NATURAL RESOURCE BASE OF THE FAIRBANKS - NORTH STAR BOROUGH, ALASKA

by

Ernest Wolff

and

Robert C. Haring

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FOREWORD

This report on the natural resource base of the Fairbanks North Star Borough is one of several continuing research projects related to community planning in Alaska. It represents an interdisciplinary effort of the Mineral Industry Research Laboratory and the Institute of Social, Economic and Government Research at the University of Alaska. The result is a synthesis of the economic development potential of natural resources in the greater Fairbanks region.

At various stages of research, faculty other than the authors have contributed their special knowledge to this project. In this regard, the suggestions of Mervin Freeman (Cooperative Extension Service), Wayne Burton (agricultural economist), and Michael Massie (forest economist) were particularly helpful. Earlier versions of the report were reviewed by Donn Hopkins, Borough Director of Planning, and by the Borough Planning Commission. The resulting exchange of ideas proved useful and led directly to an improved final report. Mr. Clem Correia and Edgar MacDonald, research assistants, contributed greatly in special areas and in the thankless, painstaking task of assembling the project and proofreading the manuscript.

This research project is part of the technical basis for preparing the Comprehensive Plan for the Fairbanks North Star Borough. The work was financed, in part, by federal funds pursuant to Section 701 of the Housing Act of 1954 (83rd Congress, Second Session) as amended.

Victor Fischer, Director
Institute of Social, Economic
and Government Research

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INTRODUCTION

In this report, the North Star Borough, Alaska is identified as the principal geographic area of study. This report is concerned mainly with the natural resource situation of the area and especially its economic implications for community planning. Because natural resource-based industries outside Borough boundaries probably will directly affect economic growth of this urban area, the natural resource characteristics of the area are expanded to include this possibility in several instances.

The purposes of the study are listed as follows--

(1) To inventory and analyze existing information and data of the Borough's geology, topography, soils, climate, forest, water and mineral resources;

(2) To identify and classify unsafe and unbuildable lands within the North Star Borough with particular emphasis on water supply conditions in and near urbanized areas; and

(3) To indicate the types of natural resource-based industries which are likely to prosper and contribute directly to an expanding economic base of the region.

Method of Research

This report mostly represents a consolidation and interpretation of existing natural resource information about the Borough. Original data were collected on certain specific points, particularly those concerning the extent of operations of several industries. An overall purpose of the project was to assemble, weigh and consider available reports and to integrate the information, an overriding consideration which restricted the method of research.

Organization of the Report

The report is divided into six chapters, of which this is the first. A summary of the project and the economic implications of the natural resource base are found in Chapter II, titled Summary and Implications. The basic content of the study is found in Chapters III through VI. An overview of geography and climate is the subject of Chapter III, and it is followed by a detailed survey of the local geology in Chapter IV. Soil and water conditions, together with an analysis of the local problems comprise Chapter V. Natural resource-based industries, especially manufacturing industries such as mining and forestry, are examined at length in Chapter VI, along with preliminary implications about which industries are likely to expand in the near future. The report is supplemented by figures and maps which depict the precise physical characteristics that are discussed in the content chapters. In addition, reference materials are divided between references cited, a special bibliography on arctic construction and similar problems for technical background and a more general annotated geology reading list of interest to most readers.

II

SUMMARY AND IMPLICATIONS

Summary of Physical Conditions

The natural resource situation which exists in the Fairbanks area has governed, and will continue to affect the types of industry which will develop in the region. The physical characteristics have given rise to many of the problems encountered in construction and must be kept in mind in any planning and development program.

Geographic and Physiographic

The Fairbanks-North Star Borough lies in the Interior Lowlands and Plateau Physiographic Province of Alaska. It contains lowlands, large basins and plains. Major rivers flow through the boundaries of this area, which is characteristic of the geography of Interior Alaska. As elsewhere, the land forms in and near the Borough are generally controlled by geology, with corresponding physiographic features of elevation, drainage basins and plateaus.

Local relief in the Borough, approximately 1500 feet, indicates a contrast in terrain and topography, i.e., from ridges to riverbed and upland to lowland. The upland area is rolling and smooth and the lowland areas extremely flat. Seasonal variations in daylight and temperature are very large. The climate is generally classified: Dfc, severe winter; moist all seasons; short, cool summer. However, local climatic differences are pronounced, i.e., an important feature of the Borough is the variation of microclimates from place to place. The localized weather is important due to temperature variations and also the seasonal incidence of ice-fog, the latter representing a serious form of air pollution.

The Borough area has been repeatedly mapped at various scales; topographically, geologically, and according to soil classification. The area contains typical cold climate geographical features. The incidence of a discontinuous permafrost zone at varying depths from the surface is particularly important. Local permafrost is altered by clearing and draining, which causes the permafrost table to recede. Ground ice, including ice-wedges and lenses, occurs within the boundaries of the Borough. Buildings which have been placed upon ground ice undergo structural distortion and failure as a result of differential settling. In addition, seasonal freezing and thawing affect public facilities, such as roads and structures, and ground frost forms readily around unheated buildings. The Borough contains geologic formations of various types and ages which directly affect soil and water supply conditions.

For summary purposes, soil classes and local geology have been grouped according to the degree of buildability in commercial and residential construction. Floodplain alluvium (except swampy floodplain), Fairbanks Loess and Birch Creek Schist are designated buildable ground. Approximately 75 percent of the Fairbanks urban area is represented by these land classes, and only 60 percent of the so-called urbanizing area is classified as buildable. Alternatively, the unbuildable classes include swamp floodplain and various types of silt and peat. These soils comprise nearly 25 percent of the local urban and 40 percent of the urbanizing land area. Several additional barriers to construction are apparent in the Borough; namely, lack of accessibility to traveled roads, and the wide presence of uncleared and seasonally flooded land. In addition to these problems of building, much of the acreage neighboring the urban areas is unavailable, especially university lands and military bases. The overall result--long term scarcity of high quality buildable areas.

Water supply conditions in the Borough vary substantially from place to place. Surface waters, such as the Chena River and Slough, would require extensive treatment prior to most economic uses. Therefore, groundwater represents the principal source. The city is situated on a great aquifer fed by local streams and runoff. The region's uplands and lowlands differ substantially in groundwater availability and quality. The Tanana "flats," designated as floodplain (filled with alluvium), is a suitable water-bearing formation. Wells drilled in the floodplain provide high water yields, minimum risk of failure and reasonable certainty of locating water within a relatively short depth from surface. These conditions prevail generally in those portions of the Borough designated as floodplain. Two qualitative considerations do arise--poor water quality and permafrost. Both considerations increase the costs and risks associated with acquiring water suitable for domestic consumption.

There are several water quality problems associated with drilling in the floodplain. They are (1) limited perched water tables, (2) the need to penetrate permafrost layers in drilling, (3) installing antifreezing apparatus, (4) well maintenance, and (5) the serious public health risks involved in contamination. The regular incidence of water discoloration and offensive odor are among the less important considerations. Water hardness is a troublesome aspect of local groundwater supplies; the most serious problems are high iron content and associated organic-high areas.

The quantity and quality of groundwater of the uplands vary greatly. In the main, well yields are much lower than found on the floodplain. Well depths of 100-150 feet are common. Wells in Fairbanks Loess (Qf), and other formations, whether perennially frozen or not, do not yield water unless they penetrate into bedrock or gravel. Water circulation often is restricted by geologic features, and bedrock yeilds water of poor quality. Even where water quality is acceptable from bedrock sources, many residential wells yield so little water that large storage tanks are maintained inside the homes.

Development of Natural Resource-Based Industries

The Fairbanks economic base, once principally dependent upon gold mining, experienced a downward trend in natural resource exploitation from 1940-1966. This trend could be reversed through a re-vitalization of mineral industries and the attraction of new manufacturers, such as those in forest products and fisheries, into the area. Over longer periods, recreation and tourism probably will become the major industry which depends principally upon the vast natural environment of Interior Alaska.

The Borough contains several distinct mining districts. At present, placer gold and lode gold mining exist only on a very small scale. The introduction of new mining technology could well change the current outlook. In the main, the major benefits of increased mining probably would be reflected in the Fairbanks wholesale and retail trade. This would offer logistical support to mining operations throughout Interior Alaska. Prospecting for lead-silver, antimony and tungsten may reveal new reserves, but the production outlook is poor. Locally, non-metallic products are mined in substantial volumes. Over the last decade, extraction of sand and gravel has been the major mining activity in terms of value. Its continued operation depends almost entirely upon the volume of new contract construction within the Borough. Overall, these mineral industries are expected to contribute $12 million annually on a sustained basis.

Alaska's weak agriculture base remains an important development problem in the Borough. Local production of selected crops, notably potatoes, has increased while other types of farming barely have survived. Many conditions have contributed to this situation; especially competing land uses, the short growing season and the price of suitable agricultural land. Together, they comprise a cost-price situation in which many farm products cannot be produced and sold locally. The economically stagnant conditions in agriculture could be altered in certain instances with suitable land policies and investment in farm units which enjoy competitive advantages.

Local forestry and fishery segments of the area remain at an "infant industry" stage of development. Small sawmills and houselog operations will continue to expand output up to a 10 million bd. ft. level of annual output for the region. Additional expansion is almost certain to occur as transportation routes are extended and public lands are made additionally available for forestry.

The recent introduction of freezer barges along the Yukon River is one of several fishery processing activities which can benefit Fairbanks. These innovations and air freight connections to northern and western communities represent important transactions. The major impact of their success will be improved logistical support of natural resources harvested elsewhere, but sold in Fairbanks markets.

Implications

The natural resource base of the Borough is, of course, critical to its economic development. To a considerable extent, resource supply conditions represent the physical capacity of the area to grow and prosper economically. Many of these conditions were identified in this study, and their economic and development implications are summarized as follows--

Of Physical Conditions and Scarcity Position

(1) Industries which prosper principally during summer months do not materially and adversely affect air pollution, e.g., mining, tourism.

(2) Seasonal migration of the labor force reduces the demand for permanent housing and corollary man-generated air pollutants.

(3) Individual microclimates, especially as they become identified in greater detail, logically lead to unique systems for classifying land on the basis of desirability for commercial and residential construction.

(4) The normally anticipated geographic dispersion of households

apparently is greater than in other urban climates, a condition which probably will continue to exist.

(5) The geological conditions identified in and near Fairbanks require a more than "typical" insight into the local geology which is necessary in urban planning and on behalf of residents.

(6) Widespread conditions of permafrost, ice wedges and frost-susceptible ground definitely limit the type of "reasonable" land uses. The amount and accessibility of "buildable" land is much more scarce than commonly believed.

(7) The present stock of commercial and residential buildings is exposed to natural conditions which cause rapid physical wear and tear. Many of the present dwellings were constructed on unsuitable foundation materials or were inadequately designed for the climate.

Of Local Water and Soil Conditions

(1) Soil and water conditions increase construction costs outside city boundaries materially.

(2) Unusual financial risks are borne by those who construct residences, i.e., likelihood of not locating water, acquiring poor quality water, and subsequent difficulties in financing.

(3) Significant amounts of land within the Fairbanks urban area are unbuildable at present. Land so classified corresponds closely with the areas in which water supplies, when available, are likely of poor quality.

(4) The developing and urbanizing portions of the Borough contain a larger proportion of unbuildable land than the present urban area.

An indirect result of this phenomenon is a correspondingly high geographic dispersion of homes as residential areas expand.

(5) Many areas of the Borough probably will be "upgraded" in terms of buildability. The first major step in this direction is land clearing and draining. These activities should precede construction by several years.

Of Industrial Opportunities

(1) Intensive mineral exploration and production, and increased forest utilization require relatively large investment in access roads and/or research. These efforts must be compared with alternate uses of public funds.

