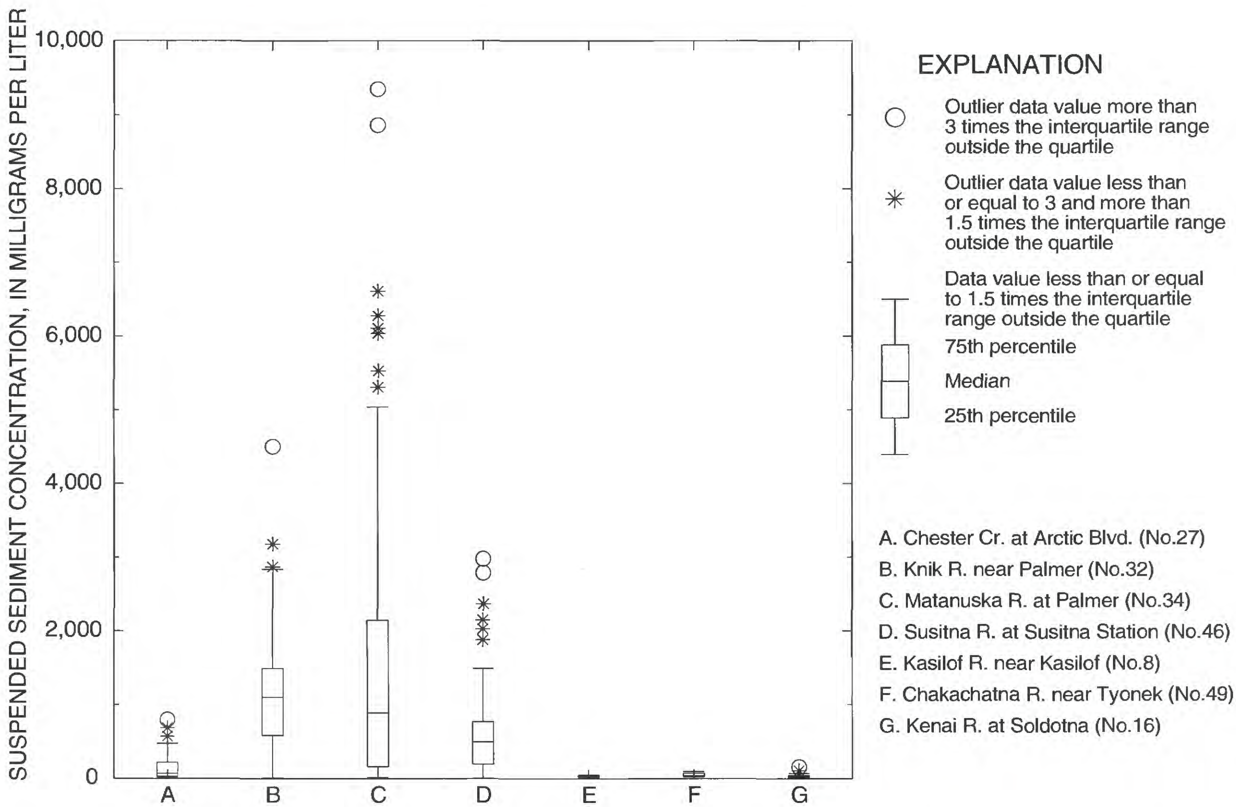


Figure 19. Boxplots of suspended sediment for seven rivers in the Cook Inlet Basin, Alaska (see figure 16 for locations).

Table 7. Annual suspended-sediment loads for major rivers in the Cook Inlet Basin, Alaska

Map No. (fig. 16)	Area and river	Drainage area (square miles)	Annual sus. sed. load (tons)	Remarks
	Susitna River Basin			
46	Susitna River at Susitna Station	19,400	29,200,000	Data from Knott and others (1987)
	Anchorage/Matanuska Area			
34	Matanuska River at Palmer	2,070	6,600,000	Average of 1958-66 water years (U.S. Geological Survey, 1959-67)
32	Knik River near Palmer	1,180	7,500,000	Average of 1962-66 water years (U.S. Geological Survey, 1963-67)
	Kenai Peninsula			
16	Kenai River at Soldotna	2,010	138,000	Computed by flow-duration technique
8	Kasilof River near Kasilof	738	869,000	Computed by flow-duration technique
	Western Cook Inlet			
49	Chakachatna River near Tyonek	1,120	143,000	Computed by flow-duration technique
	Total		*44,450,000*	

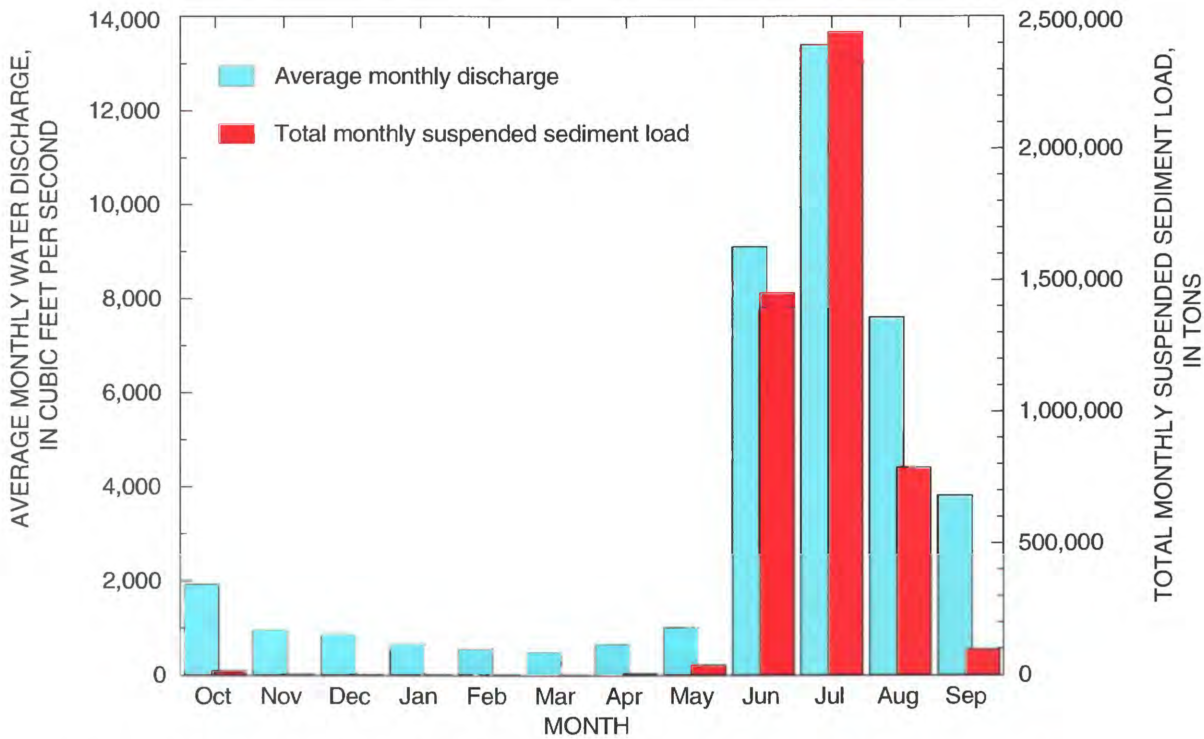
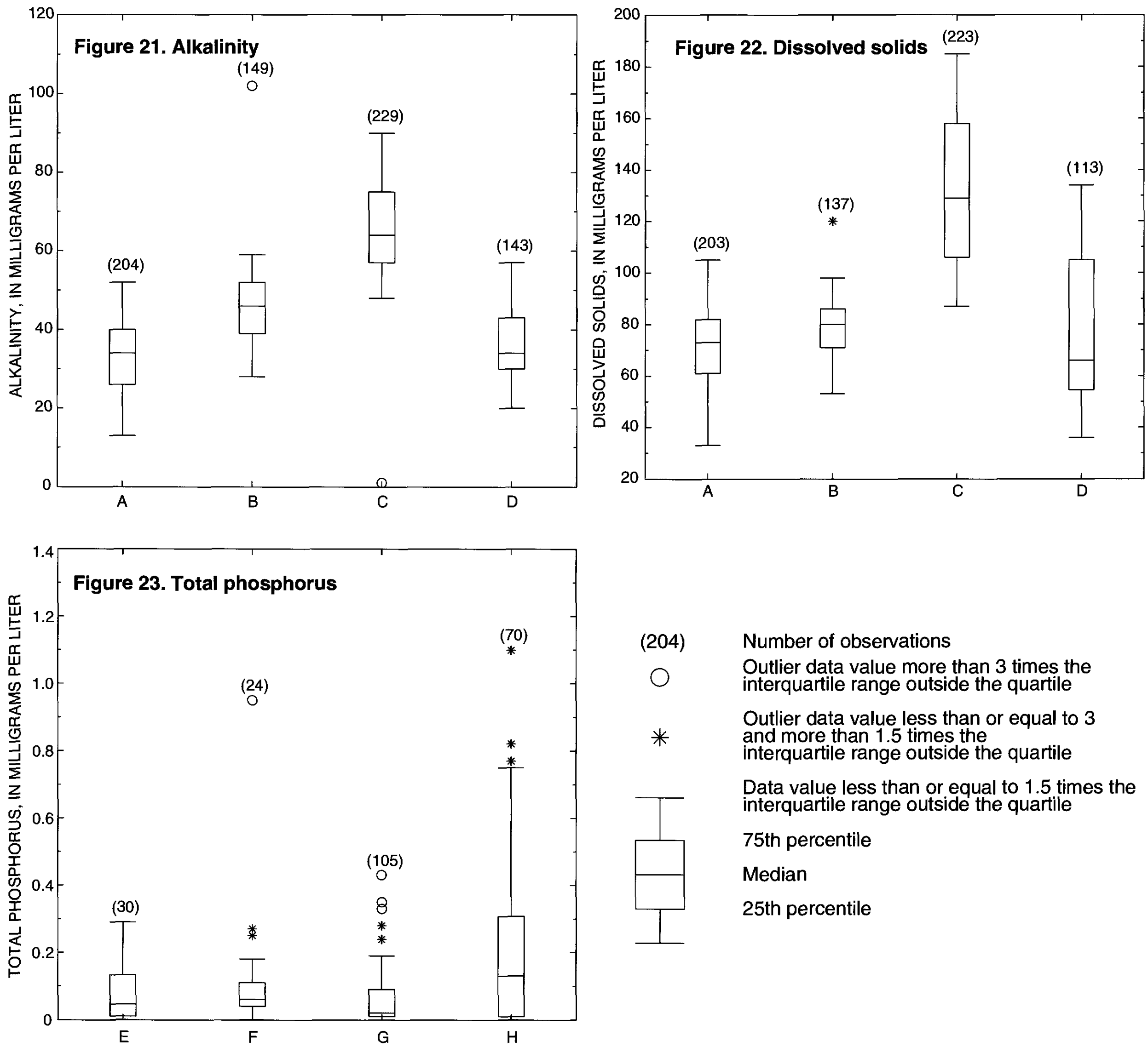


Figure 20. Monthly suspended-sediment load and water discharge for Matanuska River, Alaska. (Data from USGS annual data reports.)

