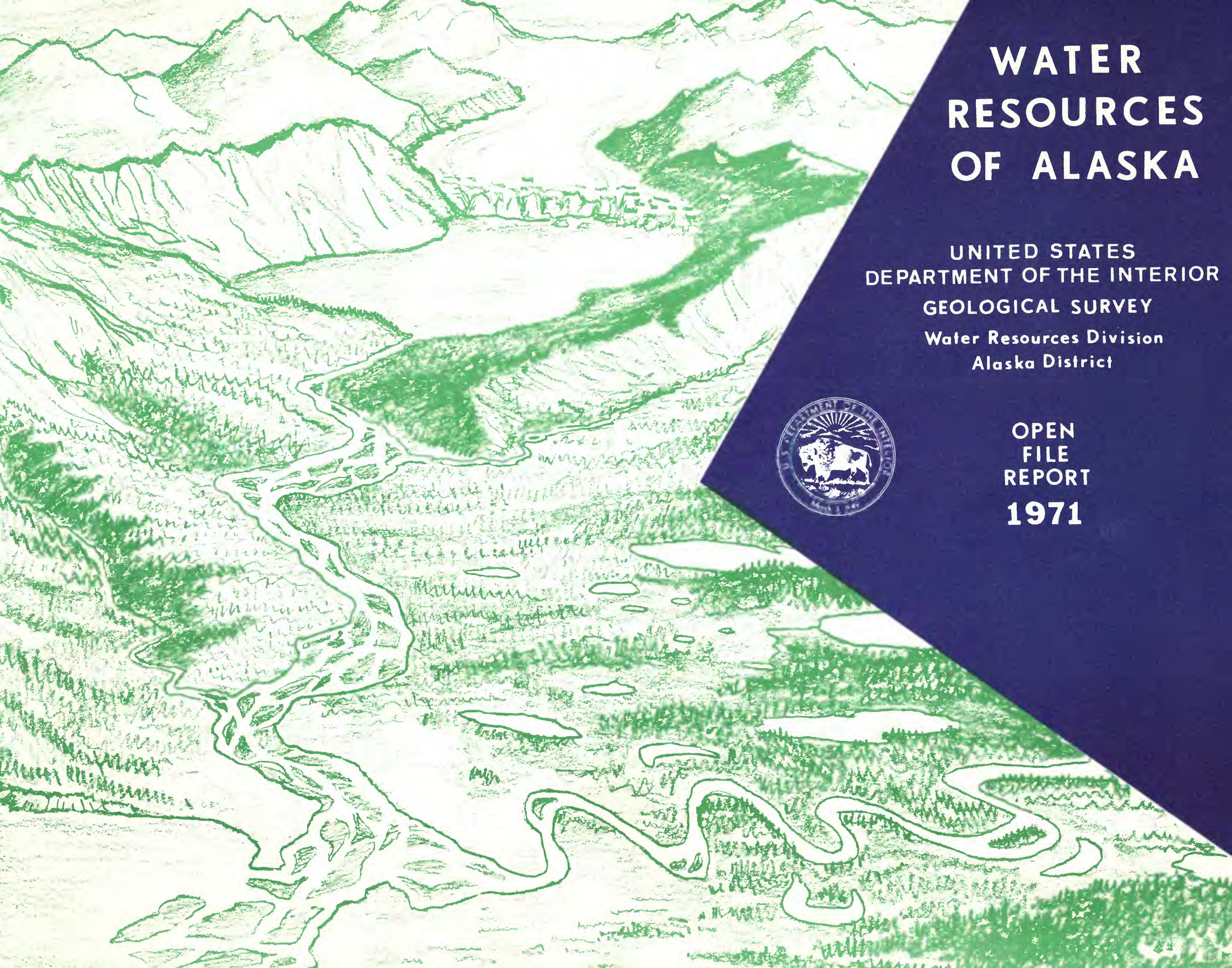

WATER RESOURCES OF ALASKA

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
Water Resources Division
Alaska District

OPEN
FILE
REPORT
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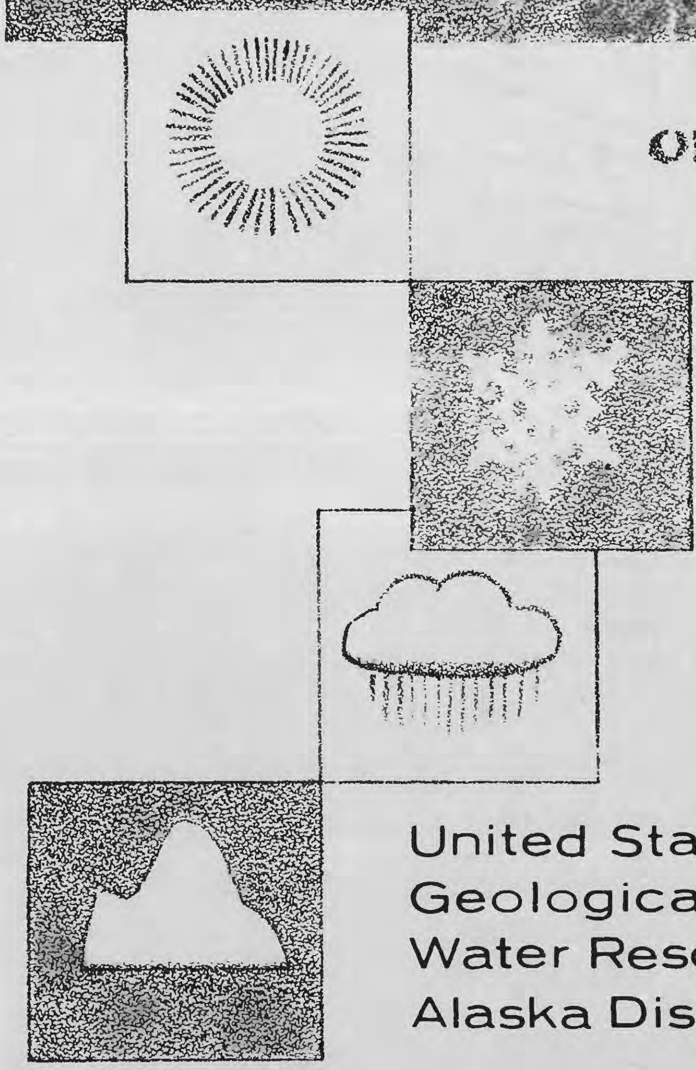

OPEN-FILE REPORT 1971

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Vernon W. Norman

United States Department of the Interior
Geological Survey
Water Resources Division
Alaska District

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INTRODUCTION

ABSTRACT

This report summarizes the existing information on the water resources in Alaska and describes the availability of surface and ground water and their quality. Climatologic factors and physical features that affect the occurrence of water are also discussed briefly. Data on water resources is deficient in much of the State; the report presents the available data in a regionalized format. A comprehensive bibliography of reports published on water resources in the State is also included.

INTRODUCTION

Alaska, largest State of the United States, has a land area of 586,400 square miles. The large land area, small population, and lack of development have caused a lag in obtaining information about water. Because of the need for water-resources information, the U.S. Geological Survey established a continuing surface-water data network in 1946 replacing previous sporadic programs guided since 1906 by mining, hydroelectric, and water-supply needs. This was followed in 1947 and 1948 by the beginning of systematic ground-water investigations and quality-of-water programs. This report summarizes existing information collected under these programs and describes availability of surface and ground water and their chemical quality. This report was prepared under the general direction of Harry Hulsing, district chief.

Because of its large size and the diversity of its physical features, the State has been divided into six subregions: the Arctic Slope, Northwest, Yukon, Southwest, South-central, and Southeast subregions. These subregions are those delineated by the Inter-Agency Technical Committee of Alaska (1970) (fig. 1). Three of these subregions (the Yukon, Southwest, and South-central) have been further divided on the basis of climate, physical boundaries, and population. Although it might be preferable to discuss some aspects of water considering only a broad climatic zonation, for uniformity the discussion in this report has been divided into sections based on the subregional breakdown.

Alaska is about one-fifth the size of the conterminous United States, but its population is only 294,607 (1970 Census, preliminary figures, June 1970), or 0.1 percent of the Nation. Most of the people live in the South-central subregion. Nearly half the population of the State lives in or near Anchorage. Table 1 lists the population of the State by subregions and indicates the relative density.

Table 1.--Population of the State of Alaska by subregions.

Subregion	Population	Population density per square mile
Arctic Slope	2,751	0.03
Northwest	9,785	0.16
Yukon	58,204	0.26
Southwest	21,782	0.24
South-central	160,631	1.61
Southeast	41,373	1.03
Total, Alaska	294,607	0.50

Figure 1.--Hydrologic subregions.

Comprehensive data on the water resources of the State are available only for parts of the Southcentral and Southeast subregions and on the Tanana Basin in the Yukon subregion. Very few data are available for the rest of the State. Consequently, this report is more detailed in discussions of these subregions.

Data for the compilation of this report were obtained also from the files of the U.S. Army Engineer District, Alaska; U.S. Army; U.S. Air Force, Alaskan Air Command; U.S. Bureau of Indian Affairs; Federal Aviation Administration; U.S. Forest Service; Alaska Power Administration; and many other State agencies. Many geologic and hydrologic reports have been consulted in the preparation of this report. A selected list of references of some of the reports most pertinent to this discussion is included.

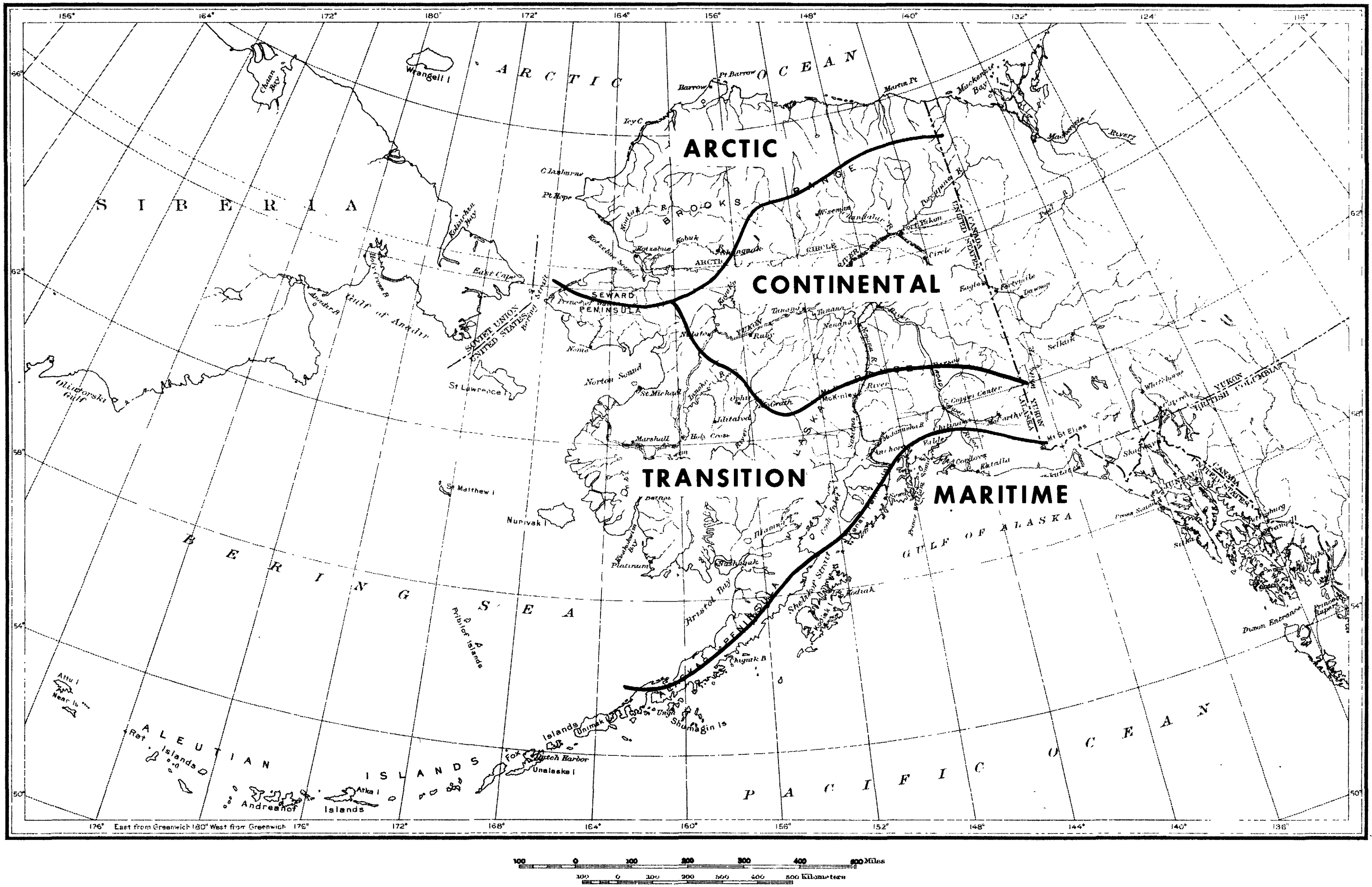


Figure 2.--Climatological zones.

PHYSIOGRAPHY OF ALASKA

Geography

Alaska occupies the great peninsula at the northwestern corner of the North American continent and is separated from the conterminous United States by part of Western Canada. Its area comprises a northern Arctic Mountain System, a southern Pacific Mountain System, and numerous smaller mountain ranges. On the north is the westward-trending Brooks Range, an extension of the Rocky Mountain System. On the south is a group of ranges forming a great arc beginning with the Coast Range on the southeast, passing into the great Alaska Range and subsidiary ranges in the middle, and then bending southwestward into the Aleutian Range. Between the Alaska and Brooks Ranges is a great lowland, of which the Yukon Valley forms the largest part; and flanking the Brooks Range on the north is a broad coastal plain, a part of the Arctic Slope and an extension of the Great Plains of Canada and the conterminous United States. On the south, the mountains generally rise abruptly out of the sea, but at the south edge of the main mass of Alaska are sizable remnants of a coastal plain.

Adjacent to these major mountain systems are rolling uplands and hills that are bounded by flat valleys, which in some places are 100 miles wide. These mountain systems exert a great influence on precipitation and climate and, consequently, on the hydrology of the State.

Alaska is divided into four major climatic zones, the Maritime, the Transition, the Continental, and the Arctic (fig. 2). This differentiation is based on the records of precipitation (fig. 3) and temperature (figs. 4 and 5). Climatological data on the subregions encompassed by the climatic zones are shown in table 2.

Table 2.--Climatological data.

Climatic zone	Part of subregion	Annual precipitation (inches)			Annual temperature (°F)		
		Max.	Min.	Avg.	Max.	Min.	Avg.
Arctic	Arctic Slope	20	2	7	90	-61	17
	Northwest	21	4	8	82	-58	20
Continental	Yukon	20	10	14	100	-76	21
Transition	Northwest	24	12	16	84	-47	25
	Yukon	25	14	19	90	-70	22
	Southwest	30	14	18	83	-33	28
	South-Central	24	12	15	86	-38	35
Maritime	South-Central	180	11	40	85	-12	40
	Southeastern	269	26	90	99	-42	43

Saarby, 1968.
Johnson, 1969.