(2) An increase in mining operations would tend to compete with neighboring recreation activities and residential construction. These problems of inter-industry compatibility could be serious in the urbanizing portion of the Borough. They are much less apparent, but potentially important, in most non-residential areas.

(3) Regulations and policies of the state and federal agencies directly affect nearly every resource-using industry which might be attracted to the Borough. The more serious areas of concern are: (a) classification of land, transfer of lands, and property rights as they affect mineral industries and forestry; and (b) water codes and similar regulations which restrict the types of mining methods (and logging) which can be employed, and increase operating costs of industry.

Future Investigations

Considering the foregoing information in broad perspective, the need for additional knowledge about the region and its characteristics is obvious and occasionally critical. Urban planning and development organizations often are dependent upon micro-geology, soil and water mapping to the nearest 50 to 100 feet, and in certain instances they must be supplied with additional information. At present in Fairbanks, this type of detail is not available, and will not be immediately forthcoming. Water supply and soil conditions in urban portions of the Borough will continue to cause high construction costs. More precise identification of these physical features would aid in the reduction of their costly effects.

Additional experiments in land clearing and draining are a priority requirement. The conversion of marginally buildable land into acreage suitable for residential construction, industry or agriculture appears entirely feasible. Over larger areas, detailed mineral exploration, updated and sensitive surveys of Interior forests (i.e., by location, species, tree size) are long overdue. Public agencies must know much more about---"What is where?"---in instituting new programs. And while industrial development programs should not stand still awaiting research, the activation of efforts to produce the information for developemnt should proceed without much delay.

III

GEOGRAPHY, CLIMATE, AND PHYSIOGRAPHIC SETTING

Geographic and Physiographic Setting

The most widely used physiographic subdivision of Alaska divides the state into (a) the Pacific Mountain System, (b) the Interior Low-lands Plateau, (c) the Brooks Range, and (d) the Arctic Coastal Plain (Brooks, 1953, p. 1, Wolff, 1964, p. 364). The Fairbanks North Star Borough lies in the Interior Lowlands and Plateau province, which is cut off from the oceans north and south by high mountain ranges. The Interior lowlands and Plateau province is further subdivided into (1) the lowlands and plains, (2) the highlands and (3) the Seward Penin-sula subprovinces (Williams, H., 1958, p. 4). The Seward Peninsula subprovince is a separate unit, but the other two occupy discontinuous areas in the Interior. It is necessary when considering a smaller area, such as the Borough, to recognize an intermediate province, the marginal upland, which separates the upland with the lowlands (Williams, J. R., 1962). Figure 1 shows these physiographic provinces of Alaska.

It normally is expected that the lowlands and the plains would be continuously situated along the major rivers and generally elongate in configuration; however, a glance at a topographic map, such as the shaded relief Map E of Alaska (U.S. Geological Survey, 1954), shows that there are large, very wide areas of lowlands along the major Interior rivers, some of which are isolated. The reason is that there are large basins in the Interior which have been and which probably are at present being

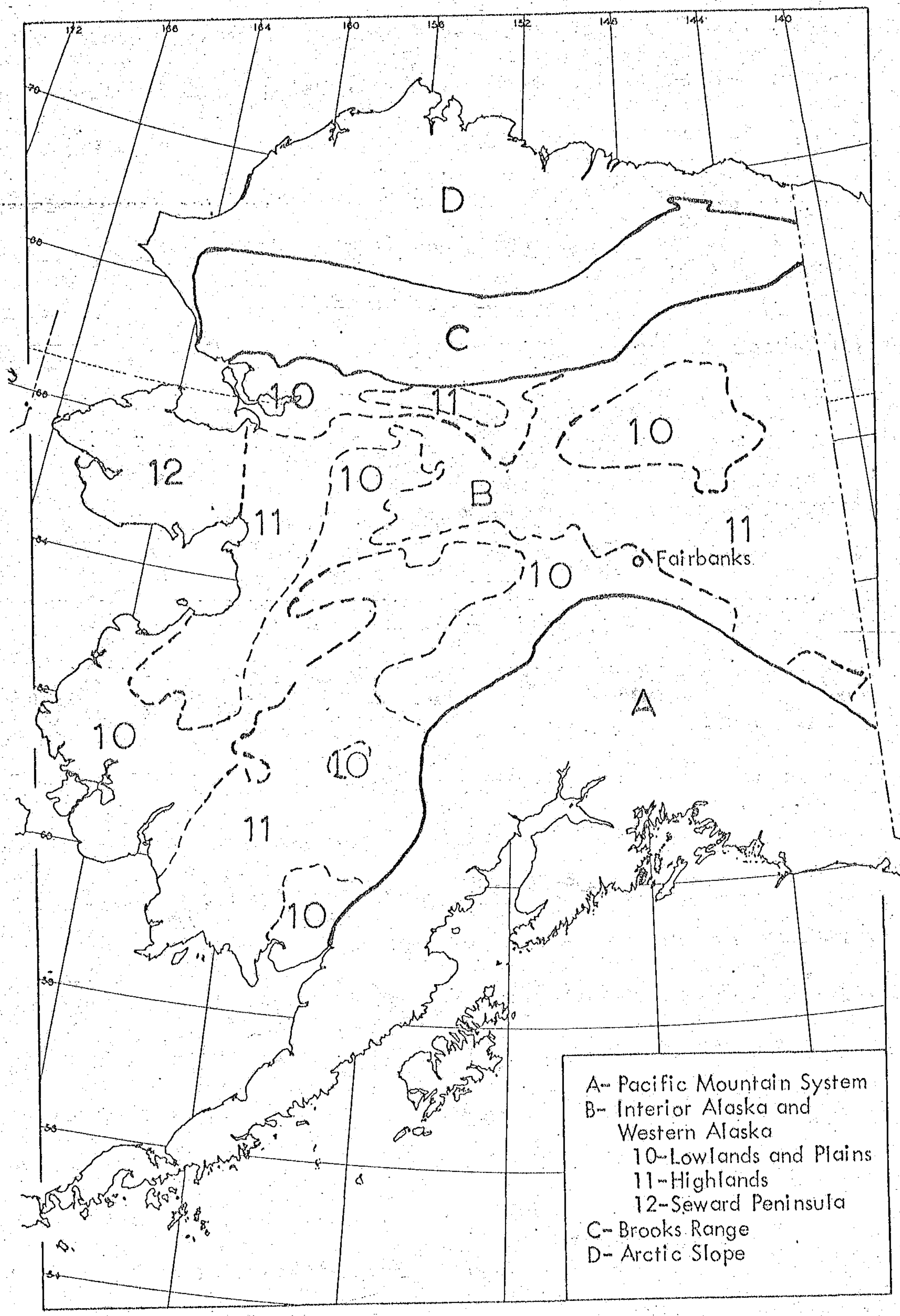

Fig. 1. Physiographic provinces of Alaska. (After Williams et.al. 1958.)

lowered by crustal downwarping or faulting. The major rivers flow from one basin to another, often cutting deep, narrow canyons where they pass across the intervening highlands. For example, this situation is found at the Ramparts on the Yukon, which downstream spreads out onto exceedingly wide floodplains when they reach the depressed basins. These basins have, of course, been filled with unconsolidated detritus of stream laid, windborne, ice deposited, and hillside creep origin. Their surfaces are now flat or very gently sloping with very little relief and dotted with lakes, stream scars and swamps. One of the largest of these "flats" is that of the Tanana River, forty miles wide (at the longitude of Fairbanks) and more than 100 miles long. This flat is bounded on the south by the Alaska Range with its many glaciers that pour large quantities of outwash into the Tanana Valley. Since even larger quantities of outwash were contributed during the Pleistocene (ice age) of the past million years, the effect has been to crowd the river toward the north side of the valley and to create a slope northward across the valley. Correspondingly, the coarser material is near the southern part of the flat with the finer material closer to the northern edge.

Where the major rivers flow from one basin to another through fairly wide valleys, such as along the Tanana River below Manley Hot Springs, the flat and swampy character of the topography of the great flats is maintained in the valley except, of course, that the flats are much narrower. On the lower reaches of the major tributary streams such as the Chatanika, Chena, and Salcha Rivers and Goldstream Creek, the topography may be classified as lowland. The filling, and, hence, widening of the lower reaches of these valleys is caused by the filling of the Tanana Valley itself. Mertie (1937, p. 31) states that below approximately the

1000 foot contour, the valleys are deeply alluviated (filled with debris) and that above that level, they are more "normal" with narrower valleys.

That part of the Borough that does not lie in the lowland sub-province - in this case, a portion of the Tanana Flats - lies in the drainage basins of the Chatanika, Chena and Salcha Rivers. These drainage basins have drainage areas of approximately 800, 1980, and 2170 square miles respectively. These rivers drain the south-central part of what Mertie (1937, p. 22) called the "Yukon-Tanana Plateau" which is the upland between the Alaskan parts of those two great rivers. This plateau is now dissected by streams to a stage that geologists call mature. If the ridge tops are taken as an indication of an older erosion surface, then the plateau would be a gently warped dome with its highest portion about 5000 feet in altitude in the east central part and sloping away in all directions. The streams have cut into this old surface to produce a local relief of about 3000 feet. That part of the plateau in which the Borough is located is on a somewhat lower part of the ancient dome but the local relief is the same. It is about 3000 feet, with ridges at 2000-3000 feet and groups of higher ridges and mountains at 4000 or occasionally 5000-6000 feet. The highest point in the Borough, 5,920 feet high, is West Point on the upper drainage of the Salcha, while the lowest - where the Tanana leaves the Borough - is about 390 feet. Near Fairbanks, in the western part of the Borough, ridge tops average about 2000 feet and gradually increase in elevation eastward.

The major drainages in the upland of the Borough are structurally controlled. That is, they flow parallel to the general foliation of the schist bedrock. In this direction, the streams erode more easily and, hence, the valleys are somewhat wider. Where streams flow across the foliation, the valleys tend to be narrower. Because the streams tend to flow either southwest or northeast, they interfinger and form very irregular divides.

Topographically, the upland ridges and hills are rolling and smooth rather than precipitous. This is due to a number of causes:

(1) the local bedrock is in most localities an easily decomposed schist (Birch Creek Schist),

(2) the hills are mantled with wind-blown silt (loess) derived from glacial outwash to the south,

(3) mass wasting or movement of loose material down the hillsides has been to a large extent by solifluction which produces subdued topographic forms, and

(4) cryoplanation by frost action produces smooth, flat areas.

Climate

Classification

The climate of any particular place is the product of several factors, among which are latitude, altitude, presence of mountain barriers, velocity and direction of prevailing winds, and insolation. By far the most important of these in interior Alaska is latitude, which superimposes its influence on all the others. The presence of the Alaska Range also has a great effect. Not only the effect of latitude on temperature must be considered, but also the extreme seasonal variation in daylight. This is a climatic factor that has a marked effect on man's activities in the north.

A number of schemes for classifying climates have been devised, but these only provide the broad outline of any particular regional climate. The local climate must be described in terms of the minor variables and local conditions to be fully understood. During the winter in Interior Alaska, these local factors produce microclimates which may vary greatly within short distances.

The two most widely used climatic classifications are those of Köppen and Thornthwaite. In Köppen's classification, Interior Alaska lies in "Type D, Humid microthermal: cold forest climates, severe winters," near the boundary of "Type E, Polar climates." The complete classification is "Dfc, Severe winter; moist all seasons, short cool summer." Although the mean annual precipitation at Fairbanks is only about 12 inches, the designation "f" (constantly moist) is justified, because the precipitation is "adequate in all seasons." The defining limits for this climatic type are: Only one to four months above 10°C, coldest month above -30°C, and adequate precipitation. This climatic type is sometimes known under the general and more descriptive name "Subarctic." It is also called "continental," implying cold winters and warm summers.

