

GEOLOGICAL SURVEY CIRCULAR 169



SUMMARY OF GROUND-WATER
DEVELOPMENT IN
ALASKA, 1950

By D. J. Cederstrom

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GEOLOGICAL SURVEY
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Washington, D. C., 1952

Free on application to the Geological Survey, Washington 25, D. C.

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INTRODUCTION

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ABSTRACT

This report discusses present and possible future ground-water developments in a number of localities throughout the Territory of Alaska. Substantial development of ground-water supplies is found only in Anchorage, Palmer, and Fairbanks. Elsewhere few wells are present and possibilities of ground-water development have been almost entirely unexplored. Large quantities of ground water of good to poor quality are available in extensive areas of intermontane sandy fill and sandy glacial deposits. Nothing specific is known of possible yields in hard-rock areas, or in rocks of any kind in southeastern Alaska. Permafrost is a factor to be dealt with in the development of ground-water supplies in many northerly localities. Much remains to be learned about the occurrence of ground water throughout the Territory, particularly with reference to the needs of growing communities, military establishments, and some areas of potential industrial activity.

INTRODUCTION

Purpose

The purpose of this report is to present the information available on the ground-water resources of Alaska. The development of well-water supplies in Alaska is still in the preliminary stage and in only three places--Anchorage, Palmer, and Fairbanks--have wells been constructed to an extent comparable to that in the majority of communities in the continental United States. A few references to springs and wells in Alaska are present in the literature, and recently records of wells in Fairbanks, Palmer, and Anchorage have been collected by the United States Geological Survey. No discussion of ground-water development in Alaska as a whole exists. It is the purpose of this report, therefore, to present a broad, general picture of ground-water conditions and to mention significant well installations to the extent that these are known, in order that some over-all idea of the potentialities and existing developments may be available to interested persons.

This report is not a complete inventory of all existing wells in Alaska but, considering the very few water-producing wells in the Territory outside the three areas mentioned, the data are thought to be sufficient to be representative.

This work was done under the supervision of A. N. Sayre, chief, Ground Water Branch, Water Resources Division, U. S. Geological Survey.

Area and scope

Systematic ground-water studies in Alaska were begun by the Geological Survey in July 1947 and have been continued since that time. As part of this study, and to some extent in close cooperation with the Alaska Department of Health, the writer has visited and discussed water-supply problems on the ground in the larger communities in southeastern Alaska, along the Gulf of Alaska, in the Kenai Peninsula, and in the Anchorage-Matanuska Valley area. In the latter area and in the Fairbanks area detailed ground-water studies have been made by the Ground Water Branch of the Water Resources Division. Very few data on the Copper River basin and the Upper Tanana Valley have been obtained. The literature has afforded a few facts about the hot springs at Circle and Manley. Scattered meager data have been collected on the Yukon Valley proper. Somewhat fuller information was obtained during visits to McGrath, Aniak, and Bethel on the Kuskokwim River where more wells exist or drilling of wells has been attempted. Data on the few wells existing at Nome and Kotzebue are available.

The data for the localities and areas mentioned provide, for many places, a reasonable basis from which conclusions may be drawn regarding the occurrence of ground water. For many other places, however, data are extremely meager or lacking entirely, and tentative conclusions made regarding ground-water potentials in such places are developed by comparison with other places in Alaska or the continental United States. The areal descriptions generally mention the geology only to the extent of delimiting areas of hard rock and unconsolidated sediments, with suggestions as to the origin of the unconsolidated sediments and their susceptibility to development by water wells. It is believed, however, that by evaluating factors as to order of magnitude it should be possible to decide, at least, at specific locations, whether ground-water exploration is warranted.

Acknowledgments

The writer wishes to express appreciation to A. J. Alter, director of the Division of Sanitation and Engineering, Alaska Department of Health, for his active interest in ground-water studies in the Territory and for the facilities provided from time to time by personnel of his department.

The office of the District Engineer, Corps of Engineers, at Fort Richardson, Alaska, furnished the writer records on wells in the Anchorage area and elsewhere. Records of

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wells at air stations of the Civil Aeronautics Authority throughout the Territory have been extremely useful. Victor Rivers of the Victor Rivers Engineering Co. of Anchorage made available records of wells in the Anchorage area.

The many citizens in communities visited, and drillers in Fairbanks, Palmer, and Anchorage, furnished information freely and are hereby thanked for their interest and efforts.

Data from a report by Charles Turnbull, sanitarian, Fairbanks District, Alaska Department of Health, on the Yukon River and many miscellaneous data provided by L. Morley, senior sanitarian, Anchorage District, have been incorporated in this report.

CLIMATE

No water-supply development in Alaska should be contemplated without taking climate, particularly temperature, into consideration. Not only should the effect of long months of bitter cold be considered in relation to well installation, lakes, streams, and distribution lines, but the insulating effect of snow cover should also be taken into account. Conversely, the mildness of southeastern Alaska as compared with most of the States in the northern United States should be fully recognized.

The table given below was compiled from Weather Bureau data.

Table 1.--Climatological data at selected Alaskan stations

	Mean annual temp (F)	Period in which mean monthly temperature is below freezing	Mean temperature of coldest month (F)	Coldest month	Mean annual precipitation (inches)	1950 snowfall (inches)
Ketchikan	45.4	(b)	33.1	Dec.	150.98	- - -
Craig	45.3	(b)	36.4	Dec.	110.64	- - -
Wrangell	43.8	Dec. to Jan.	30.1	Jan.	74.15	117.8
Petersburg	42.6	Dec. to Feb.	30.6	Jan.	107.51	106.4
Sitka	43.9	(b)	32.9	Jan.	88.91	43.6
Angoon	40.9	Dec. to Feb.	28.4	Feb.	49.42	111.1
Juneau	42.2	Dec. to Feb.	26.7	Feb.	83.72	^a 92.1
Haines	41.4	Nov. to Feb.	26.4	Jan.	57.14	- - -
Yakutat	40.3	Dec. to Feb.	29.0	Jan.	133.97	140.8
Cordova	38.2	Nov. to Mar.	14.8	Dec.	95.49	72.7
Valdez	35.8	Nov. to Mar.	19.3	Dec.	60.73	124.1
Homer	37.7	Nov. to Mar.	23.8	Dec.	29.03	26.6
Kenai	33.4	Nov. to Apr.	12.7	Jan.	18.69	47.7
Anchorage	35.0	Nov. to Mar.	11.6	Jan.	14.55	48.3
Matanuska Valley	35.2	Nov. to Mar.	13.6	Dec.	15.70	31.8
Talkeetna	33.5	Nov. to Mar.	9.5	Jan.	30.48	88.6
Fairbanks	26.1	Oct. to Apr.	-10.7	Jan.	11.90	81.2
Nenana	27.1	Oct. to Apr.	-7.5	Jan.	11.35	37.7
Galena	23.0	Oct. to Apr.	-11.0	Jan.	13.87	42.9
Kotzebue	20.3	Oct. to Apr.	-7.7	Jan.	7.56	33.3
Nome	25.9	Oct. to Apr.	3.4	Jan.	17.26	81.8
Unalakleet	26.8	Oct. to Apr.	-3.4	Mar.	13.44	29.1
McGrath	25.5	Oct. to Apr.	-7.9	Dec.	19.57	65.6
Aniak	28.3	Nov. to Apr.	-3	Dec.	20.53	26.8
Bethel	29.6	Oct. to Apr.	5.8	Dec.	18.24	35.4
Platinum	32.2	Nov. to Apr. (?)	10.0	Dec.	19.0	29.5

^a Juneau Airport.

^b Mean monthly temperature above freezing.

In coastal areas in southeastern Alaska the weather is mild, but precipitation, mostly as rain, is high. Although in some communities there is no month in which the average monthly temperature is below freezing, temperatures below freezing and precipitation in the form of snow are common in winter. Such freezing temperatures as occur in Ketchikan in southeastern Alaska will be more detrimental in freezing water-supply installations than in Petersburg, just to the north, which is slightly colder but where a heavier protective snow cover normally exists.

Sitka and Angoon make an interesting comparison. Sitka, on the western shore of Baranof Island, is warmed by the Japanese current and has little freezing weather, whereas at Angoon, in about the same latitude but farther east, on Admiralty Island, the

mean temperature for the December-February period is below freezing. Sitka has almost 89 in. of precipitation, Angoon about 49 in.

Farther up the coast, as at Cordova and Valdez, the average annual temperature is lower and the period of freezing is longer, including November and March. The total precipitation is not much less but more of it occurs as snow.

Kenai and Anchorage have cold winters with an average monthly temperature of about 12 F in the coldest month. Here, away from the open ocean, precipitation is much less (about 15 in. annually at Anchorage) although the snow cover is still fairly heavy.

North and west of the Alaska Range the average annual temperature is almost every-

CLIMATE

where below 32 F and permafrost is present in the ground. In the interior localities and on the Arctic Ocean (as at Fairbanks and Kotzebue) the average temperature in the coldest month is as low as -10 F, whereas adjacent to the Bering Sea (as at Platinum and Bethel) the average temperature in the coldest month is as high as 5 F to 10 F. In the interior localities the precipitation is low, about 12 in., and the country may be considered semi-arid. Along the Bering Sea at Nome the total precipitation is about 17 in. and on the Arctic Ocean at Kotzebue it is less than 8 in.

OCCURRENCE OF GROUND WATER

General conditions

Ground water--water in the zone of saturation--occurs in voids such as cavities, joints and other fractures, and pore spaces in various types of rock and saturates the ground up to a variable level known as the water table. The earth just above the water table is more or less moistened by water drawn up from the zone of saturation by molecular attraction (capillarity) and is known as the capillary fringe. In clean gravels the fringe may be practically absent, but in silt or clay loam it may be as much as 8 ft thick.

The zone of aeration (the zone between the land surface and the zone of saturation) between the capillary fringe and the belt of soil moisture contains very little water. At and near the surface the earth generally contains a somewhat greater amount of water, and this zone is known as the belt of soil moisture.

Where the zone of saturation lies at the surface, the zone of aeration is absent.

Some of the water falling upon the earth percolates into the ground and accumulates in the zone of saturation. From the place where it reaches the water table the ground water tends to move toward lower altitudes. It may continue to move underground until it reaches the sea, discharge as springs at the surface and contribute to the flow of streams, be intercepted by wells, evaporated, or transpired by vegetation.

In some places permeable beds sloping away from areas of high ground are overlain at lower altitudes by impermeable capping beds such as clay. Here water entering the permeable beds at higher altitudes moves down dip but cannot readily migrate upward or escape from beneath the confining layer. This water is under hydraulic pressure and said to be artesian water. It will rise in tightly cased wells above the top of the layer, and, where the land is low, the well may flow.

Glacial flour

A significant factor in Alaskan hydrology is the influence of glacial flour. In much of Alaska south of the Yukon many streams carry glacial rock flour in suspension, in quantities ranging from small to great. In most places the movement of water from these

streams to the surrounding aquifer is probably greatly inhibited by the presence of this flour. In southeastern Alaska this factor is probably negligible because rainfall is high and the adjacent water table is higher than the streams, so that ground water is almost invariably migrating from the ground to the stream. However, in the Anchorage area and on the northern flank of the Alaska Range--areas where rainfall is moderate or low, the presence of glacial flour may be of great importance. In these areas of lower rainfall large withdrawals from the ground must be replenished by percolation of water from relatively long distances underground or by recharge from local streams, originating in adjacent mountains. Where the streams are loaded with glacial flour, recharge by the streams will be considerably less than if the streams were clear, and in some places this factor may make the difference between a possible large water-supply development and a small one.

Permafrost

Large areas in Alaska are underlain by perennially frozen ground ranging widely in distribution and thickness. To the north the permafrost zone tends to be thick and continuous but to the south it thins and becomes more and more discontinuous and finally is absent.

Permafrost is an important consideration in dealing with development of ground water from alluvial deposits. Except where very thick and continuously distributed it does not preclude the acquisition of ground-water supplies, for in many places within the permafrost zone ground water may be obtained from unfrozen ground beneath the permafrost or in thawed areas between areas of frozen ground. Throughout the area north and west of the Alaska Range, permafrost is generally present in thickness great enough to be considered a real factor and its habit should be appreciated when well sites are chosen. Thicknesses of as much as 200 ft are present beneath the valley flats in the vicinity of Fairbanks but the permafrost is by no means continuous. In the vicinity of major streams and rivers permafrost is ordinarily absent, particularly on the "slip-off" side of a stream meander, but frozen ground may be close beneath the surface near a steep "cut-bank." However, here, and to some degree elsewhere near the stream, the permafrost may be thin, or at least considerably thinner than the maximum. In still fewer places half a mile or more distant from the stream, permafrost is also absent, apparently in swales marking recently abandoned stream channels.

In the Yukon Flats above Rampart, along the Koyukuk and in the Selawik-Kobuk-Noatak drainage area, permafrost may be expected to be more continuous near major streams, and it will extend to greater depths and may indeed eliminate large alluvial areas as sources of water supply, either because its thickness is such as to require wells 200 to 400 ft deep or because the alluvium is frozen all the way down to bedrock.

North of the Brooks Range permafrost extends many hundreds of feet below the surface and development of ground-water supplies

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probably is impractical, except possibly in the vicinity of the Colville River.

Drilling in permafrost by the cable-tool method generally requires no special techniques; in fact, frozen sand and silt stands well in contrast to the same material where thawed. It may be necessary that casing follow the hole, however, in order to shut off thawed running sand or silt as soon as it is penetrated and to prevent undue caving as the hole becomes warm during drilling operations. Freezing of the casing to the walls during the course of drilling generally will not occur except where the permafrost is very thick (and therefore several degrees below freezing temperature) or when the job is interrupted by periods of idleness.

A productive well obtaining water from beneath the permafrost will not freeze if the well is pumped regularly. In periods of idleness ice will collect on the inside of the casing and eventually plug it entirely. When this happens, introduction of hot water, steam, or even plain salt may be necessary to thaw out the well.

Thicknesses of permafrost greater than 150 ft have been successfully penetrated by 2-inch-diameter driven wells using a cone-shaped drive head, above which are $\frac{1}{4}$ -inch perforations, and through which a $\frac{1}{2}$ -inch thaw line projects as much as 18 in. The thaw line delivers water at a temperature of 33 F to 40 F, which melts out sufficient area to permit the intermittent driving of the 2-inch pipe. At shallow depths a skilled driller can make 30 to 40 ft in a day but below 80 to 100 ft driving is much slower and as little as 1 or 2 ft a day may be driven.

Shallow wells dug in the surficial and generally highly organic material above the permafrost do supply a small amount of poor-tasting water but these wells decrease greatly in yield or freeze in the winter. In some places permafrost has receded 10 ft or more because of construction of buildings or stripping of the insulating ground cover and in such places where the ground is sandy moderate year-round supplies have been obtained.

DESCRIPTION OF AREAS

To characterize the geology and topography of an area one-fifth the size of the continental United States in a relatively few paragraphs is an ambitious task and as such will not be attempted here. Instead, certain gross features will be pointed out which convey the general background necessary to an appreciation of ground-water-supply conditions.

Water supplies in Alaska will be sought in (a) rugged hard-rock ranges of high relief or (b) in broad intermontane valleys filled with young unconsolidated sediments. The hard-rock areas where, in time, developments will take place are almost entirely in southeastern Alaska and perhaps in some places in the Aleutian chain. Almost everywhere else water will be sought in unconsolidated

glacial, fluviatile, or glaciofluvial sediments of Pleistocene and Recent age in the valley floors and in most places miles distant from the contiguous mountain ranges. In a few places narrow stream-bed or glacial deposits at higher altitudes within the mountains or foothills will be considered for well development. Sand spits and sandy beaches along the sea will offer possibilities of furnishing small supplies in some places.

Within this somewhat oversimplified framework of possible ground-water environments are a myriad of geologic and hydrologic conditions which must be understood before ground-water developments are contemplated. Many of these features will be elaborated upon in the more detailed descriptions of areas considered below.

Southeastern Alaska

Southeastern Alaska extends as a narrow strip along the Pacific Ocean from a point a short distance northwest of Yakutat, where it joins the "Interior," southeastward for about 500 miles to a little south of Ketchikan where the Canadian boundary runs approximately east and west. Prince Rupert, British Columbia, lies a short distance to the south.

The area is made up of a coastal strip adjoining Canada, several large outlying islands, and thousands of smaller islands. Most of the islands are in the southern two-thirds of the strip and, with similar Canadian islands down the coast, enclose the well known "Inside Passage" waterway from Seattle to Juneau and Skagway. The larger outer islands in Alaskan waters, beginning at the north, are Chichagof Island (west of Juneau), Baranof Island (on which Sitka is situated), and Prince of Wales Island. Admiralty Island lies southwest of Juneau, between the Chichagof and Baranof Islands and the mainland. In the extreme southwest, as noted, Prince of Wales Island is the large outer island, and Revillagigedo Island, on which Ketchikan is situated, is the third of the large inner islands.

Southeastern Alaska may be thought of as a rugged hard-rock region of high relief consisting of many large and small islands and a typically indented coast-line area. The rocks range widely in composition and consist of igneous, metamorphic, and sedimentary types ranging in age from Paleozoic to Tertiary (Buddington and Chapin, 1929, pl. 1).

It is important to note that in southeastern Alaska unconsolidated stream and glacial deposits are very sparsely distributed. Southeastern Alaska is a typical drowned seacoast, and stream-bed deposits, glacial-outwash plains, and many of the long valleys characteristic of a region strongly dissected by streams and further deepened by glacial erosion now lie below sea level. Thus many ground-water developments in southeastern Alaska will necessarily depend on obtaining water from one of a variety of hard rocks and, in general, low yields may be expected. Further, encroachment of sea water commonly may be a problem. Unconsolidated

OCCURRENCE OF GROUND WATER

sediments are not entirely lacking, however, as for example the outwash plain of the Mendenhall Glacier near Juneau and, rather rarely, deposits along stream beds traversing gently sloping land. It is thought that these should be explored first wherever possible because hard-rock wells, in general, have rather low yields and results of drilling them are unpredictable.

In many places in southeastern Alaska wave-cut benches occur, those from 30 to 100 ft above sea level being well developed so far as the writer has observed. These are mantled by reworked glacial till in places and in fewer places the terraces are made up in part of reworked till. Such material may be suitable for small ground-water developments in some places.

At Skagway the canyon is floored by alluvial deposits of apparently high permeability, and unconsolidated sediments of Quaternary age are present at Haines. However, these occurrences should be thought of as somewhat exceptional when the province as a whole is evaluated.

Revillagigedo Island

Ketchikan

Ketchikan lies on Revillagigedo Island along Tongass Narrows, east of Prince of Wales Island. It is the southernmost major Alaskan community and is an active, thriving community, having in 1948 a population of 6,000. The main industries are fishing and lumbering.

The city of Ketchikan is located in part along a very narrow, low terrace on the sea and, as at Juneau, increases in population through the years have led to location of homes on the high slopes above the business area. The city obtains its water supply (and hydroelectric power) from a series of mountain lakes to the southeast. There was no water-supply problem there at the time of the writer's visit in the fall of 1948.

Mountain Point

Mountain Point lies along a rocky coast 10 miles southeast of Ketchikan and is a community of about 125 persons. Near the center of the community, homes are concentrated along a small flat area about 100 ft above sea level, but elsewhere small homes are found along the beach or clinging to the precipitous hillsides.

The community is a growing residential area and is connected with Ketchikan by highway.

Geology.--The area is underlain by hard rock with little, if any, alluvial cover. The bedrock is classed as greenstone volcanics of Jurassic or Cretaceous age (Buddington and Chapin, 1929, pl. 2).

Water supply.--The greater part of the community is served by a small reservoir built on a creek above the village. It is

now believed that shortages will result with moderate increases in population. Further, several outlying homes that are definitely a part of the Mountain Point community are not supplied from this source because of the expense of installing a long pipeline to these homes.

In the type of rock present, drilled wells will obtain water from random fissures in the rock, but nothing indicates that yields will be large. On the other hand, if the cost of increasing the surface-water supply is great, it would be worth while to consider obtaining the moderate amounts of water needed from wells. Because no additional stream supplies are readily available, it is believed that a separate supply for the now "detached" southwest end of the community might be most economically provided by wells, assuming that moderate yields are obtainable.