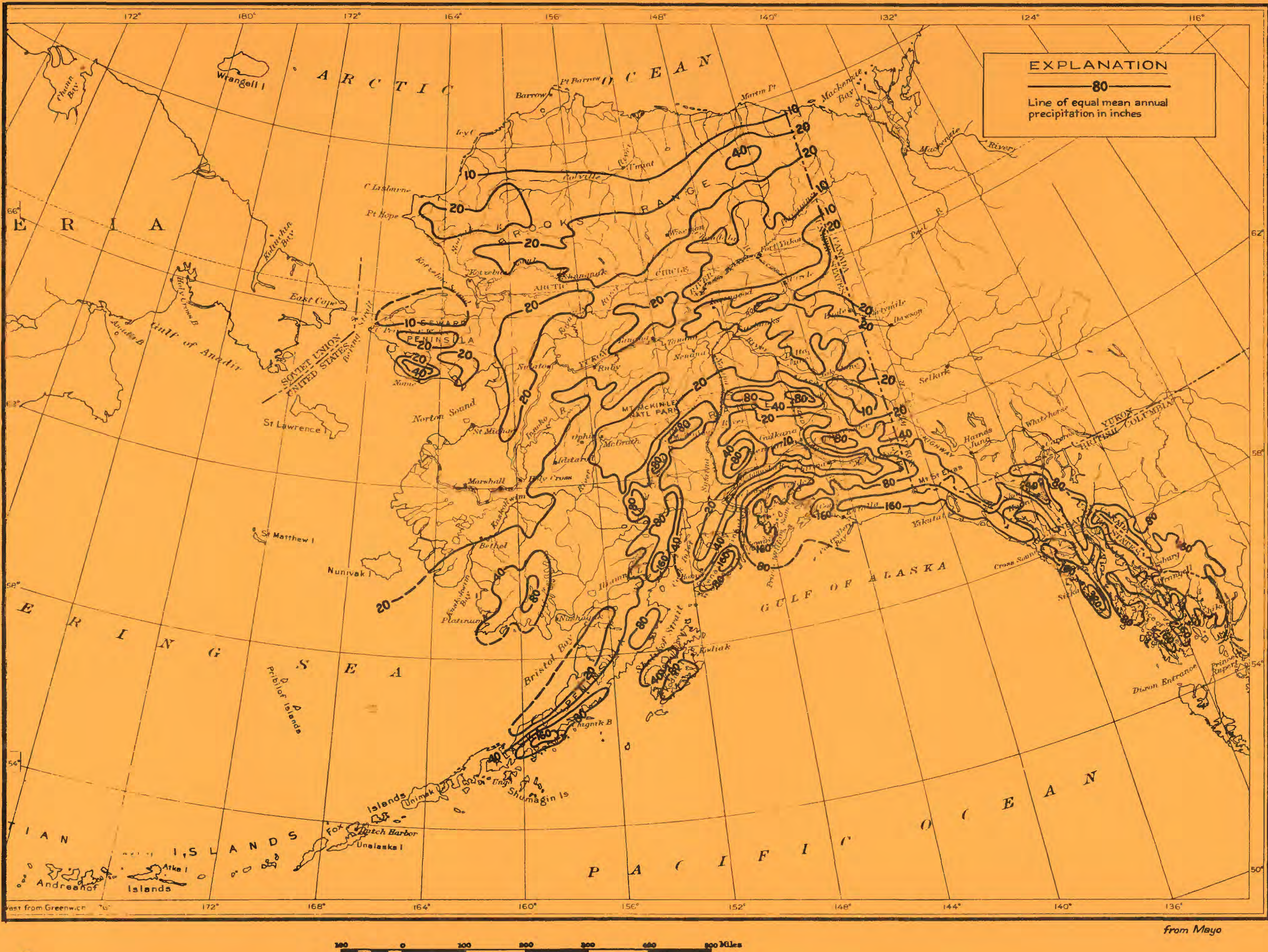


Figure 3.--Mean annual precipitation.

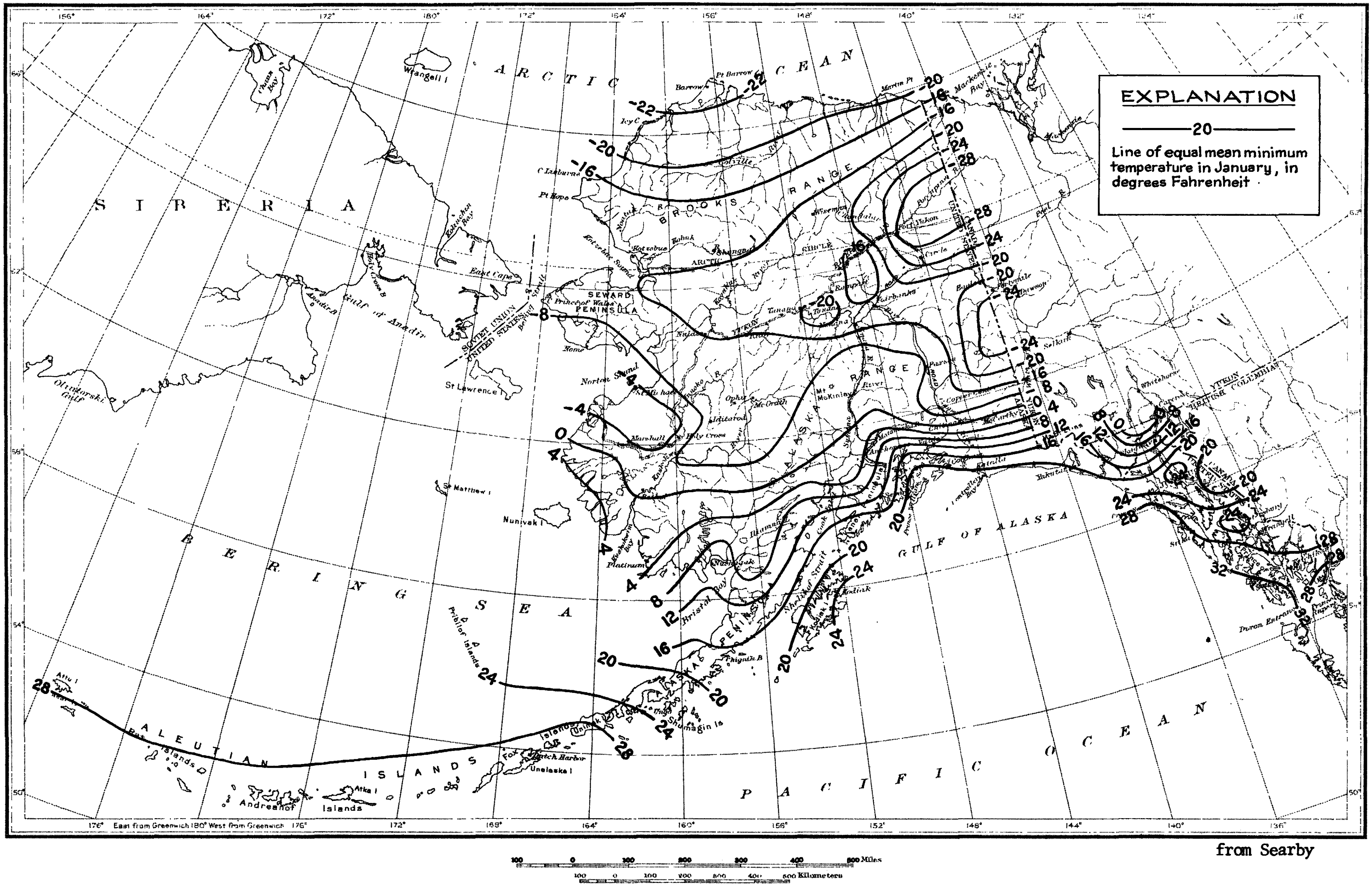


Figure 4.--Mean minimum temperature, January.

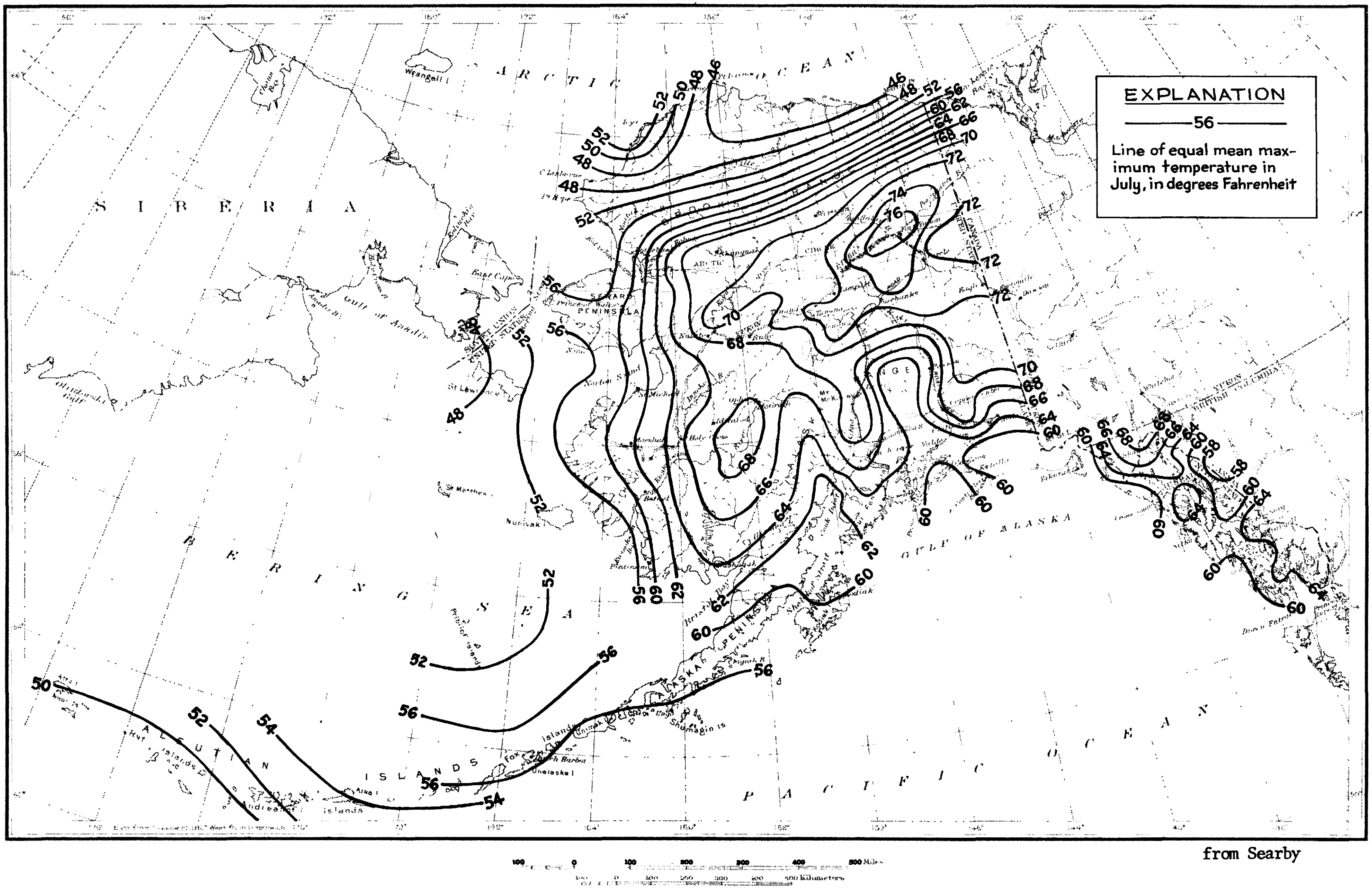


Figure 5.--Mean maximum temperature, July.

Geology

In Alaska, rocks of all the principal systems are present, from Precambrian to Quaternary. The great mountains have cores of intrusive and metamorphic (crystalline) rocks, generally Precambrian but of Mesozoic age in the Coast Range, flanked by younger sedimentary and volcanic rocks. The lower mountains and hills are formed of similar rocks or of Mesozoic sedimentary rocks. The coastal plains are formed by sedimentary rocks of Mesozoic to Cenozoic age.

Covering the older rocks of the mountains in all but their highest parts and those of uplands scattered throughout the great central valley is the drift of glaciers which occupied these highlands during the Pleistocene epoch. Glaciers dot the Coast Range and the Alaska and subsidiary ranges in the middle of the southern mountain arc. Outwash deposits derived from glaciers, plus undifferentiated deposits including some of ordinary alluvial rather than glacial origin, mantle the older rocks in large areas in the lowlands extending beyond the limits of existing or former glaciers. Large areas of these unconsolidated deposits are found on the northern coastal plain, on the north flank of the Aleutian Range and in the adjacent Nushagak River basin, on the north flank of the Alaska Peninsula to the west, and in the basins of the Susitna and Copper Rivers. By far the largest and most spectacular areas of such deposits, however, are those in the central valley, along the Yukon and its tributaries, especially the Tanana, and along the Kuskokwim, Kobuk, and Noatak Rivers. Two especially large areas are those traversed by the lower reaches of the Yukon and Kuskokwim and that in the upper Yukon-Porcupine River drainage area.

The general distribution of rocks and the major fault systems throughout the State have been delineated (fig. 6). These rocks include igneous, metamorphic, and sedimentary rocks, and also alluvial materials including glacial deposits. The relation of these rocks to the hydrology is discussed later.

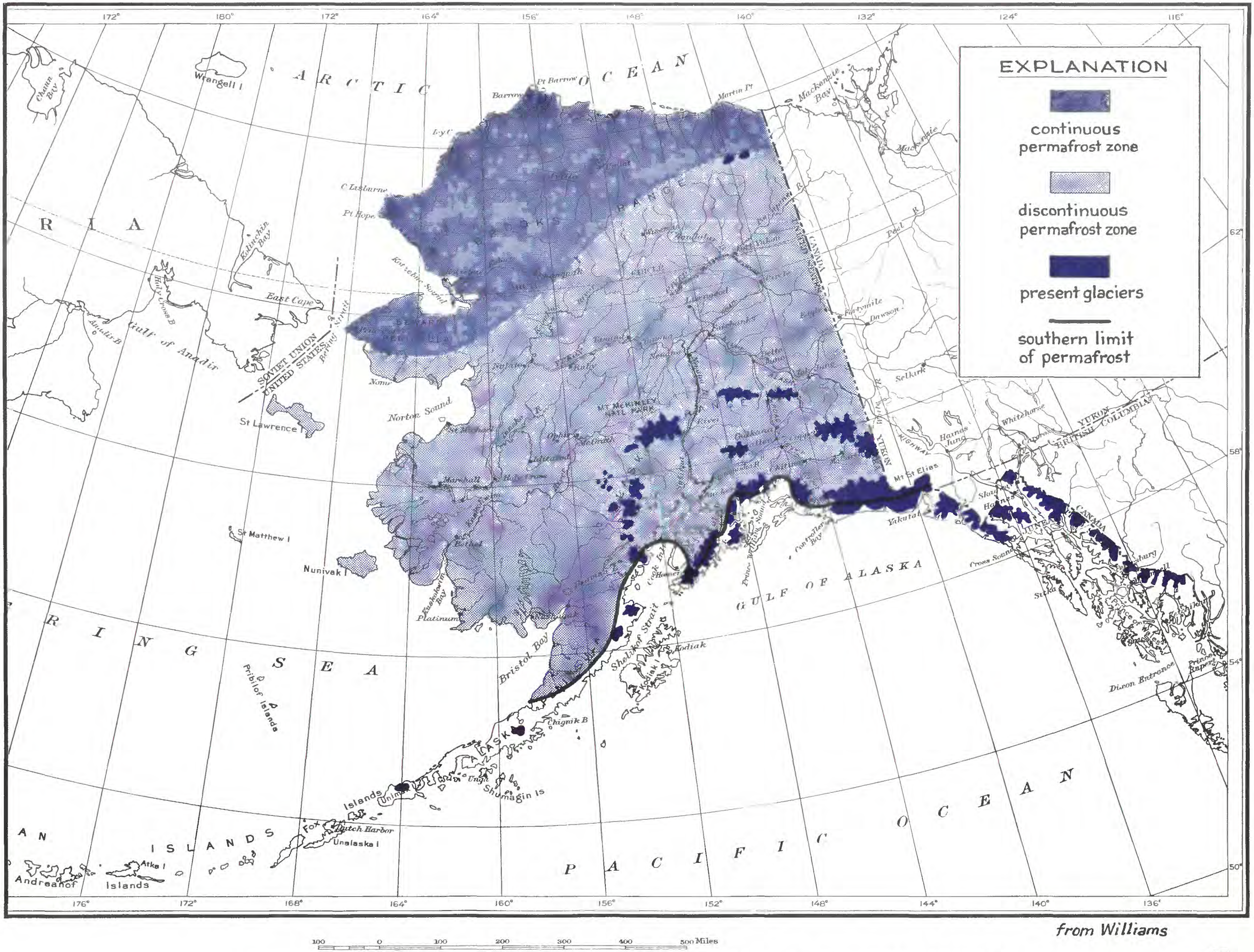
Permafrost and Glaciers

Although not unique to Alaska, permafrost and glaciers are widespread in Alaska. They affect and are affected by the hydrology.