Alkalinity—Alkalinity is a measure of the quantity of acid-neutralizing substances (buffering capacity) and can be affected by the geologic setting, wastewater discharges, and runoff from areas that have been mined. Highly alkaline water can be unsuitable for some uses. Data for alkalinity of four streams having a sufficient number of water-quality samples were summarized (fig. 21). The data indicated that the Matanuska River drainage may have slightly higher alkalinity than streams in the other parts of the Cook Inlet Basin. The difference may be due to the large amount of sedimentary rocks in the basin.

Dissolved solids—Dissolved solids in a stream or river usually are the result of rock weathering and also may be influenced by urban runoff, irrigation runoff, or industrial discharge. In sufficient quantity, dissolved solids can cause water to be unsuitable for public supply and harmful to aquatic organisms. In the Cook Inlet Basin, among streams for which dissolved-solids data are available, the Matanuska River has a higher median value than other streams (fig. 22). Again, this characteristic may be due to the large amount of sedimentary rock in the basin.

Phosphorus —This essential nutrient may be elevated to undesirable levels by a nonpoint source such as urban runoff or agriculture, and by a point source of wastewater discharge. In sufficient quantity, phosphorus can cause algal blooms and excessive growth of aquatic plants in bodies of water. It also can cause water to be unsuitable for public supply. Phosphorus data are available for only a few sites in the Cook Inlet Basin (fig. 23). Studies of two urban sites in Anchorage (Brabets and Wittenberg, 1983; Brabets, 1987) have shown increases in total phosphorus concentrations during rainfall-runoff periods. At one site in the Susitna River Basin (the Susitna River at Susitna Station) phosphorus concentrations exhibit more variation, which may be due to the high correlation between phosphorus and suspended-sediment concentration.



EXPLANATION

A. Anchor River near Anchor Point (No.5)
B. Ship Creek near Anchorage (No.28)
C. Matanuska River at Palmer (No.34)
D. Talkeetna River near Talkeetna (No.41)
E. Campbell Creek near Spenard (No.25)
F. Chester Creek at Arctic Blvd at Anchorage (No.27)
G. Talkeetna River near Talkeetna (No.41)
H. Susitna River at Susitna Station (No.46)

Figure 21. Boxplots of alkalinity for four rivers in the Cook Inlet Basin, Alaska.
Figure 22. Boxplots of dissolved solids for four rivers in the Cook Inlet Basin, Alaska.
Figure 23. Boxplots of total phosphorus for four rivers in the Cook Inlet Basin, Alaska.
(See figure 16 for locations.)

Ground Water

Residents of the Cook Inlet Basin were using ground water from springs, domestic wells, and public-supply wells long before the USGS began collecting ground-water information in the 1950's. Well-drilling companies operating in most of the major communities have drilled thousands of wells to supply the needs of individual homes, businesses, and municipal water systems. Most of these wells, however, are clustered near the major communities. Relatively little is known about aquifers in the unpopulated areas, where ground-water availability must be inferred from the surficial geology, drainage density, baseflow in streams, and other indirect methods. The geometry of aquifers is known only in parts of the Anchorage, Kenai, and Nikiski (fig. 2) areas.

The highest rate of pumping occurs in the central part of the basin, in the Anchorage, Kenai, and Nikiski areas (fig. 2). In these areas, the main production is from multiple aquifers located in outwash deposits distal from the terminal moraine of a major glacial advance. The aquifers are separated by confining units of tidal and marine silt and clay. Similar geologic conditions occur in the Point MacKenzie area (fig. 24), an area where only shallow wells have been drilled and where subsurface conditions are not well defined.

In the major river valleys of the basin, current and ancestral rivers created broad alluvial plains and ice-marginal outwash deposits. Some of these outwash deposits are in terraces and benches as much as several hundreds of feet above the valley floors. These deposits provide abundant water to many communities and individual residences.

Underlying much of the basin are Tertiary-age sandstones of the Kenai Group. Although these are not productive aquifers, in the southern part of the Kenai Peninsula they do provide enough water for many homes and small businesses. Exploratory drilling in western Cook Inlet has indicated that coal beds are among the best producers of ground water.

In the foothills and mountain ranges of Cook Inlet Basin, ground water in small quantities is obtained from low-grade metamorphic rocks. Most of the ground water produced from metamorphic bedrock aquifers is withdrawn by domestic wells in hillside areas of Anchorage and Eagle River (fig. 24).

Anchorage Lowlands Aquifers

The Anchorage lowlands are located on the eastern flank of the Cook Inlet sedimentary basin, a deep structural trough filled with many thousands of feet of Mesozoic- and Cenozoic-age (Tertiary) sedimentary deposits (Barnwell and others, 1972). Except on steep hillslopes and in high mountain areas, these deposits are overlain by glacial and alluvial deposits that reach thicknesses greater than 1,000 ft under the western part of Anchorage. These glacial and alluvial deposits form the aquifer system that supplies a large part of the water used by Anchorage consumers. The northern boundary of the lowlands aquifer system is generally accepted as the Elmendorf Moraine (fig. 3). This moraine lies north of Ship Creek on Elmendorf Air Force Base and Fort Richardson, and extends across Cook Inlet in the area between Mt. McKinley and Wasilla. Ground water in the Municipality of Anchorage is available north of the Elmendorf Moraine, but in discontinuous, poorly defined glacial aquifers. Underlying much of the lowlands south of the moraine is an extensive confining layer, the Bootlegger Cove Formation (fig. 25), which consists of dense clayey silts (Updike and Ulery, 1986). This confining layer separates the upper unconfined aquifer from an underlying confined aquifer (fig. 25).

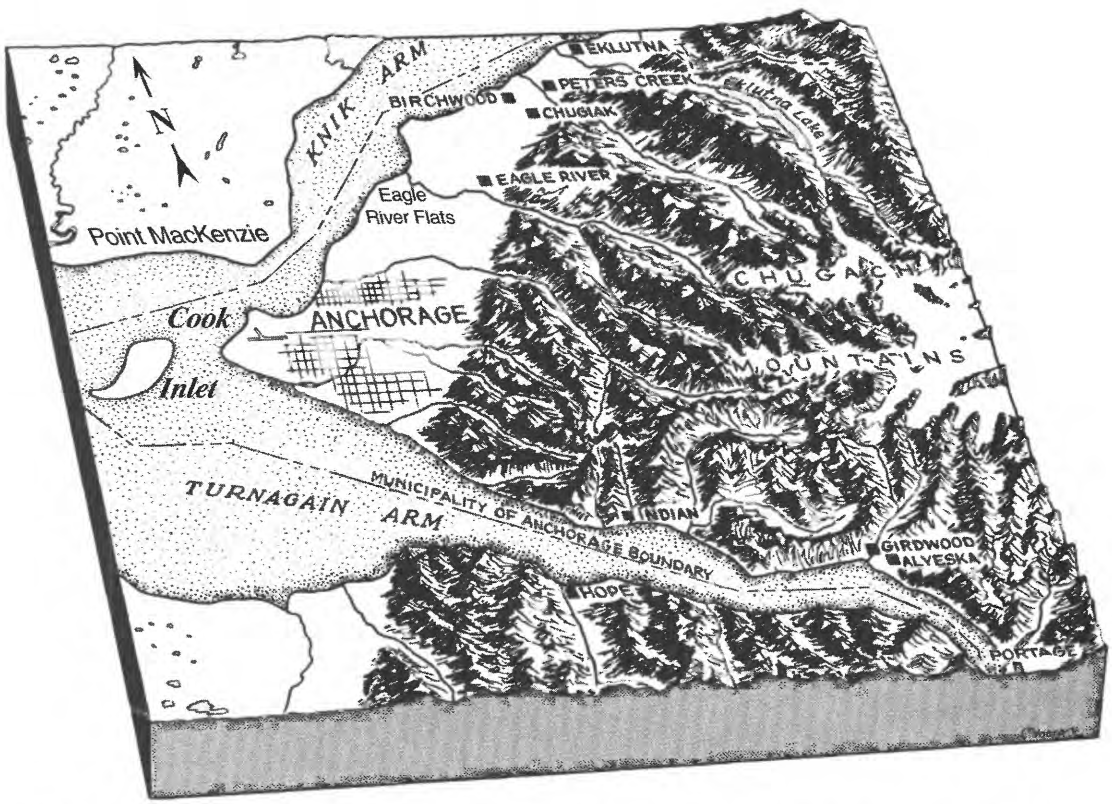


Figure 24. Location of geographic features in the Municipality of Anchorage area, Alaska.

Unconfined Aquifer

The unconfined aquifer is hydraulically connected to the many streams and lakes in Anchorage. Streams flowing from the mountains across alluvial fans lose a significant quantity of water to the aquifer. Ship Creek (fig. 3) loses more than 16 Mgal/d of water to the aquifer between the mountain front and the eastern boundary of Elmendorf Air Force Base (Barnwell and others, 1972). During the low-flow period of some winters, the creek loses all of its water to the aquifer and is dry near the eastern boundary of Elmendorf Air Force Base. Campbell Creek and its tributaries also provide large quantities of water to the unconfined aquifer as they cross their alluvial fans (fig. 25). This "recharge area" in which streams lose water to the aquifer was originally defined by Barnwell and others (1972). Some Anchorage residents, however, have incorrectly concluded that this specific "recharge area" is the only area of recharge. In fact, the unconfined aquifer is recharged over wide areas of Anchorage Bowl by direct infiltration of precipitation.

