Ground-Water Resources of the Fairbanks Area Alaska

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1590

U.S. DEPARTMENT OF THE INTERIOR

March 3, 1849

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By D. J. CEDERSTROM

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Ground-water occurrence in an area of discontinuous permafrost

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March 3, 1849

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1963

UNITED STATES DEPARTMENT OF THE INTERIOR

STEWART L. UDALL, *Secretary*

GEOLOGICAL SURVEY

Thomas B. Nolan, *Director*

The U.S. Geological Survey Library has cataloged this publication as follows:

Cederstrom, Dagfin John, 1908–
Ground-water resources of the Fairbanks area, Alaska. Washington, U.S. Govt. Print. Off., 1962.

iv, 84 p. illus., maps (part fold. in pocket) diagrs., tables. 24 cm. (U.S. Geological Survey. Water-supply paper 1590)
Bibliography: p. 54–55.

1. Water-supply-Alaska-Fairbanks area. 2. Water, Underground-Alaska-Fairbanks area. 3. Water-Analysis. 4. Borings-Alaska-Fairbanks area. (Series)

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington 25, D.C.

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By D. J. CEDERSTROM

ABSTRACT

The report describes the ground-water resources of the city of Fairbanks, adjacent surburban communities, Ladd Air Force Base, and the hilly area immediately north of Fairbanks, in east-central Alaska. The urban and suburban communities are on the floor of the Tanana Valley, whereas the largely agricultural area to the north lies on southward-facing hill slopes. The population of Fairbanks and the immediately surrounding area was estimated to be 35,000 in 1955. The economy of the area is based, in decreasing order of importance, on trade and services, gold mining, and agriculture.

The geologic formations in the area consist of the ancient Birch Creek schist, underlying the hilly and mountainous area to the north; older creek gravels, of Pleistocene age, presently mined for gold in the major stream valleys; silt and muck covering the hillsides and filling the larger valleys; and the sandy fill in the valley of the Tanana River.

Much of the ground beneath the floor of the Tanana Valley is frozen. The presently known maximum thickness of permafrost in Fairbanks is 225 feet. The ground is generally frozen on the lower slopes north of the city, but the frozen ground thins to a vanishing point up the slope.

Earth temperatures to a depth of 9 feet at one point adjacent to the water mains in downtown Fairbanks in the winter of 1953–54 are given. The marked time lag in heat penetration and the slight effect of heated water on the normal thermal regimen are noted.

Ground water occurs under water-table conditions beneath the floor of the Tanana Valley, under artesian conditions on the lower slopes, and under water-table conditions on the higher slopes and ridges. Many ground-water data were available from existing wells, and these data were supplemented by test drilling in 1948, 1949, and 1954.

The Birch Creek schist is an inferior water-bearing formation and ordinarily does not yield more than 10 gpm to wells. Old filled valleys on the mountain slopes are commonly underlain by sandy or gravelly beds, as shown by test drilling. In places, wells developed in these old valleys might yield 100 gpm or more. The importance of these old filled valleys has not been fully appreciated by potential users of moderate to large quantities of water in the area north of Fairbanks. Beds coarse enough to furnish water to wells occur only rarely in the silt and muck.

The sand and gravel of the Tanana Valley furnish large supplies of water to wells in Fairbanks and at Ladd Air Force base. A well north of Fairbanks

is reported to have yielded 3,400 gpm with a drawdown of 5.7 feet. The specific capacity of this well is, therefore, about 600 gpm per ft of drawdown. Two other wells are reported to have yielded 2,800 and 2,900 gpm but with a somewhat greater drawdown. A well completed recently at Ladd Air Force Base yields 1,500 gpm with 9 feet of drawdown. Most wells on the valley floor, however, are small in diameter and were completed without screens and developed only slightly. Nevertheless, yields as great as 50 gpm have been obtained from 2-inch wells by suction lift.

The city of Fairbanks completed a ground-water supply and distribution system in 1953. Water having a temperature of 38°F is pumped from wells and is used to cool condensers at the city powerplant, where it is warmed to 56°F or higher before being treated and fed into the distribution system. Additional heat can be added to the distribution system at several places by heat exchangers. The system is designed so that water can circulate in the mains and in the service leads as well. About 500,000 gpd was distributed in 1953.

The quality of well water ordinarily ranges from very good to extremely bad, the differences being accounted for largely by the amount of iron, and in places manganese, in solution and, to some degree, by the hardness. Most ground water in the area contains appreciable amounts of iron in solution. A few ground waters are extremely high in iron content, but some are iron free or nearly so.

The chemical character of most of the hard water high in iron is ascribed to the breakdown of sulfate by reaction with organic material, thereby liberating free carbon dioxide, which reacts with the sediments to bring iron, calcium, and magnesium into solution.

Hundreds of 2-inch wells in the Fairbanks area were constructed by the drive-jet method; practically all the larger diameter wells were drilled by the cable-tool method. A few test holes drilled as a part of the Geological Survey's studies in the area north of Fairbanks were jetted. Most wells in the area lack well screens and have not been developed fully.

Records of 418 wells, logs of 32 representative wells, and chemical analyses of 40 samples of water are given.

INTRODUCTION

SCOPE AND PURPOSE OF REPORT

This report presents the results of investigations of the ground-water resources of the area in and adjacent to Fairbanks, in east-central Alaska, begun by the U.S. Geological Survey in 1947. The area includes the city of Fairbanks, the suburban areas north and northeast of Fairbanks, Ladd Air Force Base, and the hilly agricultural area extending approximately from College on the west to Hopper Creek on the east, about 14 miles.

Fieldwork was done by the writer, who was assisted at various times by F. W. Trainer, E. G. Otton, John Kerr, and G. C. Tibbitts, Jr., of the Geological Survey. T. L. Péwé, of the Geological Survey, collected records of certain wells that are incorporated in this report.

The writer spent the greater part of 2 months in the summer of

1947 canvassing the wells in, and immediately adjacent to, Fairbanks, including those at Ladd Air Force Base. Few significant data relative to the ground-water resources of the hilly area to the north were obtained, for almost no ground water was then pumped in that area.

Beginning in June 1948, pumping tests were made on some of the wells on the flood plain of the Tanana River. Small-diameter observation wells drilled as part of the study were used in two of these tests. Later in that season, several larger diameter test holes were drilled on the slopes north of Fairbanks and yielded critical hydrologic information. In the spring of 1949, four more test holes were drilled on the slope north of Fairbanks.

Work was discontinued in the Fairbanks area until the summer of 1954, at which time a long-planned test of the suitability of the jet-drilling method in the hilly agricultural area north of Fairbanks was completed. Particularly valuable information was also obtained during that season on several wells that had been drilled recently on the slopes north of Fairbanks. Few data pertaining to the hydrology of the flood plain were collected in 1954, and most of the data in tables 1, 2, and 4 represent the results of work done in 1947 and 1948. The description and discussion of the municipal waterplant and distribution system of the city of Fairbanks, however, are based on data acquired in 1954.

The results of the earlier studies in Fairbanks were presented in small part in Geological Survey Circular 169 (Cederstrom, 1952, p. 24–27) and were drawn upon to some extent in the discussion of ground-water occurrence and drilling methods in permafrost areas in Geological Survey Circular 275 (Cederstrom and others, 1953, p. 3–4, 15, 19, 23). The operation of the jet drill in the Fairbanks area is described by the writer and G. C. Tibbitts, Jr., in Geological Survey Water-Supply Paper 1539–B.

The information presented in this report was obtained not only from test drilling and other field observations by the Geological Survey but also from householders, city officials, and members of the engineering staff at Ladd Air Force Base. Several well drillers, among them Messrs. Ortho Stevens, Maurice Butler, Elmer Erickson, Earl McClure, Clarence Prosise, and the late Ole Fisher, all of Fairbanks, contributed considerable information. Frank Mapleton and his engineering staff furnished data on the city water-supply system. Officials of the United States Smelting, Refining & Mining Co. kindly furnished recorded data and advice on drilling problems on several occasions, and special thanks are given to Messrs. Roy Earling, J. C. Crawford, and Theodore Loftus of that company.

Chemical analyses of 40 samples of water, most of which were analyzed in the laboratories of the Geological Survey, are given in table 6.

GEOGRAPHY

Fairbanks lies a little east of the center of Alaska (fig. 1). The area discussed in the present report includes the city of Fairbanks and the adjacent area, particularly the southward-facing hill slopes and ridges to the northwest, north, and northeast (fig. 2). This area lies between 147°25′ and 147°55′ west longitude and 64°48′ and 64°56′ north latitude. Fairbanks itself is at the north edge of the valley flat of the Tanana River, about 75 miles north of the Alaska Range. The westward-flowing Tanana River, which flows 3 miles south of Fairbanks, joins the Yukon about 125 miles to the west. Low hills north of Fairbanks are part of the upland that lies between the valleys of the Yukon and Tanana Rivers.

Fairbanks, its suburbs, and Ladd Air Force Base lie along the Chena River, a small tributary of the Tanana.

TOPOGRAPHY

Fairbanks lies at an elevation of 440 feet above sea level. The relief of the valley floor is slight, and differences in elevation on the flood plain are so small as to be imperceptible to the casual observer. What

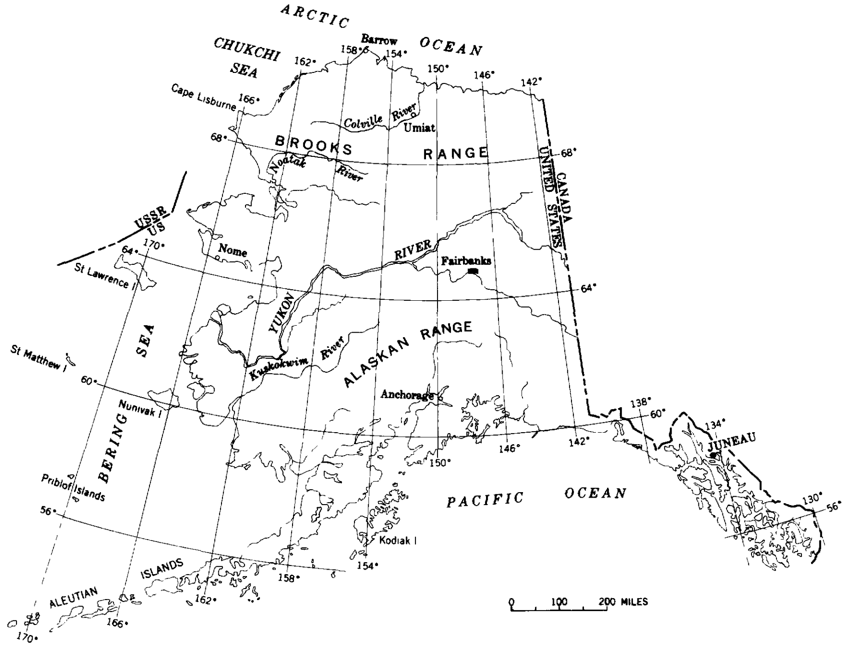

FIGURE 1.—Map showing location of Fairbanks, Alaska, and area described in this report.

little relief is present is furnished by an occasional abandoned meander scar, a swamp or small lake, or the present streams. The difference in elevation between the level of the Chena River and the flood plain, an index of maximum relief here, hardly exceeds 15 feet.

The hilly area discussed in this report, adjacent to the Tanana Valley on the north, extends to a height of a little more than 1,500 feet above sea level, although some of the hills a few miles farther north rise above 1,800 feet. This area is moderately dissected, and many hills range in height from 700 to 1,000 feet above the adjacent stream valleys; some are even higher. Rock cliffs are present locally, as at Chena Ridge and Birch Hill, where the Chena River has impinged upon hard-rock masses. The valley floors and hillsides below an elevation of about 600 feet are more subdued, however, and it is on these valley bottoms and gentle slopes that agriculture is practiced.

SETTLEMENT AND POPULATION

Similar to most Alaskan communities, Fairbanks is a comparatively densely populated place surrounded by vast areas that are almost uninhabited.

Fairbanks proper is an urban settlement in which, in 1950 (U.S. Bur. of the Census, 1952b, p. 51–56), 5,771 people lived within an area not much greater than 1 square mile. An additional 2,124 people lived in several industrial and residential areas adjacent to Fairbanks to the north and northeast and in the community of College, site of the University of Alaska, 3 miles to the northwest. Ladd Air Force Base, 2 miles east of Fairbanks, had a small military and civilian population. Houses and farms are scattered along the Ester Road from Fairbanks to the Agricultural Experiment Station, the Farmers Loop Road, the southern part of the Steese Highway, and the Steele Creek Road. By 1955 the population of Fairbanks had doubled, and the population of the area as a whole was estimated to be about 35,000 (Herman Porter, Alaska Resources Development Board, written communication, 1956).

Eielson Air Force Base, 26 miles east-southeast of Fairbanks, is outside the area of this report. Building of small homes and development of businesses proceeded rather rapidly in the last decade along the Richardson Highway between the Eielson base and Fairbanks. Beyond Eielson Air Force Base, however, no community of any size has been developed along the Richardson Highway except at Big Delta village, about 95 miles east of Fairbanks, and at Tok Junction, about 200 miles east of Fairbanks. The population of Big Delta village and Tok Junction in 1950 was 155 and 105, respectively.

The small resort settlement of Circle on the Yukon (population 83) lies north of Fairbanks, the mining camp of Livengood (population 40), which is connected with Fairbanks by highway, lies northeast. Nenana (population 242) lies to the west, but it is not connected with Fairbanks by highway.

CLIMATE

The Tanana Valley has a typically subarctic climate. The winters are long and cold, and the days in midwinter are short. The summers are short but relatively warm and are characterized by nearly continuous daylight.

The average annual temperature as shown in the table below is about 26°F. The coldest month is January, average monthly temperature 9.8°; the warmest month is July, average monthly temperature 60.9°. Wide departures from these figures are common, and temperatures as low as −66° and as high as 91° have been recorded at Fairbanks.

The average annual precipitation of 11.92 inches indicates that the climate is semiarid; however, evaporation is minimized by low temperature.

INDUSTRY

Until World War II, the economy of the area was based on large-scale gold mining, but, with the establishment of military bases and the doubling of the population in the decade from 1939 to 1949, the greatest number of people now are employed either directly by the military establishments or indirectly through civilian establishments catering to the military.

The total number of people employed in the city of Fairbanks (U.S. Bur. of the Census, 1952b, p. 51) was 2,662 in 1950. More than 700 were engaged in trade or retail services, almost 700 in Government service, 561 in construction work, 272 in transportation services, and 96 in mining. The ratio of persons engaged in gold mining to total employed, 96 to 2,662, is only about half as great as in the Fourth Judicial Division (of which Fairbanks is a part) as a whole—504 to 6,519.

The Fourth Judicial Division includes 67 people who are listed as being employed in agriculture. To the best of the writer's knowledge, these people nearly all work within the area treated in this report. Several individuals who were in the process of establishing farms or who were farming on a small scale at the time of listing were probably listed as being employed in other occupations, because they worked regularly for wages and farmed only as a sideline or in their spare time.

Selected climatological data for Fairbanks, Alaska

[Data from U.S. Weather Bureau, 1954. Means are adjusted to represent observations made at the present standard location at Fairbanks Airport]

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Precipitation, in inches													
Mean, 1921–50	0.99	0.51	0.58	0.29	0.74	1.37	1.92	2.26	1.21	0.92	0.63	0.50	11.92
Maximum, 25-year record	6.71	2.10	1.97	2.30	1.75	3.52	4.24	6.88	2.85	3.40	2.85	1.73	17.48
Minimum, 25-year record	.07	.03	Trace	Trace	.13	.26	.68	.84	.12	.08	Trace	.04	7.73
Temperature, in degrees Fahrenheit													
Mean, 1921–50	−9.8	−3.1	9.0	28.9	47.4	59.3	60.9	55.6	44.6	27.5	3.1	−9.1	26.2
Record highest temperature during month, 25-yr record	42	50	55	69	90	91	90	87	77	64	54	58	
Record lowest temperature during month, 25-yr record	−66	−58	−44	−32	0	30	34	23	12	−28	−41	−59	

AGRICULTURE

The Tanana Valley and vicinity has been farmed to some extent for more than 40 years. A typical farm is shown in figure 2. About 2,400 acres was under cultivation in the Tanana Valley in 1948, practically all in the immediate vicinity of Fairbanks (Gasser, 1948, p. 14).

The growth of crops is promoted by the length of the days in the growing season. On May 1 the sun rises at 3:19 a.m. and sets at 10:07 p.m.; on July 1 it rises at 1:10 a.m. and sets at 10:38 p.m.; on August 1 it rises at 2:48 a.m. and sets at 9:04 p.m.

The average date of the last killing frost in spring on the flood plain is May 21, and that of the first in autumn is August 30, giving an average growing season of 100 days (U.S. Weather Bureau, 1954). Killing frosts have occurred from time to time on the flood plain in midsummer. However, the frost-free season is somewhat longer at higher elevations, particularly on the southward-facing slopes, which receive more sunshine.

Over a period of 25 years, the total precipitation ranged from 7.73 to 17.48 inches, an average of about 60 percent of which was concentrated during the growing season. Dry weather very early in the growing season is not uncommon, however, and may delay the sprouting of crops. Unduly cloudy, cool, wet weather in the growing season likewise may lessen the chances of crops reaching maturity.

Nevertheless, large crops are produced during most years in the Tanana Valley, the most important of which have been potatoes, hay,

FIGURE 2.—Farm on rolling upland northwest of College, Alaska.

and grain. In recent years truck-garden crops have become important, and local retail stores and the military bases utilize increasingly larger volumes of vegetables grown locally. These are the hardy vegetables, such as cabbage, cauliflower, radishes, and peas. Tomatoes and cucumbers are grown under glass. Several berries also are raised successfully.

GEOLOGY

RÉSUMÉ OF GEOLOGIC HISTORY

The geology of the Fairbanks area was reviewed by Mertie (1937), whose report, in large part, is the basis for the following synopsis. The later work of Taber (1943) relative to the unconsolidated deposits also is drawn upon in places.

Most of the consolidated rocks in the area are a part of the Birch Creek schist of Precambrian age. These rocks are largely slaty to schistose, but hard layers, apparently quartzite and included quartz veins, have been reported by local well drillers.

Mertie (1937, p. 197) stated that these old previously folded and metamorphosed rocks were folded again in middle Tertiary time, after which long-continued regional erosion developed a maturely dissected land surface. Regional uplift in the Pliocene epoch revived erosional forces, and the extensive deposits of older auriferous gravel were laid down in some areas, particularly at Rampart in the Yukon valley. The Fairbanks area was not glaciated in Pleistocene time, although glaciation occurred on large scale in the Alaska Range to the south and in the Brooks Range to the north. Streams issuing from the glaciated Alaska Range were heavily laden with rock material, and the Tanana Valley was aggraded, the result being a higher base level of erosion. Tributary streams in the Fairbanks area at this time continued to function as normal nonglacial streams. The earliest Pleistocene deposits consist of silt, sand, and gravel, but gravel is dominant (Mertie, p. 188). These deposits are overlain by a blanket of silt of varying thickness. This silt in part is the tan silt now covering the hills in the Fairbanks area.

Most of the silt contains vegetal material. Where the content of organic material is great, the silt is black when wet and is referred to as "muck" by the miners; however, the term "muck" is loosely applied to all dark-colored silts. Where the vegetal content is relatively small, the silt is tan.

The origin of the silt is a moot question. Mertie (1937, p. 188) stated that "Some evidence leads to the belief that a considerable part of this material is airborne." Capps (1940, p. 190) likewise leans toward this view, and more recently Péwé (1955a, p. 699–724) supported it.

Taber treated the origin of the silt in considerable detail and stated (1943, p. 1480) that, if the material were windblown, dunes should be present and that a decrease in grain size away from the source should be noted. Further, he questioned (p. 1500) the power of the wind to carry "large quantities of silt out of the Tanana Valley and across a maturely dissected plateau with a major divide nearly 2,000 feet above the river to form the thick deposits in Cleary Valley." Taber noted also that "the creek valley silts cannot be distinguished from Birch Creek schists by chemical or mineral analysis" and that heavy minerals in the silt, magnetite, and ilmenite in particular, should have been sorted out if the silt were windblown. Mertie (1937, p. 189) pointed out that the silt in places contains subordinate coarse layers composed of material as large as gravel, and Taber (1943, p. 1476) indicated that the silt in a few places contains angular rock fragments as much as several inches in diameter and that these large fragments show no evidence of wind erosion. He stated further (p. 1492) that the bedding in the silt is horizontal or gently sloping toward the larger valleys and that the vertical structures characteristic of windblown deposits are lacking.

The objections raised by Mertie and Taber to an eolian origin for the silt have not yet been answered fully by the advocates of that hypothesis.

Taber (1943, p. 1493; 1953, p. 329; 1958, p. 131) advocated a hypothesis of local origin of the silts by disintegration of local country rock by frost action and removal of the products of weathering down the valley slopes by soil creep and slope wash and distribution over the valley floors by occasional floods. A corollary is that a sudden and widespread change in deposition from gravel to silt occurred when a change to a more humid climate permitted the growth of sufficient vegetation on valley slopes to retain rock waste until it was well disintegrated by freezing and thawing.