Permafrost (perennially frozen ground) is the result both of the present climate and of colder climates that occurred intermittently in the past (Williams, 1970). Permafrost is found in all parts of the State except for a strip about 25 to 125 miles wide along the southern coast, and even there a few small isolated patches persist (fig. 7). The transition from thin, scattered areas of permafrost surrounded by unfrozen ground in southern Alaska to permafrost more than 1,300-feet thick near Barrow in northern Alaska follows the climatic zonation patterns shown in figure 2.

Because permafrost is virtually impermeable, it restricts recharge, discharge, and movement of ground water and limits storage capacity. It prevents the downward percolation of water, increases direct runoff and creation of numerous lakes and swamps, and reduces the annual transpiration from plants because the low temperatures retard growth of vegetation.

Figure 6.--Generalized geology.



from Williams

Figure 7.--Zonation of permafrost and location of present glaciers.

Glaciers in the Coast and Alaska Ranges and subsidiary ranges in the middle of the southern mountain arc cover a total extent of about 17,000 square miles (fig. 7). The Bering Glacier, near Cordova in the South-central subregion, is the largest single-ice mass on the North American continent and covers an area of 2,250 square miles.

Great parts of Alaska were covered by glaciers and ice fields during the several glaciations of the Pleistocene epoch. One ice field extended along the crest of the Brooks Range from McKenzie River in Canada almost to Kotzebue Sound in northwestern Alaska. Another covered all of coastal Alaska and the Pacific Mountain System from British Columbia to the Aleutian Chain.

Glaciers are considered hydrologically to be water-storage features, and their specific influences will be discussed as appropriate later.

SURFACE WATER

Runoff

The average natural runoff in Alaska amounts to an estimated 900 thousand cfs (cubic feet per second). An additional 200 thousand cfs originate in British Columbia and the Yukon Territory and flow into the region.

The rivers and streams of Alaska drain to the Pacific Ocean, to the Bering Sea, and to the Arctic Ocean. The principal rivers draining into the Pacific Ocean include the Stikine, Taku, and Alsek, all of which originate in Canada, in the Southeast subregion, and the Copper and Susitna Rivers that drain areas of the South-central subregion (fig. 8). The Yukon River, which originates in Canada, and the Kuskokwim River, Southwest subregion, are the major rivers draining to the Bering Sea; and the Kobuk and Noatak Rivers, in the Northwest subregion, and the Colville River, in the Arctic Slope subregion, are the principal streams draining to the Arctic Ocean.

The Yukon River, by drainage area and runoff, ranks fifth among the largest river systems of the North American continent. It drains a total area of 330,000 square miles, one-third of which is in Canada. The Alaska part of the Yukon drainage constitutes roughly 40 percent of the region's land area. The Yukon River discharges more than 200,000 cfs annually. Table 3 shows the principal rivers of Alaska by subregion, drainage area, and runoff in cubic feet per second and billion gallons per day.

Table 3.--Major rivers, Alaska region, and runoff rates of selected streams in the subregions.

Subregion	River	Drainage area (sq mi)	Runoff (cfs)	Runoff (cfsm)	Average annual natural runoff (bgd)
Arctic Slope	Colville	24,000	12,000	0.5	7.8
Yukon	Yukon	330,000 1/	216,000	0.7	139.5
Northwest	Noatak	12,600	10,000	0.8	6.5
	Kobuk	12,000	13,000	1.1	8.4
Southwest	Kuskokwim	43,600	62,000	1.4	40.1
	Kvichak	7,700	22,000	2.9	14.2
	Nushagak	14,100	20,000	1.4	12.9
South-central	Copper	24,400 2/	51,000	2.1	34.0
	Susitna	20,000	46,500	2.3	27.8
Southeast	Taku	6,700 3/	11,000	1.6	7.1
	Alsek	9,500 3/	20,000	2.1	12.9
	Stikine	19,700 3/	62,000	3.1	40.1

1/ Includes 110,000 square miles in Canada.

2/ Includes 1,270 square miles in Canada.

3/ Most of drainage area is in Canada.

(Ref. WRC, 1968)

Streamflow is measured as runoff at selected stream-gaging sites and drainage basins. Runoff, in inches, shows the depth to which the drainage area would be covered if all of the precipitation that leaves an area for a given time period were uniformly distributed on it. The amount of runoff is dependent first on the amount of precipitation. After precipitation falls on an area, runoff will be accelerated or retarded by temperature, elevation of and size of drainage basin, vegetation, and permafrost.

Figure 8.--The larger rivers in Alaska.

Figures 9, 10, and 11 show the mean annual, mean annual peak, and mean annual low monthly runoff rates for the State. Following these maps indicating regional runoff rates is a series of schematic hydrographs for each subregion (fig. 12), which show characteristic trends in relative monthly runoff rates. These most notably reflect climatic influences showing a generally increasing seasonal variation in runoff northward and a generally decreasing annual runoff rate.

The temperature and presence of permafrost cause wide fluctuation in stream discharge. Because of the lack of thawed zones in permafrost, except beneath the large streams, these fluctuations are not appreciably modified by ground-water recharge or storage.

The included illustrations indicate a rather wide range of runoff characteristics. Low-lying areas within the influence of the Gulf of Alaska have high unit runoff and relatively little seasonal variation. Runoff in the mountainous areas adjacent to the Gulf is unusually high--annual unit runoff commonly exceeds 100 inches and in some areas exceeds 300 inches. At the other extreme, low runoff rates and progressively shorter summer runoff seasons are characteristic for the northern areas; from 80 to 95 percent of the annual runoff occurs during the 5-month period May to September.

The climate of the southeastern coastal area is mild and wet, similar to that of the North Pacific coast of the conterminous states. Runoff is high, although information on it is available for only scattered areas here and elsewhere in Alaska. Precipitation is measured at stations at low elevations, which do not register the larger amounts that occur at higher elevations. Its magnitude of precipitation is shown by runoff ranging from 50 to more than 300 inches from 41 measured stations (U.S. Department of Interior, 1960a, p. 4). The short, steep slopes of stream courses in this narrow coastal strip lead to rapid runoff, so that the flow of some streams diminishes markedly in dry weather. In contrast, the flow of streams fed by lakes or glaciers is more uniform. However, the glacial melt water contains a large amount of finely ground rock (glacial flour), which is difficult to remove and impairs the usefulness of the water.

The south-central coastal area receives less precipitation, but runoff in the few gaged streams ranges from about 15 to about 170 inches. A great variation in temperature and a longer period of freezing weather cause a greater variation in streamflow than in the southeast. About 70 to 80 percent of the runoff occurs in the period beginning in June and ending in September. Streamflow is low from December through April.

The Southwest subregion has a transitional climate. Precipitation ranges from 14 to 30 inches per year. Annual peak runoff usually occurs in summer or fall and may result from snowmelt or rainfall. Annual low flow is usually in late winter, although a long, dry summer can occasionally cause low flows even in glacial-fed streams. Especially in the uplands, channel icings in the winter can grow to cause flooding even when streamflow is low.

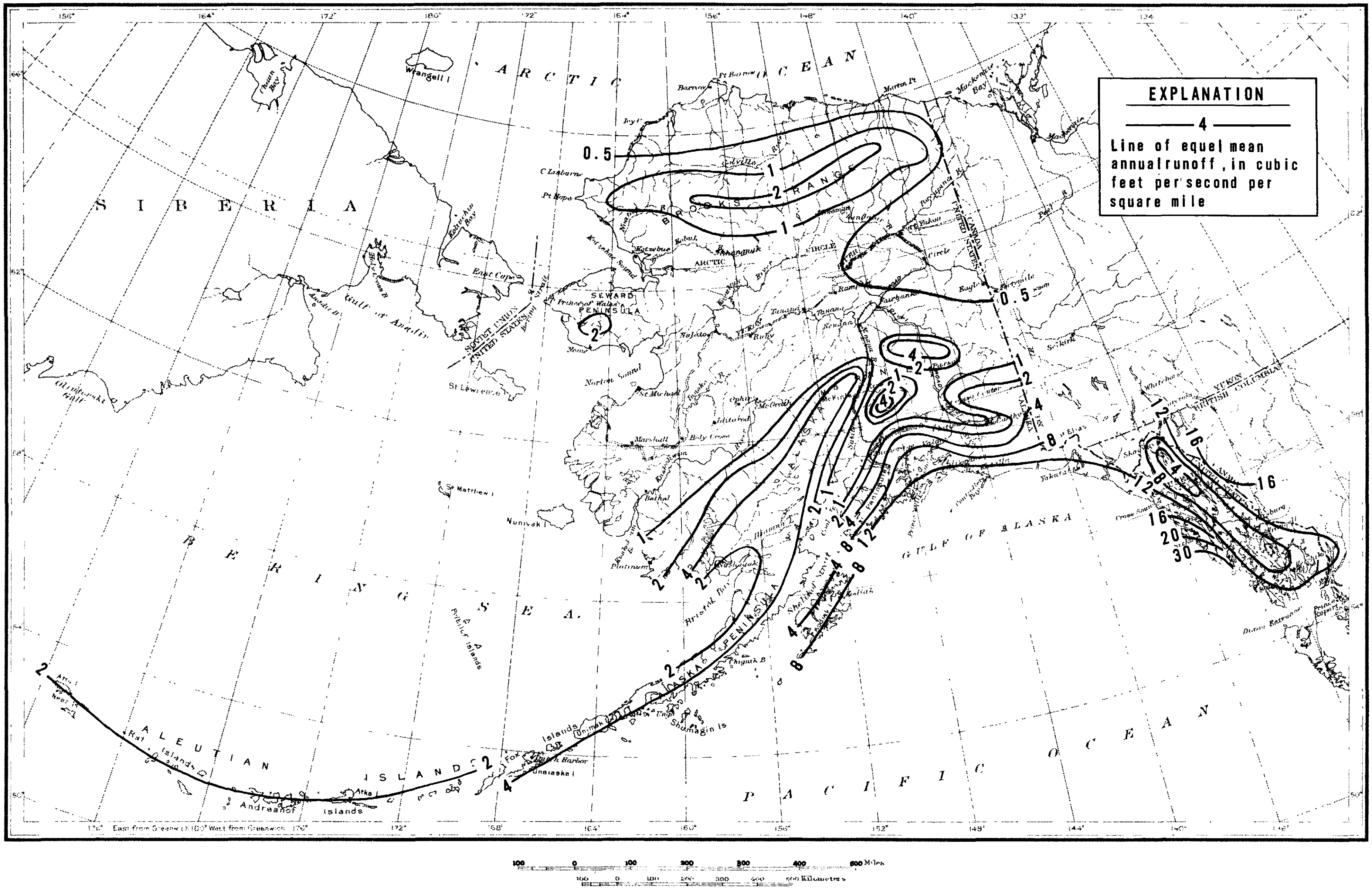


Figure 9.--Mean annual runoff.

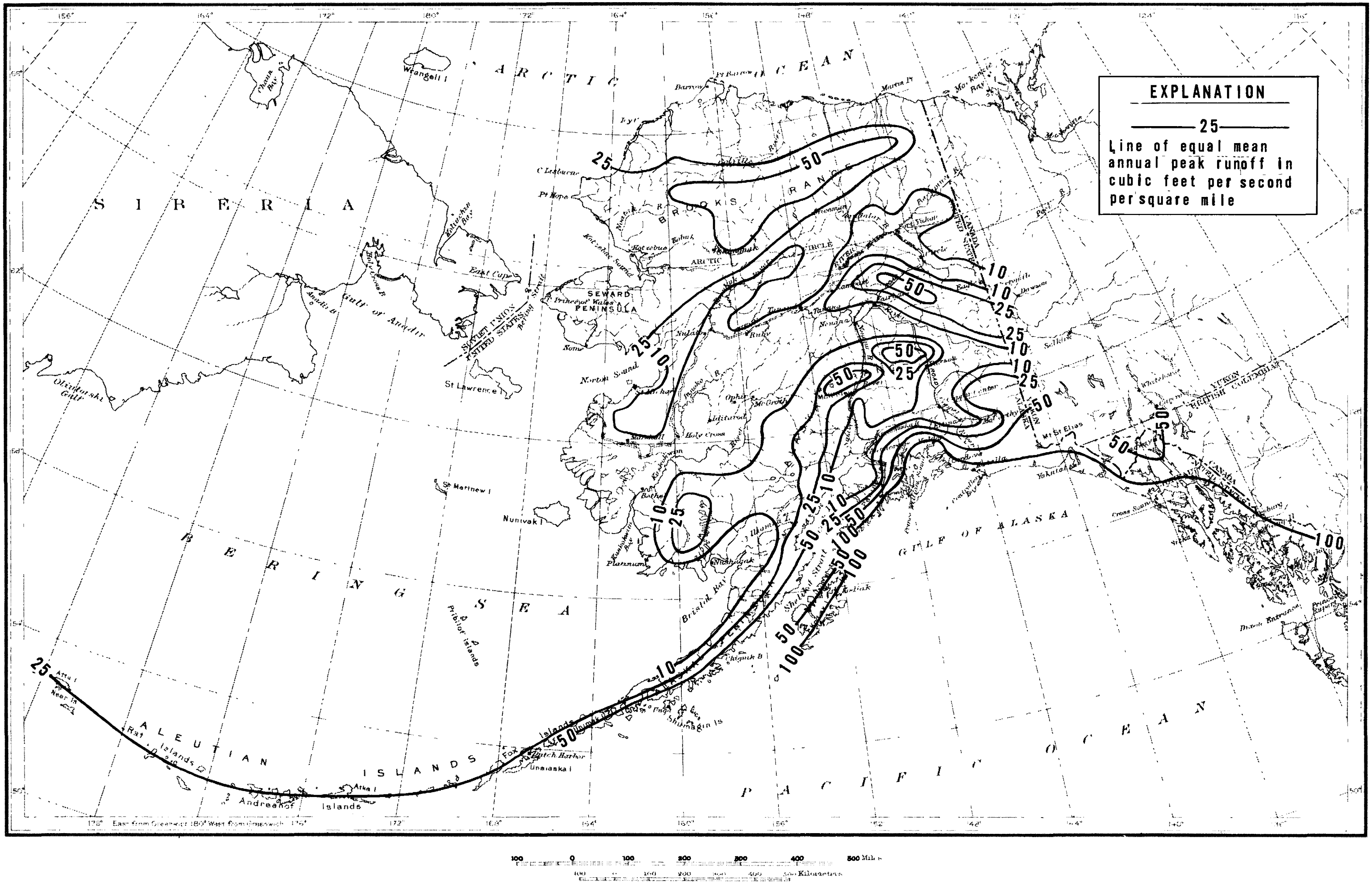


Figure 10.--Mean annual peak runoff.