Wacker

Wacker Cove lies along the shore 5 miles northwest of Ketchikan. Although only a few homes are located there now, it may be the site of a large pulp mill in the near future. The mill would provide its own water and hydroelectric power from somewhat distant streams.

Whipple Creek

The Whipple Creek area lies along the coast 8 miles northwest of Ketchikan and 3 miles northwest of Wacker. It was visited briefly on December 2, 1948. This area is now uninhabited except for a few cabins along the shore and a Civil Aeronautics Authority station at the far end. However, land was then in the process of being released for homesteading.

The area, according to plans, is laid out in four tiers of plots along the coast. The first tier will be cliffy beach-front plots; the other tiers will be on ground rising gradually from less than 50 to about 100 ft above sea level. Beyond the homestead area the ground continues to rise gradually to the base of low rounded mountains more than a mile away. Whipple Creek traverses the southeast portion of the area. In contrast to many streams in southeastern Alaska, this stream has a low grade and is flanked by "gravel" bars in places.

Geology.--The area is underlain by hard rock on which a few inches of alluvium is present. The bedrock adjacent to Whipple Creek is volcanic greenstone of Jurassic or Cretaceous age, and farther up the coast the rock is slate with interlayered sandstone of Triassic age (Buddington and Chapin, 1929, pl. 2).

Water supply.--When a community is established and incorporated it may prove most logical to dam Whipple Creek and use it as a source of supply. However, during the formative years as settlement progresses, most residents will be without a water supply unless individual wells are constructed. Individual

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well supplies will furnish only a partial answer to the problem, because private sewage disposal by cesspools in hard fissured rock will almost certainly lead to local contamination of the ground-water supply.

No simple and inexpensive solution appears for the water-supply problem there. The best solution might be for small groups of residents to drill wells on higher ground to furnish water to homes on lower ground. To avoid polluting the ground-water supply the residents high on the slope would have to install pipe lines to lead their sewage off at least several hundred feet down slope. Even this plan has its impractical aspect because the nature of the ground is such that burying both water and sewer pipes sufficiently to prevent freezing would be very expensive, even though the climate there is rather mild.

The most likely eventual solution, utilization of Whipple Creek, would be unfavorable to the extent that gravity feed probably would not be possible because the stream flows through low ground. The sanitary quality of the water could be improved by drawing the water from wells in sandy beds adjacent to the creek. Percolation of the stream water through the sandy beds to the wells should do much to clear up the contamination that undoubtedly will result from settlement in the watershed.

When the pulp mill is established, it is logical to expect that many of the mill workers will immediately take up available land in the Whipple Creek area and the water-supply (and sewage-disposal) problem will become acute shortly thereafter.

Prince of Wales Island

Prince of Wales Island, on which Hydaburg, Craig, and Klawak are situated, is the large southernmost outer island in southeastern Alaska, west of Ketchikan. It extends from the international boundary (which runs east-west) northward for a distance of about 120 miles. On the east is Clarence Strait, one of the dominant north-south waterways of the Inside Passage. On the west a few small islands lie between Prince of Wales Island and the Pacific Ocean.

Hydaburg

Hydaburg is on the southwestern side of Prince of Wales Island, about 30 miles north of the international boundary, east of the small Sukkwan Island from which it is separated by the Sukkwan Narrows. It is an Indian fishing village having about 400 inhabitants. Many small power boats are owned by local inhabitants. A community-owned cannery, recently destroyed by fire, is now being rebuilt. A modern school is maintained in the village by the Alaska Native Service.

The town is served by one airline which calls daily, weather permitting, using two- or one-engine seaplanes. Mail-boat service is less frequent.

The writer visited Hydaburg on December 6 and 7, 1948. The reservoir from which the town obtains its water supply was visited with Floyd Russel, the school principal, and Mr. Grant, acting for Mayor Charles.

Topography.--The village is on a rock-cut bench at the foot of a mountain and extends northwest-southeast along the shore. At the northwest end of the village the bench widens, and rolling ground, probably less than 100 ft above sea level, extends inland a mile or so. A large stream flows out of the hills, crosses this area of low ground, and discharges through the village proper.

Geology.--The rock cropping out in the village is black limestone. Along the trail to the dam an alluvial cover is present in which limestone fragments were noted. As the dam is approached the ground rises sharply above the bench land and the dam itself is set in granite. The Hydaburg area is underlain by rocks of Devonian age, largely graywacke, conglomerate, slate, limestone, and associated volcanics (Buddington and Chapin, 1929, pl. 1).

Water supply.--The town is supplied by water from a reservoir with a wooden dam, about 9,300 ft distant. Wood-stave pipes bring the water from the dam to the village distribution system. The supply has been ample but difficulties with low pressure have been experienced, in large part owing to the wasting of water to prevent poorly buried distribution lines from freezing. Air locks in the main line from the dam may have also contributed to the difficulty.

Town officials have considered raising the dam 8 ft, and developing small amounts of hydroelectric power. Stream-flow measurements would be necessary to indicate the desirability of this action.

According to A. Baker, district sanitarian of the Alaska Department of Health, the water supply is contaminated from time to time and requires chlorination.

Water-supply problems at Hydaburg appear to be those of distribution. Improvement of existing facilities is needed rather than a source of additional water.

Craig

Craig lies about 25 miles north-northwest of Hydaburg, on an island at the western side of Prince of Wales Island. A group of very small islands lie between Craig and the Pacific Ocean.

Craig is also a fishing village, having about 500 inhabitants, many of whom are natives. A large cannery at Craig owned by Libby, McNeil and Libby employs a few local laborers. Several power fishing boats are owned by local residents and a small sawmill is in operation. A modern school is maintained by the Territory of Alaska.

The town is served by one airline which calls daily, weather permitting. Mail-boat service is less frequent.

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The writer visited Craig on December 3 and 4, 1948.

Topography.--The village is on an island about 2,300 ft long extending east-west. Throughout most of its length the island is about 1,600 ft wide, but a narrow area near the east end is only 800 ft wide. The island rises gradually to a height of 150 ft above sea level a little west of the center.

Immediately east of Craig is another but smaller island that separates Craig from the "mainland" (Prince of Wales Island).

North of the point at which the road from Craig touches the mainland a low wave-cut terrace is developed to a small degree; south of this point the terrace extends for several hundred feet.

Geology.--Not much could be learned about the geology of the area, owing to the snow cover. No rock outcrops were seen on Craig Island. (The island was mapped as Mississippian limestone, according to Buddington and Chapin, pl. 1, but the float (loose rock) appeared to be of volcanic origin. On the mainland, rock outcrops were not found near the dam, but to the south, along the beach trail to the spring used by the cannery, the rocks were largely felsite and volcanic breccia. The spring, located about half a mile up the slope, issues from a limestone bed. This area is mapped as Devonian sedimentary rocks and associated volcanics.

Water supply.--The town is supplied with water from a wood-dammed reservoir located on the mainland mountainside. The reservoir is 3,000 ft from the village, at a reported altitude of 478 ft above sea level. Where the 8-inch line is bled to prevent freezing at night the flow was estimated to be 50 gpm. It was said that in the rainiest season the flow may be three times as great, but the quantity of water is not sufficient to supply

the town at all times. Little opportunity exists for increasing the dam storage or capturing additional water from other surface sources.

The flow from the spring used by Libby, McNeil and Libby is piped to the cannery. The flow at the cannery on December 4, 1948, was about 50 gpm; another 100 gpm was overflowing at the spring. This water is used about 3 months each year, in conjunction with an additional small supply from a stream. An analysis of the spring water is given in table 2.

The town is now planning to install an elevated storage tank to alleviate its present shortage and hopes also to pump from the cannery line at night in summer, when the cannery normally is not operating.

Estimating a need of 100 gpd per person, the town's requirements are, then, about 50,000 gpd or about 40 gpm, or approximately the minimum amount now available. Erection of a storage tank, now being considered by the town, may alleviate much of the present difficulty, but burying the mains properly to eliminate the necessity of bleeding them in cold weather will also be necessary to insure sufficient water at all times.

It was the consensus, however, that the amount of water available is too close to the minimum requirements for safety and comfort, and a moderate increase in supply is most desirable.

No additional streams or springs are available near Craig. According to Victor Rivers, the capacity of the present reservoir could not be increased except at considerable expense. Further, it seems unlikely that an increase in storage would be helpful, as the total flow of the stream is used for months at a time.

Table 2.-- Chemical analyses of water from selected wells and springs in Alaska
Analyses by Geological Survey. Results expressed in parts per million

Well no.	Owner	Location	Depth (feet)	Silica (SiO ₂)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO ₃)	Sulfate (SO ₄)	Chloride (Cl)	Fluoride (F)	Nitrate (NO ₃)	Dissolved solids	Hardness as CaCO ₃	Date collected
1		Klawak	Spring	7.9	0.47	56	4.1	6.2		188	7.7	5.0	0.3	0.2	180	157	Dec. 2, 1948
2	Libby McNeil	Craig	Spring	4.5	.01	28	3.1	6.7		96	7.1	7.2	.4	.0	104	83	Dec. 4, 1948
3	& Libby																
4	L. Wythe	Homer	113	6.6	.31	4.8	1.9	405		897	3.0	114	.4	.7	979	20	Dec. 1, 1948
5	Chamberlain and Watson	Homer	115	31	.70	55	14	56		356	3.5	14	.2	.5	350	194	Dec. 1, 1948
6	(Martin sub-division)	Anchorage	126	16	a 0.1	...	...	5.3		210	2	2	.2	.2	...	166	Sept. 9, 1950
7	R. Atwood	Anchorage	150	4.8	.03	22	37	674		188	381	795	.2	.7	2,010	207	Aug. 12, 1949
8	Huntley	Palmer	79	7.0	.02	41	4.6	5.5		102	40	5.0	0.0	1.6	155	122	Aug. 29, 1949
9	P. Lester	Palmer	37	16	.06	75	20	3.4		266	35	42	.01	35	388	490	Aug. 26, 1949
10	Town	Palmer	Spring	13	.19	42	5.6	2.9	1.3	150	6.2	1.8	.1	2.0	149	128	July 25, 1949
11	A.R.R.	Wasilla	21	15	.02	27	5.1	5.5		94	7.6	5.2	...	9.9	122	88	Aug. 31, 1949
12	F. Churchill	Chickaloon	-	17	7.15	59	24	49		376	3.1	28	.2	.4	366	246	Sept. 26, 1949
13	A.R.R.	Glenn Allen	203	40	.32	...	...	...		304	1	63	...	3.4	...	276	July 19, 1950
14	CAA	Gulkana	293	42	.86	...	...	...		266	28	230	.3	4.6	...	465	July 19, 1950
15	Resort	Manley	Spring	59	b .80	9.1	.9	121	8.2	86	48	120	...	...	417	26	Aug. 5, 1915
16	St. Marks	Nenana	16	28	9.2	84	25	8.7		370	14	8	.2	2.3	352	312	May 5, 1948
17	Rank	Fairbanks	175	28	a 8.1	49	13	6.9		206	17	2	.4	.6	218	176	Aug. 20, 1947
18	M. Agbaba		19	16	a .04	73	16	11		248	51	16	...	18	303	248	Aug. 20, 1947
19	U-Drive-It		52	24	a 2.2	61	14	12		240	25	8	.8	.9	264	210	Aug. 20, 1947
20	W. Tilman		108	24	a 47	83	18	15		304	32	21	.2	.8	345	281	Aug. 20, 1947
21	Army Permafrost Station		112	45	a 16.0	134	73	59		908	2.7	8	1.2	.9	771	210	Aug. 20, 1947
22	Road USGS 3	McGrath	101	27	.07	59	37	12		144	196	1.0	.6	.9	404	299	Sept. 2, 1948
23	Road USGS 3	McGrath	140	21	.07	122	65	17		240	378	12	.7	.6	735	572	Sept. 7, 1948
24	Buffalo Lodge	Big Delta	117	9.1	.27	...	...	..		94	30	2	.0	1.1	...	106	July 18, 1950
25	Airfield	Big Delta	200	9.0	.03	41	8.7	6.4		127	40	4.0	...	2.0	174	138	July 14, 1949
26	CAA	McGrath	250	33	11.0	64	61	..		1,340	2.5	4.0	...	.4	...	410	Aug. 16, 1948
27	T. Glazier	McGrath	28	15	1.9	120	20	62		578	30	6.5	.2	2.2	541	382	Aug. 16, 1948
28	A.N.S. Hosp.	Kanakanak ^c	64	7.2	5.0	13.0	3.6	1.6		65	3.2	10.5	...	17.7	71.6	47	July 12, 1940
29		Circle ^d	Upper spring	89	.02	21	1.0	258		172	97	248	10	...	809	56	July 18, 1949
30		Circle ^e	Cold spring	18	..	..	..	7.6		16	2.3	5.2	1.0	1.0	...	10	July 18, 1949
31	N.C. Co.	Tanana	50	23	2.7	116	33	9.4	2.4	387	7.8	69	...	1.5	458	425	July 19, 1915
32	Mission	Anvik		72	5.0	128	38	25	10	456	4.3	76	...	tr.	553	476	Aug. 21, 1915
33	Submarine camp	Nome ^c	38	68.4	2.0	197	254	1,850		293	320	3,605	...	...	7,320	1,540	July 8, 1940
34	U.S.G.S.	Kotzebue	82	9.7	68	640	1,890	14,100		1,770	1,610	26,200	...	...	45,300	9,370	Aug. 15, 1949
35	U.S.G.S.	Kotzebue	273	51	...	184	348	3,490		1,800	9.0	5,670	...	...	10,600	1,890	Aug. 29, 1949

a Estimate.
b Includes aluminum.
c Analysis by Alaska Dept. of Health.
d pH 7.3.
e pH 5.9.

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Test drilling on the mainland on the low bench along the road (and pipe line from the dam) might establish the availability of ground water in that area. Moderate supplies may be available and amenable to development without danger of salt-water contamination. Additional supplies, if needed, might be developed back from the shore east of the road.

Smaller amounts of water might be available from a well or wells drilled on the island, but it probably would not be economical to develop water there, inasmuch as the pipeline is already laid to the mainland, where the salt-water problem would be less important or even negligible.

Klawak

Klawak lies about 10 miles north-north-east of Craig. Like Craig it is situated on an islet, which is slightly less than a mile long and slightly more than a quarter of a mile wide. It is an Indian fishing village of about 400 inhabitants. Many power fishing boats are owned by local citizens and a cannery is also owned locally. The citizens are desirous of building a cooperative cold-storage plant.

Klawak was visited on December 2, 1948. The reservoir from which the water supply is obtained could not be reached because of heavy snow cover, but facts pertaining to the system were obtained from Mayor W. Peratrovitch and members of the town council.

Topography.--The islet on which Klawak is located rises to an altitude of 265 ft on the south end and to 202 ft near the north end. At its north end it is separated from the mainland by a narrow bench which is submerged at high tide. The mainland is low at the water's edge but rises gently to mountainous terrain. There appears to be an extensive but incompletely developed bench less than 100 ft in altitude.

Geology.--The village is underlain by gray fossiliferous limestone. A few small springs issue from limestone at an altitude of about 35 ft above high tide (Table 2). The bench connecting the mainland and the island is underlain by volcanic rocks.

Water supply.--The town is supplied with water from a reservoir on a mountain slope nearly 3 miles to the southeast. The supply is ample for present uses, although in winter, when lines are bled to prevent freezing, residents on higher ground are commonly without water. This difficulty could be remedied by burying distribution lines properly. However, the supply is not sufficient to support the proposed cold-storage plant; further, at times of peak operation of the present cannery, low water pressure is experienced by consumers. An analysis of the water is given in table 2.

Local citizens seem agreed that the present dam was located too low and that a dam to replace the present one should be built in a clean rock basin about 1,000 ft upstream from the present dam. Greater pressure and a more ample supply, free of silt and organic discoloration, is said to be certain if this is done.

Such action may well be the answer to the present problem. However, the present system cost \$52,000 in 1936. A new dam even more distant in the forested mountains, plus the cost of replacing and adding to the now old wood-stave line to care for the additional pressure, might make this plan prohibitively expensive. The development of hydroelectric power in connection with the proposed dam has not been considered, nor are data available for such consideration.

Ground-water supplies may be readily available on the mainland a short distance from the island. Limestone lenses may be present that might yield copious supplies of water. However, if ground water is considered, the cost of a well, an elevated tank, a pump, and the cost of operation must be taken into account.

Wrangell Island

Wrangell

Wrangell lies on the northern end of Wrangell Island, an island of intermediate size lying close to the mainland east of the north end of Prince of Wales Island. Wrangell is at the north end of Eastern Passage and about 10 miles south of the mouth of the Stikine River.

Wrangell is a fishing village of about 1,200 inhabitants, of whom about 500 are natives. A large sawmill, not now being operated, is situated there. A shrimp cannery is in operation during the summer months and many small power fishing boats are owned locally. Wrangell is a port of call for some steamships. Tourists, who come to view the totems and decorated council house, provide some local income.

In company with Victor Rivers and A. Baker, the writer visited Wrangell on December 9, 1948. The reservoir from which the town water supply is obtained was visited with Mayor George Gunderson, maintenanceman Frank Zepp, Lee Ellis, and M. M. Custard.

Topography.--Wrangell is on a low bench along the western shore of the northern point of the island. Behind the town the ground rises to a muskeg-covered terrace perhaps 100 ft above sea level. This higher terrace is 2 or 3 miles wide and constitutes all the northern end of the island except for an isolated mountain which rises to an altitude of 457 ft and forms the northernmost tip of the island. Less than 2 miles to the south and east the main mountain mass rises to an altitude of 832 ft above sea level.

Geology.--The rocks along the beach at the north end of town are black slate. The entire northern area is underlain by "phyllite, quartz phyllite, foliated quartzite, argillaceous and micaceous phyllite, and locally slate" that is "probably Ordovician to Jurassic or later" in age (Buddington and Chapin, pl. 2).

Water supply.--The Wrangell water supply is obtained from a reservoir on the mountain slope 3,500 ft east of town at an altitude of 335 ft above sea level. The supply is not

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quite adequate. In the winter, when stream flow is at a minimum and distribution lines are bled to prevent freezing, homes on higher ground are without water. During the time the cannery is in operation, low pressures in the distribution lines are also common.

It is likely that some relief from the present difficulties might be obtained by protecting the distribution lines from freezing and by installing a large capacity tank in town, but even so, the supply would be inadequate if the sawmill, now in the hands of a receiver, were to resume operations. According to local authorities, the cost of appreciably increasing the capacity of the reservoir would be \$50,000 to \$90,000. Obviously, it would be desirable to ascertain if ground-water supplies might be obtained close to the town at lower cost.

The writer believes that the muskeg-covered higher terrace immediately in back (east) of town might be profitably explored. Some roads approach or enter this area, and reaching possible drilling sites may not be difficult. The rock types, so far as water-bearing characteristics are concerned, range from poor phyllitic rocks to much more favorable quartzitic types. Exploration would, of necessity, seek out areas of favorable rocks before holes are continued to depths of more than 40 or 50 ft.

Mitkof Island

Petersburg

Petersburg is situated on the north tip of Mitkof Island, east of Kupreanof Island and just west of the mainland across Frederick Sound.

Petersburg is a thriving community of about 1,350 inhabitants, of whom about 400 are natives and the others are largely of Scandinavian extraction. Six canneries are situated there and many fishing boats are owned locally. The town is a port of call for some of the larger steamships.

Petersburg was visited on December 11, 1948. Mr. Desartes, in charge of the water-works, was contacted and the local situation was discussed.

Topography.--The community lies on the west shore of the northern tip of the island, on a very low, narrow bench. Behind the town the land rises gently to a somewhat higher broad terrace of considerable extent, which in turn rises gradually to the foot of the mountains about $2\frac{1}{2}$ to 3 miles to the south.

Geology.--Heavy snow cover prevented observation of any rock outcrops. However, the Petersburg area is underlain by "graywacke, dark-gray slate, and conglomerate with some intercalated beds of tuff, thin layers of limestone, and small limestone lentils," of Jurassic or Cretaceous age (Buddington and Chapin, 1929, pl. 2).