Downstream from the alluvial fans, the creeks gain water back from the aquifer. The aquifer discharges large quantities of water both to the creeks and to lakes, wetlands, and storm drains that ultimately flow to the creeks. Throughout the area below an altitude of about 200 ft in the Anchorage Bowl, there is virtually no point more distant than 1 mi from an area of ground-water discharge. The quantity of ground water being discharged can be estimated from streamflow measurements during periods of extreme low flow. During these periods, there is no overland runoff, and streamflow is sustained almost exclusively by aquifers discharging ground water to the streams. A commonly used baseflow statistic is

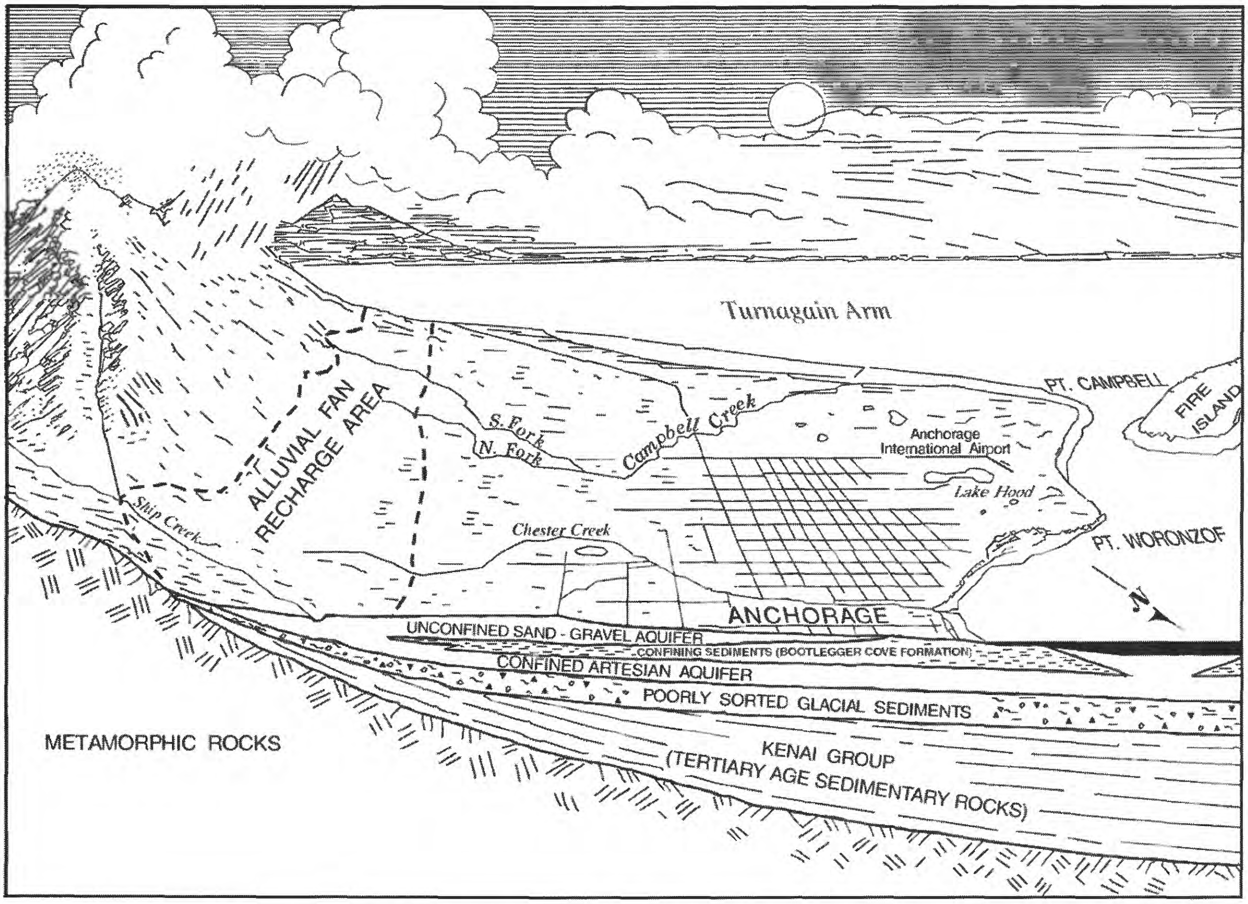


Figure 25. Sketch of subsurface conditions in the Anchorage area, Alaska (modified from Barnwell and others, 1972).

the 7-day, 10-year low flow ($Q_{7,10}$). This is the lowest flow that occurs for seven consecutive days with a recurrence interval of 10 years. In general, the annual average ground-water discharge can be safely assumed to exceed the $Q_{7,10}$. The $Q_{7,10}$ for only three Anchorage streams (table 8) totals almost 7 Mgal/d. This 7 Mgal/d does not include discharge from Fish Creek, Rabbit Creek, Little Rabbit Creek, Furrow Creek (fig. 3), and coastal areas, which collectively drain more that 30 percent of the Anchorage Bowl. Adjusting for these unmeasured areas, the discharge from the lowlands aquifers probably exceeds 10 Mgal/d.

The high density of points of ground-water discharge has great significance when interpreting the effects of pumping. Pumping from the unconfined aquifer “scavenges” local discharge. That is, it takes water that would have discharged to the stream had the pumping not intercepted it first. As a result of this scavenging of natural discharge, pumping does not produce significant drawdowns over large areas. Whether pumping from the underlying confined aquifer induces significant downward leakage through the confining layer cannot be readily deduced, because the leakage is small relative to the ability of the unconfined aquifer to capture water from streams and lakes.

Table 8. Baseflow in selected streams during late winter, Anchorage, Alaska

Map No. (fig. 3)	Streamflow-gaging station	Baseflow	
		Cubic feet per second	Gallons per day
25	Campbell Creek near Spenard (minus discharge at the mountain front)	5.0	3,230,000
27	Chester Creek at Arctic Boulevard at Anchorage	3.0	1,940,000
29	Ship Creek below Power Plant at Elmendorf Air Force Base	2.6	1,680,000
	Total	**10.6**	**6,850,000**

Confining Layer

The Bootlegger Cove Formation is more than 100 ft thick near the coast and becomes progressively thinner toward the mountain front. It vanishes along an approximate line extending from the middle of Fort Richardson to the south-southeast (fig. 3). The Bootlegger Cove Formation is bounded on the south and west by older morainal deposits through Point Woronzof and Point Campbell.

The clayey silts of the Bootlegger Cove Formation have a profound effect on the hydraulic conductivity of the Elmendorf Moraine. During the Elmendorf advance of the glacier that formerly filled Knik Arm, the glacier flowed southward and pushed up underlying sediments into a terminal moraine, the Elmendorf Moraine (fig. 26), that stretches from the mountain front, across Fort Richardson and Elmendorf Air Force Base, and continues on the west side of Knik Arm near Point MacKenzie (fig. 24). Where the underlying sediments included Bootlegger sediments, the clay and silt were incorporated into the moraine, creating a relatively impermeable moraine. Closer to the mountain front, however, the Bootlegger sediments are absent. In this area, the glacier incorporated only sorted outwash materials. The result is a single moraine that has two areas of pronounced differences in hydraulic conductivity. Near the boundary between Elmendorf Air Force Base and Fort Richardson, the moraine changes from a relatively impermeable ground-water barrier on the west to a highly transmissive aquifer on the east. A water-table map of the lower Ship Creek area (fig. 26) illustrates the effect of the moraine on directions of ground-water flow. In the eastern transmissive area, ground water recharged to the aquifer from Ship Creek flows through the moraine to discharge areas at Sixmile Lake and Otter Lake (fig. 26), and at Eagle River Flats (fig. 24) to the north. West of Fort Richardson, ground water recharged to the aquifer from Ship Creek returns to the creek near the mouth.

The water table map (fig. 26) is compiled from three sources mapped on widely separated dates. Elmendorf contours are from the U.S. Air Force (1998). Fort Richardson contours are from U.S. Army Corps of Engineers (1996). Contours south of Ship Creek are from Freethey (1976). The resulting compiled map is adequate to depict general flow directions, but it should not be construed as providing actual altitudes of the water table for any specific date.

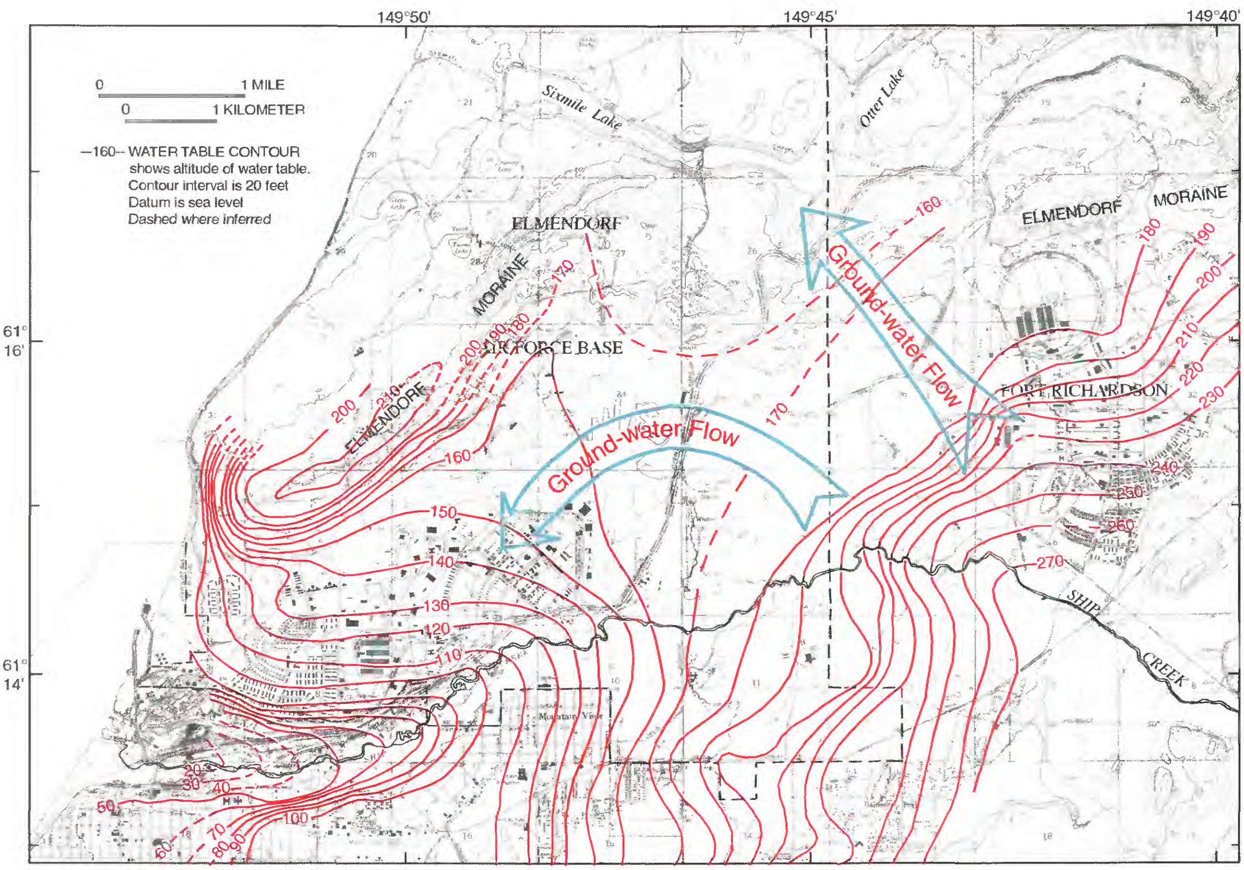


Figure 26. Water-table contours and directions of ground-water flow in Ship Creek Basin, Alaska. (Contours from Freethey, 1976; U.S. Army Corps of Engineers, 1996; and U.S. Air Force, 1998.)

Confined Aquifer

The confined aquifer below the Bootlegger Cove Formation historically has been the principal aquifer from which Anchorage municipal water utility has drawn as much as 10 Mgal/d. The aquifer extends over an area from Ship Creek to Turnagain Arm and at depths ranging from 100 to 300 ft beneath land surface. South of Dimond Boulevard (fig. 3), westward toward Point Woronzof and Point Campbell, however, the continuity of the aquifer is locally disrupted by significant confining units of poorly sorted glacial deposits. The aquifer also appears less stratified and more difficult to define.