Thornthwaite's chief contribution to climatic classification is the concept of "temperature efficiency " and "precipitation effectiveness." Temperature efficiency refers to the number of days with a mean temperature above 40°F and the amount of rise above that point. "Precipitation effectiveness" is the ratio of precipitation to evaporation. It is the high precipitation effectiveness index that allows Fairbanks' climate to be classed as "constantly moist." Under Thornthwaite's classification, the climate of Interior Alaska is called "Taiga."

Descriptive Climate

The following description of the climatic characteristics of the Fairbanks area is taken verbatim from "Soil Survey of Fairbanks Area, Alaska" (Rieger, Dement, and Sanders, 1963). It was written by C. E. Watson, State Climatologist, U.S. Weather Bureau, Anchorage, Alaska. Figures referred to in the following quotation were not reproduced in this report.

> The Fairbanks Area is near the center of the Climatological Division known as the Interior Basin of Alaska. This part of Alaska has extreme seasonal variations in temperature. Nearly all of the extreme temperatures for Alaska have been recorded in the Interior Basin. Climatic data for three stations in the Fairbanks Area are shown in table 1.
>
> The record high of 99 degrees, recorded in the Area at the University Experiment Station in July 1919, is just 1 degree less than Alaska's record high of 100 degrees, recorded at Fort Yukon in June 1915. The record low of 66 degrees below zero for the Area was recorded at the University Experiment Station and the Weather Bureau in Fairbanks in January 1934. Daily minimum readings drop to zero degrees or colder more than 75 percent of the days from November 1 to March 31. Daily maximum readings reach 70 degrees or higher about 56 percent of the days in July and August. Temperatures reach 90 degrees and higher at some time during about 20 percent of the days in the growing season.
>
> The growing season is more sharply defined than in most agricultural areas, as there is a rapid change from the warm to the cold seasons. Terminal dates of the warm season fall rather dependably within narrow limits. The dates for freeze-free periods shown in table 2 are a fairly dependable guide for agriculture and other activities. Rapid growth of crops should be maintained, so that they can mature in the short growing season. However, the growth of crops is accelerated by the many hours of available sunshine. During the months of June, July, and August, possible sunshine averages slightly more than 19 hours per day. As a result, the growth and maturity of crops is extremely rapid, particularly if temperature and moisture conditions are favorable.
>
> Temperature characteristics
>
> Table 2 shows, for two weather stations, the terminal dates of the season and the number of days between terminal dates, at specified temperatures of 32, 28, 24, 20, and 16

TABLE 1 -- Temperature and precipitation, Fairbanks Area, Alaska

Month	University Experiment Station, College, Alaska; elevation, 481 feet; data for period 1931 thru 1960						U.S. Weather Bureau Airport Station (International Airport), Fairbanks, Alaska; elevation, 436 feet; data for period 1934 thru 1960					College Magnetic Observatory, U.S. Coast and Geodetic Survey, College, Alaska; elevation, 621 feet; data for period 1949 thru 1960				
	Temperature			Precipitation			Temperature			Precipitation		Temperature			Precipitation	
	Average	Average maximum	Average minimum	Average[1]	Average snowfall	Average pan evaporation	Average	Average maximum	Average minimum	Average[1]	Average snowfall	Average	Average maximum	Average minimum	Average[1]	Average snowfall
	°F	°F	°F	In.	In.	In.[2]	°F	°F	°F	In.	In.	°F	°F	°F	In.	In.
December	- 6.8	1.5	-15.1	0.57	8.7	(3)	- 8.9	- 0.6	-17.2	0.49	9.0	- 6.7	-0.1	-13.3	0.66	11.7
January	- 7.3	1.6	-16.2	.83	13.1	(3)	-10.5	- 1.2	-19.7	.90	14.0	- 7.2	.2	-14.5	.91	15.2
February	.8	11.4	- 9.8	.51	7.7	(3)	- 2.4	9.2	-13.9	.47	7.7	- 2.8	6.0	-11.5	.64	10.8
March	12.7	25.8	- .5	.42	5.5	(3)	8.7	22.8	- 5.4	.43	7.0	12.3	23.4	1.2	.32	5.3
April	30.7	43.8	17.6	.24	2.3	(3)	29.9	41.8	17.9	.26	3.1	29.5	40.1	18.8	.13	1.2
May	47.0	60.5	33.5	.80	.3	4.21	47.4	59.1	35.7	.72	.4	47.0	58.2	35.8	.67	.5
June	58.0	72.0	43.9	1.48	.0	5.02	58.9	70.0	46.8	1.36	(4)	57.4	69.2	45.8	1.57	0
July	59.8	72.9	46.6	2.10	0.0	4.31	60.2	71.5	48.9	1.86	0	59.5	70.4	48.6	2.37	0
August	54.8	66.7	42.8	2.44	(4)	2.71	54.8	65.5	44.1	2.12	(4)	55.4	65.9	44.9	1.80	(4)
September	44.3	55.2	33.3	1.36	.4	1.31	44.1	54.0	34.2	1.12	.6	43.9	53.2	34.6	1.34	.8
October	27.2	36.1	18.2	.93	9.3	(3)	26.6	34.6	18.5	.86	9.5	25.3	32.8	17.7	.66	7.5
November	5.5	13.7	- 2.7	.63	8.8	(3)	3.5	11.6	- 4.7	.62	9.3	7.2	14.1	.4	.53	8.4
Year	27.2	38.4	16.0	12.31	56.1	(3)	26.0	36.6	15.4	11.21	60.6	26.7	36.1	17.4	11.6	61.4

[1]Inches of water.

[2]Inches of water. Length of record ranges from 12 to 26 years.

[3]Data not available.

[4]Trace.

degrees. Data in this table indicate that the University Experiment Station, situated on a slope near the boundary between the uplands and the alluvial plain, has an average freeze-free period of 88 days. The U. S. Weather Bureau Airport Station, situated on the alluvial plain, has a freeze-free period of 106 days.

For concurrent periods, the average minimum air temperatures at the University Experiment Station are generally lower than those observed at the lower lying U. S. Weather Bureau Airport Station.

There is little recorded evidence that cold-air drainage has a pronounced general effect in the vicinity of Fairbanks or College, Alaska. This does not mean that cold-air drainage does not affect local areas. The lowlands along Goldstream Creek, for example, is rimmed by high ridges and doubtless has pronounced downslope air drainage. This air drainage is capable of producing colder temperatures and a shorter growing season on the lowland than at either the University Experiment Station or the U. S. Weather Bureau Airport Station.

TABLE 2

Average dates, for beginning and end of season, at which temperature is equal to or above the °F indicated

Temperature limit	University Experiment Station, College[1]		U.S. Weather Bureau Airport Station, Fairbanks[2]	
	Terminal dates	No. of days	Terminal dates	No. of days
32°F	May 29 to Aug. 24	88	May 19 to Sept. 2	106
28°F	May 18 to Sept. 9	114	May 7 to Sept. 13	129
24°F	May 9 to Sept. 20	134	Apr. 29 to Sept. 24	148
20°F	Apr. 26 to Oct. 1	158	Apr. 22 to Oct. 1	162
16°F	Apr. 24 to Oct. 6	165	Apr. 19 to Oct. 7	171

[1]Data period, 1931 through 1960.

[2]Data period, 1934 through 1960.

The probability of having seasons of various lengths in which the temperature will not fall below stated limits is shown in figures 1 and 2. This information is valuable to farmers and others who need favorable temperatures to operate outdoor enterprises. A farmer in the vicinity of the University Experiment Station (fig. 1) can expect, for example, about half the time, or 5 years out of 10, a growing season of 88 days in which the temperature will not fall below 32 degrees. In only 2 years in 10 can he expect a season of 110 days in which the temperature will not fall below 32 degrees, but in 9 years out of 10 he can expect a season of 56 days in which the temperature will not fall below 32 degrees. A farmer near the U. S. Weather Bureau Airport Station can expect slightly longer seasons than one near the University Experimental Station, and he can determine similar probabilities for his area by referring to figure 2.

Precipitation characteristics

Precipitation in the early part of the growing season, or June, averages considerably less than that received in the eastern parts of Wyoming and Colorado, or in the western parts of the Dakotas. The relatively short growing season makes it imperative that plants grow rapidly all season if they are to mature. Although precipitation is apparently deficient in the early part of the growing season, crops generally grow fast enough to mature. This growth indicates that there is enough early spring moisture in the soil to allow crops to grow rapidly. Frost melting in the subsoil is also a source of moisture for growing crops in the first part of the season.

Potential evapotranspiration in this Area has not been accurately determined, but preliminary computations by use of the Thornthwaite (1931) method indicate that the potential (maximum) evapotranspiration is about 4 1/2 inches in August. Table 3 shows probable monthly precipitation at the University Experiment Station for May to September, inclusive.

TABLE 3--Monthly precipitation probability, University Experiment Station (1906 through 1960)

Month	1 year in 10 years will have		Median[1]	2 years in 10 years will have	
	Less than	More than		Less than	More than
	Inches	Inches	Inches	Inches	Inches
May	0.2	1.4	0.7	0.3	1.1
June	.5	2.5	1.4	.8	2.2
July	.6	3.8	1.9	.9	2.8
August	.9	3.6	2.0	1.1	3.1
September	.4	2.5	1.3	.6	1.8

[1]The midpoint of total monthly precipitation. Half the time the total monthly precipitation can be expected to be above this figure, and half the time, less.

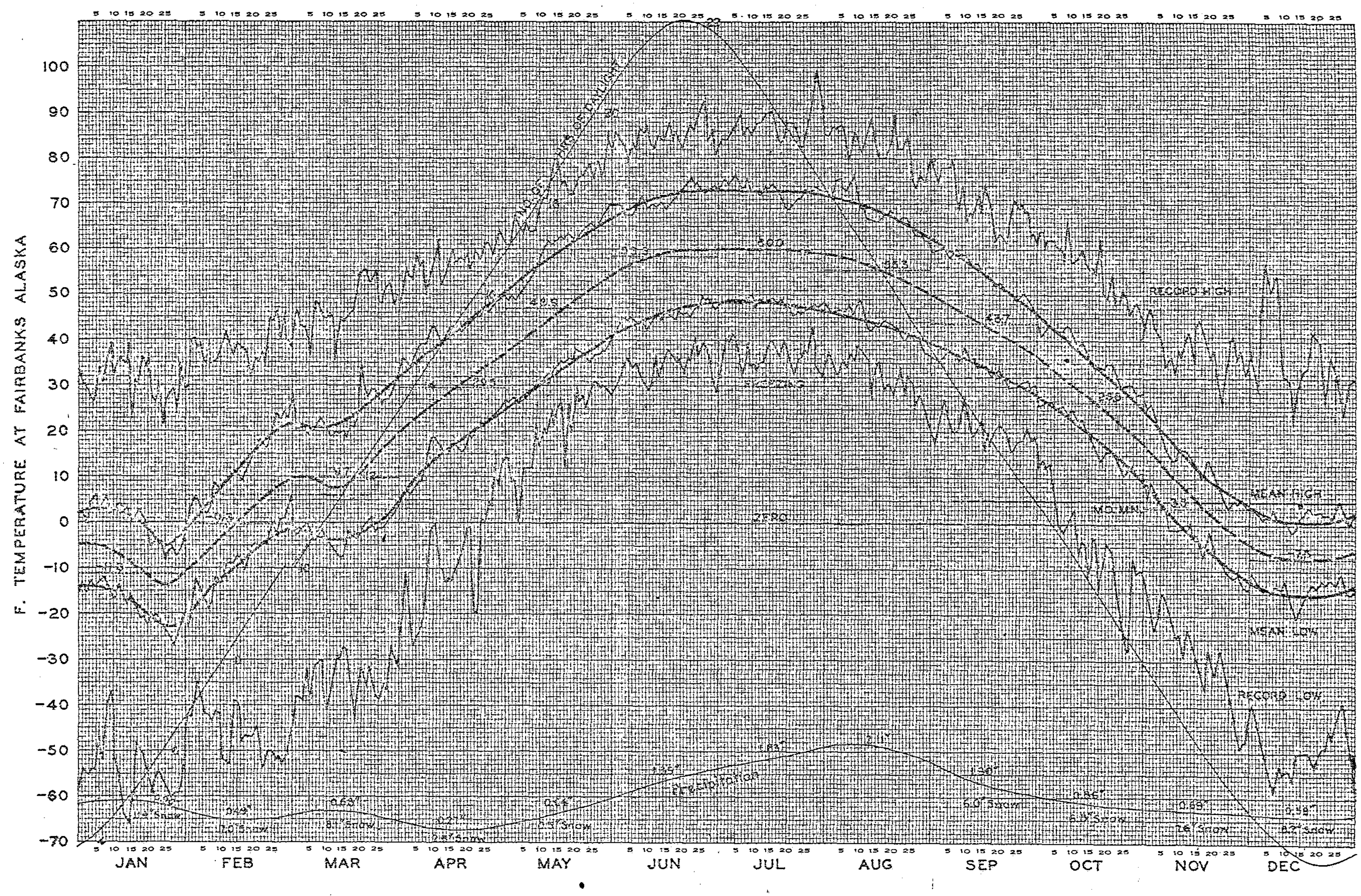

Fig. 2. Mean values of climatic parameters.