Water supply.--Petersburg has an ample supply of water obtained from the mountains to the south. The available supply was re-

cently increased by installing a second main from the dam. The pressure is kept low to prevent strain on the old distribution system. The water is discharged into two tanks on high ground back of town.

Kupreanof Island

Take

Take lies on the northwest end of Kupreanof Island just off Frederick Sound. It is approximately midway between Petersburg to the east and Sitka to the west. It is an Indian fishing village and has a population of about 400. Many small power boats are owned by local residents. In addition, about a mile to the southeast of the village, Seattle interests operate a large cannery in the summer months. A modern school is maintained by the Alaskan Native Service.

Take was visited on December 12, 1948. The small dam, the town reservoir, and the separate cannery supply were visited with Mr. Bell and others.

Topography.--The village is on a small wave-cut bench about 20 ft above mean tide level. The cliffs back of the village rise sharply to an altitude of perhaps 100 ft, and at that level another bench is developed over a large area.

Geology.--The rocks exposed along the beach are largely crystalline limestone. The area is underlain by rocks of Devonian age, predominantly graywacke and associated tuffs.

Water supply.--The town supply is obtained from a small reservoir on a very small stream flowing in an alluvial valley just northeast of the village. The supply is inadequate, the pressure head is low, and the water available is unsatisfactory because of high color. The topography is such and the stream so small that little would be gained by attempting to increase the height of the dam.

The cannery supply is obtained from a stream dammed in a rock-cut gorge high in the hills southeast of town. This stream is adequate to supply the cannery at full operation. At nights, when operations are suspended or at a minimum, the excess water from the dam is brought down to a small hydroelectric plant and sufficient power is generated to supply the lighting system of the cannery. The system is actually in use about 2 months each year.

It is possible that a satisfactory solution to the present problems at Take could be reached by arranging with the cannery interests to obtain a part of the water from the cannery system. However, other possible sources of supply may be explored.

Small supplies of ground water might be obtained at the foot of the cliff immediately behind the village or at the mouth of the small valley in which the village dam is located. There would be distinct danger of salt-water contamination at those sites, and wells developed there would have to be pumped at various rates to establish the highest rate

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of discharge possible without contamination. It seems more likely that better results would be obtained by drilling on the high ground in back of the village. A road probably could be cut past the village dam to the higher muskeg flat to permit entry of a drill rig. On the high terrace the water level probably would be reasonably close to the surface and, with a moderate lift, the water could be delivered to a tank at the surface, which in turn would supply water under ample head to the consumers in the village below.

Baranof Island

Sitka

Sitka lies on the west coast of Baranof Island on the Gulf of Alaska and is about 100 miles west of Petersburg and on equal distance south-southwest of Juneau.

The city of Sitka, founded by the Russians, has a population of about 2,300. Another 1,000 persons dwell on Japonski Island (Mount Edgecumbe) across a narrow strait.

Fishing is a major industry but the school and hospital of the Alaskan Native Service on Japonski Island and the Pioneers Home and the Presbyterian Sheldon Jackson Junior College at Sitka also are of importance in the local economy. One large sawmill is situated in Sitka, and tourists call in the summer months.

Expansion of industrial activity is foreseen in the proposed erection of a large pulp mill at Blue Lake, 6 miles east. An additional 400 families will be brought into Sitka if this project materializes.

The city is served by daily flights (weather permitting) by small amphibian planes to Juneau and to Kake and Petersburg. Sitka is a regular port of call for steamers plying the run between Seattle and southeastern Alaskan ports.

The city was visited on January 27-28, 1949. Dr. Charteras, Mayor of Sitka, and Mr. Calvin, town clerk, were contacted, and additional information pertaining to the city water supply was obtained from Vincent Beauchamp, manager of public utilities.

The business center of the city is on Sitka Harbor but the town extends about 1 mile to the east along Crescent Bay and $1\frac{1}{2}$ miles to the northwest along Sitka Channel and back from the coast about a quarter of a mile. Most of the population, however, is concentrated within a half-mile radius of the harbor docks.

Topography.--The ground rises gently from the sea to a marine-cut terrace about 50 ft above sea level. This terrace is of considerable extent, and the base of the mountains is nearly a mile from the coast. Some of this area is settled, but much of the low land outside the city limits remains a muskeg swamp. At the eastern end of the corporate limits the terrace is crossed by the Indian River. Swan Lake, about half a mile long, is near the center of the corporate limits.

Geology.--The area is underlain entirely by dark compact graywacke, so far as could be observed, and the level land and gentle slopes are mantled by a fairly thick alluvium, in part a talus-type material consisting of angular boulders in a sandy-clay matrix. Commonly, at least 8 to 10 ft of volcanic ash overlies bedrock. It is apparent that the unconsolidated material is generally more than 4 ft thick, as no difficulties were encountered in burying water and sewage lines to that depth. On one rather steep slope more than 18 ft of alluvium is present.

Water supply.--The largest part of the municipal supply is obtained by gravity feed from Cascade Creek, about 3 miles northwest of town. A secondary supply is obtained from the Indian River. Water from this source is pumped into a 500,000-gal elevated tank.

The system furnishes sufficient water for the city and Japonski Island, but in the early summer months the reserve is very low; near-shortages have also occurred in cold periods when lines were bled by consumers to prevent freezing.

Although the present supply is adequate, additional water probably will be needed if the proposed pulp mill is located near Sitka. The thought thus far has been that, after increasing the size of the reservoir on Cascade Creek, an additional supply of about 120,000 gpd might be provided by bringing in water from Blue Lake, 6 miles distant, at an estimated cost of \$250,000.

It is the writer's opinion that the feasibility of obtaining ground water might be profitably investigated. The quantity of water needed, only about 100 gpm, might be obtained from one to three wells of moderate depth sunk into bedrock in the flat area back of town, at a fraction of the cost of developing the Blue Lake supply. It is also possible that a good supply might be obtained from a well sunk in the bed or on the banks of Indian River if any appreciable thickness of sandy fill is present.

James Bay

James Bay community lies along the coast east of Sitka and consists of about 20 homes along a low rocky beach. Some of these homes are without water, a few use springs, and two have dug wells. Fairly high on the slope E. Hodges has a well dug in fill to a depth of 18 ft. The depth to water in the well is 9 ft below the surface. The water is clear and fairly soft and the well furnishes an ample supply to the electric pump supplying the residence.

It seems likely that most people in the area can obtain water from similar dug wells, but in a few places bedrock will be encountered and completion of a dug well in such places will be difficult.

Chichagof Island

Hoonah

Hoonah lies on Icy Strait on the eastern

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shore of Chichagof Island, about 40 miles west-southwest of Juneau. The community consists of about 500 natives. Fishing is the only occupation, and a large privately-owned cannery is about 2 miles west of the village.

The island is a "flag stop" on the Juneau-Sitka air route. In addition the town is served by mail boat and occasional freight vessels. Hoonah was visited on January 30-31, 1949. The beach area south of Hoonah was visited with George Martin. A recent 6-foot fall of snow prevented a detailed inspection of the terrane.

Topography.--The village lies along a narrow beach on the sea. About half a mile to the south the beach widens and an appreciable area of low ground is present, but to the north the beach narrows and cliffs rise from the sea.

Geology.--The rocks exposed along the beach north and south of the village are dark thin-bedded Paleozoic limestone and volcanics (Buddington and Chapin, 1929, pl. 1).

Water supply.--The village is supplied by water from a reservoir about 1 mile distant. The supply is generally adequate, according to Mayor Harry Douglas, except for short periods in the dry summer or in the coldest part of the winter when water is wasted to prevent freezing. Construction of another, higher dam, at a cost of more than \$30,000, has been contemplated.

As the area is underlain by limestone, it seems likely that moderate supplies of ground water might be easily available at relatively small cost. However, although a well might be located successfully on ground somewhat higher than the village where the beach widens to the south, it would be necessary that the pipe line be fed from a tank rather than directly from the pump. This cost must be considered if a supplemental ground-water supply is contemplated.

Juneau area

Auke Bay

The Auke Bay community, which may be considered a suburb of Juneau, consists of about 25 dwellings and stores lying along the north shore of Auke Bay 1.4 miles northwest of Juneau airfield. The area is shown on the U. S. Geological Survey topographic map, "Juneau, Alaska-Canada," edition of 1951.

Topography.--The settled area lies along the northeastern bank of Auke Bay, in part on a narrow marine-cut bench about 40 ft above sea level. Behind this partially developed bench the mountain mass rises rather steeply, and in one place it attains an altitude of about 1,000 ft. Immediately to the west, in the Auke Bay recreation area, the bench disappears and the road clings to the base of a precipitous mountain slope. To the east a narrow rock ridge extending north and south separates Auke Lake from the Bay. Auke Lake is half a mile wide and three-quarters of a mile long. It is fed from Lake Creek on the north and discharges into Auke Bay on the southeast.

Geology.--The area is underlain by slate and metamorphosed breccia of Mesozoic age, and Quaternary sediments have been deposited upon these older rocks. The unconsolidated material that makes the low terrace on which the Auke Bay community stands appears to be fill that was somewhat reworked by marine water during a higher stand of the sea. Similar material extending to a higher altitude is exposed about half a mile west of the community and is seen to be a mixture in which clay (glacial flour) is present throughout a mass composed predominantly of subangular fragments of small gravel. This material probably occurs at a veneer on marine cut-ruck benches except where preexisting valleys have been filled to the bench level. Well-sorted stream deposits appear to be absent immediately along the shore of Auke Bay but are almost certainly present in the flats north of Auke Lake along Lake Creek. A large area of outwash-plain deposits at the foot of Mendenhall Glacier is present more than a mile east of Auke Lake.

These deposits are mentioned here because a well located near the mouth of Duck Creek and now operated by the Civil Aeronautics Administration is sunk in these deposits. The well, which is 4 in. in diameter and 80 ft deep, yields about 15 gpm to a centrifugal pump. The water has a temperature of 49 F.

No outwash-plain deposits are present in the immediate vicinity of Auke Bay.

Ground water.--The likelihood of developing moderate ground-water supplies along the shores of Auke Bay does not seem good. Wells penetrating slaty bedrock there might have poor yields in relation to the cost of construction. At the head of the bay, the marine bench extends somewhat inland. There the unconsolidated cover material may be considered as a possible source of ground water. However, it is not certain that more than a thin veneer of cover material is present, or, if present, that it is reasonably permeable. Test drilling will be necessary before either of these factors can be evaluated.

The metamorphosed breccia between Auke Bay and Auke Lake might yield moderate amounts of water to drilled wells. Yields should be comparable to those obtained by drilling in well-jointed granite--that is, from a few to a few tens of gallons per minute.

The low ground north of Auke Lake, adjacent to Lake Creek, offers the best possibilities for obtaining moderately large supplies of ground water in the Auke Bay area. Auke Lake is a deep rock basin formed by scour of an ice tongue extending westward from the formerly longer Mendenhall Glacier. The basin itself formerly was larger than it is at present and has since been partially filled by deltaic alluvial deposits laid down at the mouth of Lake Creek. These deposits should be fairly well sorted and very permeable. Although the alluvial area is not large, withdrawal of water from the sediments should not result in depletion because of recharge from local heavy rainfall. Infiltration from Lake Creek may also occur if the lake bottom is not sealed by rock flour.

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Fritz Cove

Fritz Cove Road lies on the west side of the Mendenhall Peninsula, extending southward from the head of Auke Bay. The peninsula is a fairly symmetrical ridge, only slightly modified by remnants of a low marine-cut terrace on the seaward side. Bedrock there is metamorphosed breccia. Alluvial deposits are very sparingly present along the low terrace.

Small to moderate ground-water supplies probably could be obtained from drilled wells located on high ground back from the sea. However, domestic supplies might also be obtained from individually dug wells sunk into bedrock.

In this region of heavy rainfall these would be every reason to believe that very shallow wells sunk along the bay, on the beach itself, would tap fresh water floating on salt water. The water level in such wells would be slightly higher than sea level. However, when it is considered that the tide range is usually more than 10 ft and tides in excess of 20 ft are not rare, it is seen that wells on the beach would necessarily be a minimum of 20 ft deep in order that water be present in the well at all times. Thus there would be difficulty in insuring that water taken from the well would skim only the fresh water. Further, with such large continual movement of the tides, it seems very likely that the fresh-water layer might be mixed with salt water.

It is believed, therefore, that in this area dug wells should be located at somewhat higher altitudes back from the sea. These wells will encounter bedrock in many places a short distance below the surface but should be continued at least several feet below the water table, even though hard rock is encountered. On gently sloping ground, water may lie fairly close to the surface, but on steep slopes or on strongly dissected ground the depth to water will be greater. However, the water level in such wells may vary only a little with the rise and fall of the tides and there may be no problem of salt-water contamination.

Tee Harbor

The Tee Harbor community lies at the south end of an inlet from Favorite Channel, as shown on the Juneau, Alaska-Canada map. It consists of about a dozen dwellings and a public school. The area is of more importance than its size would indicate, because docks are being built for the unloading of waterborne freight for Juneau. By utilizing Tee Harbor and 20 miles of highway to town, more than a day's shipping time is saved. The growth of the little community therefore seems assured.

Topography.--The community lies on rather low ground at the south head of a long, narrow cove. On the east the mountain slope rises precipitously and on the west the ground rises less steeply to an altitude of 150 ft or more. To the south is a tract of more or less level heavily forested land which appears to have been built up during a 40-foot stand of the sea.

Geology.--The relatively flat, low-lying ground between the high hard-rock ridges is underlain by alluvial material, of unknown thickness. This material may be largely marine sand filling an old channel between the two ridges. On the other hand, if at the time of the 40-foot stand of the sea the low ground at the south end of the cove was not a through channel but was a topographic low only intermittently inundated by the sea, then the present unconsolidated material represents old glacial till and debris that probably were only slightly reworked at that time.

Undeveloped supplies.--The low-lying ground in back of the community is the logical area to explore for water supplies. It seems possible that a properly constructed and protected dug well might yield enough water for present needs. Small-diameter driven or jetted wells might be successful if the material present is well sorted and if bedrock or boulders do not prevent such construction. If very sandy deposits are found, it will be difficult to dig a well and driving or jetting may be necessary. If bedrock everywhere lies close to the surface or if boulders are particularly troublesome, drilling may be the only method by which an adequate water supply may be obtained.

Lynn Canal

Haines

Haines lies on a southeast-trending peninsula about 4 miles wide between Chilkoot and Chilkat Inlets, which merge to become the Lynn Canal. It is about 75 miles north-northwest of Juneau. The town has a population of about 300 but there are also 50 people (estimated) at the nearby Chilkoot Barracks, a former Army post built in 1904 but now privately owned.

Haines is the southern terminus of the Haines Highway or Haines "cut-off" which runs northwestward and connects with the Alaska Highway west of Whitehorse at mile 960. Although Haines has an ice-free harbor all winter, the highway has not yet been kept open during the winter and there is very little winter activity.

Haines is served daily by small amphibian planes and in the summer months is visited by steamers. An automobile-ferry service has been established connecting Haines with Tee Harbor. The ferry operates only when the highway is open.

Haines was visited on February 1 and 2, 1949. Mayor Ira Powell was contacted and, on the evening of February 1, local water-supply problems were discussed with the town council.

Topography and geology.--Haines and Chilkoot Barracks lie on relatively low ground that forms a waist of about 4 sq mi on the peninsula between low mountains. The mountains are largely of granitic rock but the origin of the unconsolidated material forming the low ground is uncertain, although presumably it is glacial.

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Surface-water supply.--The village is supplied by pipeline from a small creek on the mountain to the south. Shortages are common and an additional supply of water is needed. Extra water has been obtained at times from the Chilkoot Barracks system, but continuation of this practice is not considered desirable by the Haines community.

Extension of the present pipeline for 2,000 ft would make possible bringing in a new surface-water supply. However, this would be somewhat expensive, considering the small amount of additional water needed.

Use of a tarn lake, high in a cirque basin on Ripinsky Mountain across the Chilkoot River, already developed by the Army, might be considered. However, 1 7/8 mile of special pipe would have to be laid and maintained across the shifting sands of the Chilkoot River. Such a project obviously would be prohibitively expensive.

Ground-water supplies.--Several wells have been constructed at Haines, with the following results, so far as could be determined from local sources:

At Mayor Powell's home, near the business section, a dug well 40 (?) ft deep was converted into a cased well. This well flows now and is said to have yielded 15 gpm to a suction pump.

At the old barracks just north of town (not Chilkoot Barracks), a well was drilled by contractors for the Army to a depth of about 80 ft. It is reported to have yielded 150 gpm in a short pumping test made by air lift.¹ The water was said to be salty but local residents doubt that this report is true. The depth to water in the well was about 10 ft.

On the higher slope northeast of town, a well was drilled to a reported depth of 512 ft. The well now yields about 5 gpm of fresh water, by natural flow, and yielded about 30 gpm to an air-lift pump. It is reported that bedrock was not encountered in this well and that four distinct water-bearing horizons were penetrated. The only apparent reason for drilling to the depth indicated appears to be that "it was good drilling."

During the course of discussion with the council members, the question of the feasibility of utilizing the last-mentioned well was considered, particularly because the total present needs of the community amount to only 20 gpm. Further, it was pointed out that a 100,000-gallon (?) tank is located on the mountainside above the well and a 4-inch pipeline runs past the well to the tank. Negotiations for the acquisition of these facilities by the town are now being carried on.

¹ Assuming two-thirds submergence of the air line below pumping level and a water level 10 feet below the surface, the maximum drawdown would be about 23 feet.

On the morning of February 6, 1949, with Mayor Powell and Mr. McGee, the 3-foot snow cover was cleared off and it was found that the 512-foot well still flowed. Shortly after the writer left Haines that afternoon, the well was tested briefly with the fire-fighting apparatus and, as nearly as could be determined, yielded a minimum of 5 gpm with 18 ft of drawdown. Arrangements were being made to test the well accurately for a longer period with a smaller-capacity pump.

It appears that a turbine pump with about 100 ft of column might furnish enough water, 20 gpm or more, to supply the present needs of the town. Although this might be an inefficient well, in comparison with one of greater yield, very little capital outlay would be needed. Later a shallower well of higher yield might be constructed, or the well at the barracks might be put into service if it proves to yield fresh water.

Skagway

Skagway lies near the head of Taiya Inlet, about 90 miles north-northwest of Juneau and 20 miles northeast of Haines. It is the terminus of the White Pass and Yukon Railroad, which connects with the Alaska Highway at Whitehorse in Yukon Territory at the head of navigation on the Yukon River system.

Although Skagway had a population of 35,000 in the early part of the century, in 1948 it had only 700 inhabitants and is reminiscent of a western ghost town.

Skagway is served daily by small amphibious planes and is a port of call for some ocean vessels.

The city was visited on February 2 and 3, 1949, and the data presented here were obtained from Mayor Pat Carrol. Bitter cold and high wind prevented more than a cursory inspection of the area.

Topography and geology.--Skagway lies at the mouth of a flat-floored canyon which is less than a mile wide at the water's edge. The canyon floor is made up of alluvium, seemingly deltaic glacial-outwash sand and gravel. The rocks forming the canyon walls are largely granodiorite.

Water supply.--Skagway purchases its water at wholesale rates from the Skagway Public Service Co. and distributes it at retail rates to the consumers. Electric power is also purchased on the same basis. The water for both direct consumption and power generation is obtained from Lower Dewey, Upper Dewey, and Icy Lakes, high on the mountain above Skagway. The supply is small; during the winter there is not sufficient water to satisfy both water and power needs, and power is generated by diesel engines for long periods.

In the winter the water delivered is so cold that slush ice or frazzle ice tends to form in the distribution lines, and in the winter of 1946-47 the city spent \$5,000 in introducing steam, generated by a locomotive, into the lines to prevent freezing.

GULF OF ALASKA REGION

In addition to the municipal supply, several residents have private (ground-water) supplies. Most of the wells range from 16 to 30 ft in depth and are $1\frac{1}{2}$ in. in diameter. The water level is $4\frac{1}{2}$ ft below the surface in the center of town. Further evidence as to the permeability of the alluvial material is the report that the river loses volume appreciably as it enters town, and elsewhere several large springs issue from the gravels. One of these springs, at the railroad shops, is used as an emergency supply.