The materials near the base of the confined aquifer generally consist of medium-to-fine sands that overlie medium-to-fine sandstone of the Kenai Group (fig. 25). It may not be possible to differentiate the two from information contained in typical water-well logs. Geophysical logs, however, may indicate an increase in density at the boundary, probably resulting from greater consolidation of the Tertiary-age sediments. Some interpretations of oilwell logs may also distinguish the Quaternary-Tertiary boundary, but the boundary is not routinely identified.

In recent years, the Municipality of Anchorage has increased its reliance on ground water following a temporary reduction in pumping in the early 1990's (fig. 27) when

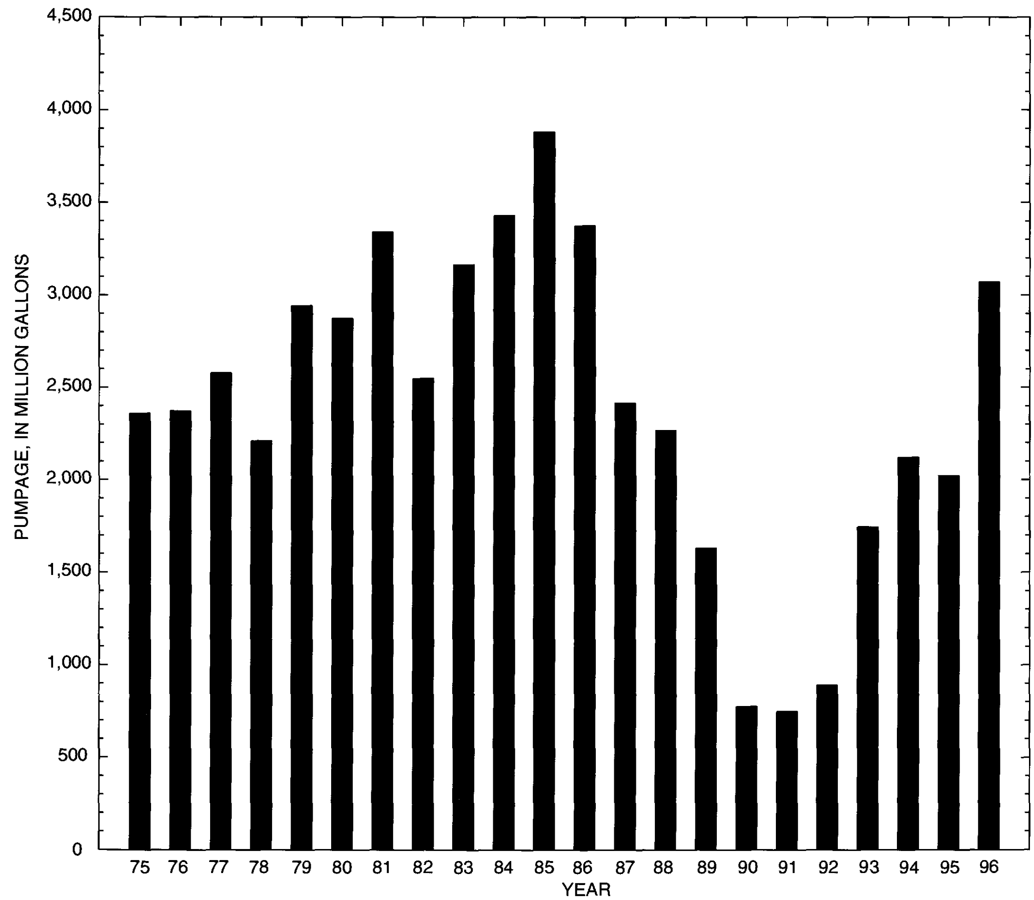


Figure 27. Ground-water pumpage data for 13 wells in the Municipality of Anchorage, Alaska water system. (Data from Anchorage Water and Wastewater Utility, written commun., 1998.)

Eklutna Lake (fig. 24) became a source of water supply. At its peak in 1985, the public-supply wells in Anchorage produced more than 10 Mgal/d from 13 wells in the municipality. During this time of peak production, the potentiometric surface of the confined aquifer was drawn down more than 50 ft.

Kenai Lowlands Aquifers

The coastal areas of the northern Kenai Peninsula near the communities of Kenai, Soldotna, and Nikiski (fig. 2) overlie aquifers that are geologically similar to those of Anchorage. That is, multiple aquifers of outwash deposits are separated by confining units of clayey silt deposited in ancestral Cook Inlet. An upper unconfined aquifer is hydraulically connected to the many lakes and streams in the area (Anderson and Jones, 1972).

The distribution of the aquifers has not been defined by drilling except in the populated areas in the immediate vicinity of the road network. The unexplored area includes the Kenai National Wildlife Refuge (fig. 1), which covers a large part of the northern Kenai Peninsula. By extrapolation from explored areas, however, the refuge likely is underlain by significant glacial aquifers.

Unconfined Aquifer

The last major advance of glaciers emanating from mountains in western Cook Inlet terminated at a moraine that trends southwest-northeast through Nikiski. Outwash from this and other glaciers entering the Kenai Lowlands deposited well-sorted sands and gravels that are the unconfined aquifer of the region. Most of the lowlands area was periodically inundated by marine waters of Cook Inlet. Fine-grained marine and tidal deposits commonly form the base of the unconfined aquifer.

The unconfined aquifer is the principal aquifer supplying water to thousands of domestic wells in the Kenai lowlands. It is generally not used, however, for the large industrial supplies in the Nikiski area nor for the municipal supply wells in Kenai and Soldotna. In the Nikiski area, early attempts to develop the unconfined aquifer for industrial water supplies created a drawdown of local lakes that was unacceptable to lakeside residents. Industries quickly converted to pumping the confined aquifers instead.

It is likely that pumping from the deeper aquifers does have some effect on the unconfined aquifer. This effect appears to be manifested as a reduction in outflow from some streams rather than a pronounced drawdown of the water table. For example, the outlet stream from Bernice Lake, about 1 mi east of Nikiski, largely has ceased to flow, except during brief periods of snowmelt or heavy precipitation.

In the Kenai-Soldotna area, the Kenai River has incised through the unconfined aquifer. At Kenai, the aquifer can be seen in outcrops along the river bluffs near the harbor. It appears as an unsaturated, buff-colored unit overlying the dark gray confining layer that is kept wet by water discharging from the aquifer above. Elsewhere in bluff exposures, the aquifer largely is covered by colluvium and not visible. Springs along the bluff, however, mark the contact between the unconfined aquifer and the confining layer.

Alluvium adjacent to the Kenai River, although saturated, is not a commonly used aquifer in the lower 10 mi of the river. In this area, the aquifer has been eroded by the river and is too thin over the confining layer to supply water to wells. Farther upstream, Kenai River alluvium and associated terrace deposits do provide water to wells.

Confining Layer

Except in the Nikiski industrial area, drilling has been inadequate to define accurately the thickness and lateral extent of the confining layer. In the Nikiski area, the confining layer is about 100 ft below land surface and appears to reflect topography (Nelson, 1981). The confining layer under the industrial area is leaky, and drawdowns in the confined aquifer stabilize within days by inducing leakage from the overlying unconfined aquifer. The upper confining layer appears to be only one of several confining units that separate multiple aquifers (fig. 28).

Upper Confined Aquifer

Where it has been explored, the upper confined aquifer is about 100 ft thick and is bounded on the bottom by a thick confining unit. It supplies much of the industrial water in the Nikiski area, about 5 Mgal/d.

The upper confined aquifer is recharged by downward leakage from the overlying unconfined aquifer. The aquifer loses water by discharge to Cook Inlet, by upward leakage to the unconfined aquifer, and by pumping. In spite of its ability to supply large quantities of water to the industrial area, it is not a universally productive aquifer. Several wells in the Nikiski area have penetrated fine-grained materials in the depth-equivalent interval of the upper confined aquifer.

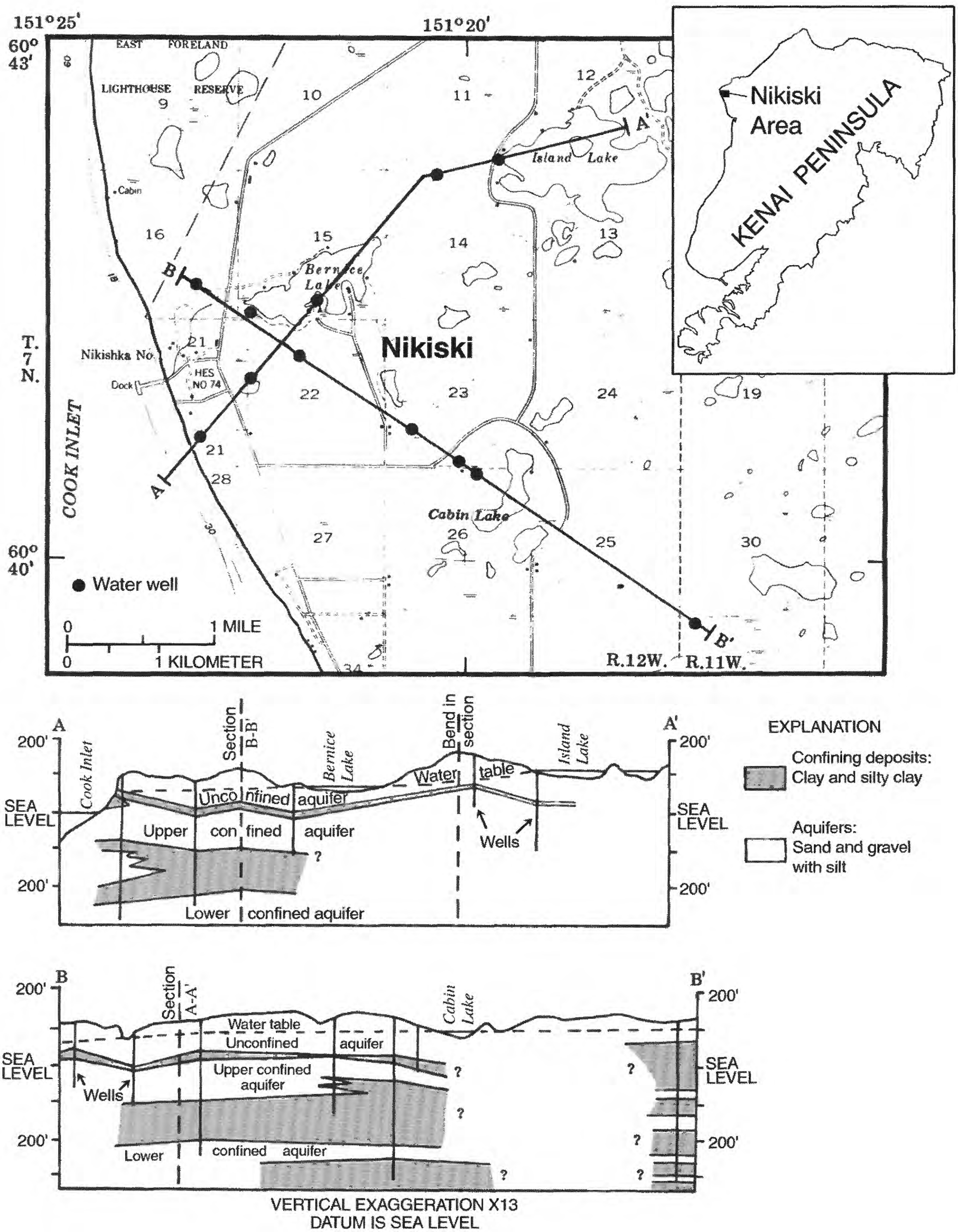


Figure 28. Geologic sections showing subsurface conditions in the Nikiski area, Alaska (modified from Nelson, 1981).