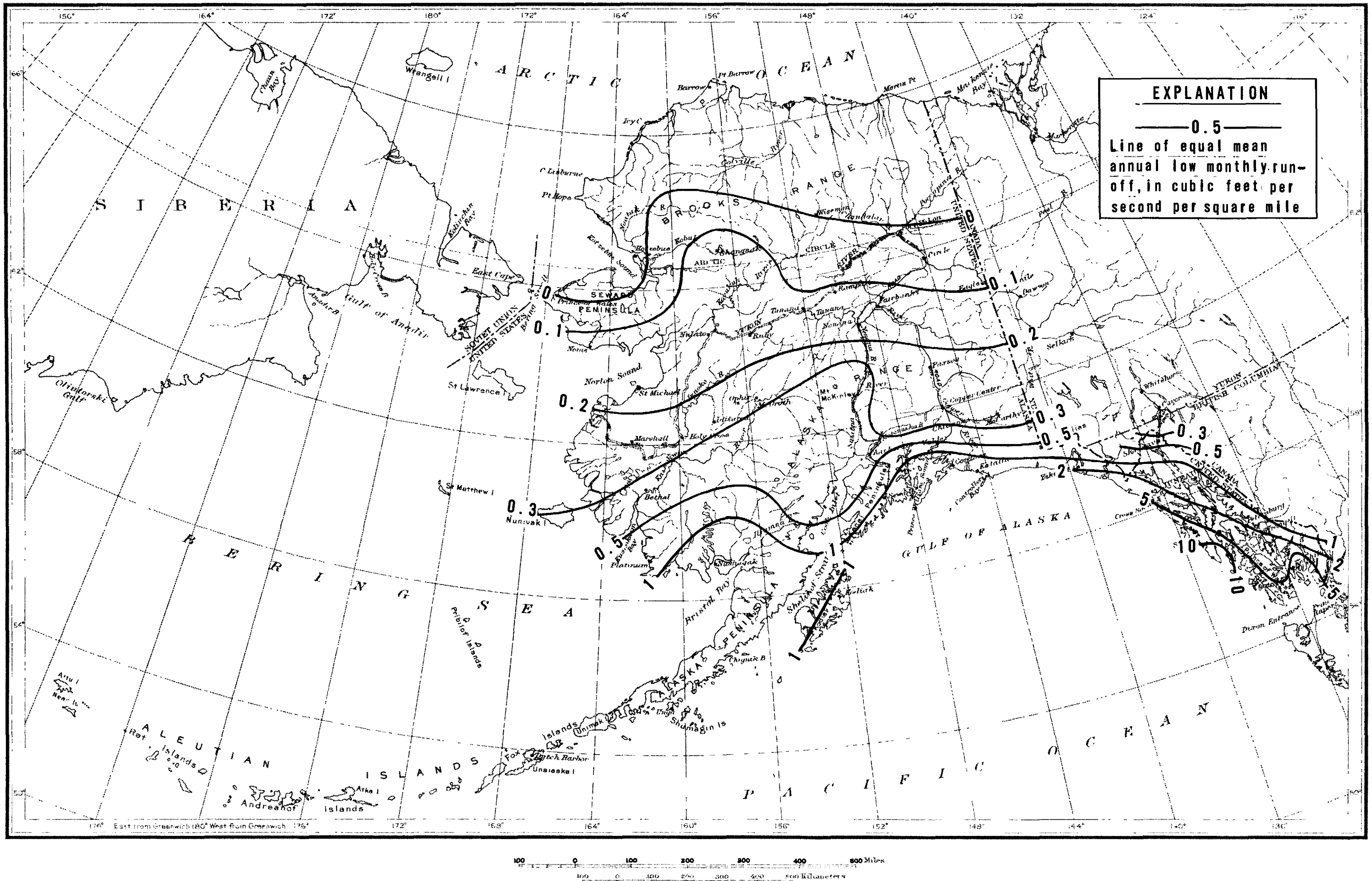


Figure 11.--Mean annual low monthly runoff.

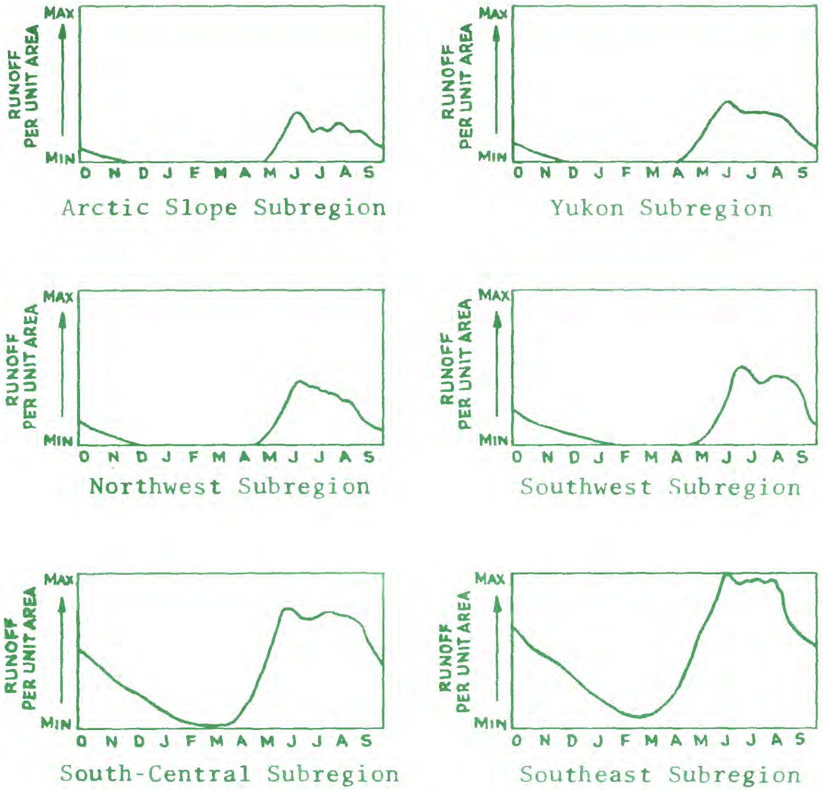


Figure 12.--Generalized relative monthly runoff rates.

In the Yukon subregion the precipitation is generally 5 to 20 inches, but locally it is higher. The climate is warm in summer and very cold in winter. The frost-free period is generally 63 to 90 days. Runoff is 8 to 40 inches or more. The variability of streamflow is similar to that of the average stream in the conterminous states.

The northern part of the Northwest subregion has an arctic climate and the southern part has a transitional climate. Precipitation ranges from 2 to 21 inches annually. The low precipitation, long winters, presence of permafrost, and numerous low mountains cause highly variable seasonal runoff but also lead to fairly low annual runoff rates. Annual peak runoff can be caused by rainstorms in the summer or by snowmelt in the spring. Very little measurable runoff occurs during most of the winter season. However, icings that fill some stream channels are common in winter, indicating that water is flowing in the streams.

The Brooks Range and the Arctic Slope have an arctic climate. The precipitation is less than 5 inches along much of the coast, but the evapotranspiration is low and most of the precipitation is retained as snow and ice. The summer is very short (average frost-free period at Point Barrow is 17 days).

The availability of data on the Tanana Basin in the Yukon subregion, the Anchorage, Matanuska-Susitna, and Kenai areas in the South-central subregion, and the Southeast subregion allows a more elaborate discussion of runoff for these areas. That discussion by subregions follows.

Yukon Subregion (Tanana Basin)

Mean annual runoff averages about 0.5 to 1 cfs per sq mi (cubic feet per second per square mile) in the lowlands and basins north of the Tanana River (fig. 9). Mean annual runoff ranges from about 1 cfs per sq mi to more than 4 cfs per sq mi in the uplands of the Alaska Range. Annual runoff varies widely.

For example, runoff from the Chena River at Fairbanks was measured at 0.36 cfs per sq mi in 1958 and at 1.32 cfs per sq mi in 1962.

Mean annual peak runoff ranges from about 10 cfs per sq mi in the lowlands to as much as 50 cfs per sq mi in steep basins in the uplands (fig. 10). Most annual peaks occur in summer from rainfall, although spring snowmelt can also cause annual peaks. Channel icing and ice-jam flooding make this area especially flood prone.

Mean annual low monthly runoff averages about 0.1 to 0.2 cfs per sq mi (fig. 11). Low flow is usually in late winter or early spring following the winter streamflow recession. Streams in many small basins probably freeze completely during most winters. During winter when there is little or no snowmelt or rain, the only large contribution to streamflow is from ground-water discharge in the channels of the larger rivers.

South-Central Subregion

Anchorage.--Streams flowing from the mountains across the lowlands are known to lose streamflow to ground water near the mountains and regain water from the ground water near the ocean. Most of the streams are fed by glaciers.

Mean annual runoff in the Cook Inlet lowlands near Anchorage is about 1 cfs per sq mi or less and increases to about 8 to 10 cfs per sq mi near Prince William Sound (fig. 9).

Mean annual peak runoff is about 10 cfs per sq mi or less in the Cook Inlet lowlands and is more than 100 cfs per sq mi at Prince William Sound (fig. 10). Mean annual peak runoff averages between 10 and 50 cfs per sq mi on most of the streams draining into Cook Inlet. The higher rates are from steeper and higher basins. The lower rates are from streams having extensive lowland drainage. The lowland basins containing many swamps or lakes have mean annual peak runoff rates of less than 10 cfs per sq mi. Floods from heavy rain are common in the late summer or fall. Spring snowmelt in lowland basins while the ground and drainages are partly frozen can cause local flooding. The Knik River near Palmer drains glacier-dammed Lake George. Breakout floods have often occurred, and a maximum flood discharge of 355,000 cfs was recorded at the gaging station, compared to the average annual discharge of 7,000 cfs.

Mean annual low monthly runoff ranges from 0.1 to 0.5 cfs per sq mi at Anchorage to about 1 cfs per sq mi in the mountains (fig. 11).

Kenai Peninsula.--Mean annual runoff ranges from about 1 cfs per sq mi on the Cook Inlet-Susitna lowlands to about 10 cfs per sq mi in the Kenai Mountains (fig. 9). Small basins in the lowlands have less than 1 cfs per sq mi annual runoff. Basins draining from the mountains west into Cook Inlet have mean annual runoff rates of about 4 or 5 cfs per sq mi. Even small basins along the Gulf of Alaska have mean annual runoff rates of more than 5 cfs per sq mi.

Mean annual peak runoff averages about 5 to 10 cfs per sq mi in the Cook Inlet-Susitna lowlands and more than 100 cfs per sq mi in the Kenai Mountains (fig. 10). Streams draining the low swamps north of the Kenai River have mean annual peak discharge rates of about 1 cfs per sq mi. Peak rates increase in the mountains, probably averaging as much as 50 cfs per sq mi in the higher mountains on the Cook Inlet side;

about 50 cfs per sq mi in small low basins; and more than 100 cfs per sq mi in high steep basins on the Gulf of Alaska side, although more than 150 cfs per sq mi have been measured.

Peak flows in the steep mountains are often accompanied by mass transport of rocks and other debris. Landslides carrying masses of sediment, including boulders, into the flooding streams have been observed in some of the small stream valleys. Floods can attain peak rates exceeding 500 cfs per sq mi. Peaks usually occur in the fall from heavy rainfall. Breakout flooding from glacier-dammed lakes also occurs.

Mean annual low monthly runoff averages about 0.5 cfs per sq mi in the western part and about 1 cfs per sq mi in the eastern part (fig. 11).

Matanuska-Susitna.--Mean annual runoff is about 0.5 to 1 cfs per sq mi in the lowlands and probably about 4 cfs per sq mi in the mountains (fig. 9). Mean annual peak runoff ranges from less than 10 cfs per sq mi in the lowlands to 50 cfs per sq mi in the mountains (fig. 10). Low basins having swamps or lakes have mean annual peak runoff rates of 1 to 5 cfs per sq mi. High steep basins have mean annual peak rates of 25 to 50 cfs per sq mi. Annual peaks are usually from fall rainstorms.

Mean annual low monthly runoff averages between 0.3 and 0.5 cfs per sq mi (fig. 11). Low flow is generally in late winter when the precipitation is stored as snowpack. During some dry years, the annual low flow may be in summer in lowland basins having extensive lakes or swamps.

Southeast Subregion

The outer coastlines and glacier-capped mountains seem to receive higher precipitation and to have more runoff (more than 10 cfs per sq mi) than the inner islands. Low basins have runoff rates of less than 10 cfs per sq mi (fig. 9). Mean annual runoff is about 10 cfs per sq mi in southern Baranof Island.

Mean annual peak runoff throughout the subregion is about 100 cfs per sq mi and generally ranges from less than 50 cfs per sq mi to more than 200 cfs per sq mi (fig. 10). For drainage basins less than 10 square miles in area, annual peak rates average about 150 cfs per sq mi and for drainage basins more than 100 square miles in area, about 50 cfs per sq mi.

Average annual peak discharge rates exceeding 300 cfs per sq mi have been measured at scattered gaging stations. Causes of such rates have not been determined but contributing factors may be high basins having bare rock or glacier surfaces; exceptionally steep, short streams; increase of precipitation with increased elevation; or unusually high precipitation rates in some basins. Mean annual peak discharge rates of less than 50 cfs per sq mi occur in small, low basins or in basins having extensive lake or swamp storage. Peaks are caused by excessive precipitation or occasional rapid snowmelt. Annual peaks are the most common during fall.

Mean annual low monthly runoff averages about 2 cfs per sq mi and generally ranges from about 0.2 cfs per sq mi for larger basins near Skagway to more than 10 cfs per sq mi for small basins on lower Baranof Island (fig. 11). Along the outer coastlines rates of more than 2 cfs per sq mi have been measured and on the mainland rates less than 2 cfs per sq mi have been measured. Higher rates occur during mild winters or in areas where lakes or aquifers contribute to streamflow.

Storage

Storage is a natural mechanism whereby water is detained in a drainage basin. In Alaska, the winter snowpack and glaciers provide most of the water storage. However, in some subregions, lakes, swamps, and ground-water reservoirs store large amounts of water. During the winter snow accumulation, streams usually recede to annual low flow; and during the spring melt season, they usually rise to annual high flow.

The State has more than 3 million lakes. Twenty lakes throughout Alaska are known to be 250 feet deep and more lakes of similar depth undoubtedly exist. Ninety-four lakes having a surface area of more than 10 square miles are known (fig. 13). The areas of the 7 largest lakes are shown in table 4.

Table 4.--Major lakes, Alaska region.

Lake	Subregion	Surface area (sq mi)
Iliamna	Southwest	1,000
Becharof	Southwest	458
Teshekpuk	Northwest	315
Naknek	Southwest	242
Tustumena	South-central	117
Clark	Southwest	110
Dall	Southwest	100

The largest lake is Lake Iliamna in the Southwest subregion having a surface area of 1,000 square miles. Throughout the Southeast and South-central subregions proglacial lakes provide the principal sources of streams. Numerous glacier-dammed lakes exist throughout Alaska. Their accumulation and periodic breakout creates hazards caused by the catastrophic flooding when the ice dams fail.

Figure 13.--Distribution of principal lakes.

GROUND WATER

Occurrence of Ground Water

Ground-water conditions in Alaska are highly variable. The principal aquifers are recent deposits of well-sorted sand and gravel incorporated within the glacial drift that covers the uplands, and in the glacial-outwash and other alluvial deposits that extend from the uplands into the lowlands.

The older consolidated rocks are much less permeable throughout Alaska, although they are capable of small yields in most places. Water is obtained from fractures or joint systems within the bedrock, and occurs in cavernous carbonate rocks that locally support discharge of large springs.

Ground-water occurrence in Alaska is complicated by several conditions. One not found in other parts of the United States is the widespread presence of permafrost. Ground water may occur above the permafrost, in thawed zones within the permafrost, or below the permafrost. The ground water occurring above permafrost is commonly seasonal. However, in some areas under current climatic conditions, the permafrost has thawed downward to a depth below that of winter frost, so that a perennial zone of saturation exists on top of the permafrost. Ground water is also available under and in the immediate vicinity of lakes and streams, including recently abandoned streams and lake beds. Other areas favorable for ground-water development, assuming the presence of permeable materials, are those where the insulating cover of vegetation has been stripped away and the ground has thawed as a result. In any given area the south-facing slopes are more likely to be thawed than the north-facing ones. Icings (masses of surface ice formed during winter by successive freezing of sheets of water seeping from the ground) are good indicators of the presence of ground water.