> Most of the rain in this Area falls during the growing season, and the amount may vary greatly within short distances. It is believed that most of the summer rain originates as moisture vapor in the Interior Basin. The frequency and intensity of showers tend to increase as the summer season progresses. The average monthly precipitation is less than one-fourth inch in April but increases to slightly more than 2 1/4 inches in August. Data on precipitation intensity are limited, but reliable, unofficial measurements indicate that rates of about 2 inches per hour have occurred in the Fairbanks Area for a period of 30 minutes. An average of about eight thunderstorms occur during the summer. Hailstorms occur almost every summer, but the hailstones are seldom large enough to cause extensive damage. Tornadoes are practically unknown. Snowfall averages about 50 inches per year at the University Experiment Station, and about 60 inches at the U. S. Weather Bureau Airport Station. However, total snow was 126 inches at the University Experiment Station and 135 inches at the U. S. Weather Bureau Airport Station during the winter of 1936-37. Snow is usually on the ground from mid-October to mid-April. The maximum depth of snow on the ground during the winter averages between 25 and 30 inches.
>
> Wind velocity is usually low. The U. S. Weather Bureau Airport Station records an average annual wind velocity of 5 miles per hour. Winds are seldom strong enough to erode the soil severely. Winds are mainly from the north and northwest, but in June, July, and August they are mostly from the southwest.

Climatological data pertinent to the above quoted description are shown graphically in Figure 2.

Freezing Index

A degree day effect often is more meaningful than the arithmetic mean as a measure of temperature. A degree day is a deviation of one degree for a period of one day from some standard. For climatological purposes, 0°C. or 32°F. is the most useful standard temperature. The sum of the negative or freezing degree days is converted to the freezing index. If the freezing (negative) degree days are added algebraically to the thawing (positive) degree days, and the sum divided by 365, the result is the mean temperature with respect to freezing. The freezing indexes for a few cities are listed below. These are approximate because they were computed from monthly mean temperatures rather than daily ones.

TABLE 1

FREEZING INDEXES AND MEAN AVERAGE TEMPERATURES FOR SELECTED CITIES

City	Freezing Index	Mean Average Temperature
Barrow, Alaska	8511	10.0
Candle, Alaska	6150	20.2
Fairbanks, Alaska	5220	26.1
Winnipeg, Manitoba	3274	36.1
Anchorage, Alaska	2120	35.0
Minneapolis, Minn.	2000	42.5
Chicago, Illinois	750	50.4
Juneau, Alaska	120	42.6

Windchill

The uncomfortable or even dangerous effects of a rigorous climate on human beings depends not only on temperature but on wind velocity. This is recognized in the concept of windchill, which notes the effect of various wind velocities and temperatures (Wolff, 1964, p. 341). The same intense calm and stability of the air that makes Fairbanks especially susceptible to ice fog makes the extreme cold more bearable. For example at 50°F below zero and no wind, the windchill factor (1800) is comparable to zero degrees with a five mile wind or 30 degrees above zero with a 45 mile wind.

Microclimates

Because of the extremely intense inversions in the Tanana Valley, the temperature varies considerably with elevation. (See section on ice fog.) Thermograph records obtained on December 28, 1962, at different elevations, from the Chena River to the top of Birch Hill, 434 feet and 985 feet in elevation respectively, show an extreme temperature difference of about 46°F (-2°F to 48°F). The temperature gradient is greater at the lower elevations, i.e., at a station only 10 feet above the Chena River station, the temperature was about 16°F warmer (-48°F to -32°F).

Mr. William Mendenhall of the Civil Engineering Department of the University of Alaska kept temperature records at his home north of the University for the year of 1965-1966. The elevation is 615 feet and the home is situated on a south facing slope. The comparison of maximum and minimum daily temperatures with those at International Airport provides an instructive insight into local microclimates. On very cold days, minus 40 to 50 at the airport, differences of 10 to 20 degrees F in mean daily temperatures were common. The largest difference, on January 18, 1966, was 23°. Monthly mean temperatures are tabulated below:

TABLE 2

MONTHLY MEAN TEMPERATURES AT CONTRASTING LOCALITIES IN FAIRBANKS, ALASKA, 1965-1966

Month	Year	Airport	Hillsite	Difference
November	1965	+ 4.5	+10.0	+ 5.5
December	1965	-12.0	- 7.5	+ 5.6
January	1966	-26.6	-13.4	+13.2
February	1966	- 7.0	- 1.2	+ 5.8
March	1966	- 2.0	+ 4.3	+ 6.3
April	1966	27.3	27.8	+ 0.5
May	1966	45.5	44.3	- 1.2
June	1966	63.1	62.3	- 0.8
July	1966	62.5	60.8	- 1.7
August	1966	57.2	55.9	- 1.3
September	1966	50.3	47.4	- 2.9
October	1966	25.8	25.9	+ 0.1

Ice Fog

Ice fog is produced by water vapor discharged during cold (-30°C) weather. Aside from a few natural sources, it is almost exclusively the product of automobiles, power plants, domestic heating, and other works of man. It is low-lying, usually about 30 feet thick, very seldom exceeding 100 feet, although thicknesses of 160 feet (50 m) have been observed directly over Fairbanks in long cold spells.

When unpolluted air cools below the freezing temperature, tiny ice crystals form by condensation after the saturation point is reached. As the air continues to cool, it can hold less and less moisture. This moisture condenses on already frozen crystals, so that the air and crystals cool slowly. The crystals grow in size, producing the beautiful and familiar displays of "diamond dust" and "sun dogs." The crystals are well formed, relatively sparsely distributed, and range in size from 30 to 100 microns in size. Thus, they present no hazard to visibility and settle rapidly.

When warm exhaust gases are discharged, however, they may cool 150°C (270°F) in a few seconds. This results in many very small crystals (10 microns) being formed, creating a serious visibility problem. Ice droplets, once formed, act as heat sinks from which heat is radiated faster than from air, i.e., the air cools still faster.

In 1961-62, estimates were made of the area's thicknesses and volumes occupied by ice fog (Benson, 1965, p. 45). Figure 3 from Benson's paper shows three areas, covering 24, 38, and 64 square miles respectively. The inner area is covered whenever ice fog is present, the next when ice fog continues several days, and the largest area only during

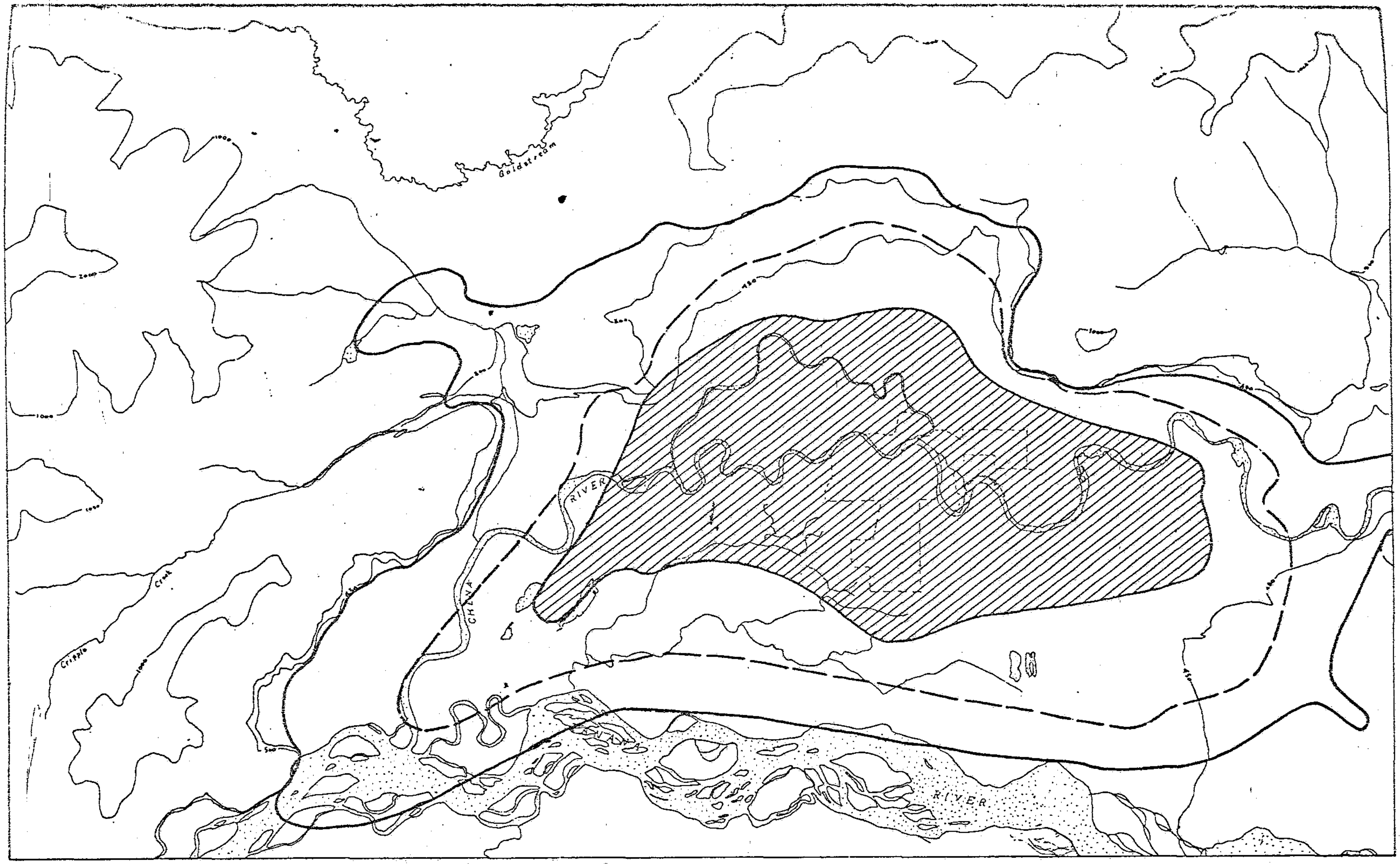

Fig. 3. Areal extent of ice fog. The cross hatched area is covered whenever ice fog is present. The area within the dashed line is covered after several days of ice fog, and the outer solid line includes the most extensive ice fogs. Recent observations from points 18 and 20 indicate that the southwestern border extends farther south than shown.

prolonged spells of very cold weather. An extreme maximum of about 75 square miles has been observed. The fog is not continuous, especially near the outer boundaries. Clear patches exist in an area at the east end of Fort Wainwright, near the University, and south and west of International Airport. The ice fog is usually thin with a well defined upper layer at 30 feet or lower. However, during long cold spells it builds up over the city, e.g., at the airport the fog will be thicker than 30 feet. The volume of fog in 1961-62 was estimated to vary between 100 to 300 x $(10)^7$ cubic meters (35 to 100 x $(10)^9$ cu. ft.).