Deeper Aquifers and Confining Layers

Deeper units are undefined except in the immediate vicinity of the industrial pumping at Nikiski. In this area, a lower confined aquifer lies at depths greater than 300 ft below land surface and is separated from the upper confined aquifer by a 100-foot-thick layer of clayey silt (fig. 28). The water from the deep aquifer has naturally occurring organic compounds in concentrations that make the water less desirable for industrial use than the water from the upper confined aquifer. The deeper ground water is, therefore, used in lesser quantities.

Matanuska and Susitna Lowlands Aquifers

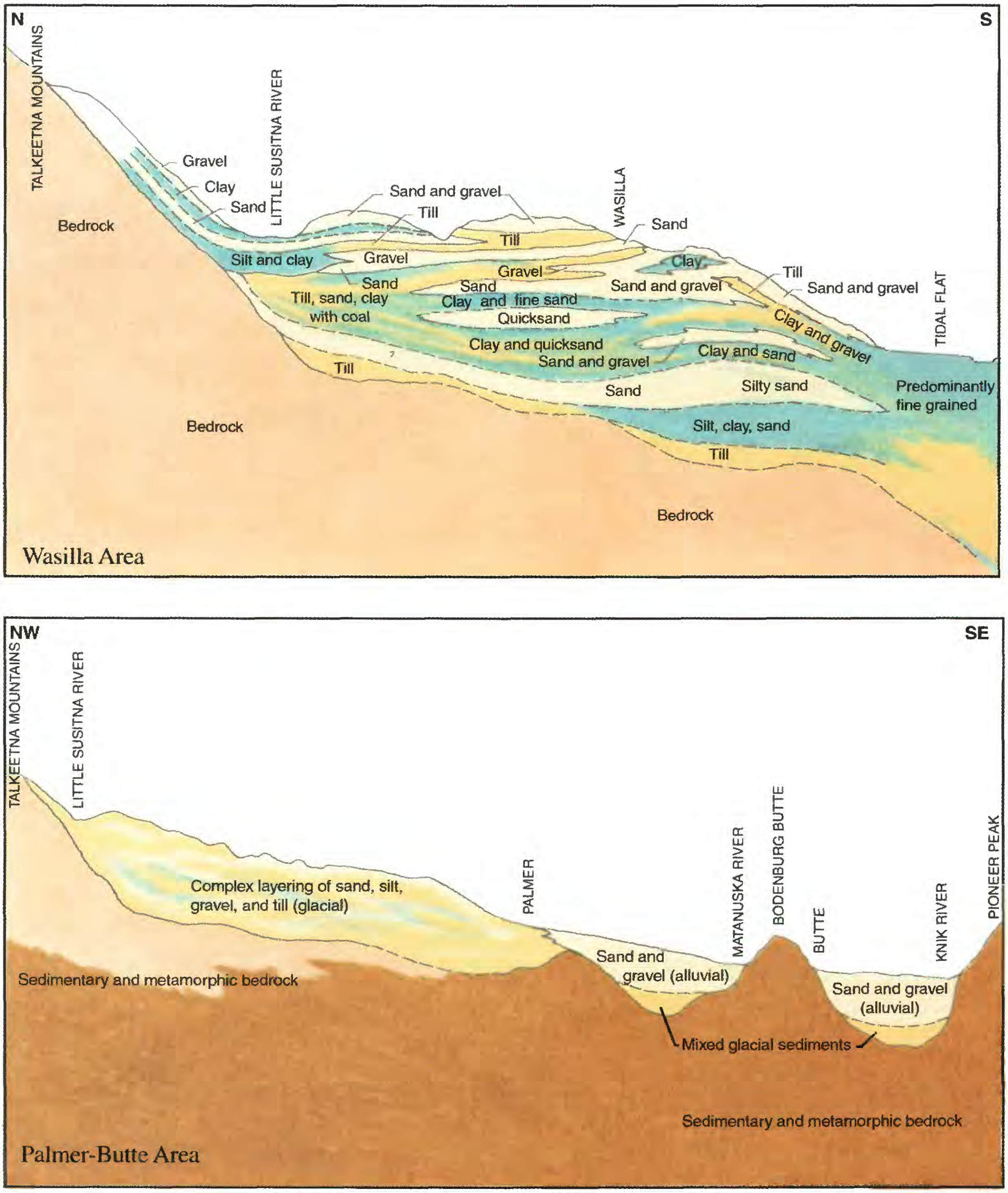
Aquifers in the lowlands of the Matanuska-Susitna Borough (commonly called "Mat-Su") (fig. 2) are not well characterized in the scientific literature. Feulner (1971) and Freethey and Scully (1980) described the general characteristics of the hydrogeology on the basis of available drillers' logs and maps of surficial geology. No regional ground-water exploration activities have been conducted, however, and no comprehensive compilations of available information are available.

Mat-Su aquifers commonly are contained in a veneer of glacial deposits overlying sedimentary and low-grade metamorphic bedrock (fig. 29). The glacial deposits are irregular in distribution and highly variable both in composition and in their ability to provide water to wells. The veneer of glacial deposits commonly thickens from the uplands towards the coast and the present channels of the Matanuska and Susitna Rivers. Thicknesses generally are less than 200 ft, although a few wells tap thicker deposits. A city-supply well in Palmer (fig. 1), for example, draws more than 500 gal/min from an aquifer at a depth of 624 ft below land surface.

In general, these glacial deposits supply adequate quantities of water for domestic wells. Locally they also may be capable of providing large quantities of water to industrial and municipal wells. Few high-capacity wells have been attempted, however, in the Mat-Su valley.

An area of particular concern to local residents is the Willow area (figs. 2 and 30), which is underlain by brackish or salty water within 100 ft of land surface. In addition to the wells shown in figure 30, several homeowners in the area southwest of Nancy Lake report salt water at a depth of about 50 ft, or about 168 ft above sea level. Along the Hatcher Pass Road, northeast of Willow, the salt water occurs at a depth of 75 ft, or about 180 ft above sea level. If this brackish water is from inundation by ancestral Cook Inlet, then the Willow area must have been uplifted more than 300 ft, the difference between these altitudes and the altitude of sea level 14,000 years ago (sea level of -140 ft attributed to Dan Mann in Péwé and Reger, 1983). This is somewhat greater than the 251 ft of isostatic uplift (subjected to equal pressure from every side) that Péwé and Reger postulated for Anchorage over the same time interval. Their estimates were based on the altitude of the top of the Bootlegger Cove Formation relative to sea level 14,000 years ago. An alternative source of the salt water is water that has been entrapped in the interstices of underlying sedimentary rock at the time of its deposition (connate water). Significant additional research would be required to determine the source.

Cutting across the Mat-Su glacier deposits are alluvial deposits of the present Knik, Matanuska, and Susitna Rivers. Although these rivers form broad alluvial valleys, the thickness of the alluvial deposits is probably not great. Gradual uplift of the land surface by isostatic rebound may contribute to incision of the rivers into underlying glacial deposits and limit the amount of aggradation of the flood plains.



VERTICAL SCALE GREATLY EXAGGERATED

Figure 29. Sketches of subsurface conditions in the Wasilla area and the Palmer-Butte area, Alaska (modified from Freethey and Scully, 1980).

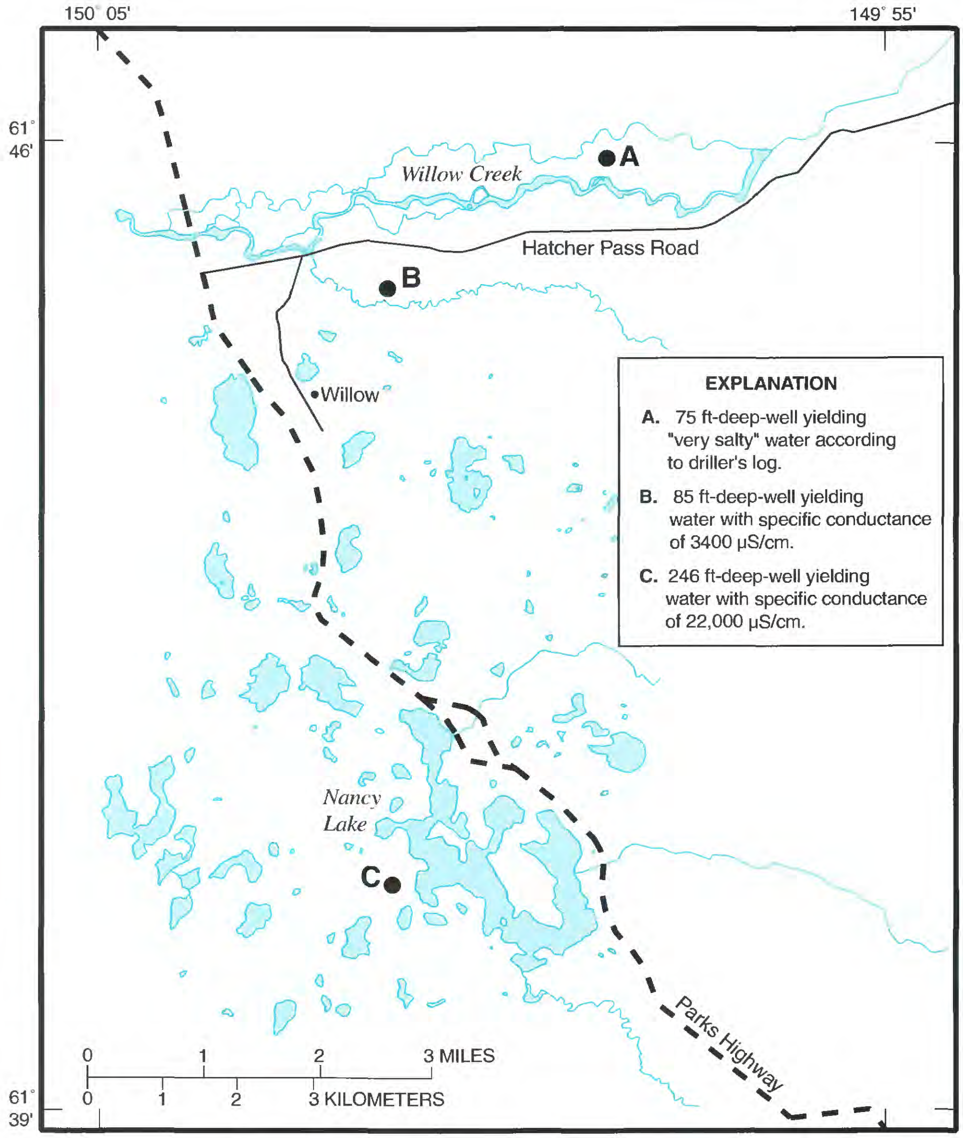


Figure 30. Location of salt-water wells near Willow in the Susitna River Basin, Alaska.