Availability of Ground Water

The following map (fig. 14) illustrates the general availability of ground water throughout Alaska. In the Central Valley of Alaska along the Yukon River and in the South-central subregion along the Susitna River, well-sorted sand and gravel in glacial outwash or alluvium provide between 1,000 and 3,000 gpm (gallons per minute).

In the vast alluvial valley of the Yukon River and its tributaries, permafrost is absent or thawed to a considerable depth in many places beneath the bodies of water and rarely extends all the way to bedrock. Hence, ground water is generally available in thawed areas and in thawed zones within the permafrost or beneath the permafrost.

Immediately adjacent to the flood-plain and glacial outwash deposits along the major rivers just discussed are deposits of similar nature in lower terraces and the lower part of alluvial fans, which probably yield 100 to 1,000 gpm. Adjacent to these deposits are the alluvial fan deposits and upland deposits, which yield less than 100 gpm. In the

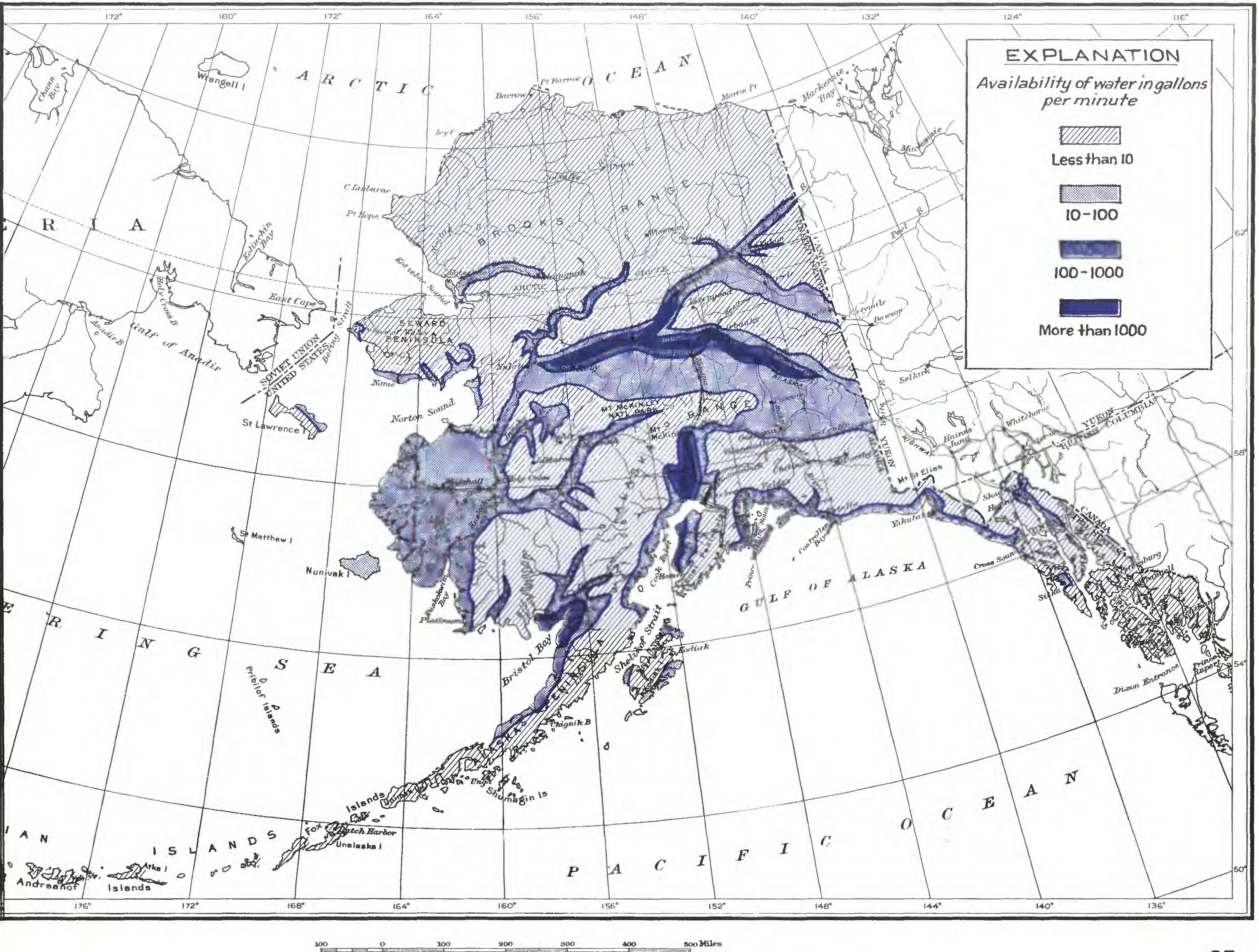


Figure 14.--Generalized availability of ground water.

alluvial fan deposits in the upland areas, the pump lifts are quite large and increase the cost of utilizing ground water. Throughout the remainder of Alaska, ground water is available from properly drilled wells, but exploration is required. In general, ground water is not available in these areas in quantities larger than 10 gpm, either because of the presence of permafrost or the lack of surficial water-bearing materials or because the water is obtainable only from fractures or joint systems in bedrock.

For detailed information relative to the ground-water conditions in areas of the State where developments have taken place, the reader is directed to the reference list that accompanies this report.

Springs

The distribution of springs throughout the State is widespread but little detailed information is available. Some of the more prominent springs are indicated in figure 15. Nearly all the published data regarding springs known to exist in Alaska are contained in a publication by Waring (1917). The reader is directed to this publication and to the other publications listed in the references for springs that have been more recently observed and described.

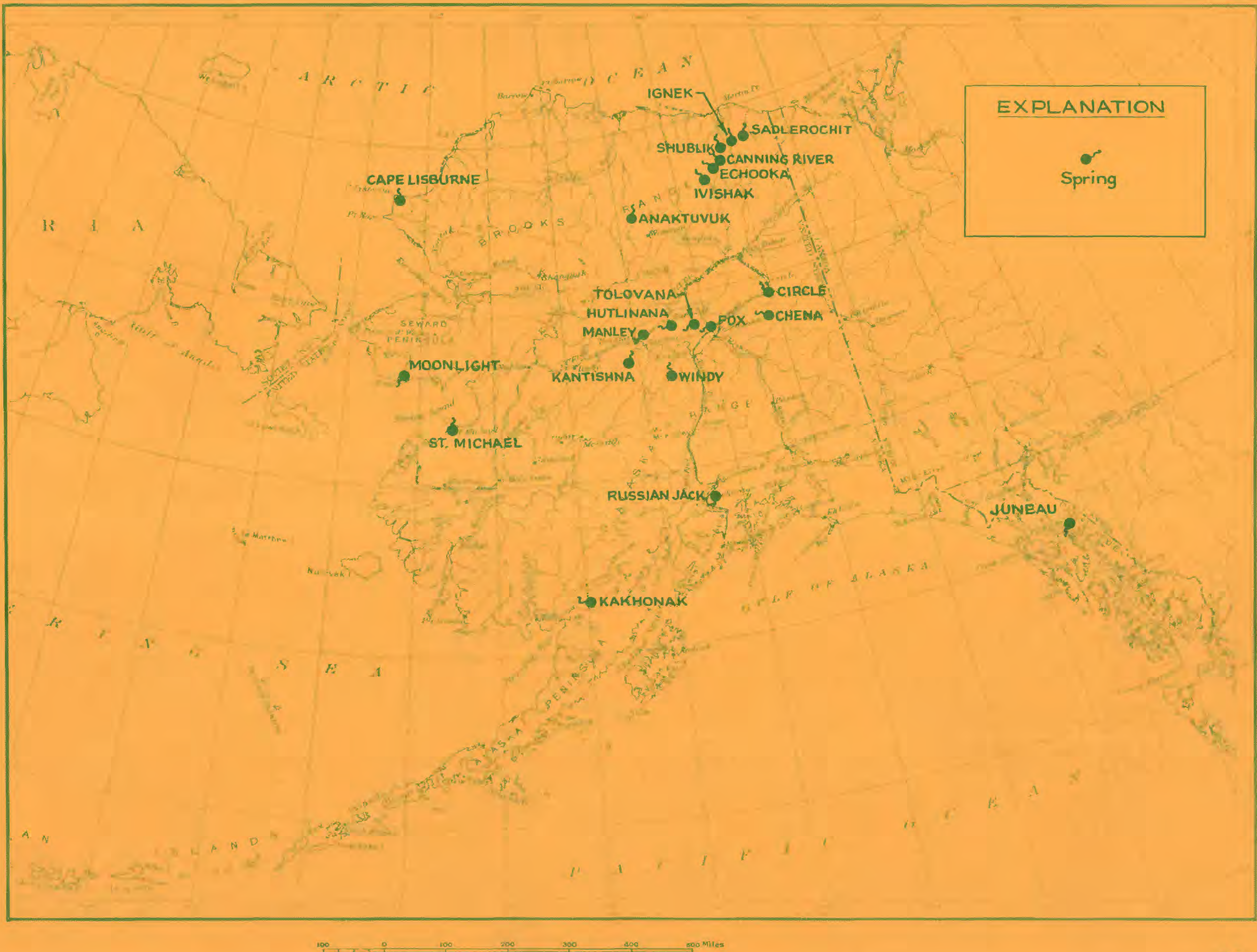


Figure 15.--Selected springs.

QUALITY OF WATER

Water is a vigorous solvent attacking many rock minerals on contact, and, where flowing, is also a powerful mechanical erosive agent. Consequently, the water found in streams, lakes, and the sea, and produced from wells, is never pure. Its dissolved mineral content, suspended sediment, and temperature, separately or in combination, control or limit utilization by man and its suitability as a habitat for fish and other wildlife. Therefore, appraisal of Alaska's water resources requires that these variations in chemical quality, suspended sediment, and temperature be considered. Because some patterns of variation characterizing surface water do not apply to ground water, surface- and ground-water characteristics are best discussed separately.

The dissolved-solids content is usually considered the most important criterion for assessing chemical quality because the acceptability of water for drinking, cleaning, heating, and most industrial uses lessens as the dissolved-solids content increases. Dissolved-solids concentrations commonly present in water range from a few milligrams per liter (mg/l) in rainwater and mountain snowmelt water to more than 35,000 mg/l in ocean water. Fresh water is now generally defined as that containing not more than 1,000 mg/l dissolved solids. By this criterion, most Alaskan streams are fresh water except where intruded by sea water near their mouths.

Water can be classified as fresh and still be regarded as unsatisfactory for use. The current standard for public water supplies recommends that the dissolved-solids content not exceed 500 mg/l (U.S. Public Health Service, 1962). Moreover, dissolved-solids concentrations of 250 mg/l, or less, are preferable for municipal and most industrial uses. Some Alaskan stream water and much of the State's ground water contain more than 250 mg/l dissolved solids. Thus, where more than one source can be considered dissolved-solids concentration may be an important criterion in selecting the source of supply for a new development in Alaska.

To most people, hardness is probably the most noticeable characteristic of water. Hardness is a property of water caused by several metallic ions but is mainly dependent on concentrations of calcium and magnesium. Hardness was originally defined as a measure of the water's soap-consuming power, but it is also a measure of the tendency to form scale on heated metal surfaces such as inside teakettles or steam boilers. However, objections to hardness depend on the user's experience, and water that appears hard to one user may be considered soft by another. The following table summarizes ranges of hardness in descriptive language used in many reports of the Geological Survey.

Hardness range (mg/l of $CaCO_3$)	Hardness description
0 - 60	Soft
61 - 120	Moderately hard
121 - 180	Hard
More than 180	Very hard

Hardness of stream water depends to a considerable extent on the kinds of rocks cropping out in the watershed areas. Thus, streams draining areas underlain by limestone or gypsum contain hard water, whereas streams draining granitic rocks contain soft water. Hardness also can be related to rainfall. Areas of high rainfall generally have streams containing softer water than those having low rainfall. Ground water is commonly harder than stream water in the same area. In Alaska, hardness is usually a secondary consideration in developing individual wells for domestic use but is an important criterion in developing larger systems.

Suitability of water for individual uses depends to a considerable degree on its ionic composition and the relative quantities of some of the ions. Many ions can be present in very small amounts, but usually only a few are present in sufficient quantity to affect use. For most purposes, knowledge of the concentrations of the four principal cations: calcium, magnesium, sodium, and potassium, and the four principal anions: bicarbonate, sulfate, chloride, and nitrate is all that is needed to evaluate a potential water source. For fresh water, calcium and magnesium are limiting at higher concentrations because they cause hardness. Sodium is generally not limiting except that low-sodium water is desirable for some who have heart disease. Potassium and bicarbonate are generally not limiting for most water uses. Sulfate and chloride can be tolerated for most purposes and are acceptable up to concentrations of 250 mg/l each, although the higher their concentrations the more corrosive the water is likely to be. Nitrate is considered undesirable at concentrations greater than about 45 mg/l because it then may cause cyanosis in infants. Fluoride is unique in that a small quantity should be present in drinking water to help prevent tooth decay. However, a slightly higher concentration of fluoride is considered undesirable because it results in staining of teeth. The level of fluoride concentration considered desirable depends on average annual air temperatures. Alaska fluoride concentrations should range between 0.9 and 1.7 mg/l. Most analyses have shown less than 0.5 mg/l fluoride, but fluoride values have ranged as high as 11 mg/l.

Silica constitutes the principal un-ionized constituent in most water. It is necessary for the growth of diatoms, small organisms that live in lakes and streams, and in some Alaskan water may be a limiting nutrient. Silica contributes to formation of hard boiler scale; so low-silica water is preferred for heating systems. Although most Alaskan surface water seldom contains more than 10 mg/l silica, some streams regularly contain as much as 30 mg/l. Silica concentrations in ground water are generally moderately higher than in surface water in the same area. Silica concentrations in the range of 30 to 60 mg/l are common in ground water in some areas in Alaska.

Iron probably causes more problems in individual water systems than any other dissolved constituent because it causes both stains and scale. The chemical state of iron in water is often uncertain. It may be ionized but generally seems to be un-ionized. Some of the iron is complexed with the ionic constituents and some with organic matter. Consequently, some water loses iron rapidly by precipitation when aerated, whereas other water retains its iron in solution for comparatively long periods. Manganese problems are similar to those caused by iron. Recommendations are that iron and manganese together should not exceed 0.3 mg/l (U.S. Public Health Service, 1962). Iron and manganese, particularly in ground water, constitute a major problem in all parts of Alaska. At many locations, iron and manganese are present in water from shallow wells but absent in water from deeper wells.

The units used in this report for expressing the concentrations of chemical constituents in solution or suspended sediment are milligrams per liter. Milligrams per liter represents the weight of solute or sediment per unit volume of water.

Using chemically equivalent concentrations, water can be classified into types, according to the dominant dissolved ions. Thus, water that contains mainly calcium and bicarbonate is classified as a calcium bicarbonate type; similarly, water that contains sodium and chloride is classified as sodium chloride type. Mixed types can also be designated such as calcium sodium bicarbonate type or sodium bicarbonate chloride type.

In this report, similarities between waters from different sources are shown in the illustrations by use of pie diagrams in which the relative amounts of chemically equivalent concentrations of the various constituents are shown as parts of a circle and the relative concentrations of dissolved solids are represented by the size of the circle.

Discussions on the types of water are based on the equivalent computations, although numerical references are to concentrations in milligrams per liter.

The surface- and ground-water sampling sites shown in the illustrations have each been assigned a unique Alaska location number. Further information on these or other sites is available at the U.S. Geological Survey, Water Resources Division Office, in Anchorage.