The contact of the Birch Creek schist and the silt is well exposed where the Chena Ridge roads begin to ascend the northeastern part of the ridge. Here the upper part of the schist is deeply weathered, although original contorted structures are well preserved. Most of this highly micaceous rock crumbles in the hand to little more than sand. The weathering of the schist here and elsewhere probably is due to repeated freezing and thawing; however, the transition from weathered bedrock to silt is abrupt, and sediment intermediate in texture between thoroughly weathered bedrock and silt were lacking in the few scattered exposures of the contact observed by the writer.

Detailed inspection of cuttings from wells (361, 391, 392, table 5; pl. 1) that penetrate appreciable thicknesses of silt underlain by schist indicate that the transition downward from typical silt into bedrock is abrupt. Elsewhere (wells 362, 367, 369, table 5; pl. 1) sand and gravel lie between the silt and bedrock.

Mertie (1937, p. 189) noted that the thick silt deposits ". . . contain, in addition to vegetal and vertebrate remains, a considerable fauna of fresh-water mollusks and diatoms." * * * "If the region, in late Pleistocene time, had been inundated by reason of barriers of any kind across the trunk streams, these deposits might well be considered lacustrine in origin." Lacking any evidence of partial damming of the Yukon, however, Mertie considered a lacustrine origin of the silt to be doubtful.

The writer does not support any particular hypothesis for the origin of the silt, nor does he attempt to solve any of what appear to be exceedingly complex problems of late Tertiary and Quaternary history. He prefers to take the attitude held by Mertie (1937, p. 185) that "Similarly, in the late stages of the glacial epoch there came into existence * * * peculiar conditions of erosion and sedimentation which are not yet fully understood."

After the deposition of the silt, and possibly at the glacial maximum, the sediments were frozen to depths of several hundred feet. In some places freezing extended all the way through the silt and muck to the gravel beneath. During this deep freezing, by a process of segregation, the muck deposits acquired their exceedingly high water content, as much as 80 percent by volume (Taber, 1943, p. 1495), and large ice lenses formed (Mertie, 1937, p. 189; Taber, 1943, p. 1524).

GEOLOGIC FORMATIONS

The geologic formations with which this report is largely concerned are the Birch Creek schist, the older creek gravels, the tan silt on the hill slopes, and the sand and gravel of the valley floor.

Much of the hillside silt and sand and gravel of the valley floor are permanently frozen. Discussion of many of the aspects of the frozen beds is given under "Permafrost."

BEDROCK

The bedrock in the Fairbanks area was described by Prindle and Katz (1913), Mertie (1937), and others. It consists for the most part of metamorphosed sedimentary rocks, chiefly schist, and of metamorphosed igneous rocks.

The name Birch Creek schist, used in several areas in central Alaska, is applied (Mertie, 1937, p. 48) in the Yukon-Tanana region to all the older Precambrian metamorphosed sedimentary rocks. These consist (Mertie, 1937, p. 49) "principally of quartzite, quartzite schist, quartz-mica schist, mica schist, feldspathic and chloritic schists, and a minor proportion of carbonaceous and calcareous schist and crystalline limestone. Quartzite schist and quartz-mica schist appear to be the more common types." Mertie (1937, p. 52) pointed out the common occurrence of quartz veins in the Birch Creek schist.

Associated with these rocks are old metamorphic rocks of igneous origin—granitic and dioritic gneiss, amphibolite, and several types of schist. In addition to all these old rocks, younger igneous and sedimentary rocks are present in a few small areas near Fairbanks. These include granite and quartz diorite of Mesozoic age (Mertie, 1937, pl. 1), sandstone and conglomerate of Tertiary (?) age (Prindle and Katz, 1913, p. 66), and basalt of probable Tertiary or Quaternary age (Prindle and Katz, 1913, p. 74; Péwé, 1955, p. 1708).

Bedrock is exposed in very few places, in spite of the fact that the area has a high relief. In many places, particularly along the high slopes, bedrock undoubtedly lies close to the surface, but is masked by a thin cover of weathered material or moss. Elsewhere, the Birch Creek schist is covered by the tan silt and associated younger alluvial deposits. The cover extends to high elevations in some places and is present on some rather steep slopes. The writer knows of scarcely more than a dozen good exposures of bedrock in the area from College to the east end of the Steele Creek Road, and most of these are in road cuts, quarries, and cellar excavations.

DEPTH TO BEDROCK

The depth to bedrock at numerous places in the Fairbanks area is known from the results of test drilling for placer gold. Some geophysical prospecting also has been done. Several wells have been drilled through the unconsolidated deposits along the hill slopes north of Fairbanks (table 3). Most of these records indicate a progressive northward decrease in the depth to the bedrock surface beneath the silt cover, but important exceptions to this general rule are noted. The depth to bedrock is greater in the stream valleys heading back into the mountains than it is beneath the immediately adjacent higher ground, which is to be expected. It is not always apparent, however, that some minor sags in the hills, hardly worthy of being called stream valleys, actually are filled stream channels of some consequence. One such filled channel was discovered in U.S. Geological Survey test hole 3 (well 369, table 3), where bedrock was reached at a depth of 140 feet instead of about 70 feet, as might have been expected from surface indications.

The depth to bedrock on the ridge on the Steele Creek Road, 1 mile northeast of its junction with the Steese Highway, was expected to be only a few feet; however, at a depth of 145 feet in well 375, the material penetrated was still unconsolidated, and it appeared that a completely masked ancient filled channel had been penetrated.

The following points may be stressed in regard to the possibility that the material penetrated was alluvium instead of weathered bedrock: (1) Drillers and geologists present had recently observed wells drilled through alluvium into bedrock; (2) sampling was good, as the well was drilled carefully by the cable-tool method; (3) the water level was high, about 56 feet below the surface, whereas the depth to water in a well penetrating only bedrock in a comparable topographic position nearby is 244 feet below the surface; and (4) large schist fragments were first noted in cuttings at a depth of 129 feet. These data in conjunction with grain-size studies, the results of which are shown in figure 3, suggest immediately that the material above 129 feet is, in fact, sorted silt and sand and that the material below 129 feet is weathered bedrock. This interpretation is given in the log (well 375, table 3).

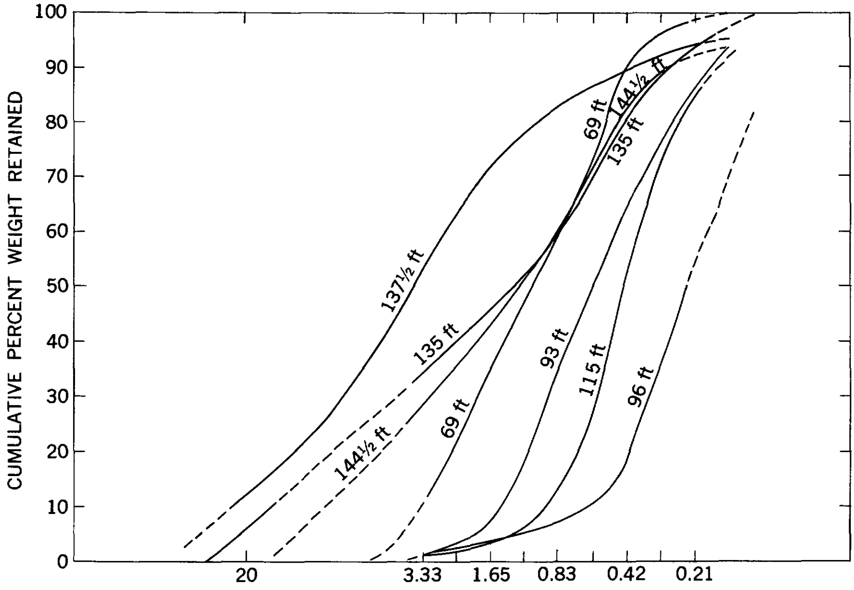

FIGURE 3.—Particle-size analyses of materials penetrated in well 375.

The cover of tan silt, on the spur projecting into the head of Columbia Creek, may be 40 to 50 feet thick, or even thicker. At the foot of the spur, however, the cover of alluvium has been nearly removed, apparently by very recent erosion, and the depth to bedrock is only 3 feet. Bedrock is exposed nearby at a somewhat higher elevation, where the west branch of Columbia Creek crosses the Steele Creek Road.

The cover of alluvium on the lower east slope of the Chena Ridge also is thin. The steepness of the ridge here suggests that the deposit of silt was thin initially. If the silt cover was initially thick, it was thinned as the Chena River impinged against the face of the ridge.

The depth to bedrock beneath the flats of the Tanana Valley in the vicinity of Fairbanks is greater than 364 feet (well 306, table 2), but how much greater is not known. Well 331b, nearer the mountains, at North Camp at the intersection of the Steese Highway and The Alaska Railroad, penetrates bedrock, according to an interpretation of the well log. The material penetrated by the well is alluvium to a depth of 158 feet, but the material at greater depth may be weathered bedrock. "Yellow clay and mica" from 161½ to 189½ feet, "yellow clay" from 189½ to 206¾ feet, and "rock" from 215 to 216½ feet are highly suggestive of deeply weathered Birch Creek schist.

"Bedrock" was reported by the driller at a depth of 129 feet in well 336 on College Road about 1⅔ miles northwest of Fairbanks; however, because this well was drilled by the drive-jet method and sampling was necessarily very poor, not much reliance can be placed on this report.

WEATHERING OF BEDROCK

The depth of weathering of the bedrock varies from place to place, but locally it may be rather great. Presumably much of the deep weathering took place in late Tertiary time, but weathering is, of course, continuing at present.

The log of well 372 is indicative of the extent to which the schist is weathered near the surface in some places. In the interval between the typical silt, which extends from the surface to a depth of 35 feet, and the fragmental bedrock material at 75 feet lies 40 feet of silt or clayey silt in which the proportion of schist fragments increases with depth. This probably is greatly weathered schist.

The same type of weathering products are penetrated at somewhat greater depth in well 363b. Here, lying above "schist" at 150 feet, the driller reported 18 feet of silt mixed with schist fragments. This section also is interpreted to be weathered schist and is so indicated in the log (table 5).

Only a few logs that show details of the Birch Creek schist at depth are available, but these few are most enlightening. The log of the S. Stowell well (well 374, table 5) on the Steele Creek Road indicates that the schist is greatly weathered all the way down to a depth of 280 feet. Much yellow clay mud was reported between 265 and 280 feet. No hard beds were encountered in the well.

The log of the Ted Lowell well (well 366, table 5), on the hill above the McGrath Cutoff, indicates that profound weathering extends at least to a depth of 145 feet, as clay is reported immediately above that depth. "Yellow clay," reported in the interval between 23 and 75 feet, certainly is indicative of profound weathering, and log entries of "yellow clay and schist" (or "yellow clay and rock") between 85 and 90 feet and between 110 and 135 feet likewise are evidence of long intense weathering. Between 135 and 145 feet the hole caved badly, which further suggested decayed material that was brought into suspension by the action of the drill. The material penetrated below 145 feet was firm, and "hard schist" was reported from 190 to 196 feet, indicating that the rock in that interval is weathered little, if at all.

On the Joe Lawlor farm (well 353, table 3) near Happy a "fracture zone" from which much mud was bailed was penetrated at about 90 feet in three different locations. The inflow of mud appeared limitless. These occurrences are suggestive of a horizontal zone of deep weathering developed at or near the water table when the water table was higher than it is at present. The walls of the well sloughed badly at 171 feet, indicating the possibility of great weathering at that depth. The water table was 140 feet below the surface.

BURIED ALLUVIUM OF UPLAND VALLEYS

Alluvium buried beneath silt and muck in valleys in the hills north of Fairbanks has considerable hydrologic significance. The deposits have been found by test drilling in several valleys, and it is likely that they underlie other localities. The alluvium may be related to coarse gravelly deposits that have been worked for their gold content in several larger valleys near Fairbanks.

Well 369, on the McGrath Cutoff, on the mountain slopes 736 feet above sea level along the course of a small perennial stream (pl. 1), penetrated gravelly deposits at moderate depth. The log of the well (table 5) shows that detrital material was first penetrated at 88 feet. Detrital material between 88 and 134½ feet largely was red to brown micaceous sand that resembled hillside wash more than a stream deposit that had been transported any great distance. From 134½ to 140 feet, however, the material was cleaner and better sorted (negligible amounts of mica or mica-schist particles) and consisted predominantly of coarse quartz sand and fine gravel.

Well 362, at an elevation of 682 feet in a well-defined valley that crosses the Farmers Loop Road and extends back into the hills (pl. 1), penetrated sandy material from 102 feet to the bottom of the well at 179 feet. The material consisted largely of well-sorted medium sand and less fine sand and silt. Inasmuch as bedrock had not been reached at 179 feet, the full thickness of sorted sandy material is unknown, and it is likely that gravelly material would be encountered at greater depth.

Well 373, at an elevation of 788 feet in another well-defined minor valley crossing the Steese Highway, penetrated 96 feet of black muck below which only 4 feet of gray medium sand was present, resting on bedrock. The well may not be on the main axis of the buried valley, and another boring nearby might penetrate somewhat thicker and coarser material before reaching schist bedrock.

A Geological Survey test hole at an elevation of 1,050 feet in the gap where the Steele Creek Road crosses a prominent ridge (well 375, table 5; pl. 1) penetrated sandy material between the depths of 93 and 129 feet. This test hole was intended to explore the difficulties of drilling in and developing water wells in the Birch Creek schist, but buried sand was penetrated instead of schist. There is no indication of sand at the surface. The gap may represent part of an earlier valley that was cut at a time when the land surface was higher than it is at present.

The gravels logged in wells 363a and 363c are found in a location now forming a topographic nose. Wells 363b and 363c penetrated bedrock at much the same elevation; in the former well only silt was present above bedrock, but in the latter well 8 feet of sandy gravel was found. These wells are about 100 feet apart. In the third well, 363a, located a little down the slope to the west, the bedrock surface is about 140 feet lower relative to sea level. Lying above bedrock is 2 feet of sandy gravel. The gravel penetrated in well 363c may be part of an old shoestring sand or bench deposit, whereas the gravel in well 363a is part of an entirely different lens or bench deposit at a much lower elevation.

A hole (391) drilled in the conspicuous saddle through which the Chena Hot Springs Road passes penetrated no sandy material, nor was there any sandy alluvium on the slope below (well 392). In both localities silt rested directly on bedrock.

Several other minor stream valleys at high elevations should contain beds of gravel, and thick beds of gravel probably underlie the larger valleys at lower elevations, such as those of Columbia and Steele Creeks. The log of well 388 (table 5) indicates that the old beds of gravel are 15 feet thick at the edge of the Columbia Creek valley. The beds should be thicker nearer the axes of this and adjacent similar valleys.

TAN SILT AND BLACK MUCK

The general character of the tan silt and black muck has been discussed in the section on geologic history and will be treated briefly here. The silt covers the lower slopes nearly everywhere and the higher slopes in many places. The maximum known thickness of the silt on the lower slopes is 313 feet (Péwé, 1955, fig. 5, p. 706); the silt is about 300 feet thick in well 368. Some organic (plant) material is present in all the silt, and the proportion of plant (and some animal) material is very high in the muck so well displayed in the mining operations of the area. However, all gradations exist between the tan silt and the black muck.

Clayey and sandy layers at the base of the silt, such as in well 367, represent a phase of the depositional cycle preceding that in which the silt was deposited. Elsewhere, as in wells 371 and 372, clay below the silt is thought to be largely residual bedrock material that had not been removed by erosion before deposition of silt began. (Compare with logs of wells 361 and 392.)

In well 388 (table 5) in the Columbia Creek valley, however, 5 feet of pea gravel, rock fragments, and silt was logged 35 feet above the base of the silt section; in well 362, along the Farmers Loop Road, relatively coarse sand is present well up in the silt sequence. These beds of coarse sand are thought to be localized stream deposits that were carried out into the areas of silt deposition.

SAND AND GRAVEL OF THE TANANA RIVER AND TRIBUTARIES

The sand and gravel deposits of the Tanana Valley are a complex system of alternating lenses of sand, gravel, and silt. Muck is recorded in a few well logs (wells 114, 339, 464, table 5). Much of the material is frozen, the maximum known depth of freezing being 243 feet (well 283).

According to Ortho Stevens and the late Ole Fisher, of Fairbanks, who have constructed hundreds of wells in the area, the 150 to 200 feet of material ordinarily penetrated in drilling is about two-thirds fine sandy material and one-third gravelly material.

The deposits apparently consist of every gradation and combination of fine and coarse material. No lens appears to be more than 15 or 20 feet thick, and ordinarily the lenses are thinner. Apparently no bed can be traced in the subsurface for any great distance, and marker beds of any kind are unknown. In brief, the heterogeneity of the formation is its outstanding characteristic.

Materials logged in wells 2b, 114, 235, and 457 (table 5) are typical of those penetrated on the valley floor in the Fairbanks area.

PERMAFROST

The ground in the Fairbanks area has been frozen to a considerable depth in Pleistocene and Recent time. Perennially frozen ground ordinarily is not continuous over wide areas on the valley floor; and thick masses of frozen ground may thin laterally, either gradually or abruptly, generally where a stream or the course of a former stream (section *A*-*A*′, pl. 2) is approached. In places along a meandering stream, permafrost ordinarily will be present close to the outer (cut-bank) side of a curve (fig. 6) but absent from the recently formed ground on the inner (slipoff) side. Permafrost may begin to form again in this new ground, however; a rudely circular lens of frozen ground perhaps 100 feet in diameter and 2 or 3 feet thick was found at a shallow depth in the large excavations made in construction of the new Alaska Railroad terminal in 1948. A similar occurrence of presumably recent permafrost was noted at Bethel (Cederstrom, 1952, p. 30). Permanently frozen ground in Fairbanks proper is relatively thin near the Chena River, but it increases in thickness southward. It is about 225 feet thick at the southern edge of the city.

Permafrost once extended near the surface in most places, but after the protective moss covering was removed the permafrost receded 10 or 15 feet in many places and seemingly more than 15 feet in a few places (section *C-C′*, pl. 2).

Where thick permafrost has been penetrated by wells in Fairbanks, the mass is ordinarily solid, and apparently unfrozen layers are absent. Near the edge of the frozen mass, however, lateral melting at different rates has produced a saw-tooth pattern in cross section. Such ground where penetrated by wells or excavations may appear to be underlain by two distinct frozen layers separated by an unfrozen layer. (See logs of wells 262 and 454, table 5.)

Permafrost penetrated in the drilling of well 243, at 521 Tenth Avenue, extended from near the surface, although not without interruption, to a depth of 155 feet. The material penetrated was sandy. Gravel, which is present in the frozen section in many wells, was not penetrated until thawed ground had been reached. Drilling was accomplished by the jet-drive method, in which initial progress is made by the water thawing of frozen material. When a depth of 70 feet was reached, circulation was lost and water was accepted by the formation for about 3 hours according to Arthur Loftus, who drilled the well. At the end of this time, the formation apparently was filled and circulation of thaw water was restored. No explanation is at hand to account for this dry (or partly dry) lens in an otherwise solidly frozen (saturated) permafrost mass unless some variant of Taber's hypothesis (Taber, 1943, p. 1495) of segregation is applicable. According to that hypothesis, water may be drawn from a chance unfrozen lens of saturated sand after freezing has progressed rather deeply. In any event, recording of this phenomenon seems worth while.

Discontinuous frozen ground extends into the lower slopes of the hills north of the city, where it gradually thins upslope to a vanishing point. The entire thickness of alluvium may be frozen in some places, as at well 368 (table 3), where the alluvium is reported to be about 280 feet thick.

Perennially frozen silty ground that has been broken for cultivation may subside as the ground thaws, but the effect may be negligible unless the ground contains ice masses (Taber, pl. 20; figs. 2–3); or, according to Péwé (oral communication, 1955), unless the moisture content of the ground is very great, as much as several hundred percent on a dry-weight basis. Melting of ice masses may produce marked irregularities in the ground surface, making the ground unfit for cultivation or even pasture.

Rockie (1942, p. 128) described the pitting of a field on the Agricultural Experiment Station due to the melting of ground ice. Somewhat similar hummocky ground developed on the McGrath tract between 1920 and 1940. The ground once was pasture land, but now is too rough to be suitable for agriculture.

In 1939 a "frost blister" developed in the valley floor above the Steese Highway near the site of well 373, according to Charles McGrath (oral communication, 1947). The mound, about 5 feet high, 20 feet wide, and 150 feet long, persisted for several weeks. Presumably, it was formed by water trapped between winter frost and permafrost, as a small trickle issued from it as it rose. The blister disappeared during the following spring.

Water occurs under artesian head in unfrozen ground beneath a capping of impermeable frozen ground on the low hill slopes north of Fairbanks, and the level at which water stands in wells drilled high on the slopes apparently is determined largely by the elevation to which the permafrost cover rises on the adjacent low slopes.

Permafrost may be a primary factor in well construction in and around the city of Fairbanks. In places where permafrost is present, shallow ground water may or may not be available above the permafrost; and where water is not available, or shallow water is deemed unsatisfactory, it is necessary to drill through the permafrost to unfrozen ground below.

GROUND TEMPERATURES AND WATER-DISTRIBUTION SYSTEMS

FAIRBANKS

The city of Fairbanks distributes water successfully and at a moderate cost through buried pipes in an area where permafrost occurs immediately below the surface in many places. The system is comparable to the system in Dawson City, Whitehorse, and Yellowknife, Canada (Cederstrom and others, 1953, p. 24–25), in that the water is circulated continuously. Experimental model studies on a small scale that led to a practical design for the Fairbanks water-distribution system were made by W. B. Page (1954, p. 56–61), of the U.S. Public Health Service, Arctic Health Research Center. More detailed model studies on a full scale were completed subsequently by R. W. Beck and Associates (Westfall, 1956), and the system was designed by that firm.