Tertiary-Age Uplands Aquifers

Tertiary-age sediments of the Kenai Group underlie glacial and alluvial deposits of the central part of the Cook Inlet Basin (fig. 31). These sedimentary rocks also outcrop around the margins of the Cook Inlet Basin, forming gently rolling hills between Cook Inlet and the rugged mountains of the Kenai, Talkeetna, and Alaska Ranges. In the Kenai Peninsula, Tertiary-age sediments form the Caribou Hills. North of Tyonek, they form hills containing abundant coal deposits. The Tertiary-age sediments commonly contain aquifers that are adequate for domestic wells. High capacity municipal and industrial wells, however, have not been developed in the Tertiary-age sedi-

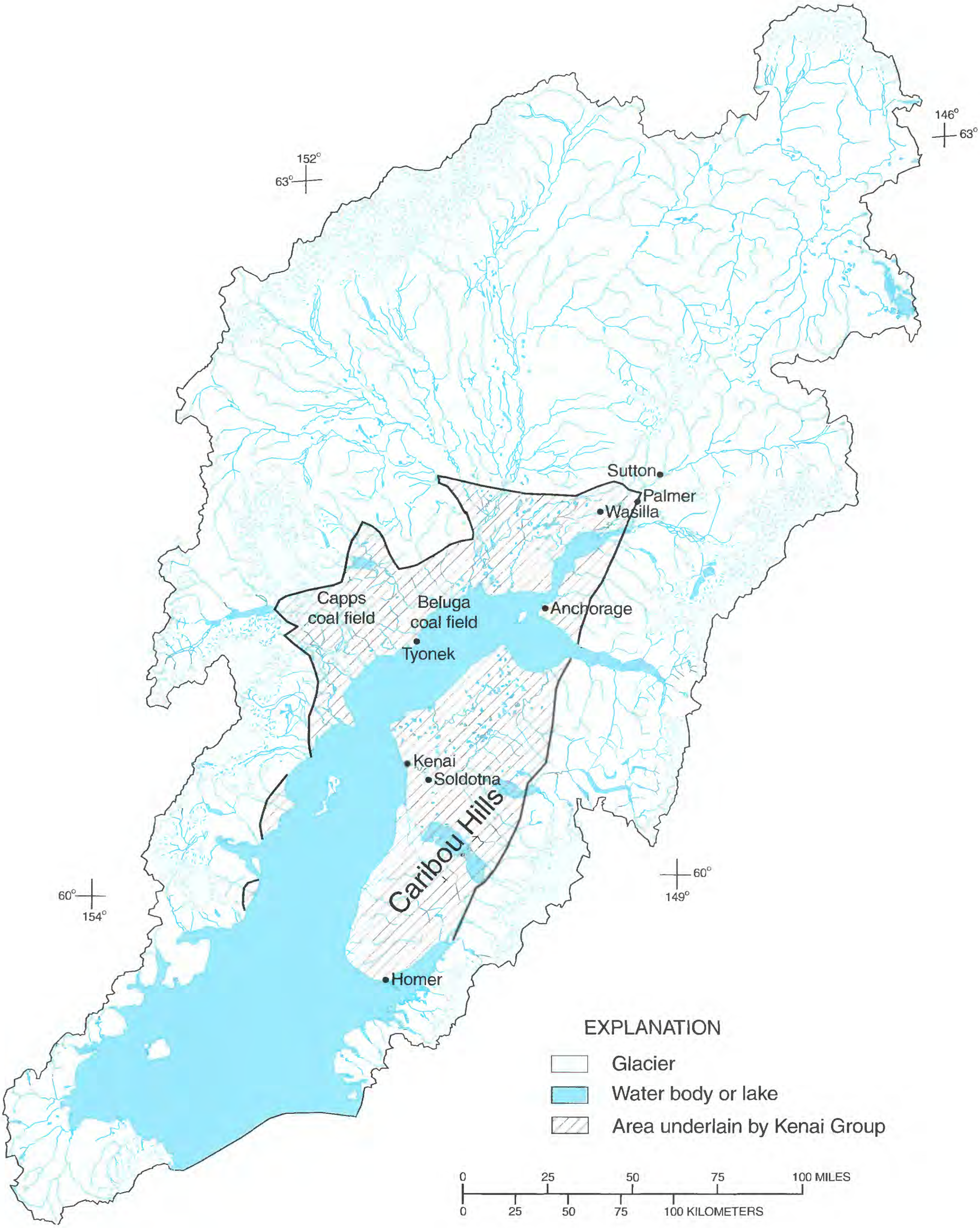


Figure 31. Areas of the Cook Inlet Basin, Alaska, underlain by Tertiary sediments of the Kenai Group (modified from Wilson and others, 1998; Magoon and others, 1976).

ments. The residential area in the hills immediately north of Homer is the most heavily developed part of the aquifers within the Tertiary-age sediments.

Most of the Kenai Group consists of weakly indurated fine sandstone that provides little water to wells (Nelson and Johnson, 1981). The more common water-bearing units are coal beds and a few conglomerates. In the Beluga coal field (fig. 31), coal is the dominant aquifer. An aquifer test of a 57-foot-thick coal unit in the Capps coal field (fig. 31) yielded a transmissivity value ranging from 15 to 46 ft^2/d (Nelson, 1985). Exploration data indicate that coal units also are significant aquifers in the southern Caribou Hills.

Igneous and Metamorphic Aquifers

Igneous and low-grade metamorphic rocks of the mountain ranges around the periphery of the basin conduct water in fractures. These fractured-rock aquifers yield water to thousands of domestic wells and many public-supply wells. All the public-supply wells, however, are of modest capacity and supply few homes. Throughout the bedrock terrain, a well supplying 20 gal/min would be considered an excellent producer.

By a large margin, the most heavily pumped area of the bedrock aquifer is the upper hillside areas of the Municipality of Anchorage, including Eagle River, Chugiak, and Peters Creek (fig. 24). In the Peters Creek area, more than 27 percent of the wells obtain water from fractured bedrock (Brunett and Lee, 1983). In the Potter Creek area of southeast Anchorage, bedrock is the principal aquifer in approximately 60 percent of the area (Emanuel and Cowing, 1982). Bedrock wells throughout most of the Municipality of Anchorage are completed in slate and graywacke of the McHugh Complex of Late Triassic age (Mesozoic). In general, more competent graywacke units are better able to supply water to wells than the softer slates. Competent rocks can hold fractures open against the weight of overlying rocks and maintain open conduits for the transmission of ground water. In the Seward Highway road cut south of Anchorage, ground water discharging from the bedrock aquifer is a common sight.

Salmon returning to spawn in one of the many streams in the Cook Inlet Basin (photo courtesy of Gary Liepitz, Alaska Department of Fish and Game).

AQUATIC BIOLOGICAL CHARACTERISTICS OF THE COOK INLET BASIN

The biological characteristics of interest for the NAWQA program include information on the spatial distribution, community structure, and relative abundance of fish, aquatic invertebrates, macrophytes, and algae. This information can be used in conjunction with physical and chemical measurements of water quality to determine the status of and trends in water quality and how it related to natural conditions and anthropogenic factors.

Fish

Fish-community analysis is an effective tool for large-scale water-quality assessments (Meador and others, 1993). Fish communities reflect the present physical and chemical characteristics of a stream along with historical conditions to which they were exposed. In addition, analyses of fish tissue for bioaccumulative contaminants, which have low concentrations in sediments or water, may reveal concentrations that represent health risks to the fish communities or possibly to humans if consumed.

The numerous cold-water streams within the Cook Inlet Basin support an assemblage of migratory and resident fish. Migratory fish include five species of Pacific salmon: chinook, chum, coho, pink, and sockeye. Resident species of fish include Dolly Varden, rainbow/steelhead trout, and round whitefish. Most of the fisheries work within the Cook Inlet Basin has focused on salmon rather than on the resident fish, because the salmon represent an important cultural, recreational, and economic component of the Cook Inlet Basin. In 1997, approximately 4 million salmon were harvested in the upper Cook Inlet fishery (fig. 32).

Of the streams draining into Cook Inlet, the three river systems supporting the greatest number of spawning salmon are the Kenai, the Kasilof, and the Susitna Rivers. For example, in the Kenai River, the number of sockeye salmon has averaged about 2.7 million since 1972 (fig. 32), with a harvest ranging from 500,000 to 8.9 million. The Kasilof River sockeye fishery has averaged about 700,000 fish per year since 1972, and ranges from 80,000 to 1.7 million sockeye (fig. 32). The third largest sockeye fishery is the Susitna River, which has provided an average of about 600,000 sockeye salmon since 1972, with ranges from 180,000 to 1.06 million (fig. 32). Many of the other streams that flow into Cook Inlet, such as the Crescent River (fig. 32), also support healthy salmon runs, but no data are routinely available for these stream systems. These streams are visited frequently for sportfishing. In 1997, Ship Creek had 62,000 angler-days and the Kenai River had 321,000 angler-days (Barry Stranton, Alaska Department of Fish and Game, oral commun., 1998). (One angler-day is equivalent to one person or a combination persons who fish for 12 hours.)

Aquatic Invertebrates

Benthic macroinvertebrates can reflect the quality of water at a site because they live in the streambed for a large part of their lives. Both by the density of their occurrence and the species composition of the community found in a stream, they can indicate the quality of habitat available to them during the time period of weeks to months. Bioassessment techniques are becoming widespread in their use as indicators of stream degradation.