Chemical Quality of Surface Water

Information on the concentration and composition of Alaskan surface water is markedly variable in coverage. Some subregions have had regular or periodic sampling extending for many years at many stream points and at a number of lakes. Surface water in other subregions is represented by only a few miscellaneous samples. Although the chemical characteristics of water in the streams and lakes of Alaska seem variable, the ranges in concentration are not as large as found in the conterminous United States. Most Alaskan streams above tidal reaches contain water of a calcium bicarbonate type generally containing less than 200 mg/l dissolved solids. In these streams the hardness generally increases with increased dissolved-solids content. The streams draining lowlands and intermontane basins usually contain harder water than the streams in the higher mountains.

The water in lakes in Alaska is more variable in mineral content than in the rivers. The water in some mountain lakes is very low in dissolved-solids content, and is little more concentrated than rainwater. Other lakes occupying lowlands near the sea, including many near the Arctic Coastal Plain, have become mineralized periodically from salts brought in either from the sea by overland flooding during storms or as ocean spray. The water in lakes in the lowlands remote from the sea is often very similar in chemical character to water in the larger rivers adjacent to them.

Representative samples of surface water from each subregion are graphically illustrated on a map of Alaska (fig. 16). The following discussion gives further information on the chemical quality of surface water for each subregion.

Arctic Slope Subregion

Streams that have been sampled in the Arctic Slope subregion generally have had dissolved-solids concentrations less than 120 mg/l. The data suggest that both the dissolved-solids content and mineral composition vary considerably between winter and summer. A July sample from the Colville River near Umiat had a dissolved-solids content of 60 mg/l and hardness of 54 mg/l; an April sample (representing late winter) had a dissolved-solids content of 356 mg/l and hardness of 318 mg/l. Except for high salinities of lakes near the Arctic Ocean, the mineral content of the surface water is probably acceptable for domestic and public supply throughout this subregion. Temperature measurements from 8 lakes and streams in the subregion indicate an annual range of 0°C (Celsius) to 3°C.

Northwest Subregion

The overall chemical quality of surface water sampled in the Northwest subregion is acceptable for most purposes. Surface-water samples generally have contained less than 200 mg/l dissolved-solids content and most have been of the calcium bicarbonate type. Water in coastal areas is generally higher in sodium and chloride contents during the summer than is water sampled farther from the coast. Streams in the western part of the subregion contain more sulfate relative to chloride than is common in most of Alaska. On the basis of 32 samples of surface water, the annual temperature ranges from 0°C to 16°C.

Yukon Subregion

In the Yukon River basin all surface water sampled has been of the calcium bicarbonate type and of acceptable quality. Samples analyzed show a range in dissolved-solids content from 5.5 mg/l in a small mountain reservoir at Indian Mountain to 213 mg/l in winter flow of the Porcupine River. A representative analysis of the Yukon River, sampled at Ruby, had a dissolved-solids content of 141 mg/l and a hardness of 114 mg/l. A few of the streams carry excessive iron content during parts of the year.

Surface water sampled in the Tanana Basin in the Yukon subregion has acceptable quality for public supply. Although concentrations of dissolved solids range from 60 to 484 mg/l, most samples are less than 200 mg/l. The dissolved-solids content is highest apparently in water from areas adjacent to the mountains and decreases toward the center of the basin. Water sampled near the center of the basin has the highest concentration of dissolved solids during

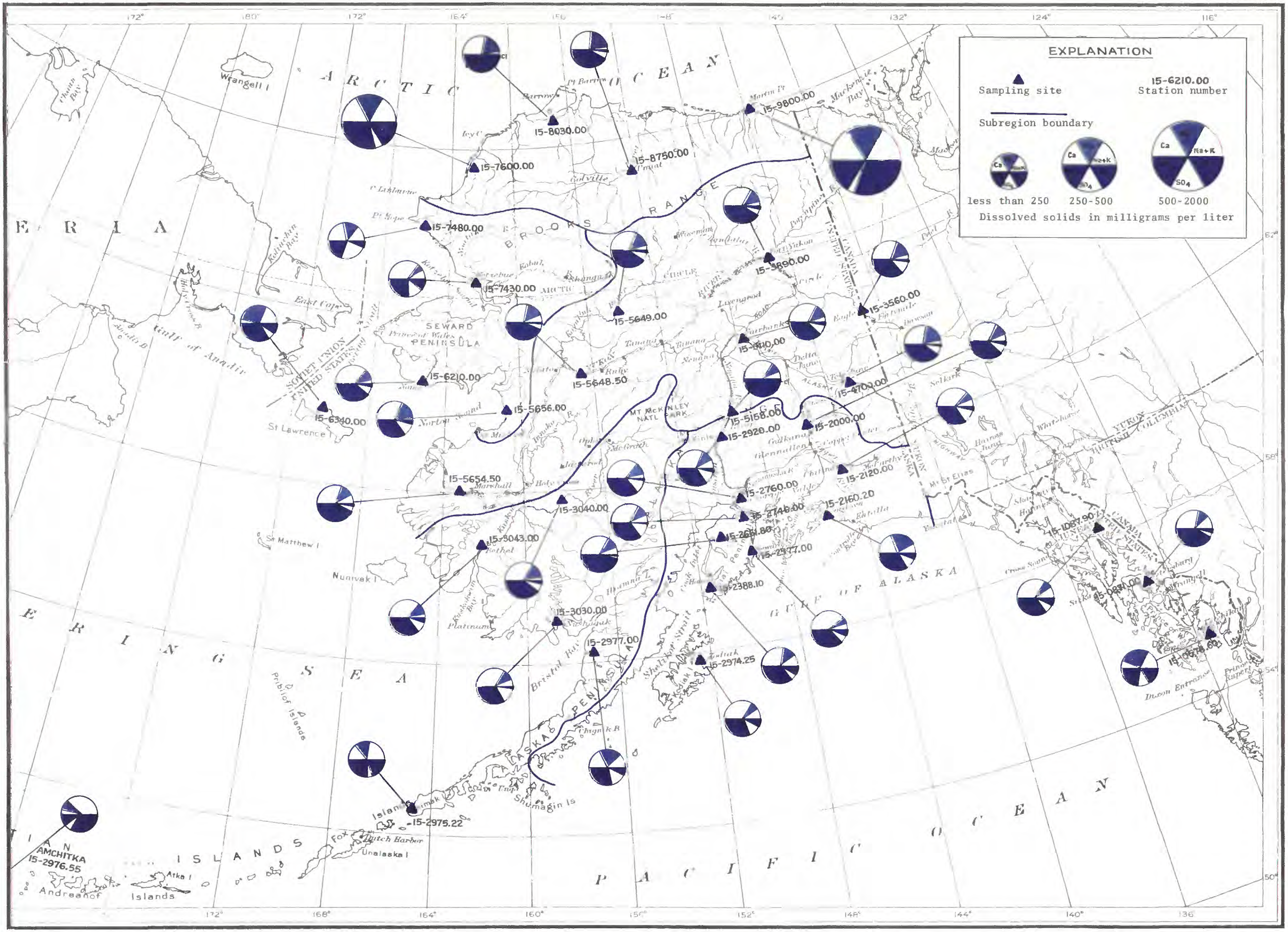


Figure 16.--Representative pie diagrams showing quality of surface water.

periods of low flow, when ground-water recharge is probably greatest. The streams flowing from the Alaska Range are generally higher in sulfate and magnesium content than are the other streams, but none contain excessive amounts of these constituents. Iron is the only constituent that is present in excessive amounts in any of the surface water sampled. Two analyses from swampy areas near the Canadian boundary have iron contents of 0.60 and 0.73 mg/l. The iron may be complexed with organic material. Lakes may be either higher or lower in iron content and color than streams, but the hardness of lake water sampled is generally less than that of the streams.

The normal summer surface-water temperatures in the Yukon subregion ranges between 7°C and 10°C, and of winter temperatures from 0°C to 2°C. The maximum recorded summer water temperature is 19°C on the Chena River near Fairbanks in June. The rivers in this subregion cool uniformly to about 0°C by October and usually remain at this temperature until about late April. Temperature data taken during periodic summer streamflow measurements of the Yukon River ranges from 6°C to 18°C.

Southwest Subregion

The observed range of dissolved-solids content in the surface water sampled in the Southwest subregion is from 22 mg/l on the Kvichak River, which discharges from Lake Iliamna, to 163 mg/l from a small stream on Amchitka Island. Most of the samples of surface water had a dissolved-solids content of less than 100 mg/l. Most streams have water of the calcium bicarbonate type of acceptable quality for public supply, although many have excessive iron content. Some water from streams and lakes, especially on the Aleutian Islands, is destructively corrosive. Temperature range of surface water sampled in the Southwest subregion is from 0°C to 10°C.

South-Central Subregion

Anchorage.--In the Anchorage area of the South-central subregion, the general range in dissolved-solids content in surface water is from 32 mg/l at South Fork Campbell Creek near Anchorage to 151 mg/l from a lake on Fire Island. All surface water sampled was of the calcium bicarbonate type. A few shallow lakes and the streams draining these lakes are high in color, and some are high in iron content. Data from 12 streams in the Anchorage area indicate the range of summer temperature is from 5°C to 12°C and averages 8°C. The range of winter temperature is from 0°C to 6°C and averages 0.6°C.

Copper River.--Surface water in the Copper River basin in the South-central subregion has an observed range in dissolved-solids content from 12 mg/l at Meals Lake near Cordova to 117 mg/l on Squirrel Creek near Tonsina. Therefore, the surface-water quality is generally acceptable. Nearly all the surface water is of the calcium bicarbonate type, typified by a sample from the Tazlina River near Glennallen, or calcium magnesium bicarbonate type, typified by the sample from Meals Lake. A sample taken from a lake on Middleton Island is the only one that shows a sodium chloride type water. Middleton Island is in the Gulf of Alaska, and the minerals there are probably derived from salt spray. The surface-water temperatures range from 0°C to 9°C.

Kenai Peninsula.--On the Kenai Peninsula in the South-central subregion, surface-water samples have a range of dissolved-solids content from 7 mg/l at Cove Creek near Whittier to 103 mg/l at Beaver Creek near Kenai. All samples are the calcium bicarbonate type. The highest summer dissolved-solids content, as well as the highest iron content, is from those streams that originate in the lowlands and drain swamps. Those streams that drain from snowfields in the east have the lowest dissolved-solids content. The range of temperature for surface water on the Kenai Peninsula is from 0°C to 17°C.

Kodiak.--On Kodiak Island in the South-central subregion, the dissolved-solids content of surface water ranges from 17 mg/l at the outlet of Terror River to 45 mg/l from Monashka Creek near Kodiak. Most of the water sampled on Kodiak Island is the calcium bicarbonate type, similar to the water from Monashka Creek, although lakes near the ocean contain water of a sodium chloride type similar to a sample taken from a lake on Woody Island, and sodium bicarbonate type water similar to a sample from a lake at Cape Chiniak Air Force station. The measured temperature of surface water on Kodiak Island ranges from 1°C to 6°C.

Matanuska-Susitna.--In the Matanuska-Susitna area of the South-central subregion, surface water has a range of dissolved-solids content from 24 mg/l at Chakachatna River near Tyonek to 234 mg/l at Caribou Creek at Sheep Mountain. All surface water sampled is of the calcium bicarbonate type. The highest dissolved-solids content in streams apparently originates in the eastern part of the area where streams drain from the coal fields northeast of Palmer. The lowest dissolved-solids content is in the glacial streams draining from the mountains on the western side. The average winter temperature of most streams sampled in the Matanuska-Susitna area is at or near 0°C and the summer high temperature is about 12°C. The average summer temperature of all streams is about 8°C.

Southeast Subregion

In the Southeast subregion, dissolved-solids contents from 38 sampling points generally range from 3 mg/l to 120 mg/l, averaging 18 mg/l in summer; and range from 1 to 105 mg/l, averaging 19 mg/l in winter. Water in the northern part of the subregion generally has a higher dissolved-solids content than water in the southern part. Surface water is generally of the calcium bicarbonate type. All of the surface water sampled was of acceptable quality and only a few of the samples are somewhat high in iron content. On the basis of 47 samples, the median summer temperature of surface water is 8°C and ranges from 3°C to 12°C. In contrast, the median winter temperature of 46 samples is 2°C and ranges from 1°C to 3°C. Temperatures were taken in basins having areas of less than 10 square miles, of 10 to 100 square miles, and of 100 to 1,000 square miles. Only two summer and two winter temperatures were taken in the largest-size basin, but even these scanty data suggest that water temperatures are more constant and lower in the larger basins.

Sediment Content

In Alaska, as elsewhere, all natural streams transport suspended sediment, although the quantity, size, distribution, and physical and chemical nature of the particles vary from time-to-time, place-to-place, and stream-to-stream. Much of the sediment originates at higher altitudes as fragmentary material produced by the mechanical disintegration of bedrock and unconsolidated material by freezing and thawing. At lower altitudes, chemical weathering assumes importance, especially where moisture is abundant. Additional sediment load comes from the activities of man such as industry, mining, highway and urban development, and farming. The quantity and nature of stream-borne sediments are influenced by the topography, precipitation, temperature, geology, soil conditions, and vegetative cover. In Alaska, the character and distribution of suspended sediment are made even more complex because of the contribution by glaciers of large amounts of very fine material (glacial flour) to many streams.

Information on the quantity and nature of suspended sediment being transported by streams is of critical importance in understanding the effects of urbanization, industrial or mining development, and farming; in predicting the effects of accumulation of sediment in reservoirs and lakes; and in assessing water quality as related to fish propagation and water treatment.

Suspended-sediment data for Alaska streams is scanty and consists only of scattered analyses. In general, nonglacial streams transport less than 100 mg/l of suspended sediment during the summer in contrast to as much as 2,000 mg/l for glacial streams. Sediment concentrations described in this section as the normal concentration represents the median (middle) value. The summer period refers to May through October. Nonglacial streams often transport their highest concentration during the spring melt or during periods of heavy rainfall, whereas glacial streams transport their highest concentration during heavy melt water, usually in middle or late summer (fig. 17). During fall and winter, glacial and non-glacial streams both carry less sediment than in summer. The normal suspended-sediment concentration between January and April is about 20 mg/l or less

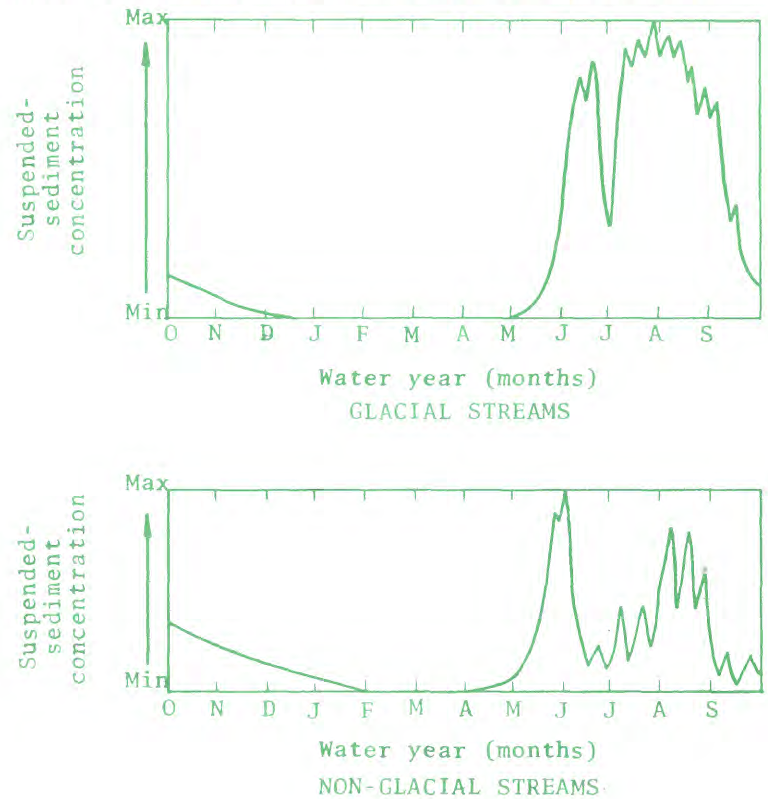


Figure 17.--Relative distribution of suspended-sediment concentrations throughout the water year.

for all streams. Less than 15 percent of the annual sediment load is carried during this period. The percentage of material finer than 0.062 mm (millimeter) (the silt-clay fraction as generally defined) transported by nonglacial streams is less than 50 percent in contrast to more than 50 percent for glacial streams. However, the percentage of fine material increases appreciably if a glacial stream flows through a lake.