Water for the Fairbanks city supply is pumped from deep wells at a temperature of 34°F, passed through the condensers of the city powerplant, and, as needed, treated and fed into the distribution lines. Water is distributed through about 7 miles of wood-stave pipe and 17 miles of steel pipe (F. H. Mapleton, General Manager, Municipal Utilities System, personal communication, 1955). Cross connections on the primary loop are 6 inches in diameter. In addition to the pumps at the central pumping station, three booster pumps provide continuous flow throughout the system at all times.

A feature of the Fairbanks system is the service connection. Service connections in conventional systems are made with small-diameter pipe, and water in them is ordinarily motionless for long periods, as a result of which they commonly freeze. Freezing of the small-diameter takeoff from the mains in the present system is avoided by use of a "pitorifice." The small-diameter intake line is fitted with a funnel-shaped end that opens out against the line of flow. Water passes into the service area and out into the main again, where the return end also has a funnel-shaped end which, in this instance, opens out in the direction of flow. Thus, continuous flow is maintained and freezing is inhibited.

To determine the minimum heat necessary for a completely safe system and to observe any significant changes in ground temperatures, five banks of thermocouples were installed at strategic locations. These were read weekly by members of the city engineering staff from October 21, 1953, to June 2, 1954, and less frequently thereafter. A set of these readings taken from the thermocouples at Sixth Avenue and Barnette Street is plotted in figure 4.

The thermocouples at Sixth Avenue and Barnette Street are buried at the following depths below the surface: 1½, 2½, 3½, 4½, 5½, 6½, 7¼, 7½, 8⅙, 8$\frac{5}{12}$, and 9⅙ feet. The thermocouples at 7½ and 8⅙ feet are immediately above and below the distribution lines.

Water was not turned into the mains until December 14, 1953; thus, the record from October 21 to December 14 represents normal ground temperatures. As the air temperatures declined from 29°F to a minimum of −20°, the ground temperature 1½ feet below the surface declined from 32.3° to 6.8°, a total of 25.5°. The ground temperature

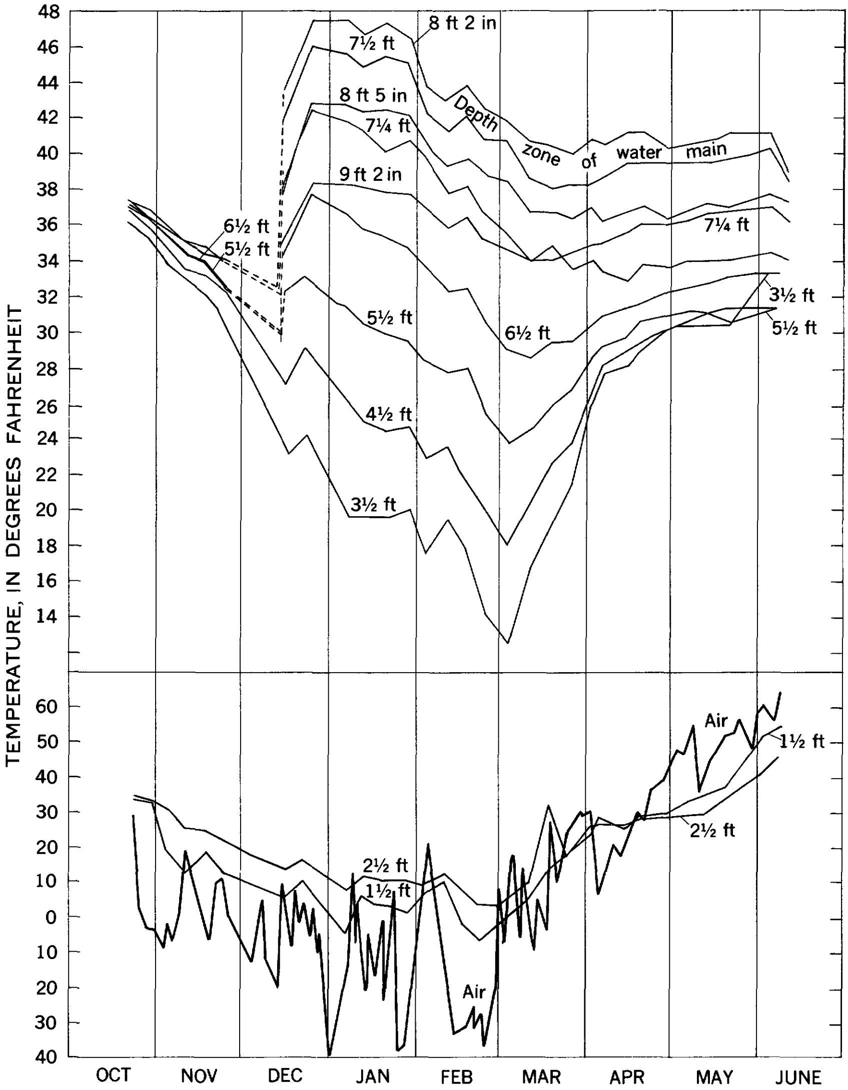

FIGURE 4.—Earth temperatures at Sixth Avenue and Barnette Street, Fairbanks, Alaska, and air temperature, October 1953 to June 1954. Depth of thermocouples below land surface, in feet, is shown on the corresponding temperature curve.

3½ feet below the surface declined 12.5°, and the decline at and below a depth of 7½ feet was about 4.8°.

Water at 50° was circulated in the mains on December 14, 1953. All ground temperatures immediately rose sharply. By December 23 those thermocouples close to the main indicated a rise in ground temperature of about 14°. The temperature rose 2.1° at a depth of

4½ feet and 1.1° at a depth of 3½feet. A greater rise registered by the 2½- and 1½-foot thermocouples, 2.9° and 4.9°, respectively, is ascribed mostly to warming of the air temperature in the period immediately before December 16. Note that the short-lived warming up of November 7 to 12 produced a sharp reversal of the downward trend of the temperature curve of the 1½-foot thermocouple and a discernible effect on that of the 2½-foot thermocouple.

The 7½- and 8⅙-foot thermocouples indicated that January temperatures in those zones tended to remain steady at about 45.5° and 47.5°, but temperatures fell about 3° in late January and very early February, presumably in response to continued low air temperatures that began on January 2. The response was earlier and greater progressively nearer the surface, although the curves are very irregular. The decline from December 23 to February 3 at 1½ feet is more than 8°. At 5½ feet it was more than 4½°, and at 9½ feet it was 1½°.

Between February 3 and 11 the temperature of the circulating water decreased by 5°, causing a decline of about 1° in ground temperature in immediate vicinity of the mains, but having little or no apparent effect at depths of 4½ feet and less.

The moderate air temperatures of early February, at which time air temperatures rose from −37° to 22°, raised all ground temperatures. A rise of 9½° was noted at the 1½-foot level, but less than a 1° rise was noted below a depth of 3½ feet.

The lag in heat penetration, beginning from the low of January 24, was progressively greater with depth, and the reversal of the temperature curves at 5½ feet and greater depths was recorded on February 18, or 25 days later.

In the succeeding 2-week period, air temperatures declined again to a low of −35°, and ground temperatures declined to the lowest levels recorded in the winter of 1953–54. The temperature at 1½ feet fell to −5°, and the temperatures at 7½ and 8⅙ feet in the vicinity of the buried mains eventually declined to 35½° and 40½°, respectively.

The time lag in heat penetration, beginning from the low of February 26, was 5 days at a depth of 3½ feet, 13 days at 6½ feet, 21 days at 7½ feet, 28 days at 8⅙ feet, and 48 days at 9½ feet.

In order that the time lag may be appreciated more fully, it should be noted that, even before time had elapsed for penetration of the cold to a depth of 9½ feet, air temperatures rose from the low of −8.9° to 46.4°. Hence, even a rapid and considerable warming up of air temperatures after a severe cold spell should not be relied upon to ameliorate the effects of the preceding low temperatures existing at the surface.

The temperature at 9½ feet on February 11 was about 36.1°, or 7.2° colder than that directly under the main at 8⅙ feet. The downward travel of heat from the main, therefore, appears to be small. Further, 2 inches above the main (at 7½ ft) the temperature was more than 3° lower than at the bottom of the main, and at 6½ feet the temperature was 9½° lower, indicating again that the warming effect of the water circulating in the main on adjacent earth materials extends only short distances. The temperature graph of the 5½-foot thermocouple is closely similar to a curve that can be drawn from temperature data obtained at a depth of 1.5 meters (4.9 ft) at a station in Skovorodine, Siberia (Muller, 1945, p. 20). Ground temperatures rose in Fairbanks in the last half of December, when water was turned into the mains, as little as 1° at 3½ feet to a maximum of about 16° at the mains, and this differential in temperature was maintained as water continued to flow and furnish heat. Circulating water, therefore, warms the ground in the immediate vicinity of mains as long as water flows, but its effect is not far reaching. Ground-temperature curves from thermocouples at 5½ and even 6½ feet showed characteristic strong fluctuations in response to air-temperature changes; and, even in the immediate vicinity of the mains and with a constant source of heat, ground temperatures declined 3° to 4° during periods of coldest weather.

In brief, the introduction of a constant source of heat accomplished the intended purpose of keeping the water from freezing, but it has not greatly affected the normal thermal regime. The temperature curves shown in figure 5 are virtually normal curves, some of which have been shifted upward slightly and a few of which are somewhat distorted. No warming of the ground to produce nearly horizontal curves with stable temperatures of, say, 35° to 45° can be detected.

Spring thaw.—The trend of air temperatures generally was upward after March 1. Air temperature rose as high as 32° on March 28, and, after a short colder period, rose to 57° on May 9. Ground temperatures near the surface increased with negligible lag as air temperature increased, but the lag increased with depth.

The effect of the latent heat of fusion of ice is apparent in the curve of the 3½-foot thermocouple. This curve rises sharply at first and then flattens as heat is consumed while ice is converted to water (the "zero curtain" of Muller, 1945, p. 17). According to the data, this flattening apparently occurs at 30.6°. This apparent depression of the freezing point probably is due to an erroneous calibration of the thermocouples. The curve of the 4½-foot thermocouple flattens a little later, and that of the 5½-foot thermocouple begins still later.

Regular measurements of earth temperatures were not made after June 10 at Sixth Avenue and Barnette Street.

LADD AIR FORCE BASE

Sporadic permafrost at Ladd Air Force Base also necessitates special measures to prevent water-distribution lines from freezing. Large concrete "utilidors" carry water, steam, and electric lines. This method of combating permafrost might be summarized best by saying that it is both effective and expensive.

OCCURRENCE OF GROUND WATER

Ground water occurs in cavities, fissures, and pore spaces in various types or rock and saturates the earth up to a variable level known as the "water table." In fine-grained material, such as sand and silt, the earth above the water table is moistened to a variable height by water drawn up from the zone of saturation by the action of capillarity. In cavernous rocks and in coarse-grained material, such as clean gravel, this "capillary fringe" may be extremely thin.

Between the capillary fringe and the belt of soil moisture, in the so-called intermediate belt of the zone of aeration, the earth contains water that is held by capillarity against the pull of gravity or water that is moving toward the water table; the amount of water depends on the number and size of the openings in the earth materials. Variable amounts of water generally are contained just below the surface in the belt of soil moisture.

GROUND-WATER RECHARGE

Some precipitation percolates into the ground and the part of it, if any, that is in excess of the demands of capillarity moves downward to and accumulates in the zone of saturation. The water table will rise if the water from rainfall or snowmelt that percolates down to the zone of saturation is in excess of that which drains laterally to feed streams. However, it will decline between periods of replenishment as water continues to drain toward the streams. This lateral movement of ground water is inhibited by friction as the water flows through small rock interstices, and in areas relatively distant from a stream the water table tends to remain higher than stream level.

The ground-water reservoir of the flood plain in the Fairbanks area undoubtedly receives accretions of water from the hills immediately to the north by both underground flow and infiltration from intermittent streams that flow out of the hills and across the valley floor. Some of the streams lose their entire flow to the beds of gravel before they reach the trunk streams. In times of high local rainfall, the water from the hills, plus ground water in the valley-flat sediments, tends to migrate toward and feed the major streams. However, in times of low local rainfall, the Tanana and Chena Rivers tend to lose water to the ground-water reservoir, to make up deficiencies resulting from low recharge and from high discharge by vegetation or by wells.

Water-level records indicate that the ground-water reservoir is recharged more in the early spring than might be expected, considering that the thick zone of winter frost may persist, in places, well into June. Because recharge to the ground-water reservoir begins about as soon as the accumulated snow begins to melt, or very soon thereafter, it seems obvious that the frozen ground above the water table is not an impermeable unit—breaks must occur or develop in it. It may well be that, as soon as melt runoff begins, rapid downward thawing occurs along the courses of the small streams and significant recharge then takes place.

Water levels from January 1950 to March 1955 in an observation well on the McGrath Cutoff (fig. 5) indicate that water levels begin to rise appreciably in April, or even early in March in some years. Parenthetically, the gradual decline of water levels shown in figure 4 is thought to be due to leakage through the overlying permafrost somewhere in the immediate vicinity.

In 1950 water levels began to rise markedly early in April. The average temperature for that month, a time of intermittent thawing, was 28.9° F. Precipitation in April was insignificant, 0.03 inch, and that in May was only 0.52 inch. Hence, the April–May rise of water level noted in the observation well, 0.70 foot, is attributed to recharge by melt water.

In 1951 the water level in the observation well rose about 0.8 foot from April 20 to 30. The total precipitation in that month was only 0.04 inch. However, the snow cover, 2.6 inches on April 1, was dissipated entirely by April 20, and it seems likely that its melt water was the source of the ground-water recharge noted in the latter part of the month.

In April 1952 precipitation amounted to only 0.54 inch, all as snow. The winter snow cover was dissipated largely by the end of April. Rainfall in May was meager, 0.34 inch. Yet recharge began in April with the first intermittent thawing and the relatively sharp rise of water levels continued through May, adding up to a net spring rise of 0.85 foot by the end of that period.

In 1953 the 0.30-foot rise of water level noted in April was due entirely to absorption of melt water, inasmuch as rainfall was only 0.01 inch during the month. Much of the snow cover in the area was dissipated during the first week in April. May rains were light,

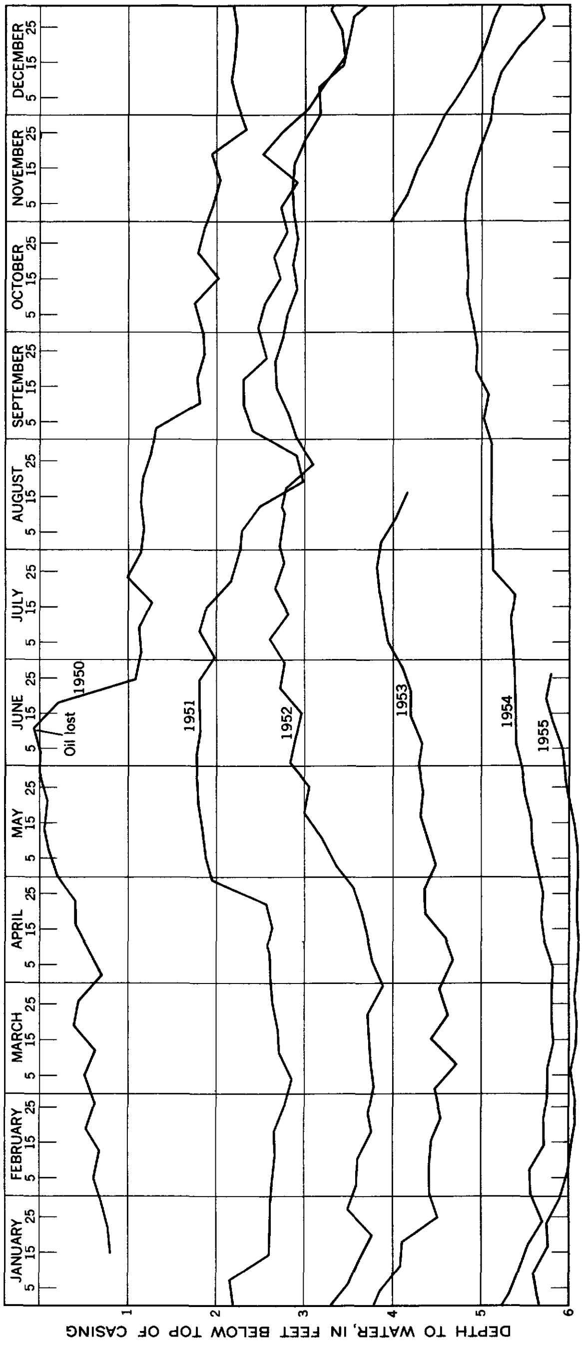

FIGURE 5.—Water level in well 370, 1950–55.

totaling 0.64 inch, and the April water level was barely maintained in May.

In 1954 water levels rose slightly in April and May, 0.35 foot. This rise may be attributed entirely to snowmelt, as precipitation during the period was negligible.

The observation well is near the upslope limit of permanently frozen ground. There is little reason to suspect that melting of permafrost in the warmer months contributes appreciably to recharge of the ground-water reservoir. Water levels (fig. 5) are related closely to times of snowmelt and rainfall, whereas recharge from melting of permafrost would result in a gradual, steady rise in water level from late spring until late fall.

The function of moss cover in Alaska with respect to infiltration of precipitation may not be understood completely, although G. L. Parker (*in* Prindle and Katz, 1913, p. 132) noted that "those areas heavily covered with moss distributed the run-off from summer rains in a more uniform manner than those with a lighter moss covering"—presumably by promoting infiltration and subsequent slow release of accumulated ground water through springs and seeps. The moss cover does not necessarily act as an absorbent barrier (Mertie, 1937, p. 194) to downward percolation of all rainwater. Although it initially may retain some of the water absorbed, because of its extensive root system it may actually promote infiltration to the water table after the soil has reached field capacity. Experiments on artificial recharge in California (Mitchelson and Muckel, 1937, p. 80) show that "the highest percolation rates are obtained on land with the native vegetation and soil covering least disturbed" and that (where large quantities of water are applied to the land) "the consumptive use of vegetation is negligible in comparison with its beneficial effect on the percolation rate." Mather (1953, p. 237) stated that the absorption of water in woodland areas may be very great indeed; the water table in a woodland area near Seabrook, N.J., was raised as much as 22 feet in one summer season by the spraying of cannery waste water as a means of disposal.

ARTESIAN CONDITIONS

In the subarctic environment with which this report is concerned, the rather odd condition exists in which perennially frozen ground may function as a "caprock" and thereby complete the conditions necessary for the occurrence of confined ground water under artesian head. It has been noted that perennially frozen ground extends various distances up hill slopes in many places in the area, and the surficial mucky silt in the valleys, also reaching back into the hills, is almost invariably frozen. Ground water percolating down the hill slopes is partly dammed beneath this frozen cover, and artesian head is built up. Flowing wells have been constructed at elevations as high as about 800 feet, more than 300 feet above the flood plain (well 373, table 3), and as low as about 490 feet, almost at the level of the valley flats.

Artesian water in and near the flood plain leaks upward through discontinuous permafrost or flows laterally through the very permeable beds of sand and gravel in the valley to points where upward leakage is possible. Thus, ground water occurs under water-table conditions beneath the high slopes and ridges, under artesian conditions on the lower slopes, and again under water-table conditions on the valley flats, as illustrated in figure 6.

As indicated in figure 6, although the piezometric surface rises rather steeply in ascending the mountain slope, the surface tends to flatten above the upper edge of the permafrost mass. However, the relatively few records of wells penetrating bedrock indicate that the water table in the hilly country is not so smooth as is shown in figure 6. Marked variations in the elevation of the water table may be due to "ponding" at higher levels by impermeable parts of the schist complex, much as water in some volcanic areas is held to high levels by dikes or ash beds. It is apparent, however, that ordinarily the water table in the hill country is high because lateral drainage is inhibited by the frozen cover that extends part way up the slopes, and the height of the water table locally is related directly to the maximum height to which the frozen cover extends; hence, where the permafrost extends farther up the slope than in an adjacent area, water levels will tend to be higher; and conversely, where there are significant low gaps in an otherwise uniform upper limit of permafrost, water levels will tend to be lower.

In times of heavy rainfall, recharge may be sufficient to raise the water table beneath the ridge to the extent that ground water may flow over the upper edge of the permafrost mass and emerge as a spring or create swampy ground at points of emergence. Possibly some swampy areas ordinarily ascribed to melting of the permafrost may owe their origin to such springs. The swamp at the head of Isabella Creek may be due to ground water emerging under the conditions described.