In all parts of the world, the ordinary temperature gradient is from warmer to cooler with increased altitude, as the cooler air settles, turbulence is created, mixing and clearing the air. In cold snow-covered areas, however, radiation from the earth's surface causes the air to cool in contact with the ground and in due time, this cooling affects higher air. Thus, the temperature gradient is from cold to warm upward, a condition known as an inversion. In Los Angeles, where such an inversion occurs at a sharp boundary and a fixed height, air pollutants can be mixed and absorbed in the air beneath the inversion. At Fairbanks in the winter, on the other hand, the inversion extends right down to the ground, and the air is extremely stable, with very little tendency to mix and dissipate the pollutants.

The air becomes more stable as the steepness of the inversion increases. The inversions at Fairbanks are among the steepest in the world, with gradients of 10 to 30°C/100 meters in the first 50 to 100 meters (6°F to 18°F per 100 feet). The greatest gradients are right at the bottom. Benson (1965, p. 51) reports a rate of 540°C/100 meters for the first 1.4 meters. This is equivalent to 3°F/foot, or 13°F between a man's feet and his chest. This, of course, is an extreme example during a very cold, calm period.

Over Fairbanks, as over most cities, there is a "heat island," so that the temperature downtown is 10°F higher than the surrounding countryside during -40 to -50°F, and about 7° higher during warmer weather. The slight depressions in the Tanana Flats, which is occupied by the rivers and sloughs, have even more stable air than areas closer to the city, and consequently radiate heat even faster, i.e., are colder than the surrounding flats. The depressions are known as "heat sinks," and have a blister of cold air over them which affects the temperature to a height of 500 feet.

During local cold weather, there is a cyclic wave motion of about 6 feet amplitude, resulting in a 3°F variation in temperature at stations near the ground. In effect, the air in the bottom of the valley is sloshing back and forth. There is also a slow gravity flow of cold air down the Tanana Valley. All of these are possible sources of turbulence, but heat sinks, heat sources, down-stream gravity flow and waves are not sufficient to break the cold air inversion. The inversion, and also the ice fog, become thicker and more intense as the cold weather prevails. If anything, a slow upward air movement tends to retard the settling of the ice droplets, and increase the height of the fog.

Ice fog remains and continues to grow, both in area and thickness, until the temperature warms up to -30°F. or so. In the low hills above the flats, the air is clear. If the inversion reaches that high, the ice fog cannot rise to that elevation because the air near the ground is so stable. For example, above the top of the inversion (something over 700-800 feet) would be in an area of more turbulence (colder air above warmer air) and hence not be subject to ice fog buildup.

Benson (1965, p. 38) estimates that the daily input of pollutants to the air in the Fairbanks area is:

TABLE 3

ESTIMATED DAILY INPUT OF POLLUTANTS INTO THE FAIRBANKS AREA ATMOSPHERE, 1964-1965

Pollutants	Estimated Daily Input (in kilograms)
H_2O	4,063,000
CO_2	4,100,000
SO_2	8,600
Pb	60
Br	46
Cl	20

He summarizes the pollution problem as follows (Benson, 1965, p. 16):

> During cold spells the lower air levels have very low winds, almost always less than 2 m sec^{-1}; this is especially true for the first 500 m which is nearly contained by the hills around Fairbanks. The existing flow consists of katabatic (gravity drainage) winds which move down the Tanana Valley. This has led to a widespread misconception that the katabatic flow drains cold air from the hills onto the flats, and especially into the lowest pockets. This would be a happy circumstance, if it occurred, because such drainage would tend to flush the air pollutants out of the city. However, the air in the flats is so much colder, and therefore denser, than that moving down from the hills, that the

latter cannot penetrate, and moves across the cold low-lying pool of air as if it were a lake. Thus, the only flushing mechanism for Fairbanks air during cold spells is "turned off," and the dense surface layers are effectively decoupled from the air above. Unfortunately, it is precisely during these cold spells, when the air is most able to stagnate that the rate of polluting the atmosphere increases because of increased demands for heat and power. Indeed, in Fairbanks, the air pollution during winter cold spells couldn't be worse, because natural and man-made factors reinforce one another in ways which invariably lead to intensification, never mitigation, of the air pollution.

Economic Geography

The geographic location of Fairbanks is especially important in considering the area's economic development potential. Severe seasonal changes in weather and the prevailing cold climate have restricted certain types of employment opportunities and create a permanent problem of "high costs" of operating businesses and households in subarctic urban areas (Haring, 1965, pp. 4-12). While certain industries face sharply increased costs of seasonal operations during winter months, counterbalancing "social" benefits arise. Ice fog conditions, which worsen materially with industrial activity, are not aggravated by the region's basic industries. Observed local trends in population growth and housing obviously are strongly and positively correlated with the historically increasing density of air pollutants and local coverage of ice fog. Overall, a potentially serious environmental problem is apparent (Haring, 1967). Several facets of it were identified in this chapter, namely --

(1) Industries which prosper principally during summer months do not materially and adversely affect air pollution, e.g., mining, tourism.

(2) Seasonal migration of the labor force reduces the demand for permanent housing and corollary man-generated air pollutants.

(3) Individual microclimates, especially as they become identified in greater detail, might easily lead to unique systems for classifying land on the basis of desirability for commercial and residential construction.

(4) The normally anticipated geographic dispersion of households apparently is greater than in other urban climates, a condition which probably will continue to exist.

This overview of geography and climatic conditions indicated many of the natural and man-created factors which affect economic development of the Borough. This physical environment is additionally specified in Chapter IV, Survey of Geology.

IV

SURVEY OF GEOLOGY

Introduction

Earth materials found at the surface or underground in a particular area should be "classified" in order to get maximum benefit from an investigation. The fundamental unit of geologists is the "formation," defined as a "mappable geologic unit." In particular, it is large enough to show and distinctive enough to recognize as a separate unit.

Obviously, if more investigative attention is paid to local detail, more units can be differentiated and mapped. The type of geologic classification and the number of units mapped also are restricted by the purposes of the investigation at hand. For example, a map intended to outline lode deposits might show several bedrock units and disregard unconsolidated deposits unless they are deep enough to be a hindrance. On the other hand, a map intended as a guide to engineering geology studies or groundwater supply studies might pay great attention to the surficial deposits and lump the bedrock units into large, single formations or groups. These two extremes are illustrated in the Fairbanks area by the following maps:

(1) Preliminary map of the bedrock geology of the Fairbanks mining district, Alaska, Forbes and Browne, 1961, University of Alaska and the Division of Mines and Minerals.

(2) Geologic map of the Fairbanks Quadrangle, Alaska, Péwé, Wahrhaftig, Weber, U. S. Geological Survey Map I-455, 1966.

The first of these does not show any surficial units; the second shows 21; they are both geologic maps.

Another type of earth materials map is the soils map. Soils are the products of more factors than just parent material. Accordingly, soils units, cut across geologic units, and often many more soils units are recognized than surficial geologic units.

Definitions

The following geographic and geologic terms are used as defined below:

Active zone - That layer of earth near the surface that freezes and thaws seasonally.

Alluvium or alluvial material - Sediment being transported or that has been deposited by stream action. Contains clay, silt, sand and gravel.

Bedrock - The solid consolidated part of the earth's crust, overlain by unconsolidated material.

Beaded drainage - Characteristic pattern of streams in polygonal ground, q.v., with angular stream paths and small lakes at the intersections of ice wedge cells.

Ground ice - Any ice occurring in permafrost. The melting of masses of irregularly distributed ground ice results in foundation trouble; small grains of regularly distributed ice generally do not cause trouble.

Ground water - Water in the ground in a zone of saturation below the water table.

Formation - A mappable lithogic unit, the fundamental rock unit of geology. Extensive enough to show on a map, distinctive enough to recognize.

Frost - Frozen ground, either permafrost or seasonal frost.

Frost action - Freezing and thawing of moisture in the ground and the resultant effects on structures in the ground or in contact with it.

Frost heaving - Generally upward movement of ground due to water freezing.

Loess - Homogeneous non-stratified, primarily silt-sized material. In many places, a rude vertical parting is present and it stands in vertical banks. As used in this report, it is of eolian (wind blown) origin.

Muck - Fine material, generally silt-sized that contains much organic material. Gray to black when frozen or wet; fetid odor upon thawing. Permafrost muck generally contains more ground ice than permafrost loess or floodplain silt.

Permafrost - Surficial deposits or bedrock in which the temperature has been below freezing for a relatively long period of time.

Permafrost table - Upper surface of permafrost.

Polygonal ground - Ground with a polygonal pattern due to subsidence of ground over thawing ground-ice arranged in a polygonal pattern, e.g., ice wedges.

Seasonal frost - Ground which is frozen due to winter cold but is not permanently frozen.

Sediment - Solid material that is being transported or has been moved from its place of origin by water, ice, or air, and has come to rest.

Silt - Sediment whose particles are "silt-sized," i.e., between clay sized and sand sized. The sizes of clay, sand and gravel are generally well known and need not be defined exactly here.

Slough - A stream which leaves a larger stream and empties back into it. This special definition applies only in Alaska.

Thaw lake or cave-in lake - Lake formed in a basin caused by the melting of ground ice in permafrost.

Thermokarst topography - Irregular topography containing hollows and caves caused by the melting of ground ice.

Unconsolidated material - The loose or poorly cemented material that covers most of the land surface.

Water table - Upper surface of the zone of saturation in the ground.

Geologic Mapping in the Borough

The area in which the Borough is located has been mapped at several scales over the years, topographically and geologically. The more important maps are as follows:

(1) Prindle, 1913, U. S. Geological Survey Bull. 525, Geological reconnaissance map, scale 1:250,000.

(2) Prindle and Katz, 1913, U. S. Geological Survey Bull. 525, Fairbanks mining district showing lode mines and placer mining ground, scale 1:62,500.

(3) Mertie, 1937, U. S. Geological Survey Bull. 872, Geological reconnaissance map of the Yukon-Tanana Plateau, scale 1:500,000.

Recent topographic mapping by the U. S. Geological Survey Topographic Branch has provided better base maps for geologic mapping and new geologic maps are much more detailed than the old ones. There are five of these new maps:

(4) U. S. Geological Survey Map I-455, 1966, Geologic map of the Fairbanks Quadrangle, 3 degrees of longitude and one degree of latitude, scale 1:250,000. This map is included in initial copies of this report (in pocket).

(5) Map GQ-124, 1959, Fairbanks D-1, scale 1:63,360.

(6) Map GQ-110, 1958, Fairbanks D-2, scale 1:63,360.

(7) Map I-340, 1961, Fairbanks D-3, scale 1:63,360.

(8) Map I-297, 1959, Western Part of Big Delta, (D-6), scale 1:63,360.