It would appear to the writer that the problem of winter water shortage and slush-ice formation could be eliminated by constructing (probably very economically) one or two wells. A deep well would yield slighter warmer water than a shallower one but, in any event, the temperature probably would be about 40 F (the mean annual air temperature at Haines is 40.9 F). A deep well probably would also have a slightly higher head than a shallower well, making for slightly more economical pumping. Chilling of the water could be inhibited by proper design and size of storage tank; it might be desirable to consider the practicability of a completely housed surface pressure tank.

Gulf of Alaska Region

Topography and geology.--The mountainous area bordering the Gulf of Alaska and extending from Mount Fairweather to Prince William Sound may be characterized, for the purpose of this report, as a region of high, heavily glaciated mountains, many of whose peaks attain altitudes greater than 10,500 ft. Here the great Malaspina and Bering Glaciers and many lesser glaciers are present. Along the sea a discontinuous lowland apron of alluvium occurs, as glacial outwash and moraines. The largest development of these deposits in this province is at Yakutat (Tarr and Butler, 1909, pl. 36), and Yakataga.

The high mountains are composed largely of igneous and metamorphic rocks, but between the alluvial apron and the higher mountains is a belt of highly folded and faulted sandstones and shales of Tertiary age.

Ground water.--The great outwash-plain deposits should yield easily many millions of gallons of water a day to wells, and even where the outwash deposits are of small areal extent it is likely that hundreds of gallons of water a minute should be obtained without difficulty. Morainal deposits may have rather poor yields, but in places drilling through such beds to outwash-plain material below may be practical. Clayey-till deposits may occur and will yield very little water.

Beneath the glacial apron Tertiary sandstones might prove to be water-bearing in places. However, it is not possible to evaluate their hydrologic qualities at present, and maximum attention should be given the shallower outwash material if large quantities of water should be desired.

The quality of water from outwash gravels will generally be excellent and preferable to water from surface ponds and lakes, which generally contain much organic matter ("muskeg

water"), and to water from most streams carrying rock flour in suspension.

Yakutat

Yakutat is about 5 miles east of the Pacific Ocean on the south shore of Yakutat Bay and about 215 miles northwest of Juneau. The village has about 200 inhabitants, almost all native. Fishing is the only industry. A cannery owned by Libby, McNeill and Libby is situated at one end of the village.

The large Yakutat airfield is located near the coast. Pacific Northern Airlines planes stop at the field on the Juneau-Anchorage run. Some Civil Aeronautics Authority and Weather Bureau personnel live in the area, either at the field or near the village.

Yakutat was visited on February 5 and 6, 1949. Mayor Joe Mallotte furnished data on the village water supply and Paul Griffith of the Civil Aeronautics Authority's maintenance department gave information on wells at the air station.

Topography and geology.--Yakutat lies on a low coastal plain which rises gently from the sea to the Barbizon Mountains, about 25 miles distant. The more distant peaks of the St. Elias Range may be easily seen from Yakutat in clear weather. The coastal-plain sediments are covered by a thick mantle of glacial-outwash deposits. The adjacent mountainous area is heavily glaciated now and the fringing coastal plain probably was once covered by ice to the same extent that the area immediately to the northwest is now covered by the enormous Malaspina Glaciers.

The area in which the airfield is situated is a monotonous muskeg flat, but the village, 4 miles to the east, is on a cliff rising steeply from the waters edge.

Water supply.--Three wells furnish the water supply at the airfield. One was dug to a depth of 18 ft; two are driven wells 14 and 18 ft deep, respectively. The depth to water is about 6 ft in the summer and 8 ft in the winter. Each well will yield up to 80 gpm with continuous pumping. Pits 15 ft in diameter and 12 ft deep have yielded as much as 200 gpm. The water is soft and slightly corrosive.

At the Civil Aeronautics Authority quarters on a high cliff near the village, a well 85 ft deep supplies eight families and a utility building. The depth to water in the well is about 60 ft. The water is corrosive.

In the village of Yakutat, Mayor Mallotte has a dug well 18 ft deep on the hillside. The depth to water is $16\frac{1}{2}$ ft. Water is obtained from a silt bed below what may be glacial till. The yield of the well is less than 5 gpm. Elsewhere, people carry water from springs, seeps, or small brooks.

The village of Yakutat, recently changed in status from a group directed by the Alaskan Native Service to an independent town, is facing a problem in attempting to provide modern services. The village is built on a hillside; gravity feed from surface lakes on

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high ground, if sufficient in quantity, would require hundreds if not thousands of feet of pipe between the lakes and the village and would deliver inferior (muskeg) water to only a part of the inhabitants, unless an elevated storage tank or pressure tank were used. At present there is no electric power in the village, although a power supply is planned. Mayor Mallotte's suggestion, that the first step might be to dig several wells and establish several water points from which people could carry water, seems logical. Later, it might be found that shallow wells dug or drilled either on the hillside or on the high ground above the village might yield sufficient water to supply the village as a whole and permit the establishment of a municipal distribution system.

Cordova

Cordova lies on Orca Inlet, which opens southward into the Gulf of Alaska. The town itself is on the east shore of the inlet and occupies the steeply sloping ground facing the sea. Cordova is 145 miles east-southeast of Anchorage.

Cordova has a population of about 1,400. It is a fishing town and has two large and five small canneries and two cold-storage plants. It was the terminus of the now abandoned Copper River and Northwestern Railroad serving the Kennecott mines. The town has air service three times a week to Valdez. Pacific Northern Airlines, on the Juneau-Anchorage run, affords daily travel in both directions. Oceangoing vessels stop regularly at Cordova.

Cordova was visited briefly on February 11, 1949. Mayor Ira Rothwell was contacted and the existing water-supply system was discussed.

Topography and geology.--Cordova is built along a steep rock slope facing the sea as shown on the U. S. Geological Survey map, "Cordova, Alaska," edition of 1951. The rock cropping out in the immediate vicinity is graywacke. To the east the mountain slope, which rises precipitously in back of town, is broken by a wide gap beyond which is Eyak Lake. The lake occupies a long, narrow rock-cut valley threading the mountains, in which local glacial scour is evident. Eyak Lake was formed when the mouth of the valley was dammed by a deposit of glacial sediments, probably morainal material, lying in the mountain gap just east of the town. During stages of maximum glacial melting, it is likely that one or more channels were cut in this moraine and subsequently were filled with permeable water-laid sand and gravel.

Water supply.--The city obtains its water from the Alaska Public Utilities Co., a private concern. Water is piped from a reservoir on the mountain east of town, about a mile distant. The supply is generally ample except in the winter, but on rare occasions there has been only enough water to supply the consumers for about 2 hr each day.

Although about 1,400 persons are served at present, it is planned that the two large

canneries also will be supplied with water during the summer of 1949 and, according to Mayor Rothwell, a demand will be created equivalent to that for at least 4,000 people. It is the opinion of Mayor Rothwell that much if not all of the additional water needed can be obtained by repairing the leaks in the dam and by increasing the height of the dam several feet. Further increases in the total supply might be obtained by developing the so-called railroad reservoir $1\frac{1}{2}$ miles from town on the north side of Eyak Lake. Pumping directly from Eyak Lake has also been contemplated.

It seems likely that fairly shallow wells of large yield might be constructed in the low land between Eyak Lake and the city of Cordova. Although the alluvial area is relatively small, perhaps less than a quarter of a mile wide and about as long, the underground reservoir would be constantly replenished by the water from the lake. The lake level is said to be more than 10 ft higher than the high-tide level, and danger from salt-water contamination probably would be negligible. Inexpensive shallow test drilling might be necessary to locate the most permeable ground in order that producing wells could be constructed with maximum efficiency. Such a supply would eliminate the long pipeline necessary in developing the railroad-reservoir supply, and the water obtained would be of better sanitary quality than that pumped directly from the lake.

Valdez

Valdez lies at the head of Port Valdez, an arm of Prince William Sound, and is said to be the "farthest north ice-free harbor in Alaska." However, the Richardson Highway connecting Valdez with interior Alaska usually has not been kept open in the winter and Valdez, like Haines, is active as a port only in the warmer months. The winter of 1949-50 private interests kept the southern part of the Richardson Highway open and trucking to Fairbanks and Anchorage continued all winter. Fishing is important in the local economy and is supplemented by a cold-storage plant. There has been a little gold mining in the area. Valdez has a population of more than 500.

The town was visited on February 7, 1949. Mayor C. G. Stith was contacted, and during the evening the local problems were discussed with members of the town council.

Topography and geology.--Valdez fronts the sea on a gently sloping canyon floor extending back to the foot of the Valdez Glacier 4 miles distant, as shown on the U. S. Geological Survey topographic map, "Valdez and vicinity," edition of 1930. This area is an outwash plain, probably marine-laid in part, and is underlain by gravel, silt, and minor clay beds. The town site is subject to flooding from meltwaters of the glacier, and a dike has been built around the town to eliminate this hazard.

Water supply.--Privately owned $1\frac{1}{2}$ -in. driven wells ranging from 20 to 30 ft in depth supply the residents with water. The depth

KENAI PENINSULA

to water is about 4 ft below the surface in the center of town. In addition there are nine 6-inch wells about 27 ft deep at various places in town that are used for fire protection. The 6-inch wells are cased with steel pipes, the ends of which were tapered by cutting, bending, and welding. The casings were then perforated and finally were driven into the ground by a pile driver. Three wells supply as much as 500 gpm to a centrifugal pump under continuous operating conditions.

The water obtained in the town is fairly soft and free of iron. A well at an abandoned Army installation across the creek just north of town is reported to have furnished discolored water high in iron or organic material. The temperature of the ground water at Valdez is reported to be 37 F.

It seems obvious that a municipal supply could be obtained easily and economically by utilizing one of the existing fire-protection wells. In consideration of sanitary conditions, however, it probably would be better to drill a well at the east (higher) end of town. It might also be desirable to attempt to develop water from a somewhat greater depth than 27 ft, with the expectation of obtaining purer, slightly warmer water. The static water level in such a well should be slightly higher than that in a shallow well.

Kenai Peninsula

The Kenai Peninsula lies between Prince William Sound and the Gulf of Alaska on the east and Cook Inlet on the west, and extends northward to a line drawn through Whittier on the east and Turnagain Arm on the west.

Topography.--The rugged Kenai Mountains, having a general altitude of 3,000 to 5,000 ft in which are many existing glaciers, lie along the eastern side of the peninsula and make up almost half the area. On the west is a broad lowland belt generally 50 to 200 ft above sea level, although rising to as much as 2,000 ft in some places.

Geology.--The mountains are made up of highly folded schist, slate, and graywacke and lesser volcanic rocks of Paleozoic and Mesozoic age, whereas the western lowland is made up of gently folded slightly consolidated sand and clay and many lignite beds, apparently of Eocene age (Martin and others, 1915, pp. 33-36).

The lowland received glacial deposits from local Kenai Mountain glaciers and from a composite glacier originating in the upper Cook Inlet-Susitna basin, and to a large extent it is now underlain by a thick basal sheet of till interstratified with local beds of water-laid sands and gravels upon which local moraines and small outwash plains are developed.

Ground water.--The glacial-outwash plains developed on the Kenai Peninsula should yield moderate to large quantities of water from place to place. Within the mountainous area the deeper and wider U-shaped valleys and canyons mouths should contain prolific water-

bearing beds. In the western lowland the occurrence of well-sorted coarse sand is more sporadic; outwash plains are not everywhere present and must be sought in areas between low, hummocky till plains and morainal ridges. In some places stratified beds within or below the till sheet must be sought by test drilling, but such beds may be less prolific than thick coarse gravelly outwash-plain deposits at the surface.

The Tertiary shale and sand beds beneath the glacial deposits may yield water to wells but nothing is known of the hydrologic characteristics of these deposits at present. Although sand and poorly cemented sandstone are present, their permeability may be low or water from them may not be of good quality. Here, too, test drilling would be desirable, considering the relative importance of the area as compared to many other areas of Alaska.

Development.--Seward and Whittier, on the mountain side of the peninsula, are important communities as ports of entry and probably will continue to be so. On the lowland bordering Cook Inlet the economy of several communities is based now on the fishing industry. However, farming may become of major importance on the Kenai lowland. Some land is suitable for the raising of crops and a great deal of land is more or less suited to the grazing of cattle. Likewise, the lowland is underlain by deposits of low-grade coal which eventually may be exploited. The peninsula as a whole attracts some sportsmen and vacationers and effort is being made to increase the tourist business. Hence it appears that the future of the Kenai Peninsula is firmly founded.

Seward

Seward lies on the east side of the Kenai Peninsula, just off the Gulf of Alaska and 80 miles south of Anchorage.

Seward, having a population of about 1,000, is a seaport having three docks. A large part of the goods for interior Alaska is unloaded at Seward and carried northward by rail. Fishing is also a primary industry and a cannery and cold-storage plant are situated in the town. The lumber mills also add to the economy of the area, as does the Territorial Seward Sanitorium, which has a total of 225 patients and personnel.

In addition to the facilities offered by the large steamships and the Alaska Railroad, the area has daily air service offered by the Christiansen Air Service, connecting Seward and Anchorage.

Seward was visited briefly on February 17, 1949. The facts presented here were obtained in large part from Mayor John Lanier and Hedley Davis, owner of the Seward water system.

Topography and geology.--Seward lies on a small alluvial shelf projecting into the sea from the west wall of a deep, wide canyon. The rock-walled bay is protected by small steep-walled islands across the harbor entrance. A short distance north of Seward

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the canyon mouth is completely filled with stream-laid alluvium of glacial origin.

Water supply.--The city is supplied from springs that issue from "boulder formations" on the steep mountainside high above the alluvial floor. At the Mount Marathon spring are three tanks having a total capacity of 25,000 gal, at Jap Creek are two tanks having a capacity of 1,000 gal, and between these is an unnamed spring and a tank having a storage capacity of 10,000 gal.

Ground water is not developed within the city limits of Seward. However, at the Seward Sanitorium, where the alluvium is spread completely across the canyon, are three 8-inch wells that are used as a stand-by supply. There are two 25,000 gal storage tanks at the hospital also. The capacities of the wells are not known, but is reported by Mr. Davis that one of them will furnish sufficient water to supply the entire hospital (a minimum of 16 gpm). It is the writer's opinion that these wells probably have very high potential yields, as they are developed in material of apparently high permeability similar to that at Valdez.

At the former Alaska Communication System radio station nearby, on land now occupied by a Mr. Bland, a 2½-inch well was driven more than 20 yr ago. This well flows about 20 gpm at a height of 2½ ft above the land surface. If a large additional supply of water were needed in the Seward area, it would seem likely that it might be available economically from shallow wells drilled on the broad valley floor just northeast of town.

Moose Pass

Moose Pass lies on the west bank of Moose Lake, which occupies one of a series of long, relatively narrow canyons extending northward from Seward through the Kenai Mountains. The village is 25 miles north of Seward on the Alaska Railroad and the new Seward-Kenai highway. Eventually the highway will be extended to Anchorage.

The village has a population of about 90. The working of small individual gold mines in the immediate area provides the local source of income.

Topography and geology.--Moose Pass lies on a narrow sloping shelf of glacial deposits, probably in part water-laid deposits formed along the edge of an ice mass or at a higher stand of the lake in glacial times. The shelf is about 10 to 20 ft above the level of the lake and terminates against steep canyon walls.

Moose Pass was visited briefly on February 17, 1949. Information presented here was given by a group of citizens at that time.

Water supply.--There are about 20 driven wells in Moose Pass, 1½ in. in diameter, ranging in depth from 10 to 16 ft. The depth to water in these wells is 5 to 10 ft below the land surface, depending on the location. The wells penetrate clay, sand, and pea gravel,

in that order. One of these wells supplies a country school having an enrollment of 16 pupils.

Robert and Edward Estes have a 16-inch pipeline leading up to a dam 175 ft above the village (a distance of 750 ft). The pipe brings water to their store and to a small hydroelectric plant. Water shortages occur from time to time, and it is planned to increase the capacity of the reservoir to a maximum of 14 million gallons.

Developing a municipal supply at Moose Pass should present no difficulties. Arrangements might be made with the Messrs. Estes to provide water under pressure, or a ground-water supply could be obtained economically from shallow wells almost anywhere along the road leading through the village. Proper protection of distribution lines against freezing, by burial in the unconsolidated alluvium, should not be difficult.

Homer

Homer lies on the north shore of Kachemak Bay near the southwest end of the Kenai Peninsula. Kachemak Bay leads out into Cook Inlet. The town is 125 miles south-southwest of Anchorage.

Homer has a population of 450, mostly white. Fishing is the major industry, and a cannery and cold-storage plant are located on the spit below town. Several gardens produce food for local consumption, and the area is being homesteaded with the expectation that the opening of the highway connecting Homer with Seward and Anchorage will provide a market for vegetables, beef, dairy, and chicken products. A dock, to be built soon by the Alaska Road Commission, will make possible direct water-borne freight shipments from the States and to and from Anchorage. Kachemak Bay is ice-free all winter.

The area has air service three times a week by the Pacific Northwest Airlines and service twice a week by the Alaska Airlines. Both lines originate at Anchorage.

Homer was visited on February 15, 1949. Several individuals gave information on the local water supplies, particularly Leroy Wythe.

Topography and geology.--The town lies on sloping ground that rises from the sea to the lowland plain, which is about 1,200 ft above sea level, as shown on U. S. Geological Survey topographic map "Seldovia (C-4), Alaska," edition of 1949, and "Seldovia (C-5), Alaska," edition of 1951. The surficial material is largely silty clay of Quaternary age; a short distance west of Homer, Tertiary coal-bearing strata crop out. The coal beds were encountered a few feet above sea level in Leroy Wythe's well. Low-rank coal has been mined near Homer and, at present, much fuel for local consumption is obtained from the beach, where coal from submarine outcrops is thrown up with each tide.

Water supply.--The town at present is poorly supplied with water. Two individuals have recently completed deep wells success-

UPPER COOK INLET

fully. Three establishments, the school, the station of the Civil Aeronautics Authority, and the Heady Hotel, have small-diameter pipelines leading to springs on the hillside. At the time of the writer's visit these were frozen up. Elsewhere the people obtain water of very poor quality from small springs in the muskeg or from small brooks on the hillside.

Leroy Wythe recently had drilled a 6-inch well 113 ft deep. "Blue clay" was penetrated to a depth of 106 ft. A water-bearing sand 1 ft thick lay between this and the underlying coal beds. The depth to water in the well was 40 ft below the surface. The yield of the well is not known. An analysis of this water (table 2) shows that it is a soft sodium-bicarbonate water containing 114 ppm of chloride.

At the Chamberlain and Watson store on the slope below Wythe's well, another well was completed at 115 ft. The log and yield are not known. The depth to water is 35 ft. This well yields water with a much lower mineral content than Wythe's well. It is, however, a hard calcium-bicarbonate water in which chloride is negligible (table 2).

Fluoride is present in small amount in the water from both wells, 0.4 ppm in Wythe's well and 0.2 ppm in the Chamberlain and Watson well. Such small quantities of fluoride are considered harmless; larger quantities up to 1.0 ppm are desirable in drinking water for children as an inhibitor of tooth decay.

Undeveloped supplies.--Two springs high on the hillside are reported to have a flow sufficient to supply the present needs of the town if moderate storage is provided. However, the quality of the water is said to be only fair, protection from contamination may be difficult, some trouble from freezing and silting may be expected, and a long pipeline will be necessary.

It is possible that a supply sufficient for the needs of the community can be developed from drilled wells of moderate depth. It seems unlikely that the yields of the present wells are great enough to meet more than minimum requirements. The water-bearing bed tapped by the present wells is a thin sand and may not be sufficiently extensive laterally to support a continued moderate demand.

Kenai

Kenai, overlooking Cook Inlet on the west shore of the Kenai Peninsula, lies 64 miles southwest of Anchorage. The village is served by Alaska Airlines and Pacific Northern Airlines, which make three stops a week. Alaska Airlines flights terminate at Anchorage and Bethel, and Pacific Northern flights terminate at Anchorage and Kodiak. The Alaska Road Commission completed a road in 1948 connecting Kenai and Seward; a branch from that road is to be constructed to connect with Anchorage.