Formations in which water occurs under artesian head beneath the permafrost cover are not necessarily sandy or gravelly. In fact, if the beds beneath the frozen capping were thick permeable sand and gravel, there would be much less likelihood that an artesian head would be built up, as most of the water, which is recharged in modest

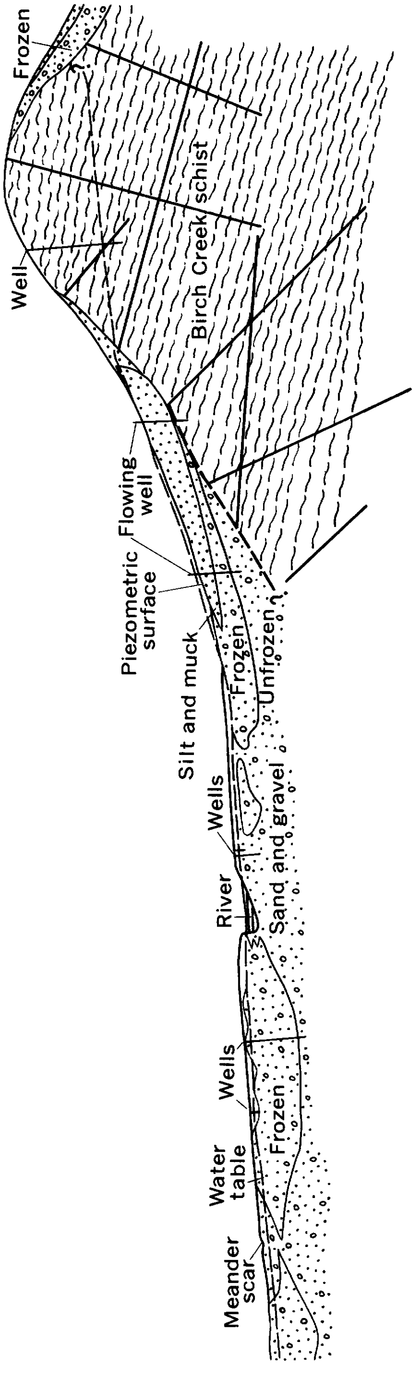

FIGURE 6.—Schematic diagram showing modes of occurrence of ground water in the Fairbanks area, Alaska.

quantities, would drain away quickly. The water-bearing formation tapped by wells 364, 368, and 373 is fractured bedrock and relatively little water moves through it. The overlying material is frozen or relatively impermeable muck. Other wells, however (369, 370, 396, 388?), tap gravelly material.

Artesian conditions may prevail much farther upslope along the minor stream valleys than on the silt-covered slopes. A capping of mucky silt, some of which may be frozen, in the stream valleys extends far back into the hills in many places. The capping of mucky silt extends to fairly high elevations in a few places, where water in the underlying gravel and fractured bedrock should be under some artesian head. The ground water in adjacent areas of unfrozen or mucky silt may be under water-table conditions.

SOURCES OF WATER AND WATER UTILIZATION

Practically all the water for human consumption and general domestic use in the Fairbanks area is pumped from wells. Several hundred privately owned wells furnish homes with water in the city and adjacent suburban areas. In addition, the city now distributes water from two large-diameter wells. Ladd Air Force Base uses water from a great many wells for all purposes.

Table water having a better taste than water from some wells is supplied by truck to purchasers. Much water from two shallow wells in Fairbanks was distributed in past years, and water from a spring at Fox, about 10 miles north of Fairbanks, still is sold in the area.

Well water is used to cool condensers at the city powerplant before it enters the municipal system. Considerable well water is used for condenser cooling and for boiler makeup at Ladd Air Force Base and at the plant of the United States Smelting, Refining & Mining Co. at Garden Island, which requires about 5,000 gpm of water at 45°F or 7,000 gpm of water at 55°F. Because the temperature of the water pumped actually is about 34°F, about 3,000 gpm (gallons per minute) is pumped during the approximately half year of full-scale field operations.

A surprisingly large number of rural residents have no wells. They haul water in barrels, catch the meager rainfall on their roofs and store it, or melt ice and snow (only in small amounts). The combination of a high cost per foot of drilling, the possibility of having to drill a well almost 300 feet deep, and (in some places) the uncertainty of the supply available is a major deterrent to many people. Where the cost of wells is moderate, as on the flood plain, almost every householder has a well.

The United States Smelting, Refining & Mining Co. is the only user of surface water in quantity. Considerable water is pumped from the Chena River for placer operations in the valley of Ester Creek, and the flow of smaller streams elsewhere in the area is distributed as needed by a combination of gravity-feed high-level ditches and pipelines equipped with booster pumps.

TEST DRILLING

The necessity of drilling test holes to obtain critical information in several places, particularly in the hilly area north of Fairbanks, became apparent after the brief field study of the 1947 season. Two 2-inch-diameter observation wells were constructed by local contractors in 1948 by the drive-jet method on the flood plain, one at the new railroad terminal and one at Ladd Air Force Base. A cable-tool rig and operators were hired later in the season to drill on the slopes north of Fairbanks. Difficulties were encountered in that the cable-tool rig was too light for some drilling, the pipe on hand was not suitable for hard driving, and some items of equipment, particularly pumping equipment, were lacking and could not be obtained locally. Nevertheless, 6 holes were drilled that fall, 1 of which was a failure owing to faulty casing. The holes ranged in depth from 85 to 174 feet; the total drilling completed was 638 feet.

Two shallow and two deeper holes were drilled with the same cable-tool rig in the spring of 1949, after which time the contract was terminated. These holes ranged in depth from 31 to 145 feet; the total drilling was 324 feet.

Because of more pressing work elsewhere in Alaska, drilling was not resumed in the Fairbanks area until the summer of 1954, when five test holes were drilled by jet drill (fig. 7). The holes, total footage 683, ranged in depth from 100 to 184 feet. The construction and operation of the jet drill and its suitability for use in the Fairbanks area is discussed in detail in another report (Cederstrom and Tibbitts, 1961). The information gained on the suitability of the jet-drilling method in the area north of Fairbanks may be as valuable as the geologic and hydrologic information gained.

The results of test drilling are incorporated in the well tables (tables 3, 4) and logs (table 5).

WATER-BEARING FORMATIONS

BEDROCK

The bedrock yields water to several wells on the slopes north of Fairbanks. Bedrock may have been penetrated by two wells on the valley flats, but these failed to yield water.

The bedrock is weathered extensively, to a depth of more than 200 feet in places (wells 366 and 374, table 3; pl. 1). Deep weathering

FIGURE 7.—Experimental jet drill used in 1954. Test hole being drilled in subordinate valley in low mountains north of Fairbanks.

may have increased the permeability of the bedrock as a whole, but in places it has produced much clayey (and sandy?) material which tends to reduce permeability.

Most wells seem to be developed in brittle zones in the schist below the level at which saturated rock is penetrated. The brittle rock in several places is silicified schist, but it is possible that other brittle rocks, such as quartzite, also may be present from place to place in the largely micaceous schist.

The brittle rocks furnish water from crevices. Where the rocks are more plastic, openings created in them tend to close up even when they are fresh. Many of the plastic rocks also weather extensively, and the resultant clayey material tends to muddy or clog a well.

YIELDS

The yield of wells obtaining water from the bedrock ranges from nearly nothing to a few tens of gallons per minute. Well 374 yields only half a gallon per minute with 40 feet of drawdown. Wells 381, 383, and 384, on the other hand, are reported to yield about 6 gpm with 20 to 40 feet of drawdown. A 2-inch well (373) on the Steese Highway that taps the upper few feet of schist yielded 20 gpm with about 14 feet of drawdown.

Three wells (363a, 363b, and 363c) drilled into the schist on the Atwood tract yield 10 to 15 gpm each. Well 363a (yielding 10 gpm) penetrated 90 feet of schist, whereas well 363c (yielding 15 gpm) penetrated only 21 feet. A well on the Spears tract (388) penetrating only 10½ feet of schist yielded 57 gpm. However, reference to the log, table 5, shows that here (and in well 363c referred to above) the schist may be recharged from a gravelly aquifer directly above. Admittedly, the uppermost part of the schist penetrated in well 388 is very permeable, but if the rock in which the well is finished were replenished only by water percolating through a large mass of schist, it seems possible that the yield would be much smaller.

The University of Alaska experienced difficulty in obtaining sufficient water for its needs from conventional wells drilled in the schist. Two sumps, 28 and 30 feet deep, off a horizontal tunnel, 250 feet long, driven northward through the schist from Ester Road, formerly supplied most of the school's water. More recently another sump was sunk to a depth of about 50 feet just off the north end of the tunnel. The lower part of this sump was enlarged to create a 12,000-gallon reservoir. Three holes were drilled at a slight upward angle from the sump into the adjacent rock. These drill holes, extending 83, 98, and 100 feet, furnish 28, 25, and 5 gpm, respectively, to the sump. The two older sumps are still in use, but their yields are not known.

Wells drilled in the schist are ordinarily continued into the zone of saturation until the first brittle ("quartz") layer is penetrated, at which point drilling is discontinued. Some persons have stated that to drill deeper would be risky in that the water might be lost. It is entirely possible that in some places the water table is "perched" on impermeable rock and that water could be lost by drilling through the perching rock, but on the other hand there is no single instance in which such loss of water has been confirmed. When the high cost of drilling in Alaska is considered, however, it is easily understandable that most wells are drilled only deep enough to obtain a dependable supply of water. This practice means that, in most of the few wells developed in the schist, no effort has been made to develop a maximum quantity of water by combining the yield from several zones. Considering the clayey nature of much of the weathered schist, however, it seems likely that, although attempts to develop several zones might be successful in some places, elsewhere this technique might result in initially muddy water requiring long pumping to clear, and in some other instances the well might not clear at all.

WATER LEVELS

The depth to water in the bedrock at higher elevations may be nearly 250 feet (wells 374, 382, table 3). The water level is much closer to the surface at lower elevations, and some wells on relatively low ground flow.

In well 381 on the Steele Creek Road, the depth to water is reported to be 638 feet above sea level (133 ft below the surface), whereas in adjacent wells (382, 383, table 3), according to reports of well owners, water levels are 539 and 563 feet above sea level, respectively. These data suggest that some of the steeply dipping schist layers are relatively impermeable and that lateral percolation is inhibited; as a result, the saturated zone is "compartmentalized," and the water table may be much higher in one such compartment than it is in an adjacent one.

Other differences in the elevation of the water table may result from variations in the permafrost. Permafrost along the slopes tends to retard the flow of water from the hilly area to the flood plain. Hence, because the upper edge of the frozen zone is very ragged, the height to which water is dammed behind it differs greatly from place to place. Further, differences in flow beneath the permafrost, depending on whether the alluvium is frozen all the way down into the bedrock or on the permeability of the unfrozen water-bearing material, may either promote or inhibit the building up of head beneath the high ground.

There are no producing wells at present on the Chena Ridge. Recently several homes have been built along this long, narrow, high ridge, which rises 400 feet or more above the flood plain. This hard-rock ridge has, at best, a thin silt cover, probably breached in many places; in addition, the silt cover probably is not frozen very far up the slope. Reasoning from conditions in other ridge areas, it may be expected that wells drilled along Chena Ridge may not encounter the water table within 300 feet of the surface unless, by great chance, water is held to a higher level by impermeable masses of rock that inhibit lateral percolation, as explained above. Further, drilling may have to be continued for some distance below the water table until a water-bearing zone is reached.

Wells on the lower slopes throughout the area that are drilled through the frozen silt encounter water in schist under artesian head; a few of these wells have a natural flow (364, 368, 373, 385).

Well 373 (table 3) is at a higher elevation than any other flowing well in the area, 788 feet above sea level, or more than 300 feet above the floor of the Tanana Valley. It is in an ancient stream valley that crosses the Steese Highway (pl. 1). In this particular locality, wells might flow at slightly higher elevations, but elsewhere in the area it is likely that wells in tributary stream valleys that tap the schist or overlying beds of sand will not flow above an elevation of 700 feet, even in the larger coves.

Well 364, at an elevation of 500 feet on the C. Sherman farm was completed in bedrock that was first penetrated at about 340 feet above sea level. The surface elevation and the elevation of the top of the bedrock were slightly higher in well 357, on the Fowler property near the transmitter of radio station KFAR. These are the lowest elevations at which material definitely identified as bedrock has been penetrated by the drill in the report area.

BURIED ALLUVIUM OF UPLAND VALLEYS

The occurrence of gravel at relatively high elevations in the area has been mentioned previously. Only three instances are known where water has been obtained from such gravels (all three being Geological Survey test holes), and it is thought that the importance of these beds is not generally appreciated.

Large yields from wells can be obtained at higher elevations only in gravelly beds of buried alluvium of upland valleys. Admittedly, most individuals do not have an opportunity to explore for these gravels, but each must sink a well on the small piece of land he has acquired and cope with the geologic and hydrologic conditions as he finds them. In most places bedrock will be encountered directly under the silt, and a successful well will result only where brittle rocks are penetrated below the water table. Such wells ordinarily can be expected to yield less than 10 gpm. The depth of wells may be as much as 400 feet, but more commonly it may be 100 to 250 feet.

Yields of wells in excess of a hundred gallons per minute may be possible in several places along the Farmers Loop Road and the Steele Creek Road from properly drilled and developed wells.

It is reported (A. H. Mick, Alaska Agricultural Experiment Station, oral communication, July 29, 1954) that some irrigation in the Fairbanks area is needed to insure the immediate germination and growth of seeds in the ordinarily dry early spring. Irrigation is economically practicable only where wells of at least moderate yield can be constructed (25 gpm might accomplish the irrigation necessary for at least a few acres). Further, some tracts of land otherwise desirable for real estate development would be virtually useless if sufficient amounts of water could not be developed on or near the land. Here, as with prospective irrigators, the consumer must seek water in specific places where there is a logical possibility of obtaining a fairly large yield from his well.

Large yields ordinarily will not be available from wells on the high well-drained land north of Fairbanks that is suitable for farming and housing developments. High yields ordinarily can be obtained only from wells in the swales marking the courses of the ancient stream valleys (pl. 1). Along these swales, excellent yields ordinarily should be available by drilling down into the gravel, generally through a silt or muck cover. Yields will be obtained only where these wells are properly screened and developed by a skilled driller using adequate equipment.

Several homes have been built recently along the road leading from the Farmers Loop Road into secs. 21 and 20 (pl. 1). One domestic well (360) drilled into the schist bedrock yields a small but adequate supply of water. However, the chances are very good that large supplies cannot be obtained from wells anywhere along this road. On the other hand, there is every reason to believe that, just below the road, in or near the valley bottom, rather large supplies of water might be obtained if coarse sand and gravel are present (as they are thought to be) at some little depth and are developed by proper techniques.

Similarly, wells 357, 361, 378, 381, and 390, on broad silt aprons along the hilly slopes, yield small quantities of water from the bedrock underlying the silt. However, along the major perennial streams—in the easternmost part of sec. 21 and in the eastern part of sec. 22, T. 1 N., R. 1 W. (as noted above); at the head of Isabella Creek (see logs of wells 369, 370); and on low ground adjacent to Columbia Creek (388), Steele Creek (380), and Hopper Creek—the older creek gravel and coarse sand may be expected to be present, and large yields to be available where wells are properly finished.

Many of the smaller tributaries may be underlain by coarse sand and gravel capable of furnishing large supplies of water to wells; but in the small valleys there is more chance that sand is absent (see log of well 373), or finer grained (363) and thinner and hence more difficult to develop, so that the wells will have only a moderate yield.

The best location for wells of large yield might be determined economically by the jetting method of exploratory drilling. Such exploration is necessary for the optimum location of wells, as demonstrated by the differences in strata penetrated in the three closely spaced wells 363a, 363b, and 363c (table 5).

Additional information on the techniques necessary to develop large supplies of water from the old creek gravel is given under well-drilling methods (p. 50–54).

TAN SILT AND BLACK MUCK

The silt is a very poor water-bearing formation, although a few dug wells obtain seepage from it. Coarser materials that are capable of furnishing appreciable quantities of water to wells commonly are not present in the silt.

A jetted well on the property of C. R. Kivlehn on the valley floor of Columbia Creek (386, table 3) is finished in a gravel layer in the mucky silt. The well flows about 2 gpm. The log of well 388 (table 5) nearby indicates that the gravel layer there is 5 feet thick.

The 7 feet of coarse sand logged in well 362 is an example of a sand in the silt sequence that might be capable of yielding a moderate amount of water to wells.

SAND AND GRAVEL OF THE TANANA VALLEY

The flood-plain alluvium of the Tanana Valley as a whole constitutes a ground-water reservoir of almost limitless capacity. Insofar as present and foreseeable needs are concerned in the area around Fairbanks and Ladd Air Force Base, the limitations that might be encountered in any well-development plan that might be conceived are those imposed by factors such as economics, mechanics of well construction, and quality of water obtained, rather than those pertaining to permeability, recharge, or storage capacity of the sediments. In the immediate vicinity of Fairbanks the concept of "safe yield" is, at best, of only academic interest. Fairbanks lies near the northern border of an alluvium-filled valley that is more than 40 miles wide. The upstream part of the valley is only slightly narrower for a distance of about 70 miles. The alluvium is water saturated to within a few feet of the surface in most places. Practically all the alluvium is fairly permeable, and most of it is very permeable. The maximum thickness of the valley fill is unknown, but the fill is more than 350 feet in the Fairbanks area. This huge very permeable saturated mass is subject to rapid recharge from the Chena and Tanana Rivers and from surface and underground flow from the adjacent mountains.

The discontinuous permafrost zone in the alluvium may inhibit recharge locally, but it has no effect on the total recharge except to increase evaporation and transpiration slightly by delaying the downward percolation of precipitation.

Silting of the riverbanks by suspended glacial rock flour will cause loss of recharge capacity, but, because the streams are constantly meandering, branching, and shifting, fresh permeable ground is constantly being uncovered along the banks, and the opportunities for recharge may be thought of as virtually limitless.

Practically every well that has been drilled in the flood plain near Fairbanks has a high yield. No failures due to lack of a suitable water-bearing formation are known. It appears that exceedingly high yields can be obtained anywhere even from poorly constructed wells that, ordinarily, are less than 250 feet deep. The depth to the static, or nonpumping, water level ordinarily is about 10 or 12 feet below the land surface and is not known to be more than 16 feet below the surface anywhere.

On the other hand, the water commonly is of poor quality, being high in iron, and the tendency of small-diameter domestic wells that tap aquifers beneath the permafrost to freeze solid is a real problem.

As shown in the records of wells, table 1, the depths of wells in Fairbanks range from 15 to 249 feet. The deepest well at Ladd Air Force Base (table 4) is 315 feet, and, north of Fairbanks, one of the wells of the United States Smelting, Refining & Mining Co. is 364 feet deep (table 2).

DOMESTIC WELLS

Nearly all the domestic wells in and near Fairbanks are 2 inches in diameter. Several drilled wells are only about 40 feet deep, a depth considered adequate for eliminating organic pollution, but most of the wells are drilled to the first unfrozen gravelly beds beneath the permanently frozen ground. Some wells were drilled deeper than the average depth at which copious safe water is available, in attempts to obtain water of better chemical quality. Most domestic wells drilled through the frozen ground range in depth from about 40 to 200 feet, but a few are deeper; well 114 is 244 feet deep for no particular reason that can be ascertained. Wells 282 and 283, respectively 249 and 243 feet deep, were drilled to those depths in order to penetrate completely a particularly thick mass of permafrost.

A rather large number of shallow domestic wells are in use. These are constructed in the many places where permafrost appears to have receded (pl. 2; tables 1, 2) below the water table or is not present at all. They range in depth from 17 to 40 feet. Where permafrost exists above the water table, which ordinarily is 12 to 14 feet below the surface, water of course cannot be had, except by going completely through the frozen ground.

YIELD OF DOMESTIC WELLS

Few data are available on the yield of domestic wells in Fairbanks, but all of them, as far as the writer is aware, yield copious supplies. Ortho Stevens, of Fairbanks, stated that he has pumped several 2-inch wells by suction at a rate of 50 gpm.

FREEZING OF DOMESTIC WELLS

Small-diameter wells that penetrate permafrost, particularly where the permafrost is thick and presumably colder than 32°F, tend to freeze. The wells may freeze in July as easily as in other months of the year, and the wells that are pumped least will tend to freeze more quickly than those that are pumped regularly and for longer periods of time. Wells penetrating thick permafrost that are left idle for a week or more almost always freeze.

Steps are taken to inhibit or eliminate freezing. Steam boilers owned by the city of Fairbanks may be called upon to steam out a well before it freezes. One or two such treatments generally prevent further freezing as long as the well is not left idle for long periods. Some individuals have an arrangement whereby excess hot water, available in the cold winter months from sources such as heating equipment, is permitted to flow down the well. Such a procedure generally forestalls freezing of even the most troublesome well. When a well freezes, it may sometimes be thawed out with common salt, but in most cases the city steam boiler is called upon to restore the well to service. No instances have been reported of damage to small-diameter wells by freezing.

FAIRBANKS MUNICIPAL SYSTEM

The present Fairbanks municipal water system began operation in December 1953. Although the casual observer might wonder why a municipal supply had not been installed years before, considering the size of the city and the ease with which ground water can be obtained, the conditions inherent in a subarctic environment are such that the supply could not be installed until a combination of available funds and the influence of public-spirited citizens and Territorial agencies operated effectively to bring about a public-facilities unit that had long been needed.

At first, many citizens opposed the construction of a water-treatment and distribution system for the very reason that ground water was easily available, either cheaply from shallow wells or at moderate cost from somewhat deeper 2-inch wells. The fact that much of the water available to the householder was of poor chemical quality did not seem important to some people.

Although copious supplies of water were available everywhere, sewage disposal continued to be a problem. The houses had cesspools or septic tanks, which ordinarily functioned satisfactorily. A great many of these were located on small lots, close to the well (which may have been a shallow well), or close to the neighbor's well, and the sanitary situation was poor in many places. In addition, during the very cold winter season, many of the cesspools and septic tanks froze and the effluent spilled out over the surface and froze, remaining until the next thaw. Public-health officials were amazed that the city had not been swept repeatedly by major epidemics, inasmuch as waterborne typhoid fever and reportedly water-borne dysentery are both known in the arctic regions in Alaska (Alter, 1950, p. 527).