The taxonomic structure of macroinvertebrate communities in streams of Alaska as a whole has been summarized by Oswood and others (1995). Most of Alaska's streams are typically characterized by low diversity and dominated by Diptera (trueflies) of which a major part are the Chironomidae (non-biting midges). The streams of the Cook Inlet Basin

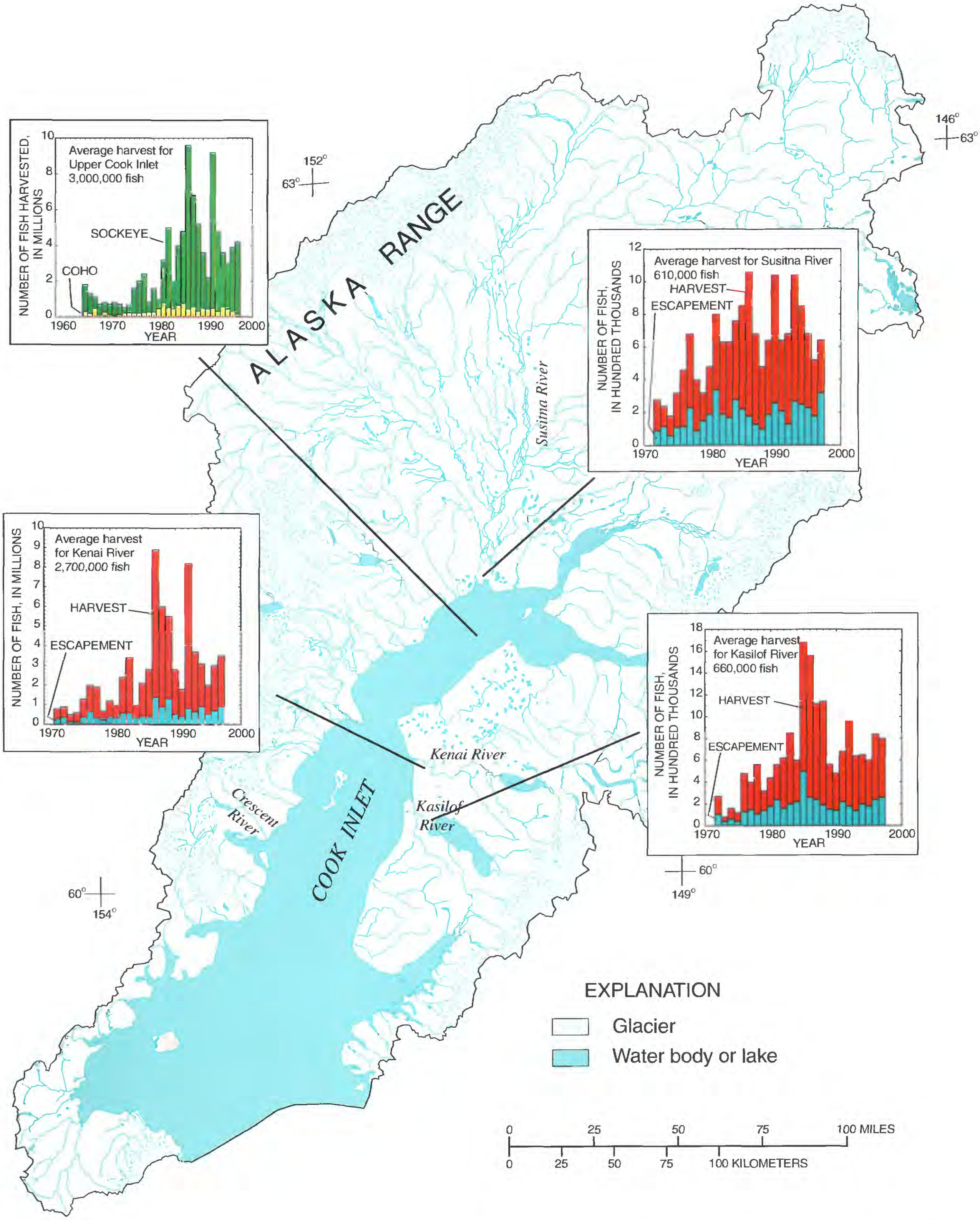


Figure 32. Salmon harvest and escapement data for selected water bodies in the Cook Inlet Basin, Alaska. (Data from Alaska Department of Fish and Game, written commun., 1998.)

are characterized by Diptera (34 percent), but Ephemeroptera (mayflies) constitute the largest percentage of the community (41 percent) (table 9). Plecoptera (stoneflies) at 17.5 percent and Trichoptera (caddisflies) at 7 percent are also higher in the Cook Inlet Basin than in other regions of the State. Where residential development influences are present, the percentage of Diptera increases (Milner and Oswood, 1995), and also where glacial runoff is a dominant part of the flow and no lakes are present, Chironomidae (Diptera) dominate (Milner and Petts, 1994).

Table 9. Mean percent composition of the aquatic insect fauna in streams of the Cook Inlet Basin, Alaska
[Modified from Oswood and others (1995)]

Fauna	Percent composition
Taxonomic structure	
Coleoptera	0.0
Diptera	34.0
Ephemeroptera	41.3
Plecoptera	17.5
Trichoptera	7.2
Functional group	
Shredders	11.6
Scrapers	11.2
Collector-filterers	6.6
Collector-gatherers	60.5
Predators	10.1

In terms of functional feeding groups, collector-gatherers dominate the macroinvertebrate community of Cook Inlet streams. They average about 60 percent by abundance (table 9) because of the dominance of Chironomidae and Ephemeroptera. Scrapers and shredders are typically about 10 percent of the community, indicating the lower importance of periphyton and leaf litter to the food web initially.

Aquatic Plants

Aquatic plants have been studied extensively in investigations of water quality because they are relatively easy and inexpensive to sample, transport, preserve, and store. As with other aquatic organisms, they are capable of accumulating certain contaminants over time above ambient concentrations in water. They are a direct measure of the bioavailability of contaminants to plants in the environment. Two groups of aquatic plants are of interest to the NAWQA program as water-quality indicators: macrophytes and algae. Several characteristics, in addition to size, make macrophytes better suited for tissue sampling and analysis than algae. Differences in species abundance of macrophytes and algae can also be valuable indicators of environmental change.

Macrophytes

Macrophytes, which are aquatic vascular plants, provide food and cover for many fish and aquatic invertebrates. A large number of birds and fish feed directly on the aquatic invertebrates and algae attached to macrophytes. In addition, some birds, fish, and invertebrates use macrophytes in their reproductive cycle during nesting, spawning, or emergence. Rooted plants help stabilize shorelines, gravel bars, and streambanks. Healthy stands of macrophytes in rivers and lakes compete with algae for nutrients and light, and can, therefore, reduce nuisance blooms.

Approximately 40 underwater and floating-leaved plants are found in the Cook Inlet Basin (Hotchkiss, 1972). The pondweed family, Potamogeton, is represented by the largest number of submersed species and a wide variety of growth forms. Other species found are water milfoils, bladderworts, and buttercups.

Algae

Algae may be either attached (periphyton) or free-floating (phytoplankton), and may be single-celled, colonial, or in filaments or chains. Information on changes in species composition and abundance of algae often is valuable for use as an indicator of water quality. As the degree of pollution increases in an area, the number of species decreases and the number of individuals of certain species increases. Phytoplankton, such as some blue-green (Division Cyanophyta) and green (Division Chlorophyta) algae, may increase greatly in number to form nuisance blooms in polluted waters. Because they are attached to a substrate, periphyton such as some diatoms (Division Chrysophyta) can reflect water-quality conditions at a specific location. In large non-wadable rivers and lakes, however, phytoplankton are more easily sampled than periphyton. The USGS has collected data on phytoplankton species and abundance for its National Stream-Quality Accounting Network program during 1974 through 1981 at the Susitna River at Susitna Station.

ANTHROPOGENIC CHARACTERISTICS OF THE COOK INLET BASIN

Population and Economic Activity

The population of Alaska in 1996 was 607,800 (Alaska Department of Labor, 1998). Of this total, about 347,000 residents live in the Cook Inlet Basin. Anchorage, the largest metropolitan area in the basin, had about 254,000 residents in 1996, and is the primary center for labor, trade, distribution, and transportation for the State. The cities and towns in the two other boroughs within the Cook Inlet Basin, the Matanuska-Susitna and the Kenai Peninsula Boroughs (fig. 2), have fewer people than Anchorage, but have grown at a faster rate since 1990 (table 10). Much of the growth outside of Anchorage is due to a shortage of available land in Anchorage and the desire for a more rural lifestyle.

Major development of the Cook Inlet Basin began with the growth of the fishing industry in the 1880's and quickly expanded as a result of mineral exploration and the need to provide transportation to and from the interior of the State. The first major population influx occurred with the construction of the Alaska Railroad during 1915-23. Anchorage was founded in 1915 (Municipality of Anchorage, 1996) as the construction headquarters for the Alaska Railroad (Alaska Railroad, 1998).

The establishment of Elmendorf Air Force Base and Fort Richardson Military Reservation (fig. 3) adjacent to Anchorage during World War II was the primary reason for the population increase from 4,230 people in 1939 to 30,060 in 1950. During the 1950's, the Korean War and Cold War brought further expansion of defense-related installations throughout Alaska, and in 1959 oil was discovered on the Kenai Peninsula. By 1960, Anchorage's population stood at 82,830, more than double what it had been in 1950 (Alaska Department of Labor, 1998).

The 1964 Good Friday earthquake initiated a major rebuilding program in Anchorage. However, the chief economic event of the decade was the announced discovery of oil on the North Slope of Alaska in 1968. Completion of the Trans-Alaska Pipeline between Prudhoe Bay and Valdez in 1977 led to fundamental changes in Alaska's economy and that of its communities. Petroleum companies established Anchorage as the Alaska base for their operations. Anchorage also was selected as the headquarters for most regional Native corporations established following passage of the Alaska Native Claims Settlement Act in 1971. By 1980, the population of Anchorage had grown to 174,400, a 38 percent increase from the 126,400 people present in 1970 (Alaska Department of Labor, 1998).

Table 10. Population data for communities in the Cook Inlet Basin, Alaska
[Data from the Alaska Department of Labor, 1998]

Location	1990	1996	Percent change
Kenai Peninsula Borough			
Anchor Point	866	1,121	29
Clam Gulch	79	93	17
Cohoe	508	579	14
Cooper Landing	243	272	12
Crown Point	62	92	48
Fox River	382	422	10
Fritz Creek	1,426	1,882	32
Halibut Cove	78	71	-9
Happy Valley	309	388	26
Homer	3,660	4,064	11
Hope	161	160	-1
Jakolof Bay	28	28	0
Kachemak	365	404	11
Kalifonsky	285	325	14
Kasilof	383	523	36
Kenai	6,327	6,950	10
Moose Pass	81	120	48
Nikiski	2,743	3,013	10
Nikolaevsk	371	555	50
Ninilchik	456	643	41
Primrose	63	62	-1
Ridgeway	2,018	2,295	14
Salamatof	999	1,011	1
Seldovia	459	395	-14
Soldotna	3,482	3,968	14
Sterling	3,802	5,378	41
Tyonek	154	148	-4
Unincorporated areas	6,751	7,297	8
TOTAL	36,541	42,259	16

Location	1990	1996	Percent change
Matanuska-Susitna Borough			
Alexander	40	35	-12
Big Lake	1,477	2,138	45
Butte	2,039	2,374	16
Chase	38	52	37
Chickaloon	145	217	50
Houston	697	976	40
Knik	272	445	64
Lazy Mountain	838	976	16
Meadow Lakes	2,374	4,685	97
Palmer	2,866	4,282	49
Skwentna	85	86	1
Sutton	308	367	19
Talkeetna	250	342	37
Trapper Creek	296	310	5
Wasilla	4,028	4,714	17
Willow	285	419	47
Unincorporated areas	23,645	28,341	20
TOTAL	39,683	50,759	28
Municipality of Anchorage			
TOTAL	226,338	254,269	12
Cook Inlet Basin			
TOTAL	302,562	347,287	15

Rapid growth continued in Anchorage through the early 1980's, peaking at an estimated 248,300 people in 1985. However, the boom period, caused primarily by an accelerated rate of government spending, was not sustainable and the economy slipped into recession in late 1985. The severity of the recession was greatly compounded by a crash in oil prices in early 1986.