Kenai has a population of 500 in summer and 250 in winter. Fishing is the major industry and, in the summer of 1948, two land canneries and one floating cannery were in

operation. There are three small lumber mills in Kenai.

Kenai was visited on February 15, 1949. H. Thornton and several other leading citizens were contacted and the local water-supply problems were discussed.

Topography.--Kenai lies on the edge of the broad lowland extending from the base of the Kenai Mountains westward to Cook Inlet. The village itself is near the edge of the cliff overlooking Cook Inlet, at an altitude of about 100 ft above sea level.

Water supply.--Kenai is supplied by dug or driven wells, most of which range from 18 to 30 ft in depth. The water-bearing material is a moderately fine-grained dark sand of a local outwash plain (Karlstrom, 1950). The driven wells are $1\frac{1}{4}$ or $1\frac{1}{2}$ in. in diameter and are equipped with drive-point strainers. One dug well on higher ground is 60 ft deep, and in a few places on low ground wells as shallow as 7 ft provide water for a household. The water obtained is soft or only moderately hard and does not contain iron. Salt water is reported in a few wells near the shore. As the water levels in the wells are above sea level, the salt water probably has not encroached from the sea but is present in the sediments near the shore under natural conditions.

A cannery at Kenai obtains its entire supply from two dug wells 10 by 11 ft across and 21 ft deep. At the Civil Aeronautics Authority station, a 4-inch well was drilled to a depth of 187 ft with no apparent change in lithology; the water is said to have become saltier with depth. The station is now supplied with water from a dug well 23 ft deep, which yields a maximum of 10 gpm.

The nearest surface-water supply is a muskeg lake 8 miles distant. It seems likely that ample water could be obtained for a town supply from a dug well located in some place protected from pollution. Whether a larger supply of fresh water is available from some coarser stratum at depth can be determined only by test drilling.

Upper Cook Inlet

Upper Cook Inlet may be used to designate the basinal area at the head of Cook Inlet and drained in largest part by the Susitna River and the Matanuska River and their tributaries. It consists essentially of a broad, low area rimmed by the Chugach and Talkeetna Mountains on the east and the Alaska Range on the north and west.

The lofty mountain ranges are made up of a complex variety of older rocks, but no attempt will be made here to describe them.

In the Pleistocene epoch the individual glaciers of the mountain ranges coalesced as they moved outward and southward down Cook Inlet and deposited alluvial material in their advance. In its erratic retreat, and particularly as the composite glacier tended to separate into individual components, other types of deposits were formed. The deposits

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directly or closely related to the movement and melting of ice were later modified in many places by streams, which continue to flow today (Capps, 1935, pp. 77-78).

Tertiary sediments crop out in places along the edges of the alluvial basin but in the central part of the basin the sediments, if present, may have been greatly thinned by erosion or even removed entirely, and Pleistocene and Recent sediments may lie directly on older hard rock.

A recently completed map of the unconsolidated sediments in the Anchorage and Knik quadrangles (Dobrovolsky, 1950, pl. 1) affords an excellent picture of the main geologic elements present in the area and the problems involved in their interpretation.

For a ground-water study, perhaps the most significant feature is the outwash plain extending from the mouth of Eagle River canyon southwestward across the area in which Elmendorf Field, Anchorage, and outlying communities are located. South of Anchorage the sand and gravel of this outwash plain grades into (or abuts?) finer sands forming much of the high ground.

The low hills adjacent to the Chugach Mountains are shown to be largely impermeable glacial till, but west of these till hills lies a narrow belt of coarse sediments succeeded by a wider belt of finer sands. North of the outwash plain lies a fairly narrow east-west belt of till forming the hills seen north of Elmendorf Field. Along the sea and in the estuaries of Chester Creek and Ship Creek blue marine clay crops out. This clay is overlapped by or interfingers with the outwash-plain sand and gravel.

In the Eagle Bay area a fairly broad pitted outwash plain is developed north of the east-west till belt. This may be contemporaneous in age with the Anchorage outwash plain, but certainly the sediments here were derived from a glacier originating to the north or northwest, whereas the Anchorage plain originated from a glacier in Eagle Canyon. The east-west till belt may well represent a lateral moraine developed along the ice tongue extending from the north or northeast and encroaching upon the Anchorage plain.

Anchorage and vicinity

Anchorage lies on the south shore of Knik Arm, which empties southward into Cook Inlet. It is probably the fastest-growing area in Alaska. The population of the greater Anchorage area was about 31,000 in 1949. It is a major air terminal. Northwest Airlines planes enter Alaska here from St. Paul and Seattle and from the Orient. Pacific Northern Airlines connects Anchorage and Juneau, and other runs terminate at Kodiak and Naknek with intermediate stops at Homer; Alaska Airlines flies to Fairbanks in the interior, to Nome via McGrath and Unalakleet, and to Bethel via Kenai, Homer, and Naknek; Northern Consolidated Airlines has a weekly flight from Anchorage to McGrath, villages along the lower Kuskokwim, and Bethel. Christiansen Air Service has flights to Seward. In addition,

nonscheduled flights are made from Anchorage to the States. The Alaska Railroad passes through Anchorage en route from Seward to Fairbanks. The Glenn Highway connects with the Alaska Highway via the Tok Cutoff (now part of the Glenn Highway) and with the port of Valdez and Fairbanks via the Richardson Highway.

Fort Richardson and the Elmendorf Air Force Base are just northeast of Anchorage. Large-scale construction at these bases under way at present and to be for several years is extremely important to the economy of Anchorage.

Anchorage is supplied at present by water pumped from Ship Creek, near the mouth of that stream within the city limits. This supply is essentially small and inadequate, and consideration is now being given to a plan to bring water in by pipeline from a reservoir on upper Ship Creek. Only parts of the greater Anchorage area are now served by city water (and sewers), and considering the low density of population and distances involved, it may not be economically feasible to serve some outlying areas in the immediate future. At present many relatively shallow dug or drilled wells serve a fairly large part of the homes in outlying districts.

Large water demands will be made by power plants which use water for cooling, if those now planned are constructed. Many housing projects are now in abeyance, pending acquisition of approved water supplies of any kind.

The water-supply problems of the area will be further increased by the building of a 400-bed hospital by the Alaska Native Service and construction of the International Airport at Lake Spenard, just south of Anchorage, and by the opening of the highway to the south establishing road connection with the communities in the Kenai Peninsula. Construction of the Eklutna dam and power plant between Anchorage and Palmer will promote the economic growth of the area to some extent.

It would appear that ground-water supplies, if obtainable in quantity, might fit into the over-all water-supply picture as follows: (1) serve areas outside the immediate network of distribution lines, (2) be tied into present and future distribution lines now carrying surface water to alleviate conditions in low-pressure spots (3) serve as emergency supplies everywhere.

Data supplied by John McAnerney of the Corps of Engineers office at Fort Richardson are most helpful in obtaining a three-dimensional picture of the geological formations and in making generalizations regarding ground-water supplies. A summary of the more significant data in the immediate vicinity of Anchorage is as follows:

At Mountain View, 2½ miles east-northeast of Anchorage, a well drilled in 1943 to a depth of 154 ft in the outwash plain is reported to have had a flow of 104 gpm. Another well, 51 ft deep, yields 35 gpm to a pump. In this well "gravel, with some dirt" was penetrated between 28 and 39 ft and "gravel and water" between 39 and 54 ft. A third

UPPER COOK INLET

well here, 44 ft deep, yields 30 gpm. "Sand and water" were penetrated between 33 and 44 ft.

"Test well 1, Air Depot," which is about $1\frac{1}{2}$ miles northwest of Mountain View at an altitude of about 200 ft, penetrated "mud" between 30 and 130 ft, gravel between 130 and 185 ft, sand between 185 and 190 ft, "mud" between 190 and 203 ft, and gravel from 203 to 228 ft. The water level is given as 154 ft and yield as 85 gpm.

In a 314-foot well $2\frac{1}{2}$ miles north-northwest of Mountain View and immediately adjacent to the east-west till belt, altitude about 200 ft above sea level, "mud" or "blue shale" was encountered between 10 and 19 ft, 70 and 85 ft, and 127 and 191 ft. Sand was penetrated between 85 and 127 ft and 200 and 218 ft, and fine sand between 225 and 300 ft. Gravel was present between 19 and 70 ft, 191 and 200 ft, 218 and 225 ft, and 300 and 314 ft. The yield is given as 80 gpm.

Presumably these wells are cased to the bottom of the hole and water enters the well through large slots or holes in the lower few feet of casing. (Installation of sand screens and subsequent development of wells to maximum yield is not yet practiced in Alaska.) If this is true, then much more water should be available from wells in such sediments if constructed with sand screens opposite all water-bearing formation. In the 314-foot well described above, 80 gpm was obtained from the gravel between 300 and 314 ft. Between depths of 191 and 300 ft is 16 ft more of gravel and 18 ft of sand which might have been developed. Some shallower beds in this hole might also have been developed, if the static water level was relatively high.

The most interesting fact to be gained here is that outwash-plain deposits are more than 300 ft thick and extend more than 100 ft below sea level in the vicinity of Anchorage.

Available data show that the water level ranged considerably in wells in the Fort Richardson area. The water level in one well near the west end of the airfield runway is only 46 (?) ft above sea level, whereas the deep well at Mountain View has a strong flow at 200 (?) ft above sea level. A 261-foot well at Fish Camp on the cliff above Knik Arm in the outwash plain north of the till belt, 3 miles north of the field, flows at an elevation of about 60 ft above sea level.

A 333-foot well, in the till belt just northwest of Elmendorf Field, penetrated very little permeable material. Water-bearing sand and gravel was found between 105 and 110 ft and sand and pea gravel between 330 and 333 ft. The only other material worthy of note is 107 ft of sand and silt between 110 and 217 ft, which may (or may not) have been too fine to screen. More gravel was penetrated in the upper zone in a nearby well drilled to a depth of 116 ft; "gravel and sand" and "gravel and silt" are reported between 80 and 116 ft.

In the vicinity of the Lake Spenard International Airport the sediments are finer-grained. A well at Hood Lake, 162 ft deep,

penetrated fine sandy material almost all the way down, described as quicksand and glacial silt. The well obtains 25 gpm from a bed of coarse sand and gravel between 151 and 162 ft. However, a well at the Campbell Point Civil Aeronautics Authority station, 2 miles west of Lake Spenard, penetrated mostly sandy material down to 200 ft. "Sand with seams of coal" was penetrated between 67 and 99 ft, silty material from 99 to 146 ft, gravel from 146 to 150 ft, "gravel and mud" from 150 to 190 ft, and water-bearing gravel from 190 to 200 ft. The water level there is 117 ft below the surface, or near sea level. The well yields 29 gpm.

The deeper material in the Civil Aeronautics Authority well is certainly similar to the coarse elements present in wells in the outwash plain at Elmendorf Field.

Very little information is on hand regarding the character at depth and the hydrologic characteristics of the gravel belt marked by the gravel quarries south of Merrill Field and south of the International Airport, although it is believed that the beds there will yield prolific water supplies.

The gravelly alluvial fan that has formed at the point where the south fork of Campbell Creek leaves its narrow mountain gorge and extends out upon the glacial gravel zone, attaining a maximum width of $1\frac{3}{4}$ miles, may be too thin to yield large quantities of water.

The quality of the better ground water in the Anchorage area shown by the analysis for one well 126 ft deep in the Martin subdivision (table 2). The water is moderately hard but low in iron. The Atwood well, 150 ft deep, yields brackish water.

The Matanuska Valley Agricultural Area

The Matanuska Valley agricultural area is a lowland lying along the north shore of Knik Arm off Cook Inlet.

Palmer, having a population of 576, lies on the north side of the Matanuska River and 50 miles northeast of Anchorage. Wasilla, having a population of about 100, is 10 miles west of Palmer.

In 1948 there was 8,500 acres of cleared land in the Valley as a whole. Farm income is generally supplemented by work in other occupations. Three or four sawmills and one cement-block plant are situated near Palmer.

Palmer is on the Alaska Railroad and has daily bus service to Anchorage and less frequent connections with other points on the Glenn Highway.

Topography.--The valley area consists in large part of a broad terrace and rolling upland adjacent to Knik Arm. The flat terrace surface is perhaps 100 ft higher than the Matanuska River and the upland somewhat higher still. The valley area is overlocked by the towering Chugach Mountains, 8 miles to the south, and by the Talkeetna Mountains, 9 miles to the north. These ranges converge a few

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miles northeast of Palmer. To the west the valley floor merges with the vast terrace bordering Knik Arm and Cook Inlet upon which are Anchorage, Kenai, and Homer.

Geology.--According to a report on the area being prepared by Frank W. Trainer, the area is underlain by three dominant formations; the gravelly beds underlying the broad, relatively low river terraces; glacial-outwash stream-bed deposits, forming longitudinal valleys and higher narrow terraces of small extent, and as a thin cover on areas underlain by till; and till, commonly forming ridges and hills but underlying some lower rolling ground and present at an unknown depth beneath much of, if not all, the glacial sandy deposits. In much of the area the surface is underlain by a few feet of Recent wind-blown silt. Bedrock crops out in the vicinity of Palmer and may be close to the surface in some other places.

Ground-water supply.--Considering the agricultural area as a whole, studies to date show that water is generally available from the gravelly sand forming the low, broad terraces flanking the major streams. The depth to water is greatest close to the high river banks. Wells should be located on low ground and back from the river for least depth and shallowest water level. The depths of wells are as much as 150 ft. It seems likely that several hundred gallons a minute may be available from properly located screened wells on the river terraces. In a few places, notably in and around the town of Palmer, bedrock or till lies at no great distance below the surface, and in such areas the terrace deposits are not productive.

Elsewhere the area is underlain by various combinations of impermeable till and restricted stream-laid deposits. Speaking generally, till forms ridges or underlies gravel-capped ridges and some of the higher gravel terraces, although in the Pittman-Little Susitna area it forms low rolling ground. Between the till ridges, narrow, long valleys filled with glacial outwash to varying thicknesses offer many opportunities for the development of small to moderately large supplies of ground water from the shallow wells in which the water level is within suction lift. In some longitudinal valleys it may be possible to develop, for a time, greater volumes of water than can be sustained for a long time because the gravelly storage area is essentially small and the underground percolation from adjacent areas is inhibited or entirely shut off by the parallel ridges of till.

Where till occurs beneath the gravel, small water supplies are easily available where the water table is above the till. Where till lies near the surface and the water table is below the top of the till, it would be desirable to seek other nearby sites, if at all possible, where the till lies deeper and water can be developed from the overlying gravel.

Where a well must be constructed in till, it may be necessary to drill deeply for only meager supplies of water.

Small flat terraces underlain by gravel, which lie higher than the broad river terraces, should be explored close to the uphill slope against which they rest in order to achieve minimum depth and highest water level.

Palmer

Palmer is supplied at present with water from Brazil Spring, $3\frac{1}{2}$ miles northwest of town, through an 8-inch pipeline. Water flows from the source by gravity. This supply was recently increased by developing additional springs in the same area.

In November 1950, after an abnormally dry summer, the flow of the main springs decreased to about 150 gpm from a normal yield of about 225 gpm. It is the feeling now of Palmer residents that a supply of as much as 500 gpm is desirable, if not absolutely necessary. Further, the spring supply was recently declared unsafe by the Alaska Department of Health.

It seems likely that a safe municipal supply can be obtained from wells in several places, but the most desirable place from the point of view of amount of water available, cost of lift to surface, and pipeline, cannot be determined until test drilling has been done and the results interpreted.

Analyses of water from three wells are given in table 2. The water is moderately to very hard but is otherwise of good chemical quality.

Wasilla

Wasilla, having a population of about 100, lies 10 miles west of Palmer. The town is a farming community but no real production has been attained yet, although much of the area is actively homesteaded. The town is on the Alaska Railroad and is connected by highway with Palmer. The bus serving Palmer and Anchorage also serves Wasilla.

Wasilla lies on an area of rolling ground, consisting of till ridges and intervening valleys filled with glacial outwash.

In the village, water for home consumption is obtained from dug wells, 25 ft or less in depth. A school which has an enrollment of about 100 pupils and is equipped with modern sanitary facilities, including showers, obtains its water from one such well. The shallow wells obtain water from outwash sand and gravel overlying glacial till of low permeability.

A safer and larger water supply for the village might be obtained from drilled wells of moderate depth if gravel beds underlie the till sheet as in the Knik area, but there is no evidence at hand yet to show whether such conditions exist. In consideration of the low water temperature and attendant freezing and the cost of pipeline, it may be more practical to attempt to develop a municipal supply here from wells, even from shallow wells if

COPPER RIVER BASIN

the area around them is protected from pollution, rather than to consider utilization of water from Wasilla Lake, less than a mile from the village.

Talkeetna

Talkeetna lies on the east bank of the Susitna River, 76 miles north and slightly west of Anchorage. The village has a population of 90, of which only a few are natives. The community is supported by gold mining in the surrounding area.

Talkeetna is on the Alaska Railroad and has river-boat service in the summer months. Alaska Airlines planes stop at Talkeetna on the Anchorage-Fairbanks run when service is requested.

The village was briefly visited on February 18 and 19 and about six of the local citizens were contacted.

Topography and geology.--Talkeetna lies on the low, level flood plain of the Susitna River. The base of the Talkeetna Mountains lies about 5 miles to the east and the base of the Alaska Range lies more than 20 miles to the west-northwest. The village is underlain by silt, sand, and gravel beds to an unknown depth.

Water supply.--There are about 35 wells in Talkeetna, nearly all of them driven, $1\frac{1}{4}$ or $1\frac{1}{2}$ in. in diameter, ranging in depth from 12 to 22 ft. These obtain water from gravel beds. The depth to water below the surface is about 5 ft in the summer and a maximum of 12 ft in the winter.

G. Weatherell has a well which was sunk 4 ft below the water level and from which 40 gpm was pumped by suction for a period of 6 hr.

At the Civil Aeronautics Authority station a 4-inch drilled well, 35 ft deep, supplies 20 persons.

The water obtained from the wells is said to be soft and very slightly corrosive. The nearest good source of surface water is a lake 3 miles away.

It would appear that a municipal supply of water of good quality might be obtained economically from shallow drilled wells. However, with regard to possible contamination, shallow wells should be located outside the village, or a deeper, properly constructed well might be located inside the village.

Curry

Curry is on the Alaska Railroad on the south flank of the Alaska Range. It lies upon a narrow alluvial plain along the Susitna River which forms an apron extending out from hard-rock hills to the east.

The village consists almost entirely of Alaska Railroad facilities--namely, a hotel, small shops, and water tank.

According to John E. Kerr, of the Geological Survey, who visited Curry August 9-10, 1950, the alluvial apron upon which the settlement is located is composed largely of poorly sorted fluvial gravel. A thin layer of "hardpan" (limonite-cemented sand or gravel?) is present at 18 ft and a "clay" stratum at 25 ft. Whether impermeable till or sorted permeable material is present at greater depth is not known.

A dug well 28 ft deep, south of the hotel, has been in use for some years but became contaminated with oil in 1948.

A new well was dug to a depth of 25 ft in 1949. This well is north of the hotel. It produced 200 to 300 gpm until the winter freeze-up, after which a supplemental supply was taken from the Susitna River. Water from Dead Horse Creek also has been used, and improvements in the supply line from this source were made in 1950.

It would appear that much might be gained here by drilling exploratory holes in the vicinity of the hotel to determine whether permeable beds exist at a depth somewhat greater than 30 ft. Water may be present in quantity and under artesian head, either from sandy beds beneath the clay or from fractures slaty bedrock.

Copper River basin

Topography.--The Copper River basin lies just north of the coastal mountains overlooking Prince William Sound and the Gulf of Alaska. It is completely enclosed by high mountains; the Chugach Mountains and Waxell Ridge on the south, the Talkeetnas on the west, outliers of the Alaska Range on the north, and the Wrangells on the east. The basin itself consists of a broad intermontane valley deeply dissected by the Copper River and its tributaries. The outlet of the basin to the Gulf of Alaska is through a steep-sided rock gorge cut through the coastal mountains.