The flood of 1948 gave pause to many when a large part of Fairbanks was inundated and contaminated water from the Chena River mixed with the shallow ground water, and cesspool levels became, in effect, the level of the floodwater.

Hence, it became accepted eventually that a sewage-disposal system was a dire necessity. To operate a sewer system it is necessary to have ample supplies of water, preferably somewhat warmer than that ordinarily obtained directly from wells, to inhibit freezing. The water supply was therefore given impetus as an adjunct to a sewage-disposal system.

The problem of inadequate or wholly nonexistent fire protection, in the absence of a large water supply in most places, continued to be a major concern to many individuals. In the limited downtown area the Northern Commercial Co. distributed both steam (for heat) and water, and in that small area an adequate supply of water for all purposes, including fire protection and a limited sewage-disposal system, was available. Construction of the present water-supply system has extended adequate fire protection to a greater part of the city.

A municipal plant for producing electricity and steam also was built as part of a complete Fairbanks utilities system. The complete system is operated as a unit, permitting several major economies. Water at a temperature of 34°F pumped from wells cools condensers at the generating plant. After performing this function the water, which then is at an average temperature of about 59°F, may be fed into the city distribution system to warm the water.

The two city wells are 24 inches in diameter and, respectively, 207 and 220 feet deep. The one well (2a), equipped with turbine pump rated at 1,800 gpm, yields 1,900 gpm with a reported 19 feet of drawdown. The second well, equipped with a pump rated at 2,400 gpm, yields 1,200 gpm with a reported 13.4 feet of drawdown. The reported specific capacity (gallons per minute per foot of drawdown) of these wells thus is 100 and 90.

The second well (2b) was sounded in May 1952 and was found to be filled with sand below a depth of 199 feet. Both wells are constructed with perforated casing from 104 to 137 feet and from 176 to 192 feet, and apparently much development will be necessary before the second well is stabilized completely and operating at peak efficiency.

After it leaves the condensers, the water is treated by aeration and by coagulation with lime and ferric sulfate and then is filtered and chlorinated. The plant has one 600,000-gpd (gallons per day) rapid-sand filter in operation. With completion of a second filter bed, the capacity was to have been increased to about 1 mgd (million gallons per day) by 1955.

About 300 service connections had been made by the summer of 1954, and the maximum pumpage at that time was a little more than 500,000 gpd.

The old dug well of the Northern Commercial Co., 54 feet deep, formerly was used as a public-supply well, serving a small downtown area. It is now used as a standby supply well for firefighting; it is equipped with a 100-horsepower turbine pump. The well was test pumped for 15 minutes recently by the city engineering staff; the well yielded 1,340 gpm with 6.1 feet of drawdown. The well has, therefore, a specific capacity of 220 gpm per foot of drawdown. This well was previously reported to yield 700 gpm with 1½ feet of drawdown.

INDUSTRIAL WELLS AND OTHER PUBLIC-SUPPLY WELLS IN THE FAIRBANKS AREA

In addition to the municipal-supply wells, several wells yield more than the small amounts of water required for household use. Most of these are 6 inches or more in diameter, but a few are 2-inch wells; 3 are dug wells.

The Pioneer well (67), at Hall Street and Third Avenue, and the Crystal well (203), at Cowles Street and Eighth Avenue, respectively 22 and 35 feet deep, are dug wells. The water from these wells is iron free and has an excellent taste. In 1947 water from both these wells was distributed by tank truck by a private concern to consumers for table use.

A dug well (302) on Garden Island, just north of Fairbanks, 75 by 60 feet in cross section and originally about 40 feet deep, is 1 of 4 wells furnishing condenser water to the United States Smelting, Refining &

Mining Co. (pl. 2). It is reported to yield 800 gpm with 30 feet of drawdown. This well once yielded about 1,800 gpm, but its yield has diminished owing to clogging of the water-bearing formation by precipitation of iron oxides.

A dug well (308) at The Alaska Railroad yards, 23 feet deep and 3 feet in diameter, furnished 20,000 gpd until the present drilled wells were put into operation, about 1950. The dug well is said to have yielded as much as 1,000 gpm for a 2-day pumping period.

Several 2-inch wells (112, 115, 191, 282, 285, 298, 299, 302) supply water to small apartment houses and other consumers of moderately large quantities of water. A few 2-inch wells (129, 211) yield as much as 50 gpm. The yield of a 6-inch well in poor water-bearing materials at a given drawdown is not much greater than that of a 2-inch well, but, where large quantities are available from the ground, only a part of the water available can be discharged from a 2-inch well because of limitations on the size of the pumping equipment that the well can accommodate or because of friction in the 2-inch pipe if the well is pumped by suction. A well of larger diameter is necessary where the static level is deep and more than a few gallons per minute is required. The aquifers at Fairbanks are very permeable, however, the water level is fairly close to the surface, and suction pumps may be relied upon ordinarily to furnish 30 gpm or more with ease.

Data on three 6-inch wells at apartment houses are included in table 1. The well at the Denali Apartments (210c) is reported to yield 15 gpm with only a slight drawdown. At the City Hall Annex, formerly the Cheechako Hotel (236), a yield of 30 gpm with 3 feet of drawdown is reported, and at Arctic Village (158) 40 gpm is pumped with less than 4 feet of drawdown. At the Fairbanks swimming pool, a 6-inch well (17) yields 150 gpm with 1.4 feet of drawdown, and a well at the Alaska Chemical Co. yields 100 gpm. A well at The Alaska Railroad terminal (321), 8 inches in diameter and 70 feet deep, is reported to yield 600 gpm. The drawdown is not known.

The wells constructed by the United States Smelting, Refining & Mining Co. to supply cooling water for condensers at the company's powerplant are the most heavily pumped wells in the Tanana Valley, and data on their discharge furnish the best available information on the water-yielding capacity of the sediments in this area. Well 308 yielded 3,400 gpm with 5.7 feet of drawdown—having, therefore, a specific capacity of 600 gpm per foot of drawdown. Few wells anywhere have a greater specific capacity. The diameter of the well is unknown, but it is probably 16 inches or more. Well 303, 16 inches in diameter, did not have the extremely high specific capacity of well

308 but it is remarkable nevertheless. In a 32-day pumping test the well yielded 2,900 gpm with a drawdown of 9.8 feet. The specific capacity of the well, therefore, was about 300. Well 306 yielded 2,800 gpm with 22 feet of drawdown. Its specific capacity, therefore, was 127. These three wells have been abandoned, owing to diminution of yield brought about by precipitation of iron. Whether sanding up of the slotted-pipe casing had occurred could not be determined.

Wells 304, 305, and 307 now supply most of the water used by the United States Smelting, Refining & Mining Co. They are 90 feet deep and are reported to yield, respectively, 2,800, 2,800, and 2,400 gpm. The drawdown is not known. These three wells are of large diameter. A 36-inch well, 301, at the plant serves largely as a standby.

WELLS AT LADD AIR FORCE BASE

Ladd Air Force Base has more than 150 wells. They range in diameter from 2 to 24 inches and in depth from 40 to 315 feet. Most are less than 130 feet deep. Only a few of these on which critical or significant information is available are listed in table 4 and shown on plate 1.

Most of the water discharged is obtained from wells 6 inches or more in diameter that serve residential areas, boiler houses, or powerplants, but much is pumped also from 4-inch wells, more than 40 of which supply mess halls and other small establishments. A few 2-inch wells have been constructed at individual dwellings. A few large-diameter wells (461, 465) are listed in table 4.

The formations penetrated are similar to those penetrated at Fairbanks. The logs of four wells at Ladd Air Force Base given in table 5 are typical of the geologic section penetrated. Permafrost is discontinuous beneath the base. Records indicate that it does not occur deeper than 153 feet (well 464) and generally is much thinner. It is absent in many places. Three separate layers of frozen ground separated by unfrozen ground are penetrated by well 454. Two such layers are present in well 460. It is thought by the writer that these phenomena represent a melting out of the more susceptible (coarser) material adjacent to unfrozen areas to form saw-tooth patterns.

Yields as much as 500 gpm have been obtained from wells 451 and 457, but most of the other wells listed are pumped at rates of 200 to 300 gpm. The specific capacity of the few wells for which data are available ranges, in the 6-inch wells, from as little as 9 gpm per foot of drawdown (well 454) to as much as 56 (well 455). An 8-inch well (464) has a specific capacity of 50, and a 4-inch well (453), presumably pumped by suction, is reported to yield 230 gpm with a drawdown of not more than 10 feet.

Most wells at Ladd Air Force Base were constructed with open-end casing, the lower 3 to 5 feet of which is slotted. In recent years wells intended to produce large quantities of water have been equipped with screens and subsequently developed by surging. Well 462 near the central powerplant, 18 inches in diameter and finished with 8 feet of 60-slot screen, yielded 1,500 gpm with 37 feet of drawdown when first tested. The well finally was finished with 20 feet of 80-slot screen and then produced 1,500 gpm with only 9 feet of drawdown. Its specific capacity of 166 is about 3 times as great as that of any previously constructed wells on the base, all of which were finished with slotted casing only.

PUMPING TESTS

Several pumping tests were made in the area in an attempt to determine the coefficients of transmissibility and storage of the sediments. In general the results were disappointing—largely, the writer believes, because of the high permeability and lenticularity of the sediments.

Very shallow cones of depression were created around pumped wells very quickly. When drawdown was plotted against time in order to apply the Theis nonequilibrium formula (Brown, 1953, p. 851), the points for measurements made more than a few minutes after pumping started gave a much flatter slope than the initial part of the curve, indicating that either lateral or vertical recharge was already effective. Recovery after pumping ceased was extremely rapid. After one well was pumped at a rate of 515 gpm for 5 hours, recovery within 0.10 foot of the prepumping level occurred in 3 minutes. In another test on a different well, after 460 gpm was pumped for 3 hours, recovery to within 0.10 foot of the static level occurred in 2 minutes. Better results might be had by utilizing only those water-level measurements obtained during the first few minutes of pumping, but a sufficient number of these measurements to draw up a suitable curve probably could be obtained only by using a recording gage in the observation well. Further, the discharge should be at least 200 or 300 gpm, and the observation well should be not more than 20 or 30 feet away from the pumped well if a measurable drawdown is to be induced. Under such conditions, however, the determination of the storage coefficient would be questionable.

The lenticularity of the beds probably is important in producing uneven water-level curves. As the cone of depression expands in the very permeable sediments, it continually impinges upon sediments of greatly different permeability, and the rate of drawdown changes somewhat as each new lens begins to supply water to the pumped well.

Several attempts were made to determine transmissibilities at Ladd Air Force Base, but the results were negative. It was apparent, however, that transmissibilities are great—several hundred thousand gallons per day per foot.

At the new Alaska Railroad terminal, where a well drilled for use as an observation well was used, the transmissibility was about 800,000 gpd per ft. The plot of the test after 100 minutes of pumping has a very sharp break, indicating that a geologic barrier was reached. It is thought by the writer that the cone of depression had exceeded the limits of the gravel lens in which the well is drilled and that water was being drawn from adjacent sandy or silty sediments.

QUALITY OF WATER

The quality of water obtained from wells in the Fairbanks area ranges from very good to very poor. The water may be characterized as an alkaline, moderately hard to hard calcium bicarbonate water which ordinarily contains appreciable or objectionable quantities of iron. Objectionable quantities of manganese also were generally associated with a high iron content in the samples analyzed. Sulfate was high in a very few samples. Chloride and fluoride were low. A few samples had a relatively high content of nitrate, which suggests possible pollution.

The hardness of the water from wells rarely is less than 100 ppm (parts per million) and more commonly ranges from 100 to 300 ppm. Only a little of the hardness is of the noncarbonate ("permanent") type, but exceptions may occur; water from well 219 in Fairbanks had a total hardness of 281, of which 32 ppm was of the noncarbonate type. Water from well 367, north of the Farmers Loop Road, was similar in this respect.

Several wells yielded water having a hardness of more than 300 ppm; a shallow well (155) in Fairbanks yielded water having a hardness of 454 ppm, of which 64 parts was of the noncarbonate type; well 368, obtaining water from schist just beneath the silt, yielded water having a hardness of 335 ppm, of which 106 was noncarbonate. Samples taken from Geological Survey test well 3 (369) at depths of 101 and 140 feet had hardnesses of 299 and 572 ppm, respectively, of which 181 and 376 ppm were noncarbonate. Analyses of water samples from 2 wells obtaining water from sandy beds in the muck, well 398 at the Army Permafrost Experiment Station and well 356 at radio station KFAR, showed that these were extremely hard waters, having hardnesses of 634 and 614 ppm, respectively, all of which was of the carbonate ("temporary") type. Water from well 363 on the

Farmers Loop Road was similar, although not so highly mineralized. Well 363, however, obtains water from the Birch Creek schist.

Well 354 on the Happy Road yielded water having a hardness of 1,220 ppm, of which 384 ppm was noncarbonate. The well is on a rolling upland northwest of College (pl. 1); the well obtains water from the schist beneath a relatively thin silt cover. It is thought that here the circulation of ground water probably is at a minimum, and that the high mineralization of water is a natural result of that poor circulation.

Most water from wells in Fairbanks contains enough iron to be detected by taste and to stain clothing, utensils, and plumbing fixtures. About a third of the consumers interviewed state that they have "good" water (relative to iron content alone), about a third have wells that yield "fair" water, and a third state that their wells yield "rusty" water. A few wells yield water that is practically iron free—for example, wells 107 and 155 (table 5)—but these are in the minority. It is the writer's opinion that most ground water in Fairbanks should be classed as containing objectionable quantities of iron.

The 4 samples from wells on the valley floor in or near Fairbanks having the highest iron concentrations contained 16, 22, 25, and 47 ppm of iron, respectively. All others were appreciably lower. Water from 2 very shallow wells (107 and 155) contained less than 0.1 ppm iron, 2 others had less than 1 ppm, and 14 others averaged 4 ppm. As little as 0.3 ppm may be objectionable.

Chloride in all samples was low.

Fluoride generally is present in small amounts. Of the 35 samples in which fluoride was determined, only 1 had more than 1 ppm, and fluoride was reported to be absent in 3 samples. About 1.0 ppm of fluoride is considered (Dean, 1942, p. 47) to lessen the incidence of dental decay in children less than 12 years old.

Nitrate, which commonly is an indication of organic pollution, was low in most samples analyzed. Water from one shallow well (67), which was sold as table water, contained 39 ppm of nitrate. Samples from wells 379 and 381 along the Steele Creek Road were high in nitrate, respectively 53 and 65 ppm. This is rather strange, as both wells are drilled in alluvium and might be considered likely to be free of organic contamination. Some wells in the hill country are drilled 6 inches in diameter and a smaller diameter casing is installed later. In such wells, unless clayey mud or a cement slurry were poured in the upper part of the hole as a seal, contamination might easily take place.

The high nitrate content, 85 ppm, of the sample from Geological Survey test hole 5 (367, table 3) probably resulted from dynamiting the hole when it had attained almost its full depth.

Of the samples of water analyzed, 4 were neutral (pH 7); 15 were alkaline, the pH being as high as 8.6; and 6 were slightly acidic, the pH being as low -as 6.4.

ORIGIN OF HARD WATERS

Most ground water from the floor of the Tanana Valley in Fairbanks and vicinity is characterized by moderate to high hardness, low sulfate relative to bicarbonate content, and moderate to high iron content. For convenience, water of this type will be referred to as Fairbanks-type water.

The low sulfate content relative to bicarbonate content in the hard to very hard waters from the Fairbanks area is thought to be due to the reaction of carbonaceous material, either organic or inorganic, with sulfate, producing free carbon dioxide (Rogers, 1919, p. 27; Waksman, 1932, p. 535; Cederstrom, 1946, p. 234). As a result of this reaction, the carbon dioxide, forming carbonic acid, takes limy material into solution as calcium bicarbonate. The sulfate is broken down in the reaction, hydrogen sulfide being one of the products. References in the literature are made to the disagreeable odors emanating from the muck (Maddren, 1905, p. 64–65; Gilmore, 1908, p. 16), which may be assumed to contain appreciable hydrogen sulfide, and it is commonly stated by drillers in Fairbanks that water from the muck stinks.

In the presence of appreciable organic material, such as the vegetal material in the muck, which produces a reducing environment, ground water becomes deoxygenated. This water, which receives accretions of free carbon dioxide both by direct oxidation of carbonaceous matter and by reduction of sulfate in the presence of carbonaceous matter, becomes corrosive and will readily attack iron-bearing minerals and bring iron into solution as iron bicarbonate. However, limy materials tend to react more quickly with the carbonic acid waters in such an environment than do iron minerals; and, as the water becomes harder, the solubility of iron compounds lessens. Also, some iron in solution may be precipitated as iron sulfite in the presence of the hydrogen sulfide resulting from sulfate reduction. Hence, the iron content, although objectionably high for ordinary uses, remains relatively low with reference to the total amount of dissolved solids.

If the solution of iron depends upon breakdown of sulfate and consequent liberation of free carbon dioxide, it follows that water having a high iron content should be low in sulfate relative to bicarbonate. This relation holds true almost everywhere in the area. Practically all the samples that had an iron content greater than 1.0 ppm had a sulfate-bicarbonate ratio of 1 to 19 or less. Three samples contained more than 30 times as much bicarbonate as sulfate; these 3 samples also were unusually high in iron. In addition to having a low sulfate-bicarbonate ratio, the total amount of sulfate generally is low in the samples that are high in iron. However, one sample that was high in sulfate, 32 ppm, also had a very large amount of iron, 47 ppm; and another (well 467, table 6) that had 93 ppm of sulfate also was very high in iron; these are exceptions.

The converse also should be true; where sulfate has not been reduced, the iron content should be low. This relation of high sulfate and low iron also holds well. In almost all the samples having less than 1.0 ppm of iron, the amount of bicarbonate was 6 times or less greater than the amount of sulfate, and 2 samples contained more sulfate than bicarbonate.

A few samples of water were exceptions to the rule, but most of these were samples from wells obtaining water from the schist. These waters have had little or no contact with organic material. Water from well 354 had a fairly high sulfate-bicarbonate ratio but also had 9.8 ppm of iron, whereas a low iron content would be expected. However, 9.8 ppm of iron is fairly low, in view of the extremely high mineralization of the sample. By comparison with total mineralization and iron content of water from wells 356 and 398, the iron content might be expected to be more than 30 ppm. The quality of water from well 467 cannot be similarly explained; although the sulfate-bicarbonate ratio was about 1 to 2, and the total sulfate was high, the iron content in the sample analyzed was 25 ppm.

The quality of ground water is different than that of surface water in the same general area. The water of the Yukon River near its junction with the Tanana has a bicarbonate content of about 95 ppm and a sulfate content of about 15 ppm (Waring, 1917, p. 102). The water of the Chena River is similar and that of the Tanana near Fairbanks is much the same. The chemical quality of these river waters is comparable to that of water of some large rivers of the United States in spite of the subarctic environment (Waring, 1917, p. 106). Hence, to explain the high mineralization of ground water in the same area by increased solubility of free carbon dioxide due to lower temperature alone is inadequate.

The action of organic material in producing free carbon dioxide by breakdown of sulfate is considered to be the largest factor in producing ground water of the Fairbanks type, which is characterized by high bicarbonate content and carbonate hardness, high iron content, and low sulfate content.. The conditions producing these waters were established in early Pleistocene time, when, in a climate somewhat warmer and more humid than at present (Taber, 1943), silt having a relatively high organic content accumulated throughout the area.

Similar waters obtained from wells outside this area may have a similar origin, considering the presence of mossy, peaty, and boggy ground practically everywhere in the arctic and subarctic. Analyses of ground waters at Chickaloon, McGrath, Nenana, Tanana, and Anvik (Cederstrom, 1952, p. 8; table 2, wells 11, 15, 25, 30, 31) also are of hard waters low in sulfate and high in iron and probably have an origin similar to the ground water of the Fairbanks type.

SUITABILITY OF GROUND WATER

Most of the analyzed waters ordinarily would be considered undesirable for many domestic uses in that they are hard and high in iron. To reduce soap consumption, to avoid staining of laundry and utensils, and to make such waters more potable, zeolite-type treatment units have been installed in many homes and in most apartment houses. These generally work well, but it has been reported that the grains of the exchange material may become coated with iron and cannot be regenerated.

Housewives using unfiltered water ordinarily employ one of a variety of prepared water softeners or detergents to reduce soap consumption and prevent yellowing of clothing. Many individuals purchase water for table use.

The raw water pumped for the new city supply (wells 2a, 2b, table 5) is a fairly hard calcium magnesium bicarbonate water containing an undesirable amount of iron. After treatment, the hardness is reduced from 155 to 81 ppm, and the iron is reduced from 2.9 to 0.08 ppm.

Several wells tapping the schist north of Fairbanks yield water having a hardness ranging from a little more than 100 to more than 400 ppm. However, the water generally is iron free and, except for its hardness, is highly desirable for domestic use. Some of the wells tapping formations in or adjacent to muck deposits yield a very highly mineralized water that is high in iron. This water is practically useless for some purposes.

All samples tested are high in calcium and magnesium and low in sodium (low percent sodium) and should be excellent for irrigation, insofar as these constituents are concerned.