Many large streams in Alaska result from a combination of glacial and nonglacial tributaries and accordingly transport suspended sediment that in its particle-size distribution and concentration reflects its dual origin.

Information on suspended sediment that is currently available for Alaska is discussed in more detail in the following pages.

The only data available regarding the Arctic Slope subregion indicates that the instantaneous suspended-sediment concentration has been measured as high as 1,650 mg/l on the Colville River and is in excess of 3,000 mg/l on Chamberlain Creek.

In the Northwest subregion fragmentary data from several streams indicates that the normal summer suspended-sediment concentration generally ranges from 10 to 100 mg/l. Winter concentration of suspended sediment in perennial streams is probably less than 20 mg/l.

In the Yukon subregion, the Yukon River is the most heavily sediment-laden stream in terms of concentration except for those streams in the Tanana Basin. During the summer the Yukon transports a normal concentration ranging from 200 to 400 mg/l suspended sediment, 70 to 80 percent of which is finer than 0.062 mm. In contrast, samples taken during the winter indicate that most streams in the subregion transport less than 15 mg/l suspended sediment between January and April.

Of streams in the Yukon subregion, the Tanana River transports the highest concentration of sediment. It receives both its principal flow and its largest quantity of sediment from streams draining the glacier fields on the north slope of the Alaska Range and the Wrangell Mountains. Samples collected from these streams indicate that their normal summer concentration generally ranges from 500 to 2,000 mg/l. In contrast, the nonglacial streams draining into the Tanana River transport only about 10 to 300 mg/l. Normal summer concentrations of the Nenana River range from 10 mg/l in the headwaters to more than 1,000 mg/l downstream, 60 to 70 percent of which is finer than 0.062 mm. Concentrations during the winter are generally less than 20 mg/l for all streams measured in this basin from January to April. The average annual sediment yield of the basin ranges from less than 100 tons per square mile in the mountains north of the Tanana River to perhaps 5,000 tons per square mile in the Alaska Range.

In the Southwest subregion, the Kuskokwim River at the sampling point at McGrath normally transports about 350 mg/l suspended sediment during the summer and 40 mg/l during the winter. At Crooked Creek, about 200 miles downstream, the suspended-sediment concentration is about 200 mg/l during the summer and 20 mg/l during the winter.

The Copper River's normal summer suspended-sediment concentration is about 1,700 mg/l for a 9-year period at a site 4 miles below Chitina, indicating that the contributions of water and sediment from glacial-fed streams exceed those from nonglacial streams.

In the Anchorage area of the South-central subregion, three streams have been sampled at different locations to determine normal summer suspended-sediment concentration: (1) Ship Creek downstream from the powerplant on Fort Richardson carries about 15 mg/l, (2) Campbell Creek at the North Fork transports about 5 mg/l, and (3) Chester Creek at Lake Otis Road crossing transports about 25 mg/l. The suspended-sediment concentration in both Campbell and Chester Creeks increases downstream, Campbell Creek to 45 mg/l at the head of Campbell Lake and Chester Creek to nearly 200 mg/l at Arctic Boulevard. In contrast, there is little increase in suspended-sediment content in Ship Creek downstream. This is explained by the density of urban development adjacent; Ship Creek having the least activity in its lower valley.

In the Kenai area of the South-central subregion, most of the stream valleys contain glaciers at their heads, and consequently the streams transport as much as 500 mg/l normal summer suspended sediment. The nonglacial streams transport less than 50 mg/l suspended sediment. In the Homer-Ninilchik area, however, several nonglacial streams transport as much as 100 mg/l of suspended sediment during the summer. During the winter most streams in the Kenai area generally transport less than 30 mg/l of suspended sediment.

In the Matanuska-Susitna area of the South-central subregion, glacial streams normally contain as much as 2,000 mg/l suspended sediment during the summer runoff period. Nonglacial streams, in contrast, generally transport only about 50 mg/l suspended sediment during the summer.

The normal summer suspended-sediment concentration of glacial streams in southeastern Alaska ranges from about 90 mg/l to 500 mg/l. The winter concentration is 10 mg/l or less. Normal summer suspended-sediment concentration in nonglacial streams in this area ranges from about 4 mg/l to 30 mg/l and the winter concentration is usually less than 10 mg/l.

Chemical Quality of Ground Water

Information about the chemical quality of ground water in Alaska is detailed for some areas, such as those near Anchorage and Juneau, but is virtually nonexistent for large parts of the State. Analyses indicate that the dissolved-solids content ranges from as low as 19 mg/l to as high as 64,200 mg/l. Most of the sampled ground water contains less than 250 mg/l dissolved solids and is considered acceptable for general use. In inland areas, calcium bicarbonate or calcium magnesium bicarbonate type water is most common. Water of sodium bicarbonate or sodium chloride type is fairly common in coastal areas. Excessive amounts of iron have been found in a rather large proportion of the well water in most subregions, and particularly in the water from shallow wells. Water from below permafrost is variable in composition; some is highly mineralized and of the magnesium sulfate type.

Figure 18 shows representative diagrams of ground-water quality in each subregion. Additional information about the general quality of water and about some anomalous types of water in the subregions is given in the discussions that follow.

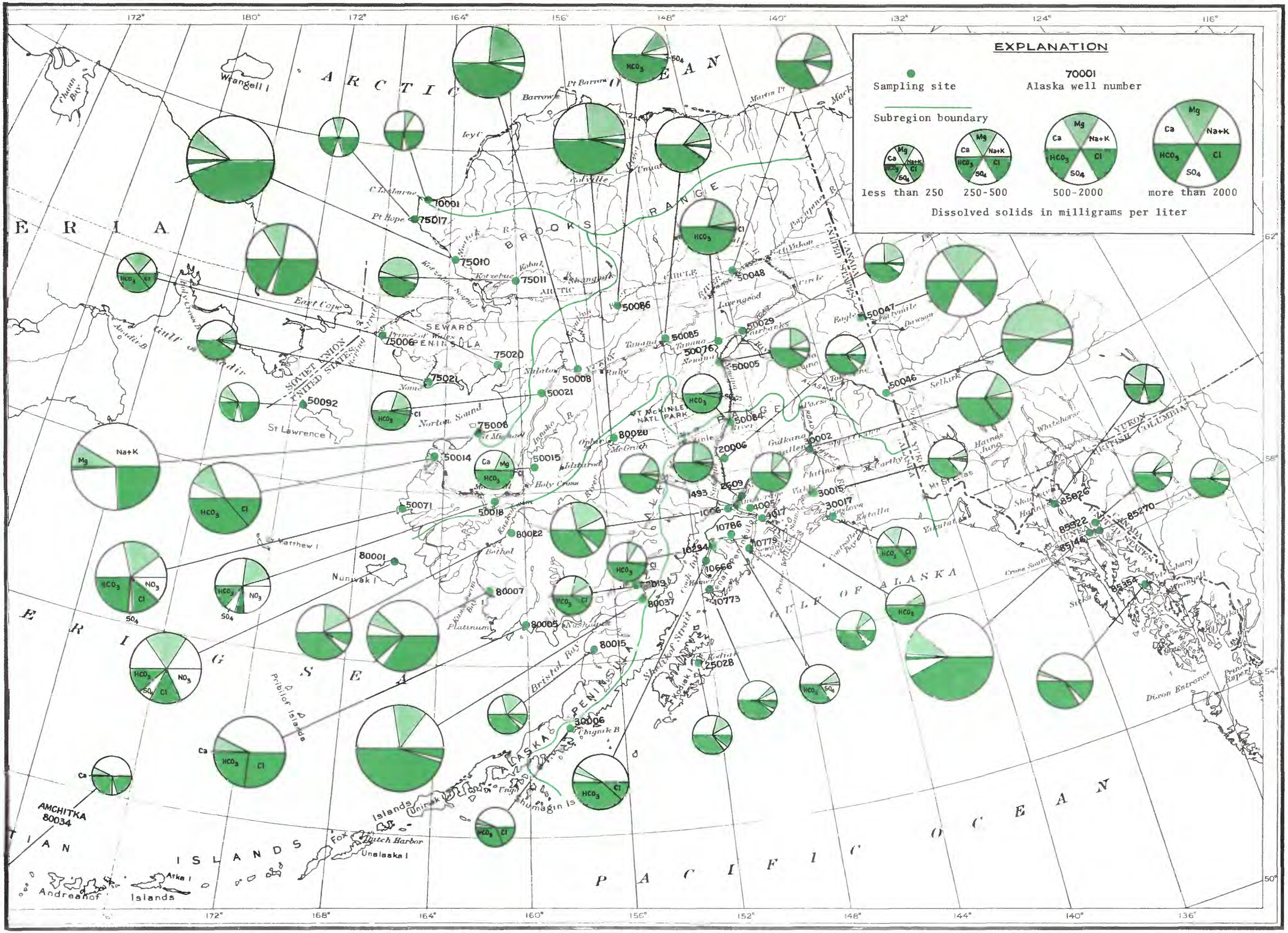


Figure 18.--Representative pie diagrams showing quality of ground water.

Arctic Slope Subregion

In the Arctic Slope subregion, periodic water samples from an infiltration gallery at Cape Lisburne increase annually in dissolved-solids content from about 94 mg/l in summer to about 225 mg/l in winter. The water is of the calcium bicarbonate type. The temperature of ground water from the gallery ranges from 1°C to 2°C.

Northwest Subregion

Ground-water quality sampled in the Northwest subregion is quite variable. Dissolved-solids contents in water ranging from 40 mg/l at Tin City to 64,200 mg/l at Kivalina have been determined. Many analyses of water from coastal communities indicate sodium chloride type water. For example, a well at Golovin yielded water having a dissolved-solids content of 27,000 mg/l, a sodium content of 8,300 mg/l, and a chloride content of 15,000 mg/l. Water from the well at Kivalina, as mentioned above, has a dissolved-solids content of 64,200 mg/l, a sodium content of 18,400 mg/l, and a chloride content of 36,800 mg/l. Dug wells 6 to 8 feet deep at Point Clarence (dissolved-solids content of 526 mg/l; sodium bicarbonate type water) and at Point Hope (dissolved-solids content of 226 mg/l; calcium bicarbonate type water) produce fresh water, but go dry in winter. Water of acceptable quality is obtained in coastal areas from wells drilled at higher elevations, as at Tin City (dissolved-solids content of 40 mg/l; sodium bicarbonate type water) and at Unalakleet (dissolved-solids content of 114 mg/l; calcium bicarbonate type water). At Kiana on the Kobuk River, a well yields water of the magnesium bicarbonate type having a dissolved-solids content of 247 mg/l. Moonlight Springs near Nome is of acceptable quality (dissolved-solids content of 135 mg/l; calcium bicarbonate type water), but some of the springs in the subregion are known to be rather highly mineralized. Ground-water temperature ranges from 1°C to 4°C.

Yukon Subregion

In the Yukon subregion, dissolved-solids content in ground water ranges from 22 mg/l at Cape Romanzof to 24,000 mg/l at Savoonga on Saint Lawrence Island. Wells inland generally yield calcium bicarbonate type water, whereas the coastal water is either sodium bicarbonate or sodium chloride type. Ground water normally ranges from 200 to 300 mg/l dissolved-solids content and, except for high iron content, is acceptable for most uses. Water from several wells exceeds suggested limits in single constituents. Wells drilled near the headwaters of smaller streams contain calcium bicarbonate type water of acceptable quality, such as wells at Hughes (dissolved-solids content 388 mg/l) and at the Air Force installation at Indian Mountain (dissolved-solids content 125 mg/l). Shallow wells drilled near the larger rivers, such as the one at Fort Yukon near the Yukon River, receive water by infiltration from the river and generally yield water of low dissolved-solids content (dissolved solids 174 mg/l; calcium bicarbonate type water). Ground water from the deeper zones beneath and adjacent to the Yukon River, however, is high in iron content and contains objectionable amounts of organic matter. Along the lower reaches of the Yukon River, even the shallow wells contain highly mineralized water, as indicated by a Bureau of Indian Affairs well at Galena that yields water containing 23,900 mg/l of dissolved solids (sodium chloride type water). Water from beneath thick permafrost, such as the Air Force installation well at Campion, is high in iron content (4.6 mg/l). At least two of the wells in the subregion yield water high in nitrate content, an example of which is a well at Russian Mission yielding 108 mg/l nitrate. A well at Saint Marys yields magnesium bicarbonate type water having a dissolved-solids content of 220 mg/l.

In the Tanana Basin of the Yukon subregion, wells along the boundaries of the area are drilled to bedrock; some yield ground water high in magnesium bicarbonate or magnesium sulphate. Water of this type is represented by a sample from a well at the proposed Customs station near the Alaska-Canada boundary that has a dissolved-solids content of 1,800 mg/l, a magnesium content of 335 mg/l, and a sulfate content of 1,120 mg/l. Ground water from the lowlands, even in the permafrost regions, is generally of acceptable quality, although many samples are high in iron content. Such water is unstable so that it is extremely corrosive to iron pipe. This is demonstrated by a water analysis for a well at Galena having a dissolved-solids content of 258 mg/l and an iron content of 6.7 mg/l. Analyses of water from three representative springs in the Tanana Basin showed: Manley Hot Springs, a dissolved-solids content of 322 mg/l (sodium chloride type water); a mineral spring near Kantishna, a dissolved-solids content of 2,900 mg/l (calcium magnesium bicarbonate type water); and a spring near Fox, a dissolved-solids content of 224 mg/l (calcium bicarbonate type water). Temperatures of ground water from wells in this area range from 0°C to 4°C, and from springs, from 2°C to 65°C.

Southwest Subregion

In the Southwest subregion, the dissolved-solids content of ground-water samples ranges from 19 mg/l at Chignik to 2,100 mg/l at Kakhonak Springs. Most of the water sampled is of the calcium bicarbonate type, but coastal water is predominantly of the sodium chloride type. Nearly all the ground water in this subregion is low in iron content and has a dissolved-solids content of less than 200 mg/l. At Kwethluk, ground water is of the magnesium bicarbonate type having a dissolved-solids content of 248 mg/l. At Eek, ground water is of the sodium bicarbonate type and has a dissolved-solids content of 1,300 mg/l. Ground water from a well at Togiak is of the sodium chloride type usually found in coastal regions where wells are subject to sea-water intrusion (dissolved-solids content of 620 mg/l). Some of the ground water sampled is high in nitrate content, as shown by water from a well at Mekoryuk on Nunivak Island, which has a dissolved-solids content of 940 mg/l, but contained 240 mg/l nitrate, which indicates possible organic pollution. Temperature of ground-water samples in the subregion ranges from 3°C to 9°C.

South-Central Subregion

Anchorage.--Ground water from the glacial and alluvial deposits of the Anchorage area in the South-central subregion is predominantly of the calcium bicarbonate type, as typified by a sample from a city of Anchorage well (dissolved-solids content of 152 mg/l). Most water from the glacial deposits contains about 150 mg/l dissolved solids. Some water from wells drilled north of the Elmendorf Moraine on

Elmendorf Air Force Base, such as a well at the Green Lake Hobby Shop, is of the sodium bicarbonate type and generally averages 250 to 300 mg/l dissolved solids. Water from bedrock wells in the area generally has somewhat higher dissolved-solids content. Although sea-water contamination of the Anchorage ground-water aquifers is not presently thought to be a problem, a possibility that sea water may be induced into wells on Fire Island by heavy pumping prompts close surveillance of water quality. Water sampled from Russian Jack Springs is of the calcium bicarbonate type having a dissolved-solids content of 132 mg/l and differing only slightly from the water commonly found throughout the Anchorage area. Temperatures of Anchorage ground water indicate a range of 2°C to 6°C.