The larger scale maps, of course, show the geology in more detail than the 1:250,000 scale map. For example, frozen peat is shown on the larger scale map whereas it cannot be differentiated on the Fairbanks quadrangle map. All of these last five maps emphasize surficial geology. The surficial deposits are diverse in origin and geological characteristics; they occupy a large proportion of the mapped area; and they are comparatively thick. Detailed mapping and comprehensive descriptions are therefore justified from the standpoint of engineering geology.

Although eight bedrock units are described in the Fairbanks quadrangle map, only four occur in the Borough. Of these, only two, Birch Creek Schist and intrusive rocks, are important. The Birch Creek Schist contains enough varieties so that it could be useful for certain purposes to subdivide it. At present, this has not been accomplished except for small areas. The intrusions have been subdivided (Forbes and Brown, 1961).

The 1:250,000 Fairbanks quadrangle map has a separate 5-page explanation of units and bibliography, (See Plate 2). The larger scale maps are self-contained with written descriptions of the geography and geology printed alongside the maps. A very useful feature is the tabular explanation of units which contains a short description of the following properties for each unit:

(1) Distribution and thickness,

(2) Terrain and natural slopes,

(3) Drainage and permeability,

(4) Permafrost,

(5) Susceptibility to frost action

(6) Bearing strength and slope stability,

(7) Excavation and composition, and

(8) Possible uses.

The table from Map GQ-110 is reproduced in initial copies of this report as Plate 3 (in pocket).

There are, as noted earlier, parts of two major physiographic provinces within the Borough. These are the Tanana lowland and the Yukon-Tanana Plateau. (See Chapter III.) The Tanana lowland consists of the almost flat floodplain occupying the northeast side of the Tanana Valley and the sloping surface of the fans, moraines and outwash that borders the mountains on the south. The Yukon-Tanana upland is a well-dissected bedrock upland, consisting chiefly of Birch Creek Schist, but also containing greenstones and intrusive igneous rocks. The lower parts of the upland are covered with silt and the lower reaches of the upland streams are deeply buried in alluvium and are quite wide.

It can be seen from the very brief preceding descriptions that the geologic units of the Tanana lowlands will be different from those of the upland. However, the lower reaches of upland streams will have much in common with the Tanana lowlands, a matter discussed later.

Cold Climate Geological Features

The unconsolidated deposits of the "surficial geology" cover much of the surface of the Borough. Most engineering structures (e.g., commercial and residential buildings) are found upon these deposits. Consequently, they are of great importance. The outstanding characteristic of the area is the effect of cold weather on the behavior of these deposits. Therefore, it is necessary to have an understanding of some of the basic principles of cold climate geological processes in order to interpret maps and descriptions of units that deal with the local region.

Moistening Effect of the Climate

Although Fairbanks has a semi-arid climate (mean annual precipitation of 11.7 inches), limited evaporation and poor drainage due to permafrost and seasonal frost work together to create a relatively moist surface, (Refer to section on climate).

Permafrost

Permafrost was defined previously as ground in which the temperature has been below freezing for a long period of time. Interior Alaska lies in what is called the "discontinuous permafrost zone," i.e., permafrost underlies only a portion of the area and does not extend to such great depths as farther north in the "continuous zone." The greatest depth so far encountered on the Tanana floodplain is 265 feet of permafrost at Mile 11 on the Richardson Highway (Péwé, 1957, p. 15). It is entirely possible that greater depths exist on some of the creeks of the upland. In the discontinuous zone, this permafrost was left from a geologic period of colder climate, and is now controlled by vegetative cover and topographic location.

In general, there is little permafrost on the south facing slopes and on ridgetops. Also, if the cover is disturbed, the upper surface of "permafrost table" recedes. Permafrost is not increasing in the discontinuous zone except in a few favorably situated localities, i.e., permafrost is favored by impermeability and organic material. Permeable material may have circulating ground water and hence be thawed.

Ground Ice

Basically there are two cold weather processes which cause damage to structures: (1) the melting of permafrost and associated ground ice, and (2) the growth and melting of ground ice during the seasonal thaw-freeze cycle. Both are primarily controlled by the grain size of the material and secondarily by permeability and drainage.

Ground ice refers to any ice segregation in frozen ground, and can be very destructive in many ways. There are three chief types of ground ice: (1) buried stream ice, (2) ice-wedge ice, and (3) ice lenses and grains that grow in place. The three types, which occur locally, are discussed as follows --

(1) Buried stream ice. It is possible for seasonal ice on streams or rivers to be covered by alluvium or muck in the spring and thus be preserved. (This type is relatively unimportant.)

(2) Ice-wedge ice. When the surface of the ground is cooled until the ground freezes and then continues to cool, it contracts and tends to crack in a polygonal pattern. Snow, hoar-frost, and meltwater move into the cracks and prevent them from closing the next spring when the surface warms up. The following winter the ground opens up along the old cracks, more snow and ice get in. Thus, through the seasons, wedges of solid ice grow that taper to sharp edges at the bottoms. The ice masses formed in this way are not all vertically positioned and wedged-shaped, but may be inclined and found in sheets. They range in size from one-fourth inch to ten feet wide, and four to thirty feet high. Their tops are usually within a few feet of the surface but may be deeper. The wedges are arranged in interconnected polygonal patterns, and each polygon is called a "cell." (Wolff, 1964, p. 114.)

Ice wedges form chiefly in silt-sized material but they may form in sand, gravel or even partially disintegrated mica-schist bedrock. Thus, during the excavation of road cuts on the campus of the University of Alaska in 1956, many wedge-shaped bodies of sand extending into bedrock were uncovered. These had the same origin as the ice wedges except that the contraction cracks were filled with blowing sand instead of ice. However, the most favorable material for growth of ice wedges is poorly drained silt containing much organic material. This material, called muck, occurs on the margins of the Tanana lowlands and on the gently sloping lower slopes. It also occurs in the floodplains of the upland streams.

It is easy to see the potentially disastrous effects of the melting of these large ice masses. This melting can be instigated by the stripping of the vegetation, or over a longer period by natural warming of the climate. For example, the melting of the uppermost ice in the cells leaves the centers high, and results in regularly spaced mounds 10 to 50 feet in diameter. This occurs regularly when land containing ice-wedged cells is cleared for agriculture, (Péwé, 1954, p. 331). Even where the relief between the centers or the polygonal ice networks is not great enough to produce mounds, a polygonal surface ("polygonal ground") is evident. For example, where small streams develop across such areas, they will be angular and contain small lakes at the junctions of the polygons. The pattern made by such streams and lakes is called "beaded drainage."

(3) Ice lenses and masses. The third type of ground ice, though not so spectacular as the larger masses, probably accounts for more local damage. This is ice that has grown in place. When local water is held in the interstices of a sediment, it is bound to the individual particles by cohesion and put under pressure. If the interstices are very small, this pressure extends all the way across the space between the grains. For example, the water in clay would be under high pressure while that in sand or gravel would be insignificant. With increased pressure, the freezing point of water is lowered, and allows the water to remain liquid at temperatures below 0°C. However, when this supercooled water is freed to migrate by capillary action, it tends to move to a point of lower pressure. At that point it starts crystallizing into ice lenses, e.g., small tabular bodies, or grains. In sand or gravel, the pressures are not great enough to allow the water to remain liquid below 0°C. Clay, on the other hand, is too impermeable at these temperatures to allow migration.

An "optimum" material for the growth of relatively large and non-uniformly distributed ice masses is silt. Also, the most ice susceptible silt contains organic material. It is also, of course, necessary to have a source of water, especially ground water that is poorly drained or has saturated sand below the silt. Materials in which ground ice can form are said to be "frost susceptible." The most frost susceptible materials are silt sized, contain organic materials, in poorly drained places, and are located where the sun's rays do not prevent the formation of permafrost. In frost susceptible materials, the lenses and dikelets may be as thick as several inches and fairly closely spaced so that the final product contains several times more ice than silt.

Construction experience in the Fairbanks area suggests that only soils containing less than 3 percent material finer than 0.074 millimeter (No. 200 sieve) can be considered nonsusceptible for frost heaving. Except for mine tailings and the gravel beneath the floodplain, no unconsolidated material in the area can meet these requirements. (Rieger, Dement, and Sanders, 1963, p. 30.)

Melting of Ice Lenses and Grains

If permafrost containing ice lenses is disturbed or if a building is placed on it, the melting and consequent differential settling may cause structural distortion or failure. The effects are similar to those observed due to the melting of ice wedges. Ground that is fine grained and contains much ice may become unstable mud upon thawing. In contrast, in some frozen floodplain gravels and sands there is ice uniformly disseminated in grains. When this thaws, there is little settling and more important, settling is uniform and does not injure the structure.

Effects of Seasonal Freezing and Thawing

Melting of permafrost is not the only process that causes damage in frost-susceptible ground. For example, when a road is underlain by organic silt that contains water, as the roadbed cools below freezing, small ice lenses will form, thickening the section by several inches (depth of frost penetration beneath a hard packed road may be extreme). In addition to disturbing the road grade during the winter, the thawing in the spring creates "mud boils" and a general softening of the road. Another dangerous situation may be created when a partially finished building is left unheated through the winter. If there is frost-susceptible material under the building or on the sides, water can get to the material and very severe damage could occur. Therefore, the ground at the sides of such an unheated building should be sloped and drained or otherwise protected.

Another serious consequence of seasonal freezing is the heaving of piling. The process and counter-measures are well described by Péwé and Paige (1963). As frost susceptible ground freezes and expands because of the formation of ice lenses, it grips any solid bodies within it. Thus, piles may be lifted several inches in the winter and when the ground thaws in the spring, the soft material slumps down below the pile and it cannot settle. In a few years, the pile may be lifted several feet.

Thermokarst Topography

The irregular topography due to the melting of the ground ice masses is called "thermokarst" topography (from "thermo" for heat plus "karst" for the topography developed on dissolving limestone). Several cultivated fields near Fairbanks have developed steep-walled pits 5 to 20 feet deep, which may have been enlarged by running water. They occur near the boundaries between permafrost areas and unfrozen ground on hillside slopes. In 1948, Péwé (1954, p. 337) counted 34 such "thermokarst pits." He estimates that thermokarst effects should begin to appear 2 to 3 years after clearing.

Another thermokarst feature which forms in areas underlain by permafrost is the thaw lake or cave-in lake. When the cover is disturbed, ground-ice begins to melt and a basin is formed that holds water and enlarges itself by further melting of ground-ice in the bottom and on the sides. Such lakes are commonly lined with dead trees that have been undermined and fallen in. The ground-ice that thaws to form these lakes is not necessarily of ice-wedge origin. More than likely, it is comprised of ice lenses and grains that have grown in place.

Solifluction and Congeliturbation

The presence of permafrost or deep seasonal frost beneath the surface of a hillside prevents drainage in the spring when the surface begins to thaw. This near-surface ground often contains a substantial amount of ground-ice. The thawed material is saturated and may flow slowly down-slope at a rate, though imperceptible, more rapid than ordinary creep. This phenomenon is called "solifluction" and the process produces long, smooth slopes and gently rounded hills. Solifluction may be speeded up because the ground that freezes and thaws each season (the "active layer"), is continuously being disturbed by frost heaving in winter and thawing in summer. This seasonal churning action is called "congeliturbation."

Aufeis

Several circumstances might cause flowing or percolating water in winter to be forced to the surface and freeze. As the water keeps coming, it spreads out and tends to build up ice fields. These fields are called "icings" or "aufeis," and their control sometimes becomes absolutely necessary if they should threaten to engulf a road or structure. These icings are colloquially called "glaciers," but that designation is incorrect and misleading.