WELL CONSTRUCTION

Wells in the Fairbanks area are almost entirely small-diameter wells constructed by the jet-drive method or larger diameter wells drilled by the cable-tool method.

JET-DRIVE DRILLING

Considerable drilling for domestic-well supplies is done by the jet-drive method in Fairbanks. The wells are 2 inches in diameter and penetrate as much as 200 feet of frozen ground.

The equipment is simple and light, consisting of a small derrick and a small engine equipped with a cathead. Pipe is pushed down into the ground and advanced by manually dropping on it a small weight fastened to a line running over a sheave on the derrick to the cathead. The drive point is made from a reducer, which is ground into a bullet shape and attached to the end of the 2-inch pipe. Above the drive point a number of ¼-inch holes are drilled for a distance of 1 to 2 feet. Through the head of the drive point a ½-inch thaw-line pipe projects a maximum of 2 feet. (The ½-in. pipe enlarges to a ¾-in. pipe about 2 ft above its lower end).

A jet of water is pumped through the small thaw line during the drilling operation and passes upward through the perforated end of the 2-inch pipe, bringing fine cuttings to the surface. This line is hung on a simple chain hoist and is slowly moved up and down so that it penetrates the sediments ahead of the drive point. When the thaw pipe is about 2 feet ahead of the drive point, it is retracted, the casing is driven as far as it will go with ease, and the process is then repeated.

Cold water is used in this process, and, according to Ortho Stevens, a driller of Fairbanks, a temperature of about 40°F is the optimum. Jet-drive drilling proceeds about three times as fast in permafrost as in unfrozen ground; one man operating a rig alone will drill, on the average, about 28 feet per day if the holes are 100 feet or less in depth. The maximum Mr. Stevens has drilled alone is 49 feet per day; in early spring drilling, and in places where working conditions were not entirely satisfactory, the footage was as little as 16 feet a day.

This method of drilling obviously has considerable merit; it is inexpensive and quick, requires very light equipment, and, where permeable gravel is present, produces moderate quantities of water. As much as 50 gpm has been obtained with less than 20 feet of drawdown from 2-inch wells equipped with suction pumps.

The disadvantages of the method are that it requires at least 10 or 15 gpm of drilling water, and the drilling becomes rather slow and difficult below a depth of 100 feet, particularly through unfrozen ground. Well construction by this method in other than highly permeable formations, such as those in Fairbanks, might be difficult, although not necessarily much more so than construction of larger diameter open-end wells. The large pebbles common in the Fairbanks area cause only minor difficulties in this type of drilling, for they are pushed aside as room is made for them by removal of fine-grained material. In many places, however, boulders can be a serious obstacle to this method of well construction. Where water levels are low and well diameters are small, only small quantities of water can be pumped; moreover, such wells freeze easily where they penetrate permafrost.

CABLE-TOOL DRILLING

The technique of drilling frozen ground by the cable-tool method is much the same as in unfrozen ground (Cederstrom and others, 1953, p. 15–16). Usually open hole is drilled until the bottom of the permafrost is reached, at which point casing is set. In some places where the hole was drilled dry through the permafrost, sand and water rushed in and filled the hole to the surface.

No difficulty with casing freezing to the walls of the hole has been reported, although presumably this could happen if the frost is thick, and hence very cold, and if there are long periods of idleness between times of advancing the casing. Frozen casing ordinarily will move after a short period of hammering, but sometimes thawing by hot water or steam is necessary. Where the frost is not very cold, there is a distinct tendency for the walls to melt and slough, and hence an open hole in frozen ground cannot be left uncased for more than a few days.

The chisel-shaped placer bit is satisfactory for drilling frozen ground, but wear of the bit on the lower outer edges is particularly rapid in frozen sand, necessitating frequent dressing.

Virtually none of the larger diameter drilled wells ending in sand or gravel are equipped with screens because they have excellent yields with a minimum of development. At the most, the lowest 3 feet of casing is perforated or slotted. It is the writer's opinion that much greater efficiency (higher specific capacity) would be obtained if sand screens were used. Further, successful wells might be completed in places at much shallower depths if sand screens were used and the well developed by surging, backwashing, and heavy pumping. Sand pumping by wells, with its consequent loss of efficiency, also would be minimized or eliminated by screening and development.

Wells tapping old buried beds of sand and stream-laid gravel near the Farmers Loop Road and Steele Creek Road will yield maximum amounts of water at a minimum cost only by using sand screens. Gold-field drilling methods, satisfactory as they are in the gold fields, will produce poor results where a maximum amount of water is to be obtained from a limited thickness of sand or sandy gravel.

A discussion of the techniques of setting screens and developing wells is not properly a part of this report. However, brief mention should be made here of these procedures in order that those who are not acquainted with sand screens and development procedures will have some knowledge of what can be done with a well to obtain water in a difficult location or to increase the yield of a small producer.

In the course of drilling, the casing should not be driven all the way into the water-bearing formation. An effort should be made first to explore the formation by drilling an uncased hole through it. Caving of the walls can be minimized by bailing slowly and keeping the hole muddy and filled to the surface with water. If the hole stands open, a suitable screen with a lead collar at the top can be lowered into the hole and sealed to the casing by tapping lightly with a swedge block.

If the hole does not stand open, the screen may be washed in; or, perhaps preferably, the casing may be driven down to the lowest point at which the screen is to be set, and cleaned out. Then, after the screen is set, the casing is pulled back by means of jacks or a trip spear, to uncover the screen, and the screen is then sealed to the casing.

After the screen is set, development can begin. This consists of removing the finer grained particles from around the screen and building up a stable filter of the larger particles around the screen, both to increase the permeability (and, hence, the effective diameter of the well) and to prevent "sand pumping," or the continual bringing in of fine sand once the well is in operation. Generally, the first step in developing is to pump continuously at a moderate rate to remove the loose fine sand in the immediate vicinity of the screen. Bailing out of sand lodging in the screen must be done carefully to avoid disturbing or damaging the screen. Next, simple "rawhiding" of the well will be sufficient to develop it to maximum capacity in many instances. Rawhiding consists in pumping the well as strongly as possible for short intervals and then shutting off the pump and allowing water in the pump column to flow back down the well. This procedure may be repeated for a matter of hours or even days and is best carried out by means of a turbine pump, although in places use of a suction pump may be successful. During the process of rawhiding, sand may lodge in the screen. If so, this sand must be removed from time to time by very careful bailing.

Where adequate pumping facilities are not available, or if intermittent pumping is not effective in bringing in the fines and increasing the yield, development probably is best done by surging. In this procedure a block just large enough to fit inside the well casing is lowered on rods or small-diameter pipe to some depth below the water level, and then is given an up-and-down pumping action by the drilling machine. This action creates alternate inflow and outflow through the screen and adjacent aquifer formation and movement of the fines. The fines will lodge in the screen and must be removed from time to time by bailing. If a simple flap-type valve is made in the surge block, it will act in part as a pump and may help remove some of the fines.

Development by means of compressed air, which agitates the particles of the aquifer and facilitates bringing in the fines, is a promising method, but it has not been used much in the Fairbanks area because of lack of facilities. Such facilities are becoming more generally available, and perhaps this method is as good as any to try first.

The choice of a screen is extremely important. A suitable screen will have openings of such size as to permit entry into the well (and subsequent removal) of the particles making up the finer grained two-thirds of the aquifer around the well. If the screen openings are too large, complete development may take an excessive amount of time or may not be possible at all, and the well may be ruined by collapse of overlying material. A screen having too small a slot size simply will not allow adequate development (removal of fines), and the yield, in some places, may be smaller than if no screen had been used.

Although the manufacturer ordinarily furnishes a screen according to the samples of the formation submitted to him, he cannot deliver the most suitable screen if the samples are improperly collected. Many times bailing will yield a sample notably finer (rarely coarser) than the formation in place. When this occurs, the person responsible for selecting the samples will have to exercise considerable judgment and perhaps make up what appears to him to be a representative sample of the formation. Samples obtained with a sand pump generally are more truly representative of the formation than are those obtained with a bailer of the dart-valve or similar type.

Details pertaining to the function, use, and selection of screens and to well-development methods have been given in the literature (Bowman, 1911, p. 98; Johnston, 1951, p. 25; Stewart, 1943, p. 25, 48; U.S. War Department, 1943, p. 192; Bennison, 1947, p. 219, 233). Additional information in pamphlet form generally is available from manufacturers of well screens.

The well diameter should be carefully considered in relation to prospective yields. A 6-inch well will not necessarily produce much more water than a 2- or 3-inch well where the formation is poor. However, if a moderate or large amount of water is available, pumping equipment to deliver the water must go down inside the well unless suction lift can be relied upon entirely. A 4-inch well will accommodate a turbine pump yielding not more than a few tens of gallons per minute, whereas a 6-inch well will accommodate a turbine pump capable of delivering several hundred gallons per minute. Wells whose diameter is smaller than 4 inches are ordinarily limited to yields of 10 or 15 gpm where the pumping level is below suction lift.

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BASIC DATA

TABLE 1.—*Records of wells in the city of Fairbanks, Alaska*

Well	Location	Owner	Driller	Depth of well (feet)	Permafrost, in feet		Reported quality of water	Remarks
					Top	Bottom		
1	1854 2d Ave.	Alaska Chemical Co.	Army Engineers	126	27	115	Rusty, hard	Diameter 6 in. Used for cooling. Pumps 100 gpm. (See log, table 5, analysis, table 6.)
2a	Grant St. and 1st Ave.	City of Fairbanks		200				Diameter 24 in. Pumps 1,900 gpm. Elevation 435 ft above sea level. (See analysis, table 6.)
2b	do	do		207				Diameter 24 in. Pumps 1,200 gpm. (See log, table 5.)
3	1319 1st Ave.	J. T. Hutchinson, Sr.	Owner	56			Good	Water level 12 ft below surface; fluctuates 1 ft annually.
5	1229 1st Ave.	E. Johnson	do	25			do	Water reported to be softer when river is high.
7	1115 1st Ave.	H. K. Carlisle		85	None(?)		Rusty	Water became rusty after flood of 1937.
9	1103 1st Ave.	W. Comstock		80+	None(?)			Well has never frozen.
11	917 1st Ave.	Q. Paolini	O. Stevens	27			Rusty, hard	
12	901 1st Ave.	City Library	do	65	15	55		
14	Blanchfield St. and 1st Ave.	Fairview Hotel	O. Fisher	140			Excellent	Good water available also at 72 ft.
16	336 1st Ave.	Mike Mintti		40			Slight iron, hard	
17	Wendell Ave., near Dunkel St.	Mrs. Ringstacy	M. Erceg	25			Slight iron	Diameter 3 in. Pumps 100 gpm. Water chlorinated.
18	217 Wendell Ave.	L. Miller		54			Rusty	
21	129 1st Ave.	Frank Mapleton	O. Stevens	60	20	55		
22	148 Hall St.	W. Knapp	Owner	45			Good	
24	220 1st Ave.	R. Hill		37			Slight iron, hard	
25	313 1st Ave.	O. Jones		65	10	60	Good	
26	325 1st Ave.	R. Gibson		96	10	25	Slight iron, hard	
28	124 2d Ave.	Matanuska Creamery	M. Erceg	82	32	33		Diameter 3 in.
29	136 2d Ave.	J. Melvin		35			Hard	Iron content varies; very high in February and March.
30	202½ 2d Ave.	M. Brown		70+	40	70	Rusty, soft	
32	221 2d Ave.	J. Schultz		48	18 34	28 39		
33	226 2d Ave.	H. Martin	O. Fisher	43	15	35	No rust; hardness variable.	
35	337 2d Ave.	Lonnie Hall	O. Stevens	52	20	50		
38	Turner St. and 2d Ave.	Northern Commercial Co.	Owner	47	(?)	47+	Poor	Tunnel extending under Chena River. Temperature 47°F, Aug. 18, 1947. Water used for boiler feed and condenser; treated before use.

TABLE 1.—*Records of wells in the city of Fairbanks, Alaska*—Continued

Well	Location	Owner	Driller	Depth of well (feet)	Permafrost, in feet		Reported quality of water	Remarks
					Top	Bottom		
39	Turner St. and 2d Ave.	Northern Commercial Co.	Owner	90	(?)	90	Rusty, hard	Supplies part of town. Dug. Yields 700 gpm with 1½ ft of drawdown.
40	823 2d Ave	G. Alexander		28			No iron, hard	Quality varies.
41	909 2d Ave	E. Van Raes	T. Collins	68	22	60	Good	Used to freeze.
42	1021 2d Ave	Russel Hubbard	O. Fisher	50	16	47	No iron, hard	Freezes regularly.
44	1213 2d Ave	Torgerson Bros		22			Rusty, hard	Irrigates tomatoes.
47	1522 3d Ave	Mrs. Adolph Wehner	Owner	76			Fair	
49	1506 3d Ave	A. Lee	do	93	7	37	do	
50	1221 3d Ave	Albert Norlin	do	42	7	17	Rusty, hard	Freezes. Quality was excellent until flood of 1937.
51a	1115 3d Ave	Edby Davis		85±	10	75		
52	210 Bonnifield St	C. Gerahty		60	30	55	Slight iron, hard	
53	1027 3d Ave	William Dunn		25			Excellent	
55	1010 3d Ave	Betty Jane	O. Stevens	28	28		Poor	
59	811 3d Ave	R. Edwards		18			Good	
61	207 Wickersham St	T. L. Lynn		99	36	76	Rusty, hard	Well used to freeze.
64	527 3d Ave	Robert Bloom	Owner	86	6	40	Soft	
66	301 3d Ave	Mrs. E. M. Tucker		87	40	80	Slight iron, hard	
67	304 Hall St	Pioneer Wells		22			Excellent	Sold as bottled water. Dug.
68	153 3d Ave	J. Hurley	O. Fisher	55				No permafrost.
69	116 3d Ave	P. Gibbert	O. Stevens	25	14	18	Good	
70	4th Ave	Miller	do	40	18	35		
71	308 Hall St	Ringstad Beverage Co.	do	18			Excellent	
74	333 4th Ave	F. Bush	O. Fisher	63	30	35	Slight iron, hard	
77	538 4th Ave	Grace Lowe		62	22	40		
78	545 4th Ave	Alaska Native Service	Owner	90				Owner reports permafrost is absent.
80	631 4th Ave	Pfaff Sewing Service	do	89	12	86		
81	632 4th Ave	June Orthman	O. Stevens	84	22	70		Yields 30 gpm to suction pump.
82	648 4th Ave	E. Jones	O. Fisher	70			Good	No permafrost, according to driller.
83	709 4th Ave	Stan Brown	O. Stevens	62	25	57	do	
85	826 4th Ave	Mrs. M. Stone		73	(?)	(?)	Excellent	Not in use: frozen solid.
86	830 4th Ave	Mrs. M. Morgan	O. Fisher	71	42	68	do	
88	831 4th Ave	C. N. Lawson	Owner	40	20	21	Slight iron, hard	
89	1022 4th Ave	L. Krize	do	40	8	30		
93	1415 4th Ave	Steve Stolpher	O. Stephens	100	10	50	Good	Water between 50 and 100 ft is poor.
94	1400 4th Ave	Pauline Goulet	do	70	25	65		Well yields 40 gpm to suction pump.
98	1100 5th Ave	R. Hoopes	O. Stevens	85	20	70		Building destroyed.
101	1009 5th Ave	W. Ward	Owner	60			Slight iron, hard	Owner reports no permafrost.
105	410 Cowles St	T. Loftus	O. Stevens	68	18	65	Excellent	
108	816 5th Ave	Clyde Burkett	Wilbur & Son	60	20	(?)	Rusty	Shallow water very poor.
110	809 5th Ave	E. Anderson	O. Fisher	70	12?	65		
112	501 Barnette St	Kupper Apts	O. Stevens	79	22	75		

113	641 5th Ave	C. Monroe	Owner		16	38	Good	Freezes regularly.
116	641 5th Ave	C. Monroe	O. Stevens	84	16	80		
117	523 7th Ave	Mrs. Nordale	A. Wehner	72	15	70		Clear ice penetrated between 40? and 62 ft, according to driller.
119	413 5th Ave	Muldoon	O. Stevens	80	15	66	Fair	Yields 30 gpm to suction pump.
122	312 5th Ave	Amos Monroe		94	10	60	do	Thin layers of permafrost from 10 to 30 ft, solid permafrost from 30 to 60 ft. Rusty water at 63 ft.
123	211 5th Ave	A. Wicken	Owner	83	6	26	do	Water level at 14 ft.
124	203 5th Ave	Ted Lowe		60	8	20		Well freezes.
125	103 5th Ave	P. Helstrom	Owner	37			Fair	No permafrost.
126	102 5th Ave	J. H. Studdert	do	38			Slight iron, soft	Do.
127	323 6th Ave	Mrs. Kosola	O. Fisher	67	11	62		
128	411 6th Ave	John Erickson	do	73	7½	72	Good	Never freezes.
129	412 6th Ave	M. Muldoon	O. Stevens	55	9	52	Fair	Yields 50 gpm to suction pump.
130	508 Lacey St	Thomas Radovitch	Owner	58	4	55	do	
133	536 6th Ave	D. Bissoff		86	8	80		Freezes regularly.
135	639 6th Ave	C. Niles	O. Fisher	85	15	50		Freezes in summer but not in winter.
136	646 6th Ave	E. Jones	Owner	44	6	36	Rusty	Does not freeze.
137	645 6th Ave	N. Nordin	O. Stevens	85	35?	68?	Rusty, hard	Froze as much as 35 ft in July 1947.
139	703 6th Ave	R. Slater		60	(?)	(?)	do	Froze once after long idleness.
143	833 6th Ave	F. Miller	C. Wehner	35			Excellent	Dug well. Water sold as bottled water.
145	926 6th Ave	C. Howard	O. Fisher	40	10	12	Good	Gravel from 18 to 40 ft.
146	Kellum St. and 6th Ave.	Manley Carr	do	40				No permafrost.
147	601 Bonnifield	S. Stenburg		64	4	24	Good	
148	1307 5th Ave	J. Larsen	O. Stevens	86	24	55	do	Does not freeze.
151	7th Ave			91	27	87		
152	1028 7th Ave	F. Lang	Owner	36	3	36	Fair	
153	1016 7th Ave	F. Ball	O. Stevens	84				No permafrost, according to driller.
155	915 7th Ave	J. Lake	Owner	15			Hard	
156	Cowles St. and 7th Ave.	Patton	O. Stevens	61	18	60		
158	Arctic Village	Federal Housing Authority.		62	(?)	(?)		Water level at 14 ft. Diameter 6 in. Yields 40 gpm with less than 4 ft of drawdown. Water treated and chlorinated.
159	741 7th Ave	O. Furseth	O. Stevens	74	9	70		
160	733 7th Ave	Sam Bulavaski	Owner	42	14	16	Good	Permafrost present in three thin layers.
163	653 7th Ave	Joseph Raats	do	114	40	85	do	Muck above 100 ft, clean quartz sand below. Water at 85 ft has bad odor.
169	541 7th Ave	Mattheson	do	121	22	103		
171	529 7th Ave	S. Hansen	Ivan Thomas	204	14	100		
174	511 7th Ave	Mrs. E. R. Farrell	do	110			Excellent	Freezes regularly.
175	612 Lacey St	J. Dallas		128				Freezes as much as 12 ft below surface.
177	313 7th Ave	Elsie McDowell	Ivan Thomas	85	13	80	Excellent	Yields 30 gpm to suction pump.
181	121 8th Ave	Jack LaCross	O. Fisher	50	15	20	do	
183	8th Ave. near Noble St.		do	107	11	102		
184	300 8th Ave	Foster	do	91	13	68		
188	531 8th Ave	H. E. Pratt	do	163	20	150		