The Anchorage economy began to recover in 1989, spurred initially by clean-up efforts after the 1989 *Exxon Valdez* oil spill and a temporary increase in oil prices resulting from the Iraqi invasion of Kuwait. The 1990 census counted 226,300 people in Anchorage, about 10 percent fewer than the 1985 peak, but still about 30 percent more than the community's 1980 population. Increased spending on capital projects by the State following the oil spill settlement and employment growth in construction and retail trade have helped fuel the local economy since 1990. Growth in tourism and in the use of Anchorage International Airport for international cargo flights also are positive developments. Anchorage's population in 1996 had increased by more than 12 percent since 1990 (Alaska Department of Labor, 1998).

Land Ownership and Land Use

Approximately 30 percent of the Cook Inlet Basin is Federal land (fig. 33). Parts of four national parks—Denali, Lake Clark, Katmai, and Kenai Fjords—are located in the basin (fig. 1). Nearly 1,800 mi^2 of the Chugach National Forest, and the 3,000 mi^2 Kenai National Wildlife Refuge also are within the study unit (fig. 1). Most likely, these areas will remain undeveloped with the possible exception of logging within the Chugach National Forest. State-owned and Native-owned lands account for 49 percent and 9 percent respectively. The remaining 12 percent is currently Federally owned, and managed by the Bureau of Land Management. This land has been selected for eventual conveyance to the State or to Native corporations.

Less than 10 percent of the Cook Inlet Basin has been developed. The two primary land uses are residential development and logging. A large part of the Native-owned land in the lower Kenai Peninsula has been or will be logged (fig. 1). Additional logging likely will occur on State-owned lands. Other possible land uses are potential mining activities near Sutton and Tyonek (fig. 1) and increased residential development near towns in the Kenai and Matanuska-Susitna Boroughs.

Water Use

Water-use data have been compiled from the USGS National Water-Use Information Program data base and from other State agencies (table 11). Surface water accounted for 54 percent of all water withdrawals in 1995 in the Cook Inlet Basin. Public supply accounted for about 72 percent of surface water withdrawn. Ground water accounted for 46 percent of all water withdrawals in 1995. Domestic wells account for about 17 percent of ground-water use.

Table 11. Estimated water use during 1995 in the Cook Inlet Basin, Alaska

[Data in million gallons per day; estimates from G.L. Solin, U.S. Geological Survey, written commun., 1998]

Category	Ground water	Surface water	Total
Public supply	12.25	26.95	39.20
Domestic (self supplied)	5.48	0	5.48
Commercial	9.50	8.16	17.66
Industrial	4.21	1.14	5.35
Other	0.19	1.27	1.46
Total	31.63	37.52	69.15

Public water supplies served about 211,000 people in 1995. An average of 39.2 Mgal/d of water were used—31 percent from ground water and 69 percent from surface

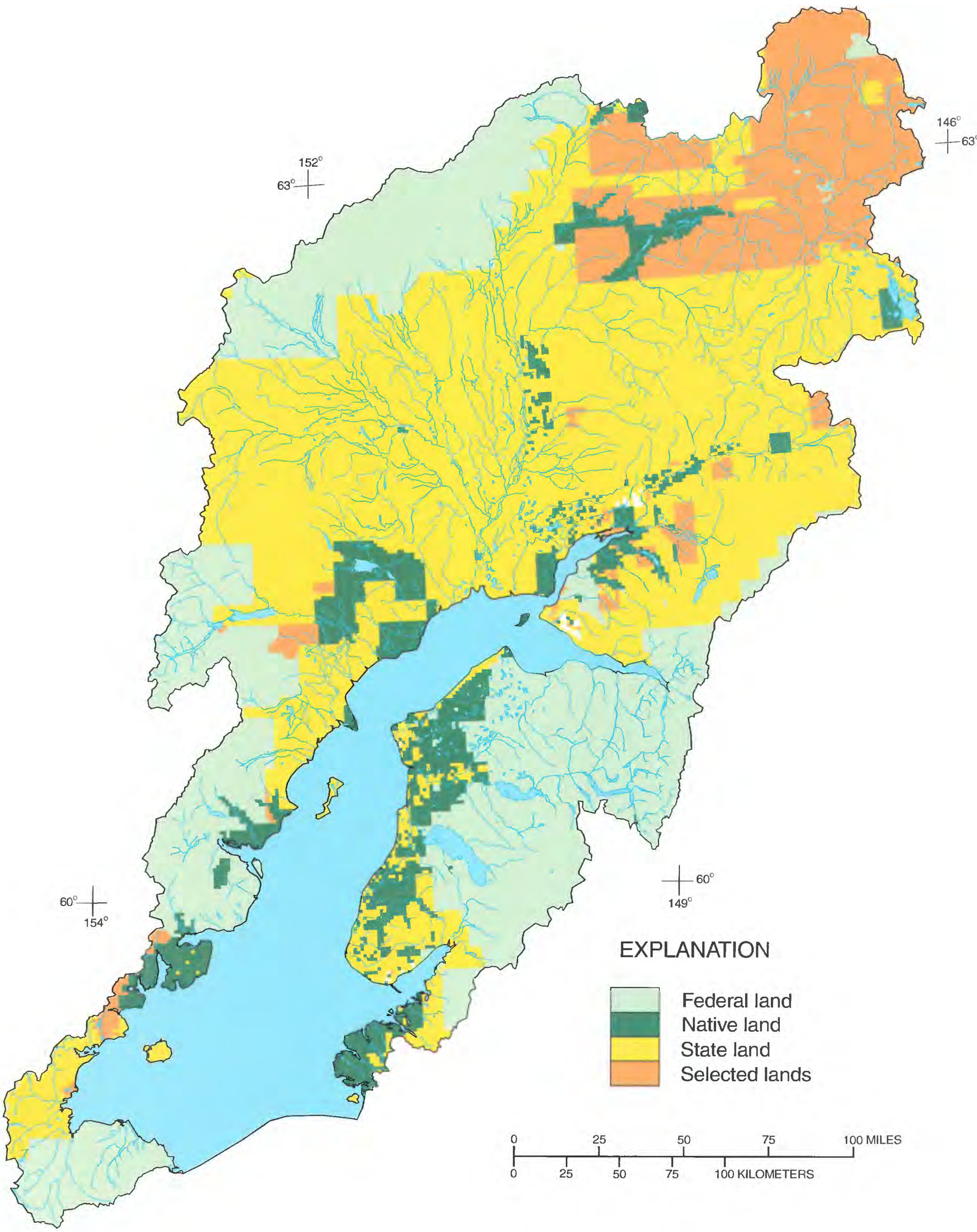


Figure 33. Land ownership of the Cook Inlet Basin, Alaska.

water. Public water supplies for Anchorage are primarily from Ship Creek (fig. 3) and Eklutna Lake (fig. 24). Ground water is the source for most other public water supplies. Domestic use accounts for 52 percent of the total public supply water use, commercial use about 30 percent, and industrial use about 4 percent. Average per capita use for public supplies in the Cook Inlet Basin is about 186 gal/d. About 125,000 people in the Cook Inlet Basin use private domestic wells. Average per capita use for domestic self-supplied water is 44 gal/d.

Consumptive use includes water that is evaporated, transpired by plants, or consumed by humans and not immediately available for use. In the Cook Inlet Basin, public supplies and domestic self supplies combined have a consumptive use of about 10 percent. Water used for commercial and industry uses have consumption rates of about 15 percent. Utility company use has a consumption rate of about 10 percent.

SUMMARY

This report describes the general environmental setting of the Cook Inlet Basin, one of about 59 study units of the USGS National Water-Quality Assessment (NAWQA) program. The primary natural and human features of the Cook Inlet Basin are as follows:

- Natural factors that influence the water quality of the streams and rivers of Cook Inlet are geology, soils, land cover, and the presence of glaciers. Human factors that influence water quality are residential development, intense recreational use, timber harvesting, mining, and petroleum development.
- The climate of the Cook Inlet Basin is variable because of its large size and range in altitude. Precipitation ranges from 20 to 240 in. annually and average air temperature ranges from 22 °F to 42 °F. About half the basin consists of moderately high rugged mountains.
- The geology is complex and consists of many types of consolidated rocks in the mountain ranges surrounding the basin and unconsolidated sediments deposited in the lowland areas. Inceptisols and Spodosols are the primary soils in the basin, and tall shrub is the most widespread vegetation.
- Discharge from streams and rivers in the Cook Inlet Basin varies depending on the presence of glaciers in a particular watershed. Melting glaciers add more water to a stream and have more sustained runoff than nonglacial streams. The total average annual surface-water discharge into Cook Inlet is estimated to be 116,000 ft^3/s, of which the Susitna River basin accounts for 47 percent. Most of the inflow to Cook Inlet occurs from May through September.
- Suspended sediment is variable in the Cook Inlet Basin depending on the presence of glaciers. The annual suspended-sediment load to Cook Inlet is more than 44 million tons. Most of the load is transported between May and September. The largest loads are from the Susitna, Matanuska, and Knik Rivers.
- Ground water is used primarily from the central part of the Cook Inlet Basin—the Anchorage, Kenai, and Nikiski areas. In these areas, ground water is obtained from multiple aquifers located in outwash deposits distal from the terminal moraine of a major glacial advance. These aquifers are separated by confining units of tidal and marine silt and clay.
- Approximately 4 million salmon per year are harvested from the Cook Inlet Basin. The three major spawning streams are the Kenai, Kasilof, and Susitna Rivers. The primary macroinvertebrates found in the streams of the Cook Inlet Basin are Diptera, Ephemeroptera and Plecoptera. In terms of the insect functional-group composition, the collector-gatherers dominate.

- The population of the Cook Inlet Basin in 1996 was approximately 347,000 people, which represents more than half of Alaska's population. The major metropolitan area is Anchorage. Communities outside of Anchorage located in the Matanuska-Susitna and the Kenai Peninsula Boroughs are growing at a faster rate than Anchorage.
- Most of the land in the Cook Inlet Basin is undeveloped and is owned by the State of Alaska or the Federal government. Parts of four national parks—Denali, Lake Clark, Katmai, and Kenai Fjords—are located in the basin. The developed land consists primarily of urbanized areas and logged areas on the lower Kenai Peninsula.
- Approximately 69 Mgal of water are used daily in the Cook Inlet Basin. About 39 Mgal of this total is used for public water supply and surface water accounts for about 69 percent of this total.

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