Development.--There is at present very little economic development of the Copper River basin, although when the Kennecott copper mines were in operation it was the one most important mineral-producing areas in Alaska. The mines are on the south flank of the Wrangell Mountains and were connected by a railroad with Cordova. At present a few individuals mine a little gold in the area. The basin is potentially important in that several highways traverse the area; the Glenn Highway enters from Anchorage and joins the Fairbanks-to-Valdez Richardson Highway. Another through highway branches off the Richardson to join the Alaska Highway at Tok. Spur highways reach Chitina on the abandoned Copper River Railroad and Nabesna on the north flank of the Wrangells.

Geology.--The high mountain ranges, bearing many large glaciers, are made up of a great variety of older rocks; these include (in the Wrangells) Recent volcanics. Mount Wrangell continues to emit a plume of vapor. Tertiary (Eocene?) conglomerate, clay, thin coal seams, sand and gravel, in places strong-

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ly tilted, are exposed in a few places (Moffit, 1912, p. 35).

The most obviously important beds for a water supply are the alluvial deposits filling the basin proper. Presumably the area was at first covered by a till sheet during the period of maximum Quaternary glaciation. With the retreat of the ice this till sheet was eroded and reworked in places and covered by vast outwash-plain deposits, in which local till sheets are interstratified. The outwash-plain sands and gravels occur as stream and lake-bed deposits (Moffit, 1912, pp. 39-45).

Gulkana

At the Civil Aeronautics Authority station at Gulkana, which is on high, level ground about 400 ft above the canyon of the Copper River, a well was sunk to a depth of 443 ft in 1945.

Blue clay was penetrated from the surface to a depth of 280 ft, interrupted only by a 6-foot gravel stratum at 99 to 105 ft. From 280 to 328 ft sand and some gravel was penetrated, below which clay continued to 416 ft. The 27 ft of sediment from 416 to 443 ft was sand and gravel. Permanently frozen ground was penetrated between 24 and 32 ft below the surface.

It is difficult to interpret this log, but it seems likely that the considerable thicknesses of blue clay represents clayey to silty lake beds and that the intervening sandy and gravelly beds are stream-laid deposits formed when the lake filled and its floor approached the local base level, or when a temporary lake dam broke and allowed heavily laden glacial streams to wash over the old lake floor.

Water obtained from a depth of 443 ft stood about 220 ft below the surface and is described as "salty." The well was later plugged below 292 ft and water obtained from sand and gravel from 280 to 297 ft. This water also was rather highly mineralized (table 2), having 200 ppm of chloride and a total hardness of 420 ppm, of which 76 ppm is noncarbonate hardness.

The chemical character of this water is unexpected and may reflect any one of several things; the lake waters in which the sediments were formed were slightly saline owing to high evaporation at the time; the area was inundated by marine waters, the residuum of which has not been flushed out; or, as a consequence of poor seaward drainage of deeper sediments in the basin as a whole, ground water has tended to become more concentrated in mineral content as transpiration and evaporation remove ground water from the basin, much as similar water originates in desert regions.

Although it appears that ground water of good quality may not be available from deep sediments in this area, it is likely that along the fringes of the basin the prospects will be better. Where water-laid sediments are present they will tend to be coarser, being closer to the mountains, and they

should contain fresh water by reason of greater circulation through them.

Glenn Allen

At the Alaska Road Commission camp at Glenn Allen, 15 miles south-southwest of Gulkana, two wells, respectively 180 and 203 ft deep, yield a hard calcium bicarbonate water containing, respectively, 32 and 63 ppm chloride. A 321-foot well at Gatewood Lodge, Glenn Allen (drilled in 1951), yielded water containing 2,400 ppm chloride.

Tanana Valley

The Tanana River, a tributary to the Yukon, flows northwestward from the international boundary along or near the route of the Alaska Highway through Big Delta to Fairbanks and beyond through Nenana to Tanana. In its upper portion it occupies a valley that is alternately broad and narrow, but beyond Big Delta the valley widens greatly and at Fairbanks the silt-laden river flows across a muskeg flat about 75 miles wide.

Development.--Fairbanks, the northern terminus of the Alaska Railroad, is the center of activity of interior Alaska. The Richardson Highway to Valdez joins the Alaska Highway at Big Delta. The Richardson also joins the Glenn Highway leading to Anchorage. The Steese Highway joins Circle, on the Yukon, and Fairbanks. Scheduled airlines connect Fairbanks with Nome, Bethel, Anchorage, and Juneau and points in the States; and bush pilots fly to intermediate Alaskan communities.

Industrial development is based largely on large-scale gold dredging near Fairbanks, at Manley Hot Springs, and at Livengood. Several small mines are operated by individuals in many widely scattered localities. Coal is mined at Healy in the Alaska Range just south of the Tanana Valley proper.

The more recent development of military bases at Ladd Air Force Base and Eielson Air Force Base near Fairbanks and the field at Big Delta have had a very great effect on the economy of the area. Some farming is carried on and some large crops have been grown profitably in the Fairbanks area in past years. The University of Alaska is situated at College, 6 miles west of Fairbanks.

Topography.--The floor of the Tanana Valley is a broad, level flood plain across which the braided stream has migrated back and forth. Slight relief is provided by the old meander-scar patterns and, more rarely, by low rounded hard-rock hills that rise above the sodden flats. In the upper portion the valley is more diverse, ranging from narrow rock-cut channels to broader lowland areas flanked by mountains a few miles distant. Several major stream valleys enter the Tanana Valley at grade and their relatively wide, level valley floors may be considered extensions of the Tanana Valley into the adjacent mountainous areas. Alluvial terraces several hundred feet higher than the present Tanana Valley floor are well developed in places, particularly adjacent to the north

TANANA VALLEY

slope of the Alaska Range. A feature of the Tanana River is that, throughout its course, it tends to impinge upon its right bank. As a result steep hard-rock cliffs are developed in places along that bank, whereas the mountain slopes of the south bank, except where the river flows through rock-cut channels, approach and merge with the valley floor much more gradually.

Geology.--The Pleistocene and Recent history of the Tanana Valley (and the Yukon as well) differs significantly from that of areas thus far discussed, in that this area was not glaciated in Quaternary time, except for insignificant local Alpine glaciation. On the other hand, the Alaska Range to the south was heavily glaciated and glacial sediments were carried northward by streams into the Tanana Valley.

Mertie (1937, pp. 186-189) gives the sequence of events much as follows: During the glacial epoch the Tanana handled and sorted a tremendous volume of debris. The volume of material dumped into the Tanana Valley by the streams issuing from the Alaska Range is thought to have caused the Tanana to move northward to essentially its present position. In its northward movement the river built up the vast alluvial plains that now lie south of the river. Tributary streams from the north began to deposit their sediment on their own valleys as the Tanana floor was built up. Coarse material was deposited upstream and silt in their lower courses. Many of the richest gold placers of the region are found in the earliest Pleistocene deposits.

After the deposition of the older Quaternary gravel, black silt having a high vegetal content, generally referred to as "muck," began to accumulate. The muck ranges in thickness from a few feet to more than 100 ft and is widely distributed upon the mountain slopes, in places up to an elevation of at least 1,200 ft. The origin of these deposits is not understood at present. Part of these sediments may have been wind deposited, but the presence of fresh-water mollusks and diatoms suggests a lacustrine origin for another part.

Much of the ground in the Tanana Valley is permanently frozen. The frozen areas generally have the form of wedges that thin toward the major streams and thicken away from them. Narrow areas of thawed ground are common beneath recently abandoned stream channels. New ground on the slip-off side of stream meanders is not frozen whereas on the cut-bank side of a meander permafrost is present close to the bank. Nearly all the flat valley floor and north-facing mountain slopes are underlain by permafrost, but the frozen ground thins upward on low mountain slopes that face south or southeast. Frozen ground may continue to the mountain top on the north-facing slopes.

Ground water.--Considerable quantities of ground water are available in the Tanana Valley but in many places the water is high in iron or organic matter or both. The common presence of permafrost presents unusual problems in the development of ground water, but these problems are disposed of readily.

Speaking of the Tanana Valley in the larger sense--that is, including the tributary stream valleys and adjacent mountain slopes, ground water occurs in the following ways: (1) in sand and gravel beneath the flat valley floors of the main stream and its major tributaries, (2) in sand and gravel lying beneath the silt cover on the mountain sides, and (3) in the weathered upper part and in deeper fissures within the bedrock.

Data on several hundred wells on the flats in and adjacent to Fairbanks are at hand as a result of Geological Survey studies in the area, and enough data are available to characterize the occurrence of ground water on the mountain slopes, largely as a result of test drilling by the Survey.

Speaking generally, a million gallons per day per well should be available from 6- to 8-inch wells 50 to 150 ft deep on the Tanana River flats downstream from Big Delta. Yields of this magnitude have been obtained from several wells in the Fairbanks area. The existing wells penetrate highly permeable gravel, which yield copious supplies of water with little or no development. A transmissibility of about 600,000 gpd per ft, a high value, has been computed from pumping tests in the area. It is the writer's opinion that, in addition to the clean gravels, less-well-sorted coarse materials might be made to produce significant amounts of water by utilization of strainers and proper methods of development, and that the total amount of water available per large-diameter well might be considerably higher than that now obtained. However, in consideration of the high yield of more easily constructed wells, in many places less than 100 ft deep, and of the rapid recharge of the strata from nearby streams, it may be that the cost of several wells located 100 ft or more apart, tapping the same clean gravel bed, would be less than that of one large well.

Drilling wells by the cable-tool method generally presents no difficulties; in fact, frozen sand and silt stand well during drilling, making progress easier than in unfrozen ground. When wells are discharged regularly no difficulty with freezing is experienced.

Several hundred small-diameter domestic wells ranging in depth from 15 to 200 ft, are in use in the Fairbanks area. These obtain water from thawed ground either in areas free from permafrost or, in permafrost areas, from above or below the permafrost zone.

These wells are constructed by driving a 2-inch pipe with a drive point, and with perforations above the drive point, through which a $\frac{1}{2}$ -inch thaw line projects. Initial progress is made by washing with the thaw line 2 or 3 ft in advance of the drive point, after which the 2-inch pipe is driven down. In many places wells up to 60 ft deep have been driven in a day or two, but elsewhere progress may be slow. Deeper wells may progress much more slowly and at times only a few feet may be gained in a day.

The small-diameter wells passing through permafrost will freeze solid if not used

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regularly, and even then some wells tend to freeze. Freezing appears to occur as commonly in July as any other month. Frozen wells may be thawed with salt or they may be steamed out. The latter process thaws the walls appreciably and the well stays thawed longer. Many householders have a device so constructed that excess hot water from hot-water tanks can be run into the well as available. This action is sufficient to forestall freezing.

The quality of ground water available in the Tanana flats is generally not of the best (table 2). Commonly well water has a high content of iron or organic matter and tastes strongly, stains badly, and is undesirable for some uses such as laundering. Many householders have small water-treatment devices, which generally operate successfully.

Very shallow wells generally obtain water of good quality, but some deeper wells likewise yield excellent water. However, some deep wells apparently tap clean sandy lenses which, when depleted of clear good water, allow water from surrounding material to flow into the well, and the quality of water discharged becomes poorer. Likewise, some wells initially yielding very poor water have improved in quality with time.

It appears that, where large quantities of water are needed, it is fruitless to search for good water in a limited area on the flats. The quality of water obtained in any one place will tend gradually to change to an average quality characteristic of that locality as a whole.

The foregoing remarks apply to the downstream, broad portion of the Tanana Valley. The upstream portions of the valley undoubtedly differ in several important respects: the sandy sediments may be expected to be coarser and less well sorted, owing to the proximity of the mountain masses; glacial till yielding very little water might be encountered at depth in some places along the south side of the narrow valley; and bedrock may be near the surface in many places. However, the quality of the water may be appreciably better throughout. Conditions are probably favorable for moderate water supplies, but not as favorable as on the broad valley floor downstream.

Water is available from high terrace deposits adjacent to the low valley flats along the north slope of the Alaska Range but, owing to the proximity of the mountains, large boulders are commonly encountered and the depth to water from the surface is great. Apparently several hundred gallons a minute, if not more, may be obtained per well.

The rocks forming the mountain slopes on the north side of the Tanana Valley will yield some water to wells in most places. Permafrost is thin or absent on the higher south-facing slopes. The low mountains are covered largely with brown silt or, in minor valleys, with black mucky silt. In places coarse sandy beds are present beneath the silty cover and will yield supplies ranging from a few to perhaps more than 100 gpm. Elsewhere the upper decayed part of the bedrock will yield at least a few gallons a minute. The depth to water depends on the

local topography and may be more than 60 ft in places, but lower down on the same slopes the depth to water may be only a few feet. Where frozen silt acts as a capping, artesian conditions may exist and wells may flow at the surface.

Manley Hot Springs

According to C. H. Turnbull (1949) of the Alaska Department of Health, there are two drilled wells in this community, respectively 75 and 40 ft deep, sunk in gravel, both of which yield hard water. Permafrost is present at 3 to 12 ft and 42 to 54 ft, respectively, below the surface.

Most of the inhabitants carry water in buckets from the "Cold Spring," a small stream fed by numerous small springs, a few of which are hot. Consideration is being given to piping water from the Hot Springs to town.

According to G. A. Waring (1917, pp. 60-62), the Hot Springs were developed in 1906 and a hotel, dairy, poultry and vegetable farm were constructed nearby. The Hot Springs, water from which is still used for a commercial bath resort, have temperatures of 125 F and 136 F and flows of 110 and 35 gpm, respectively.

Analysis shows the soft sodic water to have a total mineralization of 417 ppm. Chloride and sulfate are relatively high as compared with calcium and magnesium.

Minto

According to Mr. Turnbull, the only well in this tiny community is a dug well near the river. In an attempt to obtain water for the school, a well was driven to a depth of 60 ft in permafrost but did not reach thawed ground. River water and melted ice and snow are used for water supply.

Nenana

Nenana lies on the south bank of the Tanana River just east of its junction with the Nenana River, which flows northward out of the Alaska Range. Nenana is 47 miles southwest of Fairbanks.

Nenana has a population of 350 to 500. As it is an important transshipment point, the railroad and river boats furnish employment for most of the inhabitants, other than those engaged in trade or miscellaneous services.

The town has no highway connection with other Alaska towns but is on the Alaska Railroad and has river connection with the Yukon, an arterial path of travel in Alaska.

Nenana was visited on February 18, 1949. During that evening a meeting was held with members of the town council and local problems were discussed.

Topography and geology.--Nenana lies on the level flood plain of the Tanana River and

TANANA VALLEY

is underlain by silt, sand, and gravel to an unknown depth. The town lies within the influence of an active meander in the river and even now the ground is being slowly eroded away. More important, the meanders tend to cause the pile-up of ice with the spring break-up, and thus contribute to flooding of the town.

North of Nenana the Tanana River is cutting against the hills that extend from Nenana eastward toward Fairbanks.

Water supply.---Two wells at the railroad yards, about 6 ft square and 35 ft deep, furnish water for locomotives and for a few business establishments. The water level in these wells is a minimum of 7 ft below the surface in the summer and 12 ft in the winter. Together they yield about 600 gpm by suction lift.

Several homes have small-diameter driven wells. The water obtained from wells is said to be hard and to contain some iron. Copper heating coils may plug up with lime in 3 to 5 weeks. On the other hand, reasonably soft, iron-free water is available in some places.

Apparently, a municipal supply adequate in quantity may be obtained from wells anywhere but, as in Fairbanks, water of good quality may be difficult to obtain. Whether a soft, iron-free supply can be obtained which will remain iron-free with continued pumping is yet to be established. Each well ends in a sand or gravel lens of limited extent; as the water in the lens is depleted, water from adjacent lenses moves in and eventually a water of average (poor) quality is obtained. Thus, as in Fairbanks, ground water of poor quality tends to improve somewhat in quality with continued pumping, whereas water of good quality tends to become inferior.

Permafrost is present in the area, but not immediately adjacent to the river at the town of Nenana.

Fairbanks area

Generalizations regarding the Tanana Valley, based upon data acquired in the Fairbanks area, have been given previously, and hence only a little more need be said at this point. It is apparent that, so far as the city is concerned, the inherent difficulties lie in the treatment of the water obtained and its subsequent distribution, rather than in the quantities available.

Fairbanks is supplied at present largely by several hundred small-diameter individually owned driven wells. The Northern Commercial Co. furnishes a part of the city with water from a large-diameter dug well 90 ft deep and from a gallery driven out under the Chena River. Steam heat is also delivered during the winter, thus preventing freezing of the line; during the warmer months the water service is extended via small-diameter lines laid on the surface.

Most farms on the low mountain slopes north of Fairbanks do not have a water supply

other than a cistern, but it should be possible to obtain at least minimum amounts of ground water without great difficulty. The possibility of developing enough water for irrigation is poor in most places, but in a few places it should be possible to develop sufficient water for limited irrigation.

The Fairbanks Exploration Co., on Garden Island immediately north of Fairbanks, has made many efforts to develop clear water in large quantities for cooling generators. A well 136 ft deep is reported to have yielded 3,400 gpm with 6 ft of drawdown. Another 106 ft deep yielded 2,900 gpm with 9.8 ft of drawdown. At present water is obtained from three wells about 90 ft deep each, yielding 2,400 to 2,800 gpm with 8 to 14 ft of drawdown. A dug well 40 ft deep, 75 ft long, and 60 ft wide produced about 1,800 gpm when first completed but now yields about 800 gpm with 11 ft of drawdown. A total of about 6,000 gpm is pumped more or less continuously in the warmer months.

At Ladd Field, near Fairbanks, several wells 6 to 8 in. in diameter yield more than 500 gpm; these and a few wells of smaller yield furnish the base with water. At Eielson Air Force Base a few wells of larger yield have been constructed.

Big Delta

A well drilled along the oil pipeline 1 at mile 1,449.8 penetrated frozen material from the surface to a depth of 44 ft and thawed ground to 75 ft. The material penetrated was sand and gravel. The hole was abandoned in a clayey stratum at 75 ft. A second hole was drilled through frozen material, largely gravel, and into what was said to be frozen schist at 42 ft. This hole was abandoned at 68 ft.

At Triangle Inn, a 4-inch well 118 ft deep obtains a few gallons of water a minute. The depth to water is 90 ft.

At the Air Force Base on a higher terrace south of the river, several wells 190 to 240 feet obtain 25 to 40 gpm with 3 or 4 ft of drawdown from gravelly sands. The depth to water is about 180 ft below the surface. In one well, the driller's log reports "big rocks" from 40 to 70 ft and from 120 to 148 ft below the surface.

The temperature of the water is reported to be 40 F.

Johnson River

At the camp on the flat bench above the river along the Alaska Highway the Alaska Road Commission has a well 96 ft deep in which the depth to water is 75 ft. It is said to penetrate all gravel.

At mile 1,409.5, which is in the immediate vicinity of Johnson River, the Corps of Engineers drilled a well at the oil pipeline

¹U. S. Army, Corps of Engineers, Whitehorse, Yukon Territory, Canada, personal communication, August 5, 1948.

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station. It penetrated coarse gravelly material to a depth of 94 ft, a layer of clay and boulders (till ?) from 94 to 104 ft, "clean washed gravel" from 104 to 130 ft, "clean washed flat rocks with an abundance of water" from 130 to 135 ft, and clay from 135 to 137 ft. All the material penetrated was thawed. The depth to water was 104 ft below the surface.

Dot Lake

At mile 1,370.5 on the highway, which is 3 miles west of Dot Lake, the Corps of Engineers drilled a well at the petroleum pipeline station. The well encountered 20 ft of frozen gravel and silt, below which thawed gravel and sand extended to 128½ ft. The water level was 64½ ft below the surface.

Tanacross

At the old airfield at Tanacross one 6-inch well 43 ft deep penetrated 6 ft of silt and gravel and 37 ft of sand and gravel, all thawed. The depth to water was 31½ ft. The well is reported to have yielded 30 gpm with 1 ft of drawdown after 6 hr of pumping. The temperature is reported to have been 36½ F. A second well had almost identical characteristics. The total hardness of water obtained is reported to be 162 and 129 ppm, respectively.