TABLE 1.—*Records of wells in the city of Fairbanks, Alaska*—Continued

Well	Location	Owner	Driller	Depth of well (feet)	Permafrost, in feet		Reported quality of water	Remarks
					Top	Bottom		
189	543 8th Ave.	Robert Hoopes	O. Stevens	144	15	140		
191	Turner St. and 8th Ave.	School	do.	150	4	90		
194	688 8th Ave.	M. Thomas	do.	94	23	90	Hard	Freezes frequently in summer, less often in winter.
199	785 8th Ave.	A. Simpson	do.	56	18	54	Good	Well freezes.
201	815 8th Ave.	C. West	do.	111			do.	No permafrost present.
203	Cowles St., near 8th Ave.	Crystal Well		35			Excellent	Sold as bottled water. Well is dug.
207	1002 8th Ave.	A. W. Conradt	O. Fisher	60				No permafrost.
210	9th Ave., west of Smythe St.	Denali Apts.	Federal Housing Authority.	103	10?	110?		Yields 15 gpm with slight drawdown. Well is 6 in. across.
211	1016 West 9th Ave.	Bockner	O. Stevens	56	25	40		Yields 50 gpm to suction pump.
212	902 Kellum St.	O. White	do.	110	55	70	Good	Well has frozen.
213	903 Kellum St.	Bishop William Gordon		54			Rusty, hard	
216	829 9th Ave.	R. Persinger	Ivan Thomas	134			Good	No permafrost.
217	812 Smythe St.	L. J. Strandberg	Owner	50			Rusty, hard	Do.
218	808 Smythe St.	Norman Benson	O. Stevens	108	12	90		
219	804 Smythe St.	Warren Tilman	do.	108	9	75	Fair	"Black water" from zone containing logs at 90 ft.
223	East 9th Ave.	Leo Solburg	do.	132	16	130		
224	723 9th Ave.	Ed Hoch	O. Fisher	151	20	145	Fair	Supplies five homes. Never freezes.
227	685 9th Ave.	Paul Stryken	do.	156	7	150	Good	
228	654 9th Ave.	Alvin E. Rank	Ivan Thomas	175	33	165	do.	Water soft and rusty at first, but has changed to clear and hard.
230	621 9th Ave.	H. P. Karstens	Owner	42	26	28	Slight iron, hard	Quality of water varies.
231	613 9th Ave.	F. Nigro	O. Fisher	151	12	149		Freezes regularly.
234	513 9th Ave.	C. L. Lindberg	Ivan Thomas	85	5	78	Excellent	Do.
235	404 9th Ave.	M. Luther	O. Stevens	151	9	145	Hard, good	Do.
237	210 10th Ave.	E. Krize	do.	110	38	98		
240	1003 Noble St.	H. Criger	do.	124	12	120		Permafrost also present at 6 ft near by.
243	537 10th Ave.	R. Voight	Owner	160	4	155	Rusty	Took water for 3 hr at 70 ft during driving. Well supplies nine families.
250	803 East 9th Ave.	Star Airlines	do.	170	5	168		
251	Weeks Field	Old P.A.A. Hangar		180	30	170		Abandoned.
253	Old C.A.A. Station	O. Stevens		141	9	140		Building destroyed; well not in use.
255	541 11th Ave.	O. Koon	Owner	160	19	150	Slight iron, hard	Seldom freezes.
259	1003 Noble St.	H. Kriger	do.	144	7	143		
260	10th Ave., near Chena River.	Independent Lumber Co.	O. Fisher	40			Rusty	

262		A.C.S. Garage	Army Engineers	119	21 80 91	71 86 104		
263	11th Ave. and Noble St.	City Hall Annex	Federal Housing Authority.	168				Diameter 6 in. Yields 30 gpm with 3 ft of drawdown. Formerly Cheechako Hotel.
266	1113 Lacey St	Singer Sewing Machine Co.	do	176	20	170	Rusty, hard	
269	537 12th Ave	Eugene Rogge	do	179	29	155	Fair	
274	1221 Noble St	T. Wilson	Ivan Thomas	177	4	177+		Dry. Abandoned.
275	1401 Cushman St	G. Crouch		174	15	163	Good	
276	1400 Cushman St	Cy Grantham		27			do	Water level 12 ft below surface.
277	1508 Cushman St	Harry Sams		46			Hard	Diameter 4 in.
282	1550 Gillam Way	Alaska Road Commission Apts.	O. Stevens	249	11	238		
283	1613 Gillam Way	Santa's Bake Shop	Beaver Mining Co.	243	18	243		Clear ice penetrated at 200-209 ft.
284	635 17th Ave	Ralph DeLong	O. Stevens	178	20	178		
285	1811 Mary Ann St	Anderson Apts	Beaver Mining Co.	182	22	182		

TABLE 2.—*Records of wells on the Tanana River flood plain in the Fairbanks-College area, Alaska*

Well	Location	Owner	Driller	Depth of well (feet)	Permafrost, in feet		Reported quality of water	Remarks
					Top	Bottom		
301	Pennsylvania St., Garden Island.	United States Smelting, Refining & Mining Co.	Owner	90	20?	45?		"Townsite" well. Diameter 36 in. Pump capacity 250 gpm.
302	Pennsylvania St., Slaterville.	do.	do.	40+				Dug, 75 ft by 60 ft. Yields 800 gpm with 30(?) ft drawdown. See analysis, table 6.
303	do.	do.	do.	106				Abandoned. Diameter 16 in. Yielded 2,900 gpm with 9.8 ft of drawdown after 32 days.
304	do.	do.	do.	90				Reported yield is 2,800 gpm. Temperature 34°F.
305	Near Charles St., Slaterville.	do.	do.	90				Diameter 36 in. Reported yield 2,800 gpm
306	Church and Minnie Sts., Slaterville.	do.	do.	364				Abandoned. Diameter 36 in. Yielded 2,800 gpm with 22 ft of drawdown.
307	Church and Slater Sts., Slaterville.	do.	do.	90				Diameter 24 in. Yield 2,400 gpm. See analysis, table 6.
308	do.	do.	do.	136	22	26		Abandoned. Yielded 3,400 gpm with 5.7 ft of drawdown in a 22-hr test. Water level 11 ft below surface.
310	Charles St., Slaterville.	R. Johnson	O. Stevens	51	12	49		
312	314 Slater St., Slaterville.	E. L. Morse		22½			Excellent	Not affected by pumping adjacent well 307.
313	Pennsylvania St., Garden Island.	Standard Oil Co.	O. Stevens	40				No permafrost.
314	do.	Alaska Road Commission.	A. McLeod	95	60	70	Hard	
315	110 Church St., Slaterville.	J. Borders		28			Good	Quality is deteriorating.
316	Cushman St., Garden Island.	St. Josephs Hospital	E. Kehoughl	60			Poor	Water treated for laundry use. See analysis, table 6.
317	Park St., Garden Island.	Glen Carrington		21			Excellent	
318	Along Chena River, Garden Island.	Pioneer Brewing Co.	O. Stevens	108				No permafrost.
319	do.	O. Baumeister		90	26	26½	Fair	
320	do.	The Alaska Railroad		23			Rusty, hard	Dug well. Furnishes 20,000 gpd. See analysis, table 6.
321	do.	do.	M. Butler	70				Diameter 8 in. Slotted at 24–28, 34–40, and 67½–70 ft. Yields 600 gpm. See analysis, table 6.
322	3d St. and Fortymile Ave., Graehl.	T. Jones		75	35	70	Slight iron	

323	3d St. east of Eagle Ave., Graehl.	D. Wilder	O. Fisher and O. Stevens	74	9	73		
324	Pratt Ave. and Front St., Graehl.	J. Stanley	do	70	12	60	Good	Temperature 32¼°F (measured). See analysis, table 6.
325	2d St. and Eagle Ave., Graehl.	M. Killian		30	18	30	do	
326	Dawson Ave., near Front St., Graehl.	B. W. Kelley	Owner	20			do	
327	Front St. and Fortymile Ave., Graehl.	J. Stahler		35			Rusty	
328	Mile 1, Steese Highway.	D. Polk		28	12 20	13 21	Rusty, hard	
329	Three-fourths mile northeast of Fairbanks.	Bentleys Dairy		65+	(?)	65	Fair	Supplied dairy of 60 cows.
330	Steese Highway, south of railroad.	J. Kunkel	O. Stevens	65	13	30		
331a	Steese Highway, north of railroad.	North Camp	do	100	17	97		
331b	do	do	Army Engineers	228	18	98½		Abandoned. Failed to develop water. Schist(?) at 158½ ft. See log, table 5.
332	do	J. Gunning	Beaver Mining Co.	61	3–59			Water from gravel. Yields 30 gpm. Water level 15 ft below surface.
333	do	Farmers Cooperative storage plant.	O. Stevens	100	9	85		
334	do	Magnus Marks	do	82	6	78		
335a	do	Creamers Dairy		154	38	152		Dry. Abandoned. Seepage reported at 98 ft.
335b	Ester Road, 1 mile north of Fairbanks.	do		18			Hard	Dug. Yields 15 gpm; maximum of 1,500 gpd.
335c	do	do		84	38	64	Rusty	Abandoned.
336	Ester Road and Noyes Slough.	P. J. McDonald	O. Fisher	144	16	144+	High iron	"Bedrock" reported at 129 ft; water level 8 ft.
337	do	H. Morgan		21	21		Poor	
338	Ester Road, one-half mile east of College.	A.C.S.K.-1	Army Engineers	30	0	9½		Diameter 4 in. Yields 75 gpm with ½ ft of drawdown.
339	do	do	do	342				No permafrost reported. See log, table 5.
341	do	do	do	90	3	62		Abandoned.
342	do	do	do	100	15	84		Do.
343	Ester Road in College.	James Ryan		150	1	80		
344	One-half mile east of College.	Soil Conservation Service.	M. Butler	221	15	110		Well ends in sandy(?) muck. Water level 15 ft. Yields 2½ gpm with 135 ft of drawdown.
345	Deborah Ave., College.	Jameson		16	8	16	Slight iron	
346	do	Mockler		126	2	120	Rusty	
347	University Ave., College.	Quonset Huts	M. Erceg	90	2	90		Dry.
348	do	H. Halvorsen	Owner	23			Excellent	Depth to water 18 ft.

TABLE 3.—*Records of wells on the slopes north of Fairbanks, Alaska.*

Well	Location	Owner	Driller	Elevation (feet)	Depth (feet)	Diameter (inches)	Depth to bedrock (feet)	Water level (feet)	Remarks
350	University of Alaska	University of Alaska		480				−20	See text.
351	do	Coast and Geodetic Survey.	Delong Engineering and Construction Co.	620	310	6	80	−153	Yield small, from quartz veins at 196 and 247 ft.
352	Ester Road, west of College.	Department of Agriculture Experimental Farm.	J. Leland	500	104	6	74	−39	Yield small.
353	Happy Road	J. Lawlor	A. Anderson	714	245	6	30	−140	Sloughed at 171 ft.
354	do	M. Yankovich	do	644	203	4	137	−80	Yields 3 gpm.
356	Farmers Loop Road	Radio Station KFAR		460	358(?) 275				Reported quality poor.
357	do	C. Fowler	Beaver Mining Co	520	174	6	169	−47	U.S. Geological Survey test well 6. Yields 2½ gpm with 7 ft of drawdown.
358	do	G. Monroe	G. Monroe	527	136	6	88		
359	do	C. Johnson	M. Erceg	530	200	6	200(?)	−15	Ground frozen from 12 to 92 ft.
360	Off Farmers Loop Road.	S. Kerner	E. McClure	731	120		26?		Reported yield 5 gpm.
361	Farmers Loop Road	Creamer Tract	G. C. Tibbitts, Jr	620	184	3	183		U.S. Geological Survey test well 14.
362	Off Farmers Loop Road.	J. R. Cox farm	do	682	179	4–3		−40	U.S. Geological Survey test well 15. See log, table 3.
363a	do	Atwell Tract		560	340	6	250	−30	10 gpm from schist.
363b	do	do		580	200	6	132	+	Flow from schist 1 gpm.
363c	do	do		585	156	6	127	+	Flow from schist 2 gpm.
364	do	C. Sherman	A. Schott	540	163	2	160	+	Flows 1½ gpm.
365	Farmers Loop Road.	A. Husac	Beaver Mining Co	580	57	4		−26	U.S. Geological Survey test well 8. Silt, 0–38; muck 38–57.
366	Off McGrath Road	T. Lowell	E. McClure	854	200	2	0	−115	Yields 1 gpm.
367	do	Clegg Tract	Beaver Mining Co	711	130	4	128½	−89	U.S. Geological Survey test well 5. Yielded 5 gpm with 2 ft of drawdown. Casing at 112 ft.
368	do	E. A. Arant	E. McClure	591	307	2	280(?)	+	Flows 3 gpm.
369	McGrath Road	C. McGrath	Beaver Mining Co	736	143	4	140	−20	U.S. Geological Survey test well 3.
370	Off McGrath Road	do	do	710	124½	6–4		+8	U.S. Geological Survey test well 4. Used as observation well. Yields 7½ gpm with 35 ft of drawdown.
371	McGrath Road	do	do	737	82	4			U.S. Geological Survey test well 2. No permafrost. Pipe kinked; abandoned.
372	do	do	do	760	85	4	75	−64	U.S. Geological Survey test well 1. With casing at 67 ft yielded 2 gpm with 6 ft of drawdown.

373	Steese Highway	M. Bushey	G. C. Tibbitts, Jr.	788	108	3-2	103	+7.1	U.S. Geological Survey test well 13. Flow 5 gpm at 4 ft above surface.
374	Steele Creek Road	S. Stowell	E. McClure	1,050	280	2	2	−244	Yields ½ gpm.
375	do	Sherman Tract		1,055	145	6-4		−56½	U.S. Geological Survey test well 9. Yields 4.2 gpm with 29 ft of drawdown from sand at 105-112 ft.
376	Chena Cutoff	J. Jennings	D. Joesting	850	144	4	82	−132	Yields about 1 gpm.
377	Steele Creek Road	V. Patrick	V. Patrick	673	12	36	3	−10	Dug well. Yields 5 gpm.
378	do	R. G. Fritz	R. G. Fritz	770	70	36	39	Dry	
379	Off Steele Creek Road.	Maranatha Childrens Home.		738	130	6-5		−80	Water from gravel. Supplies 26 persons and laundry.
380	Steele Creek Road	Dr. Lundquist		587	165	¾		−7	Penetrated black muck, then gravel.
381	Off Steele Creek Road	C. Herning	G. Sample	771	165	4	60	−133	Yields 6½ gpm.
382	do	W. Eberhardt	do	788	289	4	5	−249	Yield small.
383	do	H. Herning	do	725	252	4	90	−162	Yields 6 gpm with 38 ft of drawdown.
384	do	F. Stubbins	do	748	150	4	35	−130	Yields about 6 gpm.
385	Steele Creek Road	J. Brockman	C. Herning	608	86	2	80	+	Jetted well. Frozen from 15 to 67 ft.
386	Chena Hot Springs Road.	C. R. Kivlehn	C. R. Kivlehn	634	149	2		+5	Flows 2 gpm.
387	Off Chena Hot Springs Road.	Spears Tract		676	208 (?)	6	150		Abandoned.
388	do	do		592	215½	6	205½	+	Flows 27 gpm. Water from schist.
389	Chena Hot Springs Road.	L. Loud	M. Butler	650	170	6	130	−25	Good water.
390	Chena Cutoff	O. Farkas	E. McClure	725	107	2½	52	−80	Flows 2 gpm.
391	Chena Hot Springs Road.	Mutchler Tract	G. C. Tibbitts, Jr.	745	112	3	54	Dry	U.S. Geological Survey test well 11.
392	Chena Hot Springs Road and Steese Highway.	Dave Mutchler	do	700	100+	3	83½	−56	U.S. Geological Survey test well 12. Yields 2½ gpm with 20 ft of drawdown.
393	Steese Highway		M. Butler	790	160	6	60	−120	Reported yield 23 gpm.
394	do	J. Nerland	do	570	201	4		−49	Reported yield 5 gpm.
395	do		do	680	148 (?)	6	40	−100	Reported yield 11 gpm.
396	Farmers Loop Road	Old Fox Farm	O. Fisher	480	126	2		+10	Frozen from 5 to 113 ft.
397	do	Army Permafrost Experimental Station.		490	268	4 (?)	268	+ (?)	Frozen from 2 to 176 ft.
398	do	do		520	108	4		+10 (?)	Frozen from 2 to 108 ft. Flows 40 gpm. Water from coarse sand in muck.
399	do	do	Beaver Mining Co.	600	91	4	86½	−70 (?)	U.S. Geological Survey test well 10. Frozen to 47 ft.

TABLE 4.—*Records of wells at Ladd Air Force Base, Alaska*

Well	Building	Depth of well (feet)	Diameter (inches)	Permafrost, in feet		Yield (gallons per minute)	Drawdown (feet)	Remarks
				Top	Bottom			
449	617	178	6	67	153	--------	--------	Water level 10 ft.
450	646	113	8	--------	105	450	7	Duration of pumping test 5 hr.
451	350	30	--------	--------	--------	780	7	Large dug well.
452	305	100	6	--------	--------	120	21	
454	365	106	4	13 43 65	35 47 73	--------	--------	See log, table 5.
456	384	160	8	--------	--------	515	--------	
457	384	148	2	24	42	--------	--------	Used as Geological Survey observation well. Drilled by O. Fisher.
458	285	172	--------	--------	52	160	18	
459	282	88	6	10	62	230	4	Duration of pumping test 6 hr.
460	264	180	4	4	34	--------	--------	
461	117	112	24	--------	--------	500	--------	
462	105	204	18	14	82	1,500	9	Duration of pumping test 24 hr. Well finished with 20 ft of 80-slot screen.
463	Between 136A and 140A.	80	6	--------	47	280	12½	Duration of pumping test ½ hr.
464	140A	315	4	0	36	--------	--------	See log, table 5.
465	142	105?	24	--------	--------	780	--------	
466	116	45	4	--------	--------	--------	--------	See analysis, table 6.
467	164	40	2	--------	--------	--------	--------	See analysis, table 6.
469	933	44	6	--------	31	240	13	Duration of pumping test 32 hr.
470	Zone 900	87	6	0 49	23 57	200	17½	Duration of pumping test 14 hr.
471	902	55	6	--------	--------	220	6½	Duration of pumping test 8 hr.

TABLE 5.—*Logs of wells in the Fairbanks area, Alaska*

	Thickness (feet)	Depth (feet)
Well 1		
[Half a mile west of Fairbanks; Alaska Chemical Co. Altitude 430 ft. Log by U.S. Army]		
Unfrozen: Sand and gravel	27	27
Frozen:		
Sand and gravel	79	106
Sand and gravel; ice	1	107
Sand and gravel	3	110
Sand; ice	1	111
Sand and gravel	5	116
Unfrozen:		
Sand and gravel	6	122
Sand and medium gravel	4	126
Well 2b		
[Fairbanks; Municipal waterworks. Altitude 434 ft]		
Excavated ground	31	31
Unfrozen: Sand and gravel	15	46
Frozen: Sand and gravel	14	60
Unfrozen:		
Sand and gravel; water	9	69
Fine gravel	5	74
Sand and gravel	10	84
Coarse(?) sand	3	87
Sand; water	12	99
Coarse sand and coarse gravel	2	101
Sand and gravel	3	104
Gravel	4	108
Pea gravel and sand; water	5	113
Sand and gravel	4	117
Sand and gravel; water	7	124
Clear (clean?) medium gravel	2	126
Sand	4	130
Sand and gravel; water	2	132
Sand and gravel	2	134
Coarse sand and little gravel	3	137
Pure sand, well-sorted, medium?	12	149
Sand and gravel; water	2	151
Sand; water	7	158
Fine sand	4	162
Sand and gravel; water	5	167
Sand	6	173
Fine gravel	3	176
Sand	1	177
Coarse sand	4	181
Pea gravel	9	190
Coarse sand	2	192
Quicksand	13	205
Sand	2	207

NOTE.—Intervals from 104 to 137 ft and from 176 to 192 ft designated as "good" on graphic log furnished the writer. Casing was probably perforated in these depth ranges.

TABLE 5.—*Logs of wells in the Fairbanks area, Alaska*—Continued

	Thickness (feet)	Depth (feet)
Well 114		
[629 5th Ave., M.P. Station; Fairbanks. Altitude 440 ft. Log by U.S. Army]		
Fill	1	1
Frozen:		
Sand and muck	15	16
Sand and some fine gravel	8	24
Sand	3	27
Sand and some gravel	8	35
Unfrozen:		
Sand and gravel	5	40
Sand and some gravel	12	52
Sand and some medium gravel	8	60
Sand and gravel	11	71
Sand and fine gravel	13	84
Sand and medium gravel	13	97
Sand and fine gravel	28	125
Sand	44	169
Sand and some gravel	2	171
Sand	25	196
Muck	6	202
Sand	7	209
Sand and some gravel	4	213
Sand and coarse-medium gravel	6	219
Sand	21	240
Sand and gravel	4	244
Well 235		
[404 9th Ave., Fairbanks; John Kupper. Altitude 440 ft. Log by Ortho Stevens]		
Unfrozen: Muck	9	9
Frozen:		
Muck	7	16
Sand	13	29
Coarse gravel	11	40
Gravel	7	47
Coarse gravel	4	51
Sand	10	61
Coarse gravel	3	64
Gravel	3	67
Coarse gravel	4	71
Sand	3	73
Coarse gravel	7	80
Gravel	3	83
Sand	21	104
Gravel	4	108
Coarse gravel	3	111
Gravel	4	115
Sand	29	144
Unfrozen: Gravel; water	7	151

NOTE.—Jet driller's log.

TABLE 5.—*Logs of wells in the Fairbanks area, Alaska*—Continued

	Thickness (feet)	Depth (feet)
Well 262		
[ACS garage, Fairbanks. Log by U.S. Army]		
Unfrozen: Sand	21	21
Frozen:		
Sand and gravel	8	29
Sand and medium gravel	30	59
Sand and gravel	12	71
Unfrozen: Sand and medium gravel	9	80
Frozen: Sand and medium gravel	6	86
Unfrozen: Sand and medium gravel	5	91
Frozen: Sand and medium gravel	13	104
Unfrozen:		
Sand and some gravel	2	106
Sand	3	109
Sand and gravel	3	112
Sand and fine gravel	2	114
Sand and medium gravel	2	116
Coarse gravel	1	117
Medium gravel	2	119
Well 331b		
[Steese Highway and Alaska Railroad, Fairbanks; North Camp. Altitude 440 ft. Log by U.S. Army]		
Unfrozen: Sand	18	18
Frozen: Sand; some wood at 34½ ft and some mud at 61 ft	80½	98½
Unfrozen:		
Fine hard sand; with a little water-bearing coarse gravel at 132 ft	60	158½
Green clay	3	161½
Yellow clay and mica	28	189½
Yellow clay	17½	207
Green clay	8	215
Rock	1½	216½
Dark clay	11½	228

NOTE.—The formations between 158½ and 228 ft probably weathered Birch Creek schist.