Importance of Choosing Routes and Sites Carefully, With Some Examples

From the foregoing description, it is obviously important to estimate frost-susceptibility, the presence of permafrost and ground-ice conditions for a particular area. This estimation can be accomplished with reasonable success by closely noting the land surface position with respect to slopes and creek bottoms, drainage conditions, any polygonal ground and vegetation. Of great value in making such an estimate is Plate 3, reproduced from the geologic map of the Fairbanks (D-2) quadrangle, (GQ-110). A few examples that emphasize the importance of location are easily noted in the Fairbanks-College area:

(1) The paved road connecting Fairbanks and College has stood up well and is still fairly smooth except where it is forced to swing to

the north to avoid the Noyes Slough. Here it leaves the floodplain alluvium and it crosses onto the "Qsu" unit or peat and organic silt of the geologic map (D-2).

(2) The College community Church was built about 1949 with no serious foundation problems. A few years later, an auxiliary building was constructed no more than 10 feet north of the Church. The boundary between the river alluvium on the south and organic silt on the north is sharp and apparently almost vertical (See Figure 4). The auxiliary building, a block structure, was underlain by organic silt and peat containing much ground-ice, and failed completely within a short time because of extreme differential settling.

(3) At Ballaine Lake, a thaw lake one mile north of the University, a building was erected in 1944 on "Qsu" (Péwé, 1958). Extreme differential settling by melting of ice caused very serious damage. Apartment buildings erected more recently across the road (east) are located on fields that have been cleared for several decades. Since thermokarst mounds or pits had not developed on the field to any great extent, it probably was not underlain by ice wedges or large lenses. At any rate, the permafrost table would have receded in the time since the field was cleared and the new buildings probably have safe foundations.

(4) Several buildings have been erected on the Fairbanks loess (QF), laying north of the Qsu of the last example. These buildings are on frost-free ground and hence will experience no damage from settling nor from heaving as long as they are heated during the winter. Where drainage is poor, it could be dangerous to leave them unheated. A small frame house, located in section 29 (T1N, R1W), built on piles and located in Qsu near the boundary with the Fairbanks loess, was lifted several inches when the ground around the pile froze. The house was heated, but not enough heat was transferred to the ground to prevent freezing.

Origin of the Silt and Muck Deposits

The origin of the widespread silt and muck deposits was debated for many years among geologists. The dominant theories of origin were (1) by settling in large lakes and (2) by the disintegration of schist bedrock. Both have now been discarded, except for small areas of analysis. The theory now almost universally accepted postulates a windblown origin.

Although extensive glaciers existed in the Alaska and Brooks Ranges, and smaller ones were active in the higher parts of the Yukon-Tanana Plateau, Interior Alaska was not extensively glaciated during the Pleistocene Ice Age. Glaciers which extended to perhaps 50 miles of Fairbanks on the south provided very large amounts of finely ground material to the streams. This was picked up by the wind and deposited as a blanket of loess over the Interior. There has been, of course, much creep and erosion of the originally deposited loess, so that in general, it is thinner on the tops of ridges and missing altogether in certain places. Péwé (1955, p. 699) states that the upland silt is "1-80 feet thick on tops of low hills,---10-100 feet thick on the middle slopes of higher hills, and thins to a few feet on the higher slopes of ridges 800-2000 feet above the valley." A 202 foot thickness is reported at Gold Hill (Péwé, 1955, p. 709). This material, called the Fairbanks loess (Qf) on the maps of the area, contains a few thin layers of volcanic ash in the loess. There were two periods of loess deposition, separated by a period of warming and erosion (Péwé, 1958).

The "muck" of the lower slopes and valley bottoms is reworked loess that has been transported downhill by creep, solifluction, and other mass wasting processes. In the process, more or less organic material, including vegetation and mammal remains, has been incorporated. This material is designated "undifferentiated perennially frozen silt (Qsu)" and "Organic silt (Qso)" by Péwé (1958) and is so labeled on the maps cited. It is the most susceptible to formation of ground ice of any material in the area. Depths of 165 feet have been reported (Prindle and Katz, 1913, p. 107), but it is not known whether this also included some of the loess.

Descriptions of Geologic Units

The geologic maps that cover parts of the Borough show certain separable rock units as geologists have interpreted them. Physical characteristics of these units as they influence engineering properties are listed in Plate 3. In accordance with standard procedures, these units are briefly described below from the oldest to the youngest units.

Hardrock Units, Metamorphic and Igneous

(1) Birch Creek Schist (P€bc on all maps)

The Birch Creek Schist, the oldest rock in the area, consists of several varieties. Quartzite and quartz-mica schist comprise the largest proportion of the unit. Forbes and Brown (1961) list the following varieties from the Cleary Summit area.

Pelitic Schists and Quartzites
- micaceous quartzites
- quartz-mica schists
- mica schists — muscovite and/or biotite
- garnet-mica schists — w/rare staurolite or andalusite

Gneisses
- garnet-mica gneisses
- epodite bearing biotite gneisses

Amphibolites and Lime Silicate Rocks
- tremolite-carbonate-schists
- chlorite-carbonate-quartz schists
- clinozoisite-carbonate-quartz schists
- clinozoisite-actinolite-phogopite-oligoclase schists
- amphibolites
  - oligoclase-epidote amphibolites
  - garnet-biotite amphibolites

Marbles
- chlorite bearing tremolite marbles
- clinozoisite marbles
- phlogpite marbles
- silicious marbles

Generally, the Birch Creek Schist provides good foundations and is well drained. The micaceous varieties break down rapidly by weathering and may be subject to sliding if foliation planes dip in the same direction as the slope. The micaceous varieties do not make suitable construction material for the same reason. Certain metamorphosed limestones in the Birch Creek Schist might provide marble for building purposes, but to date they have been little used. Fractures in the upper parts of the unit provide small to moderate amounts of groundwater.

The Birch Creek Schist is the host rock for most of the gold deposits of the Yukon-Tanana Plateau and in the Borough. Calcareous zones in the schist have been mineralized with scheelite (tungsten ore).

(2) Undifferentiated pre-middle Ordovician rocks (pO, Bull. 872)

Mertie (1937, p. 65) describes a sequence of metamorphosed sedimentary rocks that crop out between Fairbanks and Livengood. They are distinguished from the Birch Creek Schist by being less severely metamorphosed. There is also a large outcrop of similar rocks south of the Chena River that has been assigned to this same unit; more recent workers also believe that the assignment is valid (Weber, personal communication, 1966). Mertie (1937, p. 71) cites Prindle as reporting for this outcrop "more quartzite, shale, slate, phyllite, chert, chert conglomerate, greenstone, and limestone of which the dominant types are derived from sandy and argillaceous sediments." This outcrop generally has an east-west elongate pattern and lies south of the Chena River, with its northern boundary about at the Chena. It crosses the Salcha and extends easterly to the headwaters of the Charley River. There is some evidence that these rocks extend westward to include Birch Hill, College Hill, Chena Bluff and Moose Creek Bluff.

These rocks, being less regionally metamorphosed than the Birch Creek Schist, are more susceptible to contact metamorphism around intrusions and some beautiful decorative building stone has been found in skarn areas around intrusions, such as at Moose Creek Bluff. Otherwise, their engineering characteristics are about the same as those of the Birch Creek Schist except that they probably do not contain the easily disintegrated micaceous varieties found in the Birch Creek Schist. They are just as favorable as host rocks for gold veins as the Birch Creek Schist.

(3) Greenstone intrusive rocks (Dbi in Bull. 872, Dbu on Fairbanks Quadrangle map)

Metamorphosed mafic and ultramafic rocks crop out in an intermittent linear pattern between the Chena and Salcha Rivers. Little is known about the rocks in this outcrop. Mertie (1937, p. 203) says that they are in part ophicalcite (serpentine marble) and are in places extensively serpentinized. If these rocks are similar to those of Livengood, they should present no foundation problems, but serpentine, if fractured and sheared, has some tendency to slide in preferred directions. Therefore, special attention should be paid to any outcrops crossed by roads. Present workers do not believe that the area covered by these rocks are as great as shown on Mertie's map. In particular, the large outcrop along the north fork of the Little Salcha River, which was mapped largely on the basis of viewing from a distance, is non-existent except for a patch at the extreme east end, (F. R. Weber, personal communication, 1966). The linear outcrop farther up the river does exist. These rocks crop out at Wood River buttes (Péwé, Wahrhaftig, Weber, 1966) and a magnetic anomaly indicates that they lie under the Tanana River alluvium in line with the outcrop. It is the authors' opinion that the linear outcrop patterns of the serpentine indicated that some of them were squeezed into place during and after consolidation. These may outline shear zones parallel to the structure of the country rock.

The serpentine at Livengood contains grains of chromite, and Mertie suggests (1937, p. 204) that "ores of nickel and possibly platinum may possibly be found in the vicinity of these ultra-basic rocks." There is a nickel prospect on the outcrop north of the Salcha River above the Splits, (Joesting, 1942, p. 18). This type of ultramafic intrusion has rarely formed large mines of chromite and the chances are probably small that any will be found.

(4) Igneous granitic rocks (grd in Bull. 872, Mzi on Map I-455, gr on others)

Granitic rocks outcrop at a number of places in the Yukon-Tanana Plateau. Most of these cover only a few square miles, but in the eastern part there are very large outcrops, e.g., the Charley River batholith, cut by the headwaters of the Salcha. The rocks include granite, quartz diorite and quartz monzonite. The granites may be classed as biotite, biotite-muscovite, muscovite, and biotite-hornblende, and Mertie (1937, p. 213) reports one small outcrop with tourmaline and fluorite. A number of more silicic varieties also occur, e.g., quartz porphyry, alaskite, aplite, and pegmatite. Diorite without quartz is rare; there are a few basic differentiates of this group, such as gabbro, quartz-gabbro, and even ultramafic rocks.

From the standpoint of engineering geology, there is probably little difference among these varieties. All provide strong, solid foundations free from frost problems. In a few places where the products of weathering have accumulated, there may be thick accumulations of sticky clay but these usually occur only in streambeds.

Brown (1962), writing only of the Pedro Dome area, recognizes two periods of intrusion. Hornblende-biotite quartz diorite intrusions are provisionally dated as Jurassic-Cretaceous, and quartz-monzonite porphyry as Cretaceous-Tertiary. The earlier (quartz diorite) rocks have altered equivalents occurring as dikes 10-100 feet thick and the later ones (quartz-monzonite) have an extremely altered equivalent that occurs in stocks. The mineral deposits of the Pedro Dome area are derived from hydrothermal solutions genetically related to the quartz monzonite intrusions (Brown, 1962, p. 124).

(5) Basalt (Tb on Map I-455 and Map GQ-124)

A few small outcrops of "dark gray and black, or brownish basalt, closely jointed and deeply weathered, with local pillow or columnar structure" occur on the lower slopes and hills in the vicinity of Fort

Wainwright (Péwé, Wahrhaftig, Weber, 1966). There are also outcrops on Kokomo Creek and Fourth of July Hill north of Fairbanks.

This basalt should present no special problems in engineering geology. It makes good road material and solid foundations. Jointed basalts are good aquifiers in many places, but the outcrop area of these is probably too small to provide much of a reservoir.

Tertiary Units

Two poorly consolidated formations of Tertiary Age are defined in the literature, but so far as is known, their chief distribution is outside the Borough. These are the Coal Bearing Formation (Tcb) and the Nenana Gravel (Tn). They crop out along the north flank of the Alaska Range. The coal bearing formation, which contains the coal of the Nenana and Healy River areas, lies in basins in the older bedrock.

The Nenana Gravels are someqhat younger (Pliocene) and are less well consolidated. Along with correlative rocks in the Yukon-Tanana Plateau, they are reported to contain small amounts of gold which may have contributed to later placers, although this has not been proven. The only known occurrence of Tertiary gravel in the Borough is a small outcrop near Fourth of July Hill north of Fish Creek.