Tanana Bridge

At mile 1,330.1 along the pipeline the Corps of Engineers drilled a well to a depth of 45 ft. The depth to water was 9 ft below the surface.

Northway

One of the two wells drilled for the Corps of Engineers along the pipeline at mile 1,288 on the north side of the Tanana Valley encountered "decomposed and hard granite-slanting formation" at a depth of 115 ft. The other encountered "hard granite" at 177 ft. The alluvial material above was frozen silt and sand in each place. Only a little water was obtained from the first well from bedrock and presumably a somewhat better yield was obtained from rock in the second well.

At the Northway field, south of the Alaska Highway and far out into the broad valley, a well drilled for the Army encountered 25 ft of frozen muck and 65 ft of frozen sand and silt containing lenses of clear ice. The thawed material below 90 ft has largely sand and gravel; a "coarse gravel and sand" between 227 and 246 ft was developed in the well. The depth to water is 7 ft. The well is reported to have yielded 30 gpm with no observable drawdown.

A well drilled for the Civil Aeronautics Authority at Northway similarly encountered fine silty and mucky sediments in the upper part of the hole (frozen to a depth of only 46 ft). Below a depth of about 100 ft the

sediments were coarser and gravel appeared at 111 ft, but apparently it was necessary to go to 237 ft to obtain a sand-free gravel for open-hole development. Gravel and coarse sand is reported between 210 and 237 ft. The well was pumped for 8½ hr at 30 gpm. The water level is about 16 ft below the surface.

International boundary

At mile 1,249.7 on the Alaska Highway, which is near the international boundary, a well 203 ft deep penetrated only thawed ground. The material encountered was described as sand and "fine rocks"; the well was pumped at a depth of 135 ft and again at 203 ft but both times sand ran up the casing and the hole was finally abandoned.

Kuskokwim Valley

The Kuskokwim Valley extends from the area near Lake Minchumina, which is 150 miles southwest of Fairbanks, southwestward to Kuskokwim Bay opening on the Bering Sea, a straight-line distance of about 400 miles. The valley is sparsely developed, and the economy is based largely on gold, platinum, and (formerly) quicksilver mining. Many individuals, particularly the natives, in the several tiny villages work at canneries along the coast in the summer.

The Kuskokwim River flows through a broad alluvium-filled valley above McGrath. From McGrath to Aniak it flows through a narrow rock gorge, but below Aniak it flows across the vast soggy delta formed in the lower reaches of the Kuskokwim and Yukon Rivers.

Lake Minchumina

The settlement at Lake Minchumina consists of a Civil Aeronautics Authority station and field on the air route from Fairbanks to McGrath and Fairbanks to Nome. The area is low and characterized by muskeg flats and lakes.

A well drilled at Minchumina penetrated clayey gravel, largely, to a depth of 48 ft, where 4 ft of water-bearing gravel was penetrated. At 52 ft the drill reached bedrock.

The water obtained is said to be of fair quality but has a high iron content.

McGrath

McGrath is a community of about 100 inhabitants, most of whom are white. It is situated on a low slip-off slope of the river on the southeast flank of the Kuskokwim Mountains. It is important as a trading center for small mines in the adjacent area and as an intermediate stop on the Anchorage-Nome flights. Scheduled planes on the Fairbanks-Bethel run likewise stop at McGrath. Some hunting and trapping are done locally by natives.

Information on ground water at McGrath

KOSKOKWIM VALLEY

was obtained largely from Arthur Flat of the Alaska Native Service.

At the Civil Aeronautics Authority station a well was drilled to a depth of 262 ft. Sand and silt, for the most part, was penetrated to a depth of 230 ft. This was not developed, presumably because of difficulty of holding out the fine-grained material without a screen, and drilling was continued into underlying gray slate to a total depth of 262 ft. Casing, the lower 12 ft of which was perforated, was set at 242 ft. The water level in this well was about 20 ft below the surface. The maximum yield is not known; the pump installed is reported to furnish more than 6½ gpm. The water appears to have a high iron content.

A dozen or so driven domestic wells have been constructed at McGrath; these develop gravelly sediments encountered at 10 to 35 ft beneath overlying silty material. Ample water for a small roadhouse is obtained from such a 1¼-inch driven well by means of a small suction pump. The water obtained from these wells generally contains a little iron.

It is interesting to note that, where permanently frozen ground has not been encountered, these driven wells have generally been put down in 1½ to 3 hr. Permafrost is generally absent near the river but, as in Fairbanks, appears some distance away as a thin wedge and thickens with distance from the river.

Farewell

Farewell is an emergency landing field on the west flank of the Alaska Range at the west end of Rainy Pass, through which planes fly on the Anchorage-McGrath-Nome run.

A well drilled here at the Civil Aeronautics Authority station encountered "boulders, gravel, and frost" to a depth of 125 ft, below which "sand and clay" extended to 292 ft. The available log does not indicate the composition of the deeper material but, according to Earl Young, who drilled the well, water was obtained from a boulder formation, presumably extending from 292 to 348 ft.

The depth to water was 338 ft, according to Earl Young. This is rather surprising, because it might be expected that water would occur under artesian head. Presumably the overlying clayey beds are breached at a lower altitude. Possibly ground water may occur under artesian head in adjacent, less deeply dissected, areas.

Aniak

Aniak lies on the south bank of the Kuskokwim River about 135 miles from the mouth of that river. It is on the west flank of the Kuskokwim Mountains and at the head of the vast Yukon-Kuskokwim delta. Aniak is 325 miles west of Anchorage, 270 miles southeast of Nome, and 95 miles northeast of Bethel.

Aniak has a population of about 200, a large part of whom are Eskimos. Subsistence

is gained from work in placer camps and fisheries, some distance from Aniak, and in hunting and trapping locally. Some lumber is produced at Aniak. The town is served by river boats in the summer. Northern Consolidated Airlines furnishes service three times a week from Fairbanks to Bethel.

A stop-over was made at Aniak on February 26, 1949. The data given below were obtained from Sam Voich and other citizens.

Topography and geology.--The village lies on the flood plain of the Kuskokwim River. The material near the surface is coarse sand. Permafrost is not present in these recently formed deposits.

Water supply.--There are about 13 small-diameter driven wells in town, ranging in depth from 35 to 60 ft. The largest producer is the well at the school, which is 60 ft deep. A jet pump provides water for about 32 pupils. The school has modern sanitary facilities.

The depth to water in the wells varies with the river level and is as little as 15 ft below the surface in the summer and as much as 28 ft below the surface in the winter.

The water obtained has an excellent taste, is slightly hard, and has only a trace of iron.

Bethel

Bethel lies on the lower Kuskokwim, 50 miles from the mouth of the river on Kuskokwim Bay. It is 400 miles west of Anchorage.

The village has a population of about 325, about 300 of whom are Eskimos. Subsistence is gained by work in the canneries in the summer, fishing, and trapping. Some individuals are employed at the Alaska Native Service hospital a mile south of town.

The village is at the head of navigation for ocean-going vessels and is a point of transshipment for goods destined up river. Alaska Airlines makes two flights weekly from Anchorage via Naknek, and Northern Consolidated has three flights weekly from Fairbanks via McGrath.

Topography.--The village lies on a broad, low flood plain on the north bank of the Kuskokwim delta. The Civil Aeronautics Authority airfield lies on a similar low flood plain on the south bank of the river opposite the village.

Geology.--The region is underlain by silt and fine sand. The nearest hard-rock hills are 65 miles to the north on the Yukon and at the base of the Kilbuck Mountains 50 miles to the southeast. The area has long been receiving sedimentary material that has been transported a long distance and consequently is fine in texture. In part much of this fine material may be wind-blown. However, at some past stage of erosional history the valley was considerably narrower, the hard-rock hills were closer, and coarser material was deposited. Hence it is expected that coarse sands

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and perhaps gravel will be encountered at depth.

A well recently drilled by the Civil Aeronautics Authority penetrated fine silt at the surface, fine sand from 20 to 109 ft, and medium (?) sand from 109 to 197 ft. A few pea-sized pebbles were mixed with the finer material from place to place and a little clay is reported at 117 ft, 135 ft, and 165 ft. It seemed likely that this well could be developed and put into use by installing a suitable screen. It was subsequently reported that this was done successfully by forcing a drive-point strainer on a 4-inch pipe below the bottom of the 6-inch hole.

The village of Bethel is underlain by permafrost. A hole at the hospital drilled to a depth of 165 ft (100 ? ft below sea level) was still in frozen ground when it was abandoned. The whole village of Bethel is on frozen ground but, at the Civil Aeronautics Authority field across the river, on the inside of a meander loop, only a foot or two of permafrost is present at a depth of 15 ft. The ground there has been recently formed and permafrost has had little opportunity to develop.

The Bethel town site is subject to flooding and is being eroded actively by the river.

Water supply.--The residents use river water or river ice purchased from a private supplier. The larger purchasers pay about \$5.00 per 1,000 gal. The hospital has a pipeline from the river which operates fairly well in the summer but is costly and cumbersome to operate in the winter. Further, the quality of the river water obtained is inferior in that it has a poor taste and generally contains some colloidal glacial flour that is not filterable. Drinking water for the hospital is derived from a winter ice supply.

At the Civil Aeronautics Authority station shallow ground water high in iron content is available, but at Bethel, underlain by permafrost, shallow water cannot be obtained and septic tanks, lacking drainage facilities, simply fill, overflow, and freeze.

It is obvious that Bethel needs a water supply for both town and hospital. A river-water source is impractical because of the poor physical, chemical, and bacteriological quality, and because of the added cost of preventing freezing.

Unfrozen water-bearing coarser sands undoubtedly lie below the fine sands penetrated in the first 120 ft at Bethel, but where these are can be determined only by test drilling. However, considering the location of Bethel in the permafrost belt, it seems likely that in most places permafrost would not extend so deep as to include all zones of relatively coarse sediments.

Bristol Bay

The lowland area facing Bristol Bay, in the broad valley of the Nushagak River, lies between the Aleutian Range to the southeast

and the Kilbuck Mountains on the northwest. It was an area of glacial scour when ice tongues extended from both the ranges toward Bristol Bay. In later stages there was much glaciofluvial deposition as the glaciers retreated. It seems likely that considerable thicknesses of outwash material are present here and that prolific water-bearing beds are common.

Naknek and Dillingham are the two major towns. A few canneries are located along and near the bay but activity here is almost entirely seasonal.

Naknek

Logs of wells at Naknek provided by John McAnerney, geologist, Corps of Engineers, Alaska District, at Anchorage, make possible a broad characterization of the area.

Naknek lies on the east shore of Kvichak Bay off Bristol Bay on the north flank of the Aleutian Range. It is west-northwest of Mount Katmai.

Naknek well no. 2 penetrated "water sand" between 30 and 36 ft, "glacial silt and gravel" from 65 to 103 ft, "water sand" from 103 to 105 ft, "quicksand and gravel" from 105 to 145 ft, "water sand" from 145 to 148 ft, and "quicksand and gravel" from 148 to 168 ft. The well furnished 100 gpm. It may be presumed that, if sand screens were installed in such a hole opposite the better materials, a much greater yield might be obtained.

Naknek well no. 1, 8 in. in diameter, obtained 155 gpm from coarse white sand penetrated at a depth of 97 ft.

The "Rapids well" at Naknek penetrated "gravel" between 35 and 90 ft, and "water gravel" between 171 and 176 ft. Most of the other material penetrated appears to have been fine in texture. The well, 6 in. in diameter, yields 20 gpm.

At the Alaska Communications System station (at the airfield ?) pea gravel was penetrated between 34 and 47 ft and "quicksand and water" between 57 and 69 ft.

If sediments underlying the town of Naknek are similar to those described above, there is little doubt that a municipal supply could be obtained easily from wells.

Snag Point (Dillingham P. O.)

Snag Point is a community of about 100 persons, mostly natives, and is the trading center for the several small communities and canneries in the Nushagak Bay area. It is less than 10 miles northeast of Dillingham and 55 miles west-northwest of Naknek. According to Mertie (1938, p. 70) an 8- to 6-inch well was sunk for the Alaska Portland Packers Association to a depth of 213 ft, where fine gravel and black sand were penetrated. The well was located at an elevation of 60 ft and a "strong flow of fine clear water" was obtained that rose to within 15 ft of the surface. The well filled with sand and was finally abandoned.

BRISTOL BAY

Clarks Point

Clarks Point is a native community of about 25 persons and the location of a cannery. It is about 20 miles south of Dillingham, but on the east shore of Nushagak Bay. A well was drilled here for the Columbia River Packers Association to a depth of 186 ft (Mertie, 1938, p. 71). Some brown, discolored water was obtained from the gravel at 175 ft, the depth to which ice (permafrost ?) was reported. No other details are available.

Dillingham and Kanakanak (Kanakanak P. O.)

A well exists at the Alaska Native Service hospital at Kanakanak, but no records of wells are available at Dillingham, nearby. The well at Kanakanak is 64 ft deep and, according to an analysis made by the Alaska Department of Health, the water is fairly soft, is high in iron content, and has only 10 ppm of chloride.

Yukon Valley

In the summer of 1949 Charles Turnbull of the Alaska Department of Health made a sanitary survey covering the Yukon from Rampart to Holy Cross, as well as a few adjacent areas. The following facts are taken from his report.

The small Yukon River communities consist mostly of Indians except for a few traders and Civil Aeronautics Authority or other governmental personnel. Along the lower reaches of the river, however, the Eskimo population becomes significant. There is little economic development other than that connected with small-scale gold-mining operations. The natives do some trapping and fishing.

With the exceptions noted below, Rampart, Tanana, Kokrines, Ruby, Galena, Koyukuk Station, Nulato, Kaltag, Anvik, and Holy Cross on the Yukon, Hughes and Allakaket on the Koyukuk, and Hologachaket and Shageluk on the Innoko River (entering the Yukon at Holy Cross) obtain their water supply from cisterns, from the river, or from melted ice and snow. It seems likely that in many of these communities inexpensive drive-point wells might be driven to gravels at no great depth to furnish a stable, easily available, safe water supply. Where permafrost underlies the villages, the problem is obviously more difficult.

Circle Hot Springs

Waring (1917, pp. 51-53) described the hot springs at Circle on the Yukon. The adjacent land was first homesteaded in 1909 and later developed as a resort, the water being used for baths, for irrigating vegetables, and for domestic use. The total flow is about 340 gpm and the temperature of the water in the bathhouse is 110 F.

Samples collected in 1949 show that the upper large spring yields a fairly soft sodic

water containing 95 ppm of sulfate and 248 ppm of chloride. It is of particular interest to note that the water contains 10 ppm of fluoride, a content much too high for drinking water. Continued use by young children, will result in permanent mottling of tooth enamel.

Tanana

Tanana lies on the north bank of the Yukon, just below its junction with the Tanana River. It is 132 miles west-northwest of Fairbanks. Tanana has a small native population, and fishing and hunting are the primary occupations.

The village is served by river boats in the summer. Northern Consolidated Airlines furnishes service three times a week.

Topography and geology.--The village and Civil Aeronautics Authority field lie on the flood plain of the Yukon River. Immediately west of the field (downstream) the flood plain terminates against a gentle slope underlain by hard rock.

Water supply.--At the Northern Commercial Co. a 50-foot well drilled into bedrock is said to yield 52 gpm. The water is hard.

According to Waring (1917, p. 87) water from the same (?) well has a total hardness of 415 ppm, largely carbonate hardness. The iron content is 2.7 ppm. However, two other wells near the river yield "good" (iron-free ?) water.

The Alaska Native Service hospital and school both obtain water from dug wells about 30 ft deep.

Ruby

Ruby, on the high bluff on the south side of the Yukon River was once supplied in the summer months by water piped from a spring just south of the village. The distribution lines have since been torn up.

Galena

Galena lies on a meander on the north bank of the Yukon River. It is 273 miles west of Fairbanks and 254 miles east of Nome. The native village of Galena has about 100 (?) inhabitants who subsist by fishing and trapping. The Army field, a ferry station formerly used by the Russians in taking planes from Fairbanks to Siberia, is located nearby.

Water can be obtained from shallow wells in the village, but the quality of water is bad and the villagers prefer to carry water from the Yukon River.

There are drilled wells at the Army base having a maximum depth of 235 ft. The supply is ample but the water is hard and contains much iron. It is disagreeable in taste, and water for drinking purposes is provided from steam condensate.

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Anvik

According to Mr. Turnbull, "a driven well was located in front of the Mission which was used until this past year (1948), when the missionary-in-charge had it removed. This water was hard."

According to Waring's published analyses (1917, p. 97) this water was similar to but slightly harder than the hard well water from Tanana and contained 5.0 ppm of iron.

Holy Cross

A well 100 ft deep at Holy Cross mission penetrates bedrock and, used in conjunction with a 4,000-gallon tank, furnishes water for the mission and two domiciles. Another well, 30 ft deep, also penetrating bedrock, is no longer used.

The villagers use river water in both winter and summer.

Hughes

At Hughes on the Koyukuk River, the trader obtains a supply of excellent water from a driven well 13 ft deep.

Marshall

Marshall lies on the lower Yukon about 150 miles from its mouth. It has a population of about 150, most of whom are Eskimos. Some gold dredging is done in the vicinity and during summer months many natives work in the Bristol Bay canneries.

According to John E. Kerr of the Geological Survey, who visited Marshall in the summer of 1949, chloritic and andesitic rocks, and tuffs crop out at the surface on the higher ground back from the river. Near river level a little fine- to medium-grained sandy alluvium overlies bedrock.

Two dug wells are in use in Marshall. They are near the river. One obtains water from fractured tuff, the other from andesite.

It seems likely that properly constructed and protected dug wells on low ground might provide a reasonable amount of water safer than that used at present. Wells drilled into bedrock here might have small yields, but still sufficient for most purposes.

Norton Sound

St. Michael

St. Michael is on the northeast end of an island in Norton Sound, immediately adjacent to the mainland. It is about 50 miles northeast of the North Fork mouth of the Yukon and 125 miles southeast of Nome.

The village of St. Michael has a population of 153, including one white man. The Northern Commercial Co. employs many of the natives for the greater part of the summer to

operate its freighting service between St. Michael and Marshall on the Yukon River, but the major seasonal employment is in the Bristol Bay canneries. A few of the natives are engaged in herding reindeer and all hunt, fish, and trap to some extent.

The village has weekly seaplane airmail service. Bush pilots utilize the sandy beach. About four times each summer, steamships of the Alaska Steamship line stop at St. Michael, and tugs of the Northern Commercial Co. unload more frequently.

St. Michael was visited briefly on September 1, 1949, by John E. Kerr. Paul Ivanoff, school teacher, provided the information presented here.

St. Michael, founded by the Russians during the 1860's, flourished as the leading port of Alaska as a transfer point for State-side cargo consigned to the interior. From here steamboats plied the Yukon River as far inland as Dawson, Yukon Territory, a distance of more than 1,300 miles. St. Michael ceased to function as the supply point for interior Alaska upon the completion of the Alaska Railroad in 1923. At that time St. Michael had an estimated population of 7,000. U. S. Army troops were garrisoned in St. Michael until 1925.

Topography and geology.--The seaward or west-facing beach at St. Michael is sandy, whereas the protected or east-facing beach, is strewn with large blocks of disintegrating basalt. The town is built on the east-facing beach on a bluff about 30 ft above sea level. Much of the island near the village is underlain by a very black silty, mucky deposit perhaps 20 ft in thickness. Permafrost occurs on the island at a depth of about $3\frac{1}{2}$ ft and is known to extend to a depth of at least 6 ft. Beneath the thin alluvial cover lies basaltic lava, which is vesicular in places. It is thought that this lava is of Recent age.

Water supply.--The chief sources of potable water at St. Michael are rain water during the summer and ice during the winter. However, on the mainland, about 2 miles from the town, a large spring issues from the beach. This spring is used as a source of water by the tugs and steamships that visit St. Michael. During high tide the mouth of the spring is inundated; during this period water is taken by boats while standing about 600 ft off the high-tide shore line in 10 ft of water. The spring flows in such volume that mixing of fresh and salt water is essentially nil.