TABLE 5.—*Logs of wells in the Fairbanks area, Alaska*—Continued

	Thickness (feet)	Depth (feet)
Well 339		
[Ester Road, half a mile east of College; ACS Station. Altitude 440 ft. Log by U.S. Army]		
Open gravel fill	4	4
Unfrozen:		
Sand and muck	10	14
Sand and gravel	24	38
Sand and medium gravel	3	41
Sand and gravel	15	56
Sand	12	68
Sand and gravel	9	77
Fine sand and medium gravel	2	79
Sand and fine gravel	2	81
Sand and medium-coarse gravel	3	84
Sand	19	103
Sand; some coarse and pea gravel	2	105
Sand	11	116
Sand and muck	3	119
Muck	21	140
Muck and some sand	5	145
Sand	21	166
Sand and fine gravel	6	172
Sand and muck	32	204
Sand	5	209
Fine sand and medium gravel	3	212
Fine sand, medium gravel, and muck	2	214
Sand and fine gravel	10	224
Sand and muck	10	234
Muck	8	242
Sand and wood	2	244
Sand, some fine gravel, and muck	3	247
Sand	15	262
Sand and muck	9	271
Sand	9	280
Muck and some sand	7	287
Sand	7	294
Muck and sand	4	298
Sand	9	307
Granite sand	5	312
Granite sand and muck	1	313
Granite sand	4	317
Sand and muck	1	318
Sand	8	326
Sand	9	335
Sand and bedrock fragments	4	339
Sand	3	342

TABLE 5.—*Logs of wells in the Fairbanks area, Alaska*—Continued

Well 357

[1½ miles north of College Farmers Loop Road; C. Fowler. Altitude 520 ft. Log by E. G. Otton]

	Thickness (feet)	Depth (feet)
Unfrozen:		
Silt, grayish-buff	15	15
Muck, black (water in hole at 20 ft)	7	22
Frozen:		
Muck; ice crystals	8	30
Dark-gray silt	55	85
Silt and a few fragments of plant debris	10	95
Unfrozen:		
Gray-black silt and wood fragments	65	160
Gray silt	9	169
Dark-gray silt; rock fragments consisting of angular pieces of dark schist and white opaque quartz	1	170
Rock	4	174

NOTE.—U.S. Geological Survey test hole 6.

Well 361

[4 miles north of Fairbanks (sec. 22) Farmers Loop Road; Creamer tract. Altitude 620 ft. Log by G. C. Tibbitts, Jr.]

	Thickness (feet)	Depth (feet)
Tan silt	36½	36½
Dark-gray silt with abundant wood fragments	88½	125
Tan silt; micaceous below 173 ft	58	183
Birch Creek schist	1	184

NOTE.—U.S. Geological Survey test hole 14.

Well 362

[4 miles north of Fairbanks (sec. 23). Farmers Loop Road; J. R. Cox farm. Altitude 682 ft. Log by G. C. Tibbitts, Jr.]

	Thickness (feet)	Depth (feet)
Light-tan silt	17	17
Gray silt	82	99
Gray silt with mica flakes and some sand	3	102
Coarse sand with little silt	7	109
Gray silt	28½	137½
Black and white medium sand	2	139½
Medium to coarse iron-stained quartz sand with abundant schist fragments; water(?)	2½	142
Silt	1	143
Medium-coarse iron-stained quartz sand with abundant schist fragments; water	19	162
Fine sand	2½	164½
Gray silt	13½	178
Fine iron-stained quartz sand	1	179

NOTE.—U.S. Geological Survey test well 15.

TABLE 5.—*Logs of wells in the Fairbanks area, Alaska*—Continued

Well 363a

[3½ miles north of Fairbanks (sec. 26) off Farmers Loop Road; Atwell tract. Altitude 560 ft]

	Thickness (feet)	Depth (feet)
Silt	248	248
Sandy gravel; water	2	250
Schist	90	340

Well 363b

[3½ miles north of Fairbanks (sec. 26) off Farmers Loop Road; Atwell tract. Altitude 580 ft]

	Thickness (feet)	Depth (feet)
Silt	132	132
Silt mixed with fragments of schist	18	150
Schist; water below 165 ft	50	200

NOTE.—Frozen between 19 and 60 ft. (Material between 132 and 150 ft is probably weathered schist)

Well 363c

[3½miles north of Fairbanks (sec. 26) off Farmers Loop Road; Atwell tract. Altitude 585 ft]

	Thickness (feet)	Depth (feet)
Silt	127	127
Sandy gravel; water	8	135
Schist; water	21	156

NOTE.—Casing extends to 147 ft. Blasted at 152 ft.

Well 366

[4 miles north-northeast of Fairbanks (sec. 23) off McGrath Cutoff; Ted Lowell. Altitude 854 ft. Log by Earl McClure]

	Thickness (feet)	Depth (feet)
Schist and clay	23	23
Yellow clay; stands well	52	75
Hard schist	5	80
Schist and yellow clay	10	90
Loose rock, difficult to keep hole straight	20	110
Yellow clay	25	135
Rock and clay; caves badly, necessary to case	10	145
Schist rock and quartz veins	45	190
Hard schist; water	6	196

TABLE 5.—*Logs of wells in the Fairbanks area, Alaska*—Continued

Well 367

[4 miles north-northeast of Fairbanks (sec. 24) McGrath Cutoff; Clegg tract. Altitude 711 ft. Log by D. J. Cederstrom and E. G. Otton]

	Thickness (feet)	Depth (feet)
Tan silt	78	78
Gray-brown sandy silt with some angular schist fragments	2	80
Same as above with pebbles as much as 3 in. across	4	84
Gray-brown sandy silt with some small rock fragments	14	98
Brown stiff clay with much grit	4	102
Gritty clay, buff-gray	4	106
Brown silt	3	109
Very tough gray clay	9	118
Silty gray sand	5	123
Yellow clay	2	125
Gray silt and yellow clay	3½	128½
Schist bedrock	1½	130

NOTE.—U.S. Geological Survey test hole 5.

Well 369

[1 mile west of Steese Highway on McGrath Cutoff; McGrath tract. Altitude 736 ft. Log by D. J. Cederstrom]

	Thickness (feet)	Depth (feet)
Chocolate-brown silt	12	12
Brown silt with fragments of schist; seep at 30 ft	34	46
Brown silt with many schist fragments	11	55
Yellow clay with fewer schist fragments as much as 3½ in. across	33	88
Red-brown medium schist sand	11	99
Red-brown schist sand; water	8	107
Red-brown sand with schist fragments	1	108
Brown well-sorted medium sand	4	112
Red-brown medium coarse sand; water	3	115
Fine brown sand	2	117
Sand with many coarse angular fragments	3	120
Fine brown sand; slow drilling	1	121
Medium-brown sand becoming coarser, with large angular fragments at 125 ft. At 127 ft excellent medium sand but very little water	4½	125½
Coarse yellow quartz sand with quartz and slaty schist fragments and moderate fines; water	5	130½
Medium red-brown sand becoming coarser; larger fragments at 132 ft; water(?)	4	134½
Coarse yellow gravelly sand; formation is loose; casing bails down without drilling; water	1½	136
Blue clay with blue schist fragments	½	136½
Coarse gray quartz sand with some gravel; water	1½	138
Dark medium-coarse quartz sand; water	2	140
Rock	1½	141½
Dark medium-coarse quartz sand alternating with rock; water	1½	143

NOTE.—U.S. Geological Survey test hole 3.

TABLE 5.—*Logs of wells in the Fairbanks area, Alaska*—Continued

Well 370

[1 mile west of Steese Highway below McGrath Cutoff; McGrath tract. Altitude 710 ft. Log by D. J. Cederstrom and E. G. Otton]

	Thickness (feet)	Depth (feet)
Unfrozen: Black muck	15	15
Frozen: Black muck	13	28
Unfrozen:		
Jet black muck	12	40
Black silt; gray when dry	18	58
Gray silt with fine gravel	1	59
Gray sand, becoming coarser with depth	10	69
Brown clay	13	82
Silty brown clay grading down to coarse sand and gravel	41	123
Gravelly (schist) sand; water	1½	124½

NOTE.—U.S. Geological survey test hole 4. Well drilled in frost hummock below road. Used as observation well.

Well 372

[One-half mile west of Steese Highway, McGrath Cutoff; McGrath tract. Log by D. J. Cederstrom]

	Thickness (feet)	Depth (feet)
Chocolate-brown silt	35	35
Gummy bright yellow silt with schist fragments	12	47
More clayey silt with schist fragments (weathered schist?)	5	52
Clayey silt with increasing schist fragments (weathered schist?)	23	75
Coarse fragments with much less clay (probably weathered schist); water	8	83
Schist bedrock, unaltered	2	85

NOTE.—U.S. Geological Survey test hole 1.

Well 373

[Steese Highway, three-fourths mile north of junction with Steele Creek Road; M. Bushey. Altitude 808 ft. Log by G. C. Tibbitts, Jr.]

	Thickness (feet)	Depth (feet)
Unfrozen: Fill	2	2
Frozen:		
Muck	5	7
Muck with abundant wood chips	88	95
Tree trunk	1	96
Unfrozen:		
Brown quartz sand and small schist fragments	4	100
Schist fragments	3	103
Yellow schist; water	5	108

NOTE.—U.S. Geological Survey test hole 13.

TABLE 5.—*Logs of wells in the Fairbanks area, Alaska*—Continued

	Thickness (feet)	Depth (feet)
Well 374		
[Steele Creek Road, 1 mile north of junction with Steese Highway; Stanley Stowell. Altitude 1,050 ft Log by Earl McClure]		
Soil	2	2
Yellow clay and schist	28	30
Yellow clay and schist rock with quartz veinlets; harder	15	45
Dark-yellow clay and soft schist	5	50
Yellow clay and schist	110	160
Dark clay and caving rock; hole cased to 190 ft	19	179
Micaceous schist	83	262
Schist; water	3	265
Yellow clay and schist	15	280
Well 375		
[Steele Creek Road, 1 mile north of junction with Steese Highway; C. Sherman tract. Altitude 1,055 ft. Log by D. J. Cederstrom]		
Tan silt	11	11
Yellow silt with small schist fragments	16	27
Light-brown sandy silt	6	33
Tan to yellow silt	36	69
Coarse brown sand; water	2	71
Sandy silt	14	85
Tan silt	4	89
Sandy silt	4	93
Coarse brown sand	2	95
Very coarse brown sand; water	1	96
Fine brown sand	9	105
Fine to coarse brown sand; water	7	112
Fine brown sand	3	115
Medium-coarse sand	2	117
Fine sand	3	120
Coarse sand; water	5½	125½
Fine sand	3½	129
Weathered sandy schist; cuttings brought up by bailer are sand with numerous large schist fragments	16	145

NOTE.—U.S. Geological Survey test hole 9. Schist fragments in most of silt and sand between 7½ and 129 ft, as large as 1 in. across, but ordinarily ¼ to ½ in. across. (See fig. 3.) Most of the material appeared to be frozen except for the water-bearing coarse sands. Below 129 ft, the weathered rock material may also have been frozen except for a heaving sand between 132½ and 135 ft.

	Thickness (feet)	Depth (feet)
Well 387		
[South of Chena Hot Springs Road, one-third mile east of Columbia Creek; Spears tract. Altitude 676 ft]		
Silt	150	150
Silt mixed with fragments of schist (weathered schist?)	7	157
Schist	46	203

TABLE 5.—*Logs of wells in the Fairbanks area, Alaska*—Continued

Well 388

[South of Chena Hot Springs Road, one-fourth mile east of Columbia Creek; Spears tract. Altitude 592 ft]

	Thickness (feet)	Depth (feet)
Silt; frozen to 102 ft	150	150
Pea gravel with subordinate rock fragments and silt; water; flow 2 gpm	5	155
Silt	35	190
Gravel mixed with silt	10	200
Sandy gravel; water	5	205
Schist; water	10½	215½

NOTE.—Cased to 209 ft.

Well 391

[Chena Hot Springs Road, one-fourth mile east of Steese Highway; Mutchler tract. Altitude 745 ft. Log by G. C. Tibbitts, Jr.]

	Thickness (feet)	Depth (feet)
Soil	2	2
Brown silt	26	28
Yellow silt	26	54
Soft schist	11	65
Harder schist; quartz veinlets at 65, 74, 92, and 111½ ft; water seep(?)	47	112

NOTE.—U.S. Geological Survey test hole 11. Jetted.

Well 392

[Chena Hot Springs Road and Steese Highway; Mutchler tract. Altitude 700 ft. Log by G. C. Tibbitts, Jr.]

	Thickness (feet)	Depth (feet)
Soil	1	1
Dark-brown silt	82½	83½
Soft schist; water	5½	89
Hard schist	11	100

NOTE.—U.S. Geological Survey test hole 12. Jetted.

Well 399

[Steese Highway; U.S. Army Permafrost Experimental Station. Altitude 600(?) ft Log by J. E. Kerr]

	Thickness (feet)	Depth (feet)
Unfrozen: Soil	1	1
Frozen:		
Gray silt	11	12
Muck	35	47
Unfrozen:		
Muck	31	78
Sandy muck	2	80
Green clay with quartz pebbles	6	86
Coarse sand	½	86½
Sand	1½	88
Very coarse sand	1½	91

NOTE.—U.S. Geological Survey test hole 10.

TABLE 5.—*Logs of wells in the Fairbanks area, Alaska*—Continued

Well 454

[Heating plant, building 365; Ladd Air Force Base. Log by U.S. Army]

	Thickness (feet)	Depth (feet)
Unfrozen: Sand and fine gravel	13	13
Frozen: Sand and some fine gravel	22	35
Unfrozen: Sand and some fine gravel	8	43
Frozen: Sand and some fine gravel	4	47
Unfrozen:		
Clay, sand, and muck	6	53
Sand and some fine gravel	11	64
Sand and muck	1	65
Frozen: Sand and muck	8	73
Unfrozen:		
Sand	10	83
Sand and coarse gravel	3	86
Sand and medium gravel	1	87
Sand and fine gravel	7	94
Sand and medium gravel	12	106

Well 457

[Observation well near building 384; Ladd Air Force Base. Log by F. W. Trainer]

	Thickness (feet)	Depth (feet)
Unfrozen:		
Muck and sand	7	7
Gravel and some sand	5	12
Sand and gravel	10	22
Sand	2	24
Frozen:		
Sand	3	27
Gravel	5	32
Coarse gravel	5	37
Gravel	3	40
Partially frozen: Gravel	2	42
Unfrozen:		
Sand	5	47
Sand and fine gravel	5	52
Gravel	21	73
Coarse gravel	5	78
Gravel and sand	19	97
Gravel	10	107
Gravel and sand	9	116
Gravel	8	124
Sand	1	125
Gravel	8	133
Sand and gravel	2	135
Sand	9	144
Sand and gravel	3	147
Gravel	1	148

Table 5.—*Logs of wells in the Fairbanks area, Alaska*—Continued

	Thickness (feet)	Depth (feet)
Well 464		
[Boiler house, building 140A; Ladd Air Force Base. Log by U.S. Army]		
Frozen:		
Muck	5	5
Sand and gravel	31	36
Unfrozen:		
Sand and gravel	58	89
Sand	65	154
Sand and gravel	2	156
Sand and gravel (10 percent)	10	166
Sand; medium gravel (10 percent)	2	168
Sand	1	169
Sand and medium gravel	8	177
Sand (95 percent); fine-medium gravel	8	185
Sand	6	191
Sand and muck	4	195
Sand	5	200
Sand and muck	10	210
Sand	8	218
Sand and some fine gravel	3	221
Sand and muck	7	228
Sand and some medium gravel	6	234
Sand and muck	5	239
Sand, muck, and some fine gravel	3	242
Sand and muck	4	246
Sand and some medium gravel	1	247
Sand and muck	10	257
Muck and some sand	17	274
Muck and sand	9	283
Sand, some muck, and gravel	5	288
Sand and muck	5	293
Sand and some fine gravel	1	294
Sand and muck	18	312
Muck	3	315

TABLE 6.—*Analyses of water from wells in the Fairbanks area, Alaska*

[Chemical constituents, in parts per million; analyses by U.S. Geological Survey]

Well	Date of collection	Depth (feet)	Silica (SiO_2)	Iron (Fe) Total	Manganese (Mn) Total	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue on evaporation at 180°C)	Hardness as $CaCO_3$		Specific conductance (micromhos at 25°C)	pH
																Total	Noncarbonate		
1	Aug. 20, 1947	126	39	16	0.32	37	9.1	5.8		164	4.4	1.4	0.3	0.7	175	130	0	255	8.2
2a [1]	July 27, 1954	200	23	2.9	.31	44	11	5.6	3.3	176	19	1.5	.3	.2	268	155	11	308	7.1
2a [2]	do	200	23	.08	.00	18	8.7	5.3	3.0	[3] 71	25	7.8	.3	.2	126	81	22	189	8.6
14 [4]	Aug. 20, 1947	140	36	8.9	1.7	41	8.5	9.1		172	12	1.8	.3	.4	194	137	0	285	7.6
38	do	Tunnel	26	2.0		41	9.0	3.9		154	17	2	.4	.6	176	140	14	271	
39	Oct. 17, 1949	90	33	5.3	.5	54	13	7.6		209	21	7.5	.1	.2	240	188	16	375	7.0
67	Nov. 21, 1949	22	17	.73		74	16	40		245	59	30	.0	39	396	250	50	667	6.8
155	Aug. 20, 1947	15	16	.09		131	31	40		476	84	44	.4	1.1	582	454	64	1,030	
212	do	110	33	3.2		43	11	5.1		186	7.2	2.0		.8	194	152	0	301	
213	do	54	27	7.0		64	13	11		254	18	6	.4	.6	265	213	5	410	
228	do	175	28	8.1		49	13	6.9		206	17	2	.4	.6	218	176	7	348	
238	do	113	32	2.5		42	9.9	5.8		172	14	0	.8	.9	190	146	4	290	
302	do	40+	25	1.7		54	11	6.2		213	16	1.0	.0	.5	219	180	5	353	
307	do	90	26	3.5	.03					165	16	1.0		.4				290	
316		60	16	3.6		28	5.2	4.1		94	18	2	.4	1.1	121	92	14	179	
320 [5]	Aug. 20, 1947	23	11	.43	.00	28	5.1	6.2		102	18	.6	.3	.3	124	91	7	196	7.9
321 [6]	July 15, 1948	70	16	14		33	7.8	5.0		127	18	1.2	.2	.2	145	114	0	239	7.3
324 [7]	Aug. 20, 1947	70	24	22	1.0	43	9.6	7.0		178	13	1.4	.2	.2	187	147	1	298	8.0
351	Oct. 17, 1949		14	.06		70	25	6.7		333	8.7	6.2	.4	.4	295	278	4	520	7.3
354	Aug. 18, 1954	203	18	9.8						1,020	200	7	.5	.4		1,220	384	2,060	6.7
356	Oct. 21, 1948	275	28	43		144	62	28		780	24	4.6	.2	6.1	681	614	0	1,080	7.2
363c	Aug. 18, 1954	156	17	5.3		95	48	15	2.4	534	29	1.0	.1	.3	479	434	0	766	7.1
366	do	200	10	.11						132	6	2	.6	2.8		106		216	7.0
367	Oct. 8, 1948	130	17	.18		57	25	23		244	22	1	.3	85	351	245	45	540	7.2
368	Aug. 17, 1954	307	21	.31						279	130		.8	.4		335	106	632	6.8
369	Sept. 2, 1948	101	27	.07		59	37	12		144	196	1.0	.6	.9	404	299	181	587	7.4
369	Sept. 7, 1948	140	21	.07		122	65	17		240	378	12	.7	.6	735	572	376	1,020	7.3
373	Aug. 10, 1954	108	16	.48		74	21	8.5	3.7	242	85	.5	.2	1.4	350	271	72	536	7.1
375	June 25, 1949	108	16	26		16	8.9	8.0		106	3.3	2.5		.0	107	76	0	173	6.8
375	July 14, 1949	140	19	.68				6.4		96	5.3	.5		1.6		72		159	
377	Aug. 31, 1954	12	20	.04						120	20	2	.1	.4		122	24	266	6.7
379	Aug. 30, 1954	130	23	.01						357	14	1	.8	53		363	70	720	6.4
381	do	165	15	.02						529	16	1	.0	65		475	42	867	7.0
383	do	252	18	.01						472	50	2	.0	4.4		390	3	730	7.0
384	do	150	27	.03						380	8	2	.8	5.4		315	4	603	6.9
385	July 12, 1949	86	24	.47		80	28	9.7		380	22	0		1.2	352	314	3	583	
398	Aug. 20, 1947	108	45	16		134	73	59		908	2.7	8	1.2	.9	771	634	0	1,250	
455	Apr. 23, 1951	82	36	.44	.13	40	11	4.3		160	17	1.5	.3	3.5	193	145	14	284	7.5
466	Apr. 13, 1951	45	21	8.8	1.9	86	17	2.6		305	16	15	.2	2.1	312	284	34	547	7.1
467	do	40	19	25	4.0	68	12	157		360	193	44	.3	2.1	677	219	0	985	7.9

[1] Raw water. [2] After treatment. [3] Includes the equivalent of 7 ppm of carbonate (CO_3). [4] From well. [5] 0.2 ppm boron (B). [6] 0.02 ppm boron (B). [7] 0.1 ppm boron (B).

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