Copper River.--In the Copper River basin of the South-central subregion, dissolved-solids content of ground water ranges from 111 mg/l from a well at Valdez to 14,500 mg/l from a spring near Glennallen. Most of the springs sampled in the interior part of the area yield water of the sodium chloride or calcium sodium bicarbonate type. Water obtained from wells shallower than about 150 to 200 feet is generally of a calcium bicarbonate type. This is demonstrated by water from a well at Glennallen (dissolved-solids content of 383 mg/l). Deeper wells generally contain sodium chloride or sodium calcium bicarbonate type water, such as the well at Rosents Cafe in Glennallen (dissolved-solids content of 2,400 mg/l). Ground water from wells sampled in the coastal lowlands is generally lower in dissolved-solids content and is a calcium or sodium bicarbonate type water, such as at Valdez (dissolved-solids content of 110 mg/l) and at Cordova (dissolved-solids content of 140 mg/l). Water from deeper wells and from mineral springs exceeds the suggested limit set by the U.S. Public Health Service for chloride, sulfate, magnesium, or a combination of chloride and sulfate. Water from shallow wells and wells on the southern flanks of the Kenai-Chugach Mountains is generally low in iron and other mineral content. Temperatures of ground water from wells range from 3°C to 4°C and from springs from 4°C to 30°C.

Kenai Peninsula.--The range in dissolved-solids content of ground water in the Kenai Peninsula of the South-central subregion is from 40 mg/l from a well at Summit Lake Lodge to 740 mg/l from a well at Homer. Most of the ground water sampled has about 140 to 150 mg/l dissolved-solids content. Ground water in the subregion is either of the calcium bicarbonate type, such as water from Silver Tip station (dissolved-solids content of 58 mg/l) or of the sodium bicarbonate type, such as water from the Ninilchik school (dissolved-solids content of 380 mg/l). A few wells yield calcium magnesium bicarbonate type water, such as that of the White Alice station near Homer (dissolved-solids content of 187 mg/l). Water containing the highest dissolved solids is found along the western and southern extremities of the area; it is of the sodium bicarbonate type. Iron concentrations as much as 30 mg/l and 10 mg/l are found in some wells in the Homer and Kenai areas, respectively. The water containing the highest iron concentration is apparently from wells completed in surficial deposits. Water from some wells near Homer also contains methane gas, which constitutes a hazard if allowed to accumulate in water systems. The temperature of ground water in the area ranges from 3°C to 6°C.

Kodiak.--The dissolved-solids content of ground water sampled near Kodiak in the South-central subregion ranges from 44 mg/l from test wells augered in 1968 to 1,500 mg/l from a Federal Aviation Administration well on Woody Island. Water sampled inland is generally of acceptable quality, although somewhat high in iron content. Analyses of springs on Kodiak Island show the water to be of acceptable quality and low in dissolved-solids content. The temperature of ground water in the area ranges from 2°C to 13°C.

Matanuska-Susitna.--The ground water sampled in the Matanuska-Susitna area of the South-central subregion ranges in dissolved-solids content from 31 mg/l from a seasonal spring at Sheep Mountain to 195 mg/l from a well drilled at Palmer. Most of the water is of the calcium bicarbonate type, typified by a well at Talkeetna having a dissolved-solids content of 111 mg/l. One well at Palmer, which is the deepest well in the area (624 feet), produces water of a sodium bicarbonate type having a dissolved-solids content of 195 mg/l. Water containing the highest dissolved-solids content is generally found in the eastern part of the area. Several wells sampled near Palmer reportedly yield water of high nitrate content. Near Palmer many of the wells and springs also contain considerable boron. The deep well at Palmer, for example, has the highest measured concentration of boron in the area, averaging about 2.5 mg/l. Boron in concentrations of more than 2 mg/l constitutes a problem in using ground water for irrigation. Concentrations in excess of this are not considered permissible by the U.S. Department of Agriculture (U.S. Dept. of Agriculture Handbook 60, 1954) in irrigation supplies for such crops as barley. Ground water temperature ranges from 3°C to 7°C.

Southeast Subregion

Dissolved-solids content of the ground water sampled in the Southeast subregion ranges from 25 mg/l to 19,000 mg/l, both from wells at Juneau. Most of the ground water sampled is of the calcium bicarbonate type, represented by ground water from the Juneau area, containing 93 mg/l dissolved solids. Some of the ground water sampled is of the sodium bicarbonate type, as that from a well at Petersburg having a dissolved-solids content of 480 mg/l, or is of the sodium chloride type. A bedrock well near Haines yields water of the calcium sulfate type containing 420 mg/l of dissolved solids. Most of the ground water sampled is of acceptable chemical quality, although some is high in iron content. The temperatures of ground water samples range from 2°C to 6°C.

CURRENT WATER USE AND POTENTIAL FOR DEVELOPMENT

Total water use in Alaska is estimated to be 50 to 55 mgd (million gallons per day). In much of the State, particularly the northern and western parts, water is obtained in the summer directly from lakes and rivers and in the winter from deep lakes or large streams by cutting through the ice, or by melting ice. About 25 communities have municipal water systems, supplied from surface water, ground water, or conjunctive use of surface and ground water. Private wells serve many homes and businesses, mostly in the Southcentral and Southeast subregions. Infiltration galleries installed in the alluvial deposits of stream valleys also supply water in some areas. Springs are used for water supplies only to a minor extent.

The potential for development of Alaska's vast water resources has scarcely been touched. The great rivers amd large lakes throughout the State have the capability of providing water supplies, transportation routes, recreation, and water power far beyond present use. Ground-water potential is certainly many times that of current development despite the problems caused by the presence of permafrost.

The following discussion pertains to current water use and potential for development of water supplies. The vast recreational and water-power potentials are beyond the scope of this report.

Arctic Slope Subregion

Total water use on the Arctic Slope, including current oil-well drilling requirements (1969), is estimated to be more than 400,000 gpd (gallons per day). No community in the subregion has a municipal water supply. In the summer, water is obtained directly from lakes and rivers and in the winter by cutting holes in the ice of deeper lakes or larger streams or by melting ice. A military installation at Point Barrow uses about 11,000 gpd of water from Imikpuk Lake. Several DEW-LINE stations along the northern coast each obtain about 1,000 gpd from lakes. Ground water from a gallery at Cape Lisburne is pumped into storage during summer. Use from this source averages about 5,000 gpd.

The most extensively distributed water on the Arctic Coastal Plain is in lakes, but the quality and quantity of available lake water restricts its use. Other sources of water on the coastal plain are the large rivers in the eastern part of the subregion. These rivers generally carry a high suspended-sediment load during the summer and are frozen in winter. Ground water in thawed alluvium underlying these major rivers may provide a year-round water supply. Water may also be available throughout the year at the locations of icings along the flood plains. Reconnaissance of the subregion in early 1969 confirmed the existence of active icings, flowing springs, and open-streamflow channels. Each such late-winter occurrence of flowing water indicates the presence of ground water. In the Arctic Foothills and Brooks Range, lakes are less prevalent and the flood plains of rivers are less extensive. Consequently, development of water is more difficult. Available data show that only small quantities of brackish water are available from ground water below the permafrost in these areas. Some ground water may be available, however, from springs issuing from limestone formations in the eastern part of the Brooks Range.

Northwest Subregion

Total water use in this subregion is estimated at less than 250,000 gpd. The largest uses of water are probably those of the communities of Nome, Kotzebue, and Unalakleet. The military installations in this area generally use about 5,000 gpd each. Water is obtained principally from lakes or streams, from infiltration galleries, and wells developed in the alluvium of stream valleys. Some water is obtained from wells in bedrock, or from springs. Nome is supplied with water from wells developed in alluvial or bedrock aquifers and from Moonlight Springs. A military installation near Kotzebue pumps surface water into storage during the summer and utilizes the water throughout the remainder of the year. This is one means of utilizing the seasonal flow of rivers in the area. Unalakleet obtains water throughout the year from an infiltration gallery. Communities in the northern part of the subregion obtain water during winter by melting ice and snow or by cutting holes in the ice and obtaining water directly from deep channels of the larger streams.

The greatest opportunity for economical development of large supplies of water in the subregion is probably in the alluvial-filled valleys southeast of Nome. Permafrost is discontinuous there or has been thawed more deeply than the winter frost. Otherwise, the same water-supply problems exist in this subregion as in the Arctic Slope subregion. Ground-water development requires intensive exploration. One opportunity is suggested by flow data on the Kobuk River, which show that the streambed alluvium apparently continues to accept ground-water recharge during the winter. Although no drilling has been done to verify this, infiltration galleries in the stream channel or wells adjacent to the stream may provide year-round water supplies.

Yukon Subregion

Water use in the Yukon subregion, excluding the Tanana Basin, is estimated to be about 400,000 gpd. Water is obtained principally from ground-water sources and has been developed for municipal, industrial, military, domestic, and to some extent, irrigation use and in placer-mining operations. In addition to the 400,000 gpd estimated above for the Yukon subregion, 11 to 12 mgd are used in the Tanana Basin. Of this total, the military installations use about 7.5 to 8 mgd, Fairbanks uses approximately 2.0 to 2.5 mgd, and the smaller communities throughout the area use the remainder. Although a few communities are supplied by water from wells, the military installations are the primary users of ground water within the subregion. Most of the small communities still obtain their water supply directly by pumping from streams during both the summer and winter. In addition, springs, especially thermal springs, have had some local use for many years for small farming operations and at summer resorts. The amount of water used in this manner, however, is negligible compared to the total use of water in the subregion.

The potential for developing large supplies of ground water is probably greater in this subregion of Alaska than in any other subregion. The presence of considerable thicknesses of water-bearing sands and gravels provides excellent opportunities for developing water for domestic, industrial, municipal, and irrigation use. Estimated supplies of 1,000 to 3,000 gpm can be obtained from appropriately constructed wells or infiltration galleries along the Yukon and its principal tributaries. The potential for development of surface water in this subregion is also worthy of consideration.

Southwest Subregion

Total water use in the Southwest subregion is estimated to be about 800,000 gpd, about 500,000 gpd of which are used at military installations and at other government sites. The only known municipal water-supply system is at Dillingham. Many small villages use one or more wells, but few data are available regarding them. Springs are used for water supplies on Amchitka and Shemya Islands.

Although little development has taken place in this subregion, the potential for development of ground water from the water-bearing materials within the Kuskokwim Valley is large. Within this valley considerable thicknesses of materials are capable of yielding in excess of 100 gpm per well and possibly more than 1,000 gpm from properly constructed wells in the coarser alluvium. Recognizing the agricultural potential of parts of the subregion, it would be prudent to explore the possibility of developing ground water for irrigation use in strategic locations.

South-Central Subregion

Anchorage

Water development is primarily in and near the city of Anchorage. Present water use in the Anchorage area is approximately 30 mgd. The water supply is obtained from surface and ground water. An average of 20 mgd is diverted from Ship Creek, and an average of 10 mgd is pumped from wells.

The full potential for water-supply development within the Anchorage area has not been reached. Shallow ground-water sources in alluvial-fan areas east of the city along the front of the Chugach Mountains are currently being developed by the city. Other potential well locations are available in the lowland area south and west of the city center. Ground-water yield can be increased from 10 mgd to approximately 25 mgd in the future. Artificial recharge techniques, currently under study, could increase this estimate of future yield.

Dams on Ship Creek, a nonglacial stream, and Eagle River, a glacial stream, could provide additional surface-water supplies. Other possible surface sources include Peters Creek, Bird Creek, and the Eklutna River. The combined annual flow of these streams is approximately 900 mgd.

Copper River

The estimated use of water in the Copper River basin is about 75,000 gpd. Information on water development in this area is scanty and is principally available from the coastal areas. Cordova obtains its water from a nearby lake and Valdez uses ground water. In addition, a few military and governmental installations obtain small quantities of water from wells.

The potential for developing ground water in the Copper River basin is favorable in areas along the major streams where adequate thicknesses of water-bearing material are available for either the construction of wells or the installation of infiltration galleries. However, quality of water in some areas may be marginal.

The Copper River basin has a very large potential for developing surface water. The anticipated needs for municipal, industrial, and domestic supplies in such areas as Valdez can probably be satisfied by the use of surface water.

Kenai Peninsula

Total water use on the Kenai Peninsula is estimated to be from 5 to 5.5 mgd. Ground-water use has undergone considerable development in the Kenai-North Kenai industrial area, where approximately 3 mgd of ground water are used. The Collier chemical plant uses the largest quantities in the production of fertilizer. Domestic use from ground water in the Kenai-Soldotna area is about 1 mgd. Seward utilizes an estimated 1 mgd of surface water and has emergency capacity of about 1 mgd available from ground water. Present use at Seldovia averages about 350,000 gpd from surface-water sources; and use at Homer is about 100,000 gpd, from ground water.

The greatest potential for development of additional water in the area probably lies in the use of surface water such as the Kenai River; however, the Kenai River and most other large streams in the area contain glacial flour and the water would require treatment prior to use. Large supplies of ground water could also be developed by the use of galleries or wells in appropriately located sites along the major stream valleys or in glacial deposits adjacent to them. Although the potential in most of these areas has not been explored, tests in the Beaver Creek valley, which already produces more than 300 gpm of ground water for use in the Kenai area, show that the area would bear additional development. Wells producing from 500 to 1,000 gpm probably could be developed in favorable deposits within the major stream valleys in this area.

Kodiak

The municipal water use in the Kodiak area is about 3 mgd. When the local canneries are operating, this use increases to approximately 5 mgd. The total average use of water probably does not exceed 4 mgd. The present water supply for the city of Kodiak is obtained from a series of reservoirs on Pillar Creek. Ground water is utilized for water supply only from a few individual wells. No large supplies from ground water are known.

The largest potential for development of water in the Kodiak area is in the use of surface-water sources. The sources that are receiving consideration are Monashka Creek and the Buskin River. Ground water could also be developed in moderate quantities from the alluvium of the major valleys south of Kodiak, particularly the valleys of the Buskin River and Russian Creek. However, the distance that water would have to be transported from these potential development areas would be prohibitive and impractical considering present needs.

Matanuska-Susitna

The total water use in the Matanuska-Susitna area averages less than 500,000 gpd. Palmer uses about 150,000 gpd of ground water and Tyonek uses about 50,000 gpd, also ground water. Use of surface water is still undeveloped except for minimum local irrigation during dry summer months. The area between Palmer and Willow has a large number of lakes that are increasingly utilized for recreation.

The greatest potential for water-resources development at economical cost would be in the use of ground water from alluvial deposits underlying the flood plains of the major rivers such as the Matanuska and Susitna. In places within these valleys considerable thicknesses of water-bearing materials would contribute more than 500 gpm to appropriately constructed and located wells. In some areas, infiltration galleries might yield even larger quantities of ground water. In addition, the major rivers in this area would supply large quantities of water provided the water was treated to eliminate the suspended glacial flour.

Southeast Subregion

The total water use in this subregion is estimated at between 14 and 16 mgd. Most of the water used is from surface-water sources, but ground water is the principal source of supply at Juneau, Sitka, and Skagway and also at Yakutat, Petersburg, Hyder, Craig, Ketchikan, and at several military and other government installations throughout the subregion.

The favorable potential for development of both surface and ground water has barely been touched in this subregion. Ground water is available in the major stream valleys in alluvial materials, particularly in the lower parts of these valleys. These deposits are less extensive than in other areas in Alaska but should provide adequate supplies for domestic and for some municipal and industrial use. Surface water is also available and is quite desirable for most uses because many lack the glacial debris so prevalent in Alaskan streams.

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