Another, more important, source of water is Johnsons Lake, on the island itself and about three-quarters of a mile distant, between the sea and the town. This lake measures approximately 500 by 600 ft and is about 12 ft deep. While troops were garrisoned at St. Michael, the Army installed (above ground) a 3-inch galvanized pipeline from the lake to the town. It is estimated that the daily consumption was in excess of 500,000 gal. After the Army abandoned St. Michael, this water system was for a time maintained by the

NORTON SOUND

Alaska Commercial Co. and the Northern Navigation Co. and the 3-inch line is reported to be usable at present. There is also, in apparently good working order, a 10,000-gallon storage tank in the gymnasium that was erected by the Army.

No well of any type has ever been constructed at St. Michael, but it is reasonable to expect that a drilled well would yield water in appreciable quantities from the underlying basalt.

The surficial material on the island is a silt or a silty muck about 20 ft thick. A part of this (at least 6 ft) is rendered impermeable by permafrost and the remainder probably would not constitute an aquifer.

If the basalt near Johnsons Lake is vesicular it should be a good conduit and most wells drilled into bedrock near this lake would be successful. Shallow wells drilled at other locations on the island probably would be successful if they also were fed by continuous or connecting vesicles of the basalt.

Unalakleet

Unalakleet lies on the east shore of Norton Sound on a bay-mouth bar at the south of the Unalakleet River. It is 147 miles east-southeast of Nome. The town has a population of more than 400, almost all being Eskimos. For a living the residents hunt and fish, and work in the placer mines near the head of Norton Bay.

The area is served by small boats in the summer months. Unalakleet is a stop on the Alaska Airlines, which makes four flights a week from Anchorage to Nome.

Unalakleet was visited on February 26, 1949. Mr. Warbelow, Alaska Native Service teacher, Frank Ryan, postmaster, and Mr. Roseneau of the Civil Aeronautics Authority were contacted and the local water-supply facilities were discussed.

Topography and geology.--The village lies on a sand bar built across the estuary of the Unalakleet River, a relatively small stream lying in a broad valley extending northeastward to the Yukon. The Yukon may have discharged into the ocean through this channel at one time. The sand bar on which the village is situated is about 20 ft above sea level and projects southward about $\frac{1}{2}$ mi from a submountainous area. The bar is about a quarter of a mile wide. East of this bar is a swampy estuary. South of the village of the Unalakleet River finds its way to the sea.

The bar is known to be sandy and probably contains gravel. The fill in back of the bar may be made up largely of clayey or fine sandy sediments, but these may overlie coarser material brought down by the Unalakleet (or Yukon) before the bar was formed.

Water supply.--At the mission and at the schoolhouse are two wells, partly dug, partly driven, about 30 ft deep. The depth to water

in these wells is about 8 ft. According to Mr. Ryan, one of these wells yields a minimum of 10 gpm with 20 ft of drawdown. The water-bearing formation is yellow fine- to medium-grained sand. The water is soft and contains no iron but is slightly corrosive. Its slight saltiness may be due to salt spray from the ocean rather than to salt-water intrusion induced by pumping.

Most of the water used by the villagers is obtained from small creeks nearby or from a spring 5 miles distant.

Moderate quantities of water, less liable to pollution than the present supply, might be obtained just north of the village from rather shallow wells, but to develop larger quantities would require exploration near the hard-rock hills. Water developed there might be small in quantity, however, and would require an expensive pipeline and maintenance if the water were to be used at the present village site.

Seward Peninsula

Nome

Nome lies on the south side of the Seward Peninsula on the Bering Sea. It is 545 miles west-northwest of Anchorage and 135 miles southeast of the international boundary, at the Diomed Islands. Nome has a population of about 1,500, of which many are native. In largest part, Nome owes its economic life to the placer-gold mines in the area.

Ocean vessels make Nome a regular port of call in the warmer months. The city is served by Alaska Airlines, which has four flights weekly from Anchorage via McGrath and Unalakleet, and by Pan American Airways which has two flights weekly from Fairbanks.

Topography and geology.--Nome lies on a long, even coastal plain along the open sea. The ground rises very gradually to the low mountains a few miles north of the city. This long slope is underlain by Quaternary alluvial deposits in which the placer gold occurs (Smith, 1910, pl. 2).

Water supply.--Most of the city is supplied by water hauled from the Bourbon Spring well, developed in alluvial gravels about half a mile north of the city limits. This well is about 20 ft deep and yields about 90 gpm with 5 ft of drawdown. The water is hard but free of iron. During the summer water of an excellent quality is supplied by the United States Smelting and Refining Co. by pipeline from Moonlight Springs, about 3 miles north of town at the foot of the mountains. A few other shallow wells in the alluvium supply the hospital and residences on the north side of town overlooking Dry Creek. Nearer the shore, the presence of permafrost has been a deterrent in the construction of wells, and along the water front driven wells, which encounter bedrock at a depth of 40 (?) ft, have proved to yield brackish water.

There is a well at Submarine Camp, about 2 miles up (west) Snake River on the south

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bank and almost a mile inland from the sea. This drilled well passes through the alluvium at about 30 ft and water is developed from bedrock below that depth. The well flows about half a gallon a minute at the surface. The chloride content of this water is about 3,600 ppm (table 2).

It seems that here, as in Palmer, brackish water is trapped in the bedrock fissures; natural seaward percolation of fresh water from the hills has not been sufficient to flush out the salt water that had entered the formation at some previous higher stand of the sea.

The alluvium of the plain on which Nome is built is not very permeable and much of it is frozen to bedrock. However, it seems apparent that, if a municipal supply were to be developed, a properly constructed well in the younger, highly permeable unfrozen alluvium in the bed of nearby Dry Creek should yield an ample supply of water. The distribution of such a supply during the cold months through pipes laid in permafrost would present an engineering and economic problem, however, requiring real effort in its solution.

Teller

Teller lies on a narrow spit that extends northward, separating Grantly Harbor on the east from Port Clarence on the west. Port Clarence is partially separated from the Bering Sea by the long, curving spit on which Point Spencer is situated. Teller is 62 miles north-northwest of Nome and 83 miles east-southeast of the international boundary at the Diomed Islands.

Teller has a population of 125, almost all Eskimos. Some of the villagers find work in the nearby tin mines, some fish for seal or salmon, and some trap. Much ivory carving is done.

The village is served by boat service from Nome.

Teller was visited on February 25, 1949.

Topography and geology.--Teller lies on a very narrow gravel spit extending northward into Grantly Harbor; to the east is open water and on the west is a narrow, shallow fresh-water lagoon separating the Teller spit from the larger spit of which it is a part. The lagoon extends back (south) to a spring-fed lake and is generally fresh. A dam at the outlet of the lagoon maintains the lagoon level about 4 ft above sea level. However, the lagoon and, in fact, the whole village of Teller is subject to recurrent flooding and salt-water inundation.

Water supply.--There are several dug wells and one driven well in Teller. The 2-inch driven well at the school is about 20 ft deep; the depth to water below the ground surface is about 12 ft. A dug well at the Teller Commercial Co. has a similar depth and water level. The water is not used for drinking because of sanitary considerations and because it has been salty since a marine inundation some years ago.

It is the opinion of the local residents, shared by the writer, that, because the lagoon is 4 ft higher than the bay (held at that level by the gates at its outlet) and because the spit is made up entirely of gravel, the ground water at Teller is lagoon water draining toward the bay.

Water for drinking is taken from the spring at the lake in summer and from ice on the lake in winter. Cisterns also are used in summer.

Although ground water is available beneath the village, the probability of sanitary pollution and salt-water contamination is such that this source is considered undesirable for a municipal supply. It is the writer's opinion that ground water could be sought on the ridge west of the village, across the narrow lagoon. There permafrost is present, but it may not be very thick. The hill is mantled with old beach deposits that may extend below the permafrost, and the acquisition of a small community supply may not be difficult. A short pipeline, about 550 ft long, might be all that is necessary to bring the water to the village.

It would be possible to bring water from the spring at the head of the lake, but the expense involved might make such a plan impractical. A pipeline laid beneath the lake and lagoon (the lagoon level might be lowered temporarily to permit ditching below freezing level) might eliminate the freezing problem entirely, but the length of the pipeline, about 3 miles, would still make the project expensive.

Arctic Coast

Kotzebue

Kotzebue lies at the northwest tip of Baldwin Peninsula, about 32 miles north of the Arctic Circle and 183 miles northeast of Nome. Hotham Inlet, a bay receiving the drainage from two major rivers, the Noatak and the Kobuk, as well as the smaller Selawik River, lies to the east of Kotzebue. Kotzebue Sound on the west opens directly into the Chukchi Sea. Kotzebue itself is on a narrow spit, about half a mile wide, and is separated from the main mass of the Baldwin Peninsula to the east by a lagoon.

There are about 525 people at Kotzebue, including the hospital personnel and patients. Of this total, about 75 persons are white, the remainder being Eskimos. Kotzebue is an important center of Arctic activity; mail is dispatched in several directions (one route served by dog team in winter); supplies are furnished for towns along the Arctic Coast and up the three rivers draining into Hotham Inlet. Many find work in the four major placer gold fields in the outlying country. Others fish, hunt seal, walrus, and polar bear, or trap land animals. Considerable ivory carving is done in the area. Under care of the Federal Government, a herd of 1,600 reindeer are grazed within 100 miles of Kotzebue. The village is also a medical center by virtue of the Alaska Native Service hospital of 20 beds, to which a 24-bed

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tuberculosis unit is about to be added. The importance of Kotzebue as a trading center is seen in the fact that during the summer as many as 1,000 Eskimos from distant villages are camped on the beach.

The area is served by one or two visits each summer by a commercial steam vessel, by two visits per summer by an Alaska Native Service vessel, and by boat service twice a month to Nome in the June-September period.

Topography and geology.--Kotzebue lies on a narrow finger or spit on the northwest end of the Baldwin Peninsula. The area, including the whole north end of the peninsula, is flat and rises to not more than 30 or 40 ft above sea level. The peninsula as a whole appears to be a remnant of a once more extensive coastal plain now dissected by erosion. The spit on which the village is situated is probably composed of sand and gravel recently thrown up by the sea but somewhat older coastal-plain deposits lie at shallow depth beneath the Recent sandy sediments.

Water supply.-- During the long winters about 90 percent of the water used by the villagers is melted snow and ice. All the drinking water is obtained in that way. In the summer some water is caught in cisterns and a little is obtained from the dug wells in the village, but most of the water is brought in by dog team from nearby small creeks.

The Civil Aeronautics Authority station has a well 35 ft deep, but it is subject to freezing from September to April. The water in this well is said to be hard in the summer but soft in the winter.

The hospital has a dug well 30 ft deep under the building which occupies a recently thawed area in the permafrost. The depth to water is about 10 ft below the surface. This well was pumped at a rate of 200 gpm for 24 hr, during which time the water level declined 3 ft in the first hour and $1\frac{1}{2}$ in. farther in the next 23 hr. This would indicate that much more water was discharged than the amount available from a small thawed area under the hospital, and it would appear that water percolated into the area from a thawed zone between the winter frost and the permafrost.

Water from the hospital well is excessively hard but does not appear to contain much iron. However, the hardness is such that hot-water lines become clogged with lime in less than a month and a softener has been installed. Condensate from the steam radiators is used for drinking.

Shallow-well installations thaw a small area of permanently frozen ground extending out from the well and perhaps beyond the heated buildings in which they are located. These thawed areas are fed from the water lying above the permafrost, and continuous recharge occurs in the summer months. However, in the colder months the recharge is smaller as winter frost descends and narrows the zone of free water, and the water levels in the wells decline. However, early in the spring the water level rises sharply, perhaps as

much as 8 or 10 ft, overnight. This is interpreted to indicate that in the very early spring the downward progress of winter frost has reversed, a percolation channel is eventually opened by thawing, and confined water--under pressure between the winter frost and permafrost--literally gushes into the well.

The concept of winter water under pressure is borne out by an incident related by Arthur Flat of the Alaska Native Service. A few years ago a native family erected a sod house on the flat tundra in back of the village but was forced to move in midwinter when water came up through the floor and flooded them out. The thawed surface under the dwelling acted as a vertical conduit for water otherwise trapped between winter frost and permafrost.

The occurrence is a parallel with the icing of a domicile shown in "Permafrost or permanently frozen ground and related engineering problems" (Muller, 1945, fig. 41). Locally free water is trapped between the permafrost and winter frost. The winter frost tends to grow downward and in places winter frost merges with the permafrost and free water is forced away laterally. In places the free water becomes "pocketed," and if it does not freeze, being under pressure it may bulge up the surface to form frost mounds, such as those observed in the valley of the Noatak River to the north. Where the winter frost seal is thawed, as in the case of the Kotzebue dwelling mentioned, water is forced upward. In early spring, channels to these trapped pockets thaw out and wells fill rapidly.

Deep test drilling.--In the summers of 1949-50 a test hole was drilled near the Alaska Native Service hospital to determine the presence or absence of fresh water at depth. Although beset with many mechanical and other difficulties, a cased 6-inch hole was finally drilled to a depth of 325 ft.

The results of drilling may be summarized as follows: Gravel extended to a depth of 23 ft, below which blue mud extended to 79 ft. Between 79 and 83 ft thawed gravel was encountered from which salt water was obtained. Between 83 and 238 ft the section penetrated was largely frozen blue clay or mud, becoming increasingly sandy and bouldery with depth. At 238 ft a pool of gas under high pressure was encountered that lifted the heavy string of drill tools several feet in the air, showered the immediate area with mud particles, and continued to emit gas at decreasing pressure for more than 24 hr. The thawed ground below 238 ft graded into brown silt that continued to 325 ft without change. The thawed silt was saturated with salty water.

It appears, then, that circulation of water from highland areas to the east and north has been insufficient to flush out the salt water with which the sediments were saturated, and deep drilling would tap only saltier water. For this and other reasons, the well was discontinued at 325 ft.

SUMMARY OF GROUND-WATER DEVELOPMENT IN ALASKA, 1950

Ground water above permafrost.--It seems possible that something might be done to acquire a shallow water supply free from contamination of the various kinds commonly present.

An extension of the present shallow-well systems in a protected area might be made on a large scale, but without special measures such wells would have very low yields in the winter.

The writer believes an installation embodying the following steps would be well worth trying.

1. A section of tundra at least 100 by 200 ft, but preferably larger, be stripped of its heavy moss cover in order that melting of the upper part of the permafrost may occur by natural means in the summer.

2. Natural melting be augmented by pumping water onto the stripped area from nearby warm ponds (the summer temperature in these ponds is in excess of 80 F at times).

3. Natural melting may be promoted by excavating the stripped area to the water table, for water or saturated sand will transmit (absorb) heat rapidly, in comparison to dry ground (Muller, 1945, p. 24).

4. Melting may be promoted also by pumping out of the area intermittently from several wells dug in the stripped area, thereby insuring thorough circulation and effective action of the warm water above the permafrost.

5. With the advent of colder weather the stripped area would have to be protected, as the heat transmissibility of frozen ground is great (Muller, 1945, p. 53). Dry gravel fill should be added to bring the bottom of the excavation a foot or two above the water level. In any event an adequate snow cover should be promoted by constructing snow fences or by other means.

6. Pumping in the fall when no recharge is taking place will lower the water table and hence lessen the possible thickness of frozen saturated ground resulting from winter's frost, thereby lowering heat losses somewhat.

7. Lateral migration from adjacent areas should occur through at least a few restricted channels along the perimeter of the stripped area all winter long if free water occurs generally between the permafrost and winter frost, as suggested above. The extent that such recharge occurs will determine the extent to which this plan would be successful as a moderate source of supply in the January-March period.

Point Hope

Point Hope is a sand spit extending westward into the Chukchi Sea of the Arctic Ocean, about 155 miles northwest of Kotzebue. It is native village of perhaps 100 inhabitants who live by fishing and hunting.

A dug well 3 ft deep along the gravelly beach, away from usual sources of contamination, supplies a little drinking water in the warmer months. A somewhat deeper dug well on higher ground at the school yields a discolored "tundra" water.

Considering the latitude and prevalence of permafrost, it seems unlikely that much can be done here to increase the ground-water supply. However, the schoolhouse well might be developed to supply more water than at present for some domestic uses.

SUMMARY OF GROUND WATER DEVELOPMENT IN ALASKA

Ground-water supplies have been exploited to a minimum extent, or have not been exploited at all, in most places in Alaska. Exceptions to the generalization exist, however, Fairbanks and Palmer being the most outstanding. In nearly all other areas, available supplies have not been fully exploited or explored for many reasons, most of them perfectly adequate. The most important reasons why well-water supplies have not been developed are:

1. Lack of facilities for drilling wells. This factor may be considered in two ways--(a) physical absence of materials, equipment, and skilled drillers in most localities or (b) high cost of transporting personnel and equipment. In some places the nearest source of any facilities may be hundreds of miles distant; transportation of material and personnel to a specific site may be difficult, time consuming, and exorbitantly expensive, relative to the value of a modest well installation. Lastly, (c) even where well-construction facilities exist, certain types of installation are too expensive for most individuals to consider. A number of wells 60 to 100 ft in depth have been drilled in Anchorage. The cost of such a well cannot be met by all individuals desiring wells, and probably very few people could afford wells of significantly greater depth even if they wished to have them. In Fairbanks, on the other hand, relatively cheap driven wells can be installed and there are hundreds in a small area.

2. Lack of knowledge of good potentials. In a few localities where shortages exist or are imminent, the possibility of acquiring additional supplies of water from the ground at practical cost have not been considered because of an almost complete lack of knowledge of water wells and their characteristic yields. This situation is more typical in southeastern Alaska than elsewhere in the Territory.

Another phase of this same factor is the lack of definite guides to well characteristics in many areas where the value of ground water is appreciated. Most individuals cannot and many small communities cannot or will not risk the cost of exploration and, as an alternative, they develop existing, certain surface-water supplies even though these

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supplies are not considered particularly desirable.

3. Lack of knowledge of well-drilling techniques, particularly the use of screens in fine sands, either as drive-point screens on small-diameter wells or larger-diameter tubular screens in deep drilled wells. There are undoubtedly many small villages along the Yukon River where cheap home-made wells could be completed by using screens where coarse sand and gravel are lacking. In other areas, such as Palmer and Anchorage, larger supplies could be developed from existing drilled wells by utilizing modern screens.

4. Gravity-fed surface-water supplies.--Stream supplies have been utilized in many places to good advantage. Elsewhere, gravity supplies have been developed at fairly high cost and have obtained small, undependable quantities of water of poor sanitary quality. It seems obvious that in some places the desirability of naturally filtered and protected ground-water supplies, the cost of pumping which is moderate, should be considered more closely before tens and even hundreds of thousands of dollars are committed to long pipeline installations obtaining water from distant streams.

5. Frost and permafrost.--In the far north ground-water supplies may be unavailable because permafrost extends from the surface to great depths. More commonly, in the more settled northerly areas, permafrost may be less than 200 ft thick but may extend to within inches of the surface, and here relatively shallow cheaply constructed wells cannot be used, though ample water may be available from moderate depth.

Elsewhere in areas of discontinuous permafrost ample water may be available from cheap shallow wells in thawed areas but the difficulty and expense of maintaining thawed pipelines in permanently frozen ground or ground subjected to deep winter frost (where lines cannot be readily buried to a proper depth) are prohibitive. Consideration must also be given to the freezing of the wells themselves and the freezing of small-diameter lines extending from the mains to the consumer.

6. Tradition.--Many individuals have lived in Alaska all their lives or for many years, getting along as best they could on small, inadequate supplies of water. The urge to acquire ample supplies of water is probably not as great here as in areas where much of the population regards an essentially limitless supply of water as an absolute necessity.

Evaluating these factors, it seems likely that ground-water developments are as meager as they are largely because of the expense of obtaining, or nonavailability of, facilities to construct wells and because of expense of maintaining distribution lines in a cold climate. Lack of appreciation of ground-water potentials or lack of knowledge of data in specific localities has been a large factor in many areas. Lack of knowledge regarding specific localities will continue to be an important economic factor in the development of ground-water supplies, and it will be alleviated in part as drilling by private, municipal, and governmental agencies is done from time to time in various localities.

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