Quaternary Unconsolidated Deposits

Quaternary unconsolidated deposits cover much of the Borough, even in the upland areas. Since many of these deposits are deep, their engineering properties are of great importance. Most recent maps have emphasized surficial geology, and twenty-one units of unconsolidated surficial material are described on the five recent U. S. Geological Survey maps of the region. These are lumped into fewer units in other surveys (Alaska Department of Public Works, 1959). Figure 5 indicates which units are shown on different maps.

(1) Dune sand (Qd on Map I-455)

Alaska has a wide distribution of eolian material (Black, 1951). In addition to the windblown silt, already discussed, there are stabilized sand dunes along the south side of the Tanana River. The only dune sand in the Borough, however, is in a small area on the lower Wood River. Dune sand is well sorted and permeable and probably unfrozen. It should make excellent foundations and provide good water. If construction on this material is planned, the subsurface should be investigated to determine if it can withstand earthquakes without flowing as at Huslia in 1958 (Davis, 1960).

(2) Glacial deposits (Qrm, Qro, Qhm, Qhq, Qho on Map I-455)

During glacial advances there was glacial ice in the southern part of the Fairbanks quadrangle, which left moraine outwash, and in some places alluvial fan deposits. Morainal material is poorly sorted, consisting of silt, sand, and gravel with boulders greater than 3 feet in diameter. Permafrost is present but the ice content is low. The outwash deposits and alluvial fan deposits consist of material deposited by melt water and hence are similar to alluvium. The outwash and fans are well sorted, very permeable and contain excellent ground water. They are locally frozen but contain little ground ice.

In the highest parts of the Yukon-Tanana Plateau, there are a few small areas that formerly contained glaciers. There are no large areas of morainal material in the Borough but outwash (Qro) covers a considerable area in the southern part of the bombing range. This material has characteristics as noted above.

(3) Perenially frozen silt, undifferentiated (Qsu on all maps)

This is the "muck" of the area, consisting of the retransported Fairbanks loess which has moved down to the lower slopes and valley bottoms. It incorporates much organic material, including vegetation and animal remains. It covers the valley bottoms of many of the creeks of the uplands and almost all of the lower parts of the valley slopes. It also borders the north side of the Tanana Valley, occupying large areas north of Fairbanks between the valley alluvium and the Fairbanks loess. It is everywhere frozen, permafrost ranging from 3 to 200 feet in thickness in valley bottoms, and causes very poor drainage conditions. It is the ideal material for the formation of both types of ground ice and is very frost susceptible. It provides poor foundations unless it can be kept frozen, but foundation conditions are somewhat better near the upper edge where it is in contact with loess. This unit may be recognized by several criteria: it is dotted with thaw lakes, is poorly drained, and may have polygonal ground. The vegetation also is typically that of frozen and poorly drained ground; spindly black spruce and marsh grow in discontinuous patterns.

On some of the larger scale maps, the more organic varieties have been differentiated into organic silt (Qso) and peat (Qp). Both of these units are extremely poor for construction purposes of any kind.

Péwé (1958) says "Good for mosquito studies!!!" Another unit separated on the larger scale maps is silt composing alluvial fans (Qsf). This is silt brought down by streams and deposited over the alluvial fill of the larger floodplains where it forms a veneer as thick as 30 feet. Drainage is better than in Qsu, and although generally frozen, ground ice does not present a problem.

(4) Fairbanks loess (Qf on all maps)

This is the silt blown from the bars of glacier-fed streams during the Ice Age. It is homogeneous, massive, well sorted, and locally cemented. Loess characteristically has some vertical structure, and it has good permeability vertically and fair permeability laterally. It will stand in nearly vertical cuts and has good bearing strength when undisturbed. Loess should not be disturbed as this causes it to lose its cohesiveness. Groundwater is deep; permafrost is absent except possibly on poorly drained north facing slopes. Frost susceptibility is low except in a few poorly drained places, although any silt may become strongly frost susceptible if a good supply of water is available. The Fairbanks loess occurs on low hilltops and higher slopes, and thickness ranges from a veneer near the tops of the hills to more than 200 feet near the lower slopes. It has been subject to gullying in the past during a period of less rainfall than at present, but it is not gullying now except where the vegetation has been stripped.

(5) Torrential fan deposits (Qtf on Map I-455)

These deposits border the foothills of the Alaska Range, but do not occur in the Borough. Generally, they are well drained and porous, but may contain some silt.

(6) Dune sand, reworked (Qdr on Map I-455)

Along the lower part of the Wood River, there are some small areas of organic, silty sand derived from sand dunes. They underlie undrained depressions, and permafrost and ground ice are probably present at shallow depths.

(7) Abandoned floodplain alluvium (Qab on Fairbanks Quadrangle map)

This unit occurs in areas south of the Tanana River and is quite similar to the present Quaternary alluvium. It contains slough and swale deposits of silt.

(8) Alluvial-fan deposits (Qaf on Fairbanks Quadrangle map)

This unit occurs south of the Tanana floodplain and consists of well stratified gravel. Locally it is perennially frozen with a low ice-content. It makes a good construction material and provides safe foundations. The groundwater in this unit contains less dissolved solids and organic material than it does farther north in the present floodplain. The size of the material is larger than that of the floodplain because it is nearer the mountains. Boulders 18 inches thick in diameter are common 10 miles from the mountains.

(9) Reworked creek gravel - Placer tailing (Qg on all maps)

On the Big Delta (D-6) map, this category includes unreworked creek gravel. The gravel provides excellent construction material and foundations, but has no soil cover. The material from which it was derived and which underlies the silt and muck on all upland streams is well stratified into layers and lenses of poorly sorted, sandy gravel with particles up to 24 inches in diameter. It is perennially frozen with little ground ice. The dredge tailings themselves contain few fines, but are developing vegetation. They are very permeable and make good foundations.

(10) Swamp deposits (Qs on Map I-455)

This unit consists of peat and silt more than five feet thick with poor drainage and standing water. It is perennially frozen and contains much ground ice, is very frost susceptible and poor for construction of any kind.

(11) Floodplain alluvium (Qa on Map I-455; Qal on Fairbanks D-1, D-2, D-3, Big Delta D-6 maps)

This unit occupies the low flat central parts of stream valleys and generally consists of two facies: gravel and silt. The gravel contains particles from 1/4 inch to 3 feet in diameter. Gravel is almost always overlain by 1 to 20 feet of silt, and very little gravel occurs at the surface. Below the mouth of the Chena River floodplain, the silty facies predominates. The silty facies also occurs in the old swales and sloughs.

The gravelly facies is well drained. Although it may be frozen in perhaps half of the area for depths of from a few feet to 250 feet, the ground ice is interstitial and does not create serious problems, i.e., bearing strength is excellent.

The silty facies, where it occurs in swales or sloughs, is indicated on the larger scale maps as Qs. It is less well drained, is very frost susceptible and contains many small ice segregations that may be thick enough to allow settling when they melt. The thickness of the silt is usually less than 10 feet, but may be as great as 25 feet. Frost heaving in winter may be a problem.

Not all of the formations described above occur in the Fairbanks area. Figure 4 is a diagrammatic cross section along a north south line running through the peat bog on the College Road. This cross

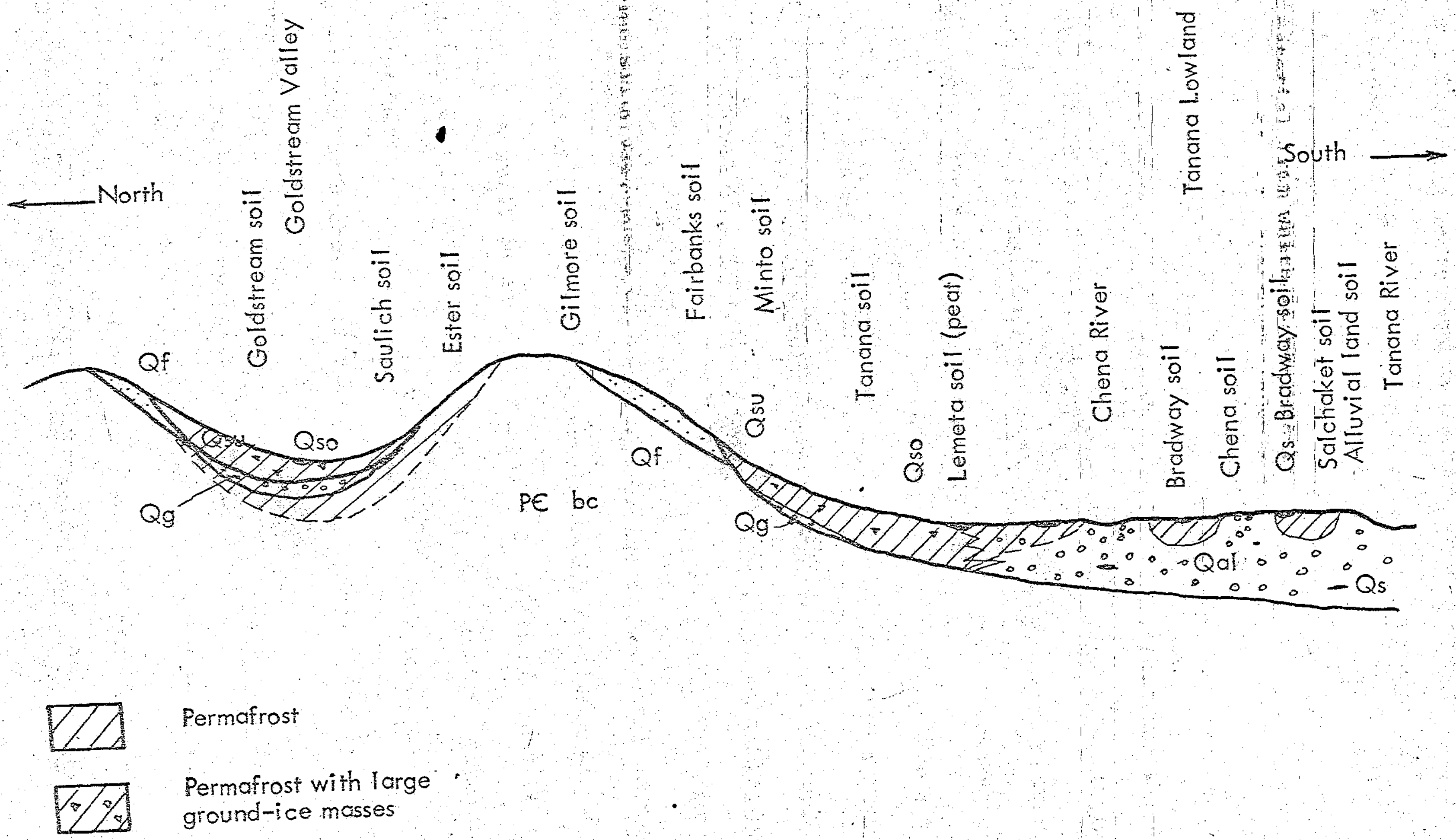

Fig. 4. Diagramatic cross section showing location of geologic units and soils. (After USGS Bull. 989-F and S.C.S. Series 1959, No. 25.)

section also shows the location of soil types. The different geologic maps show different units, and these have been tabulated in Figure 5 so that equivalent units can be traced from one map to another.

Earthquakes

The Borough lies on the northern edge of a curving seismically active belt that parallels the Alaska and Coast Ranges and the Aleutian Islands. It is common to feel earthquakes from farther south in the belt or from small magnitude earthquakes with epicenters nearer Fairbanks. About every decade, a shock of magnitude 7 or greater occurs somewhere in Interior Alaska. Figure 6, after Davis, (1963), shows the distribution of the epicenters and indicates that there are a number of active faults involved.

The amount of earthquake damage is dependent, to a large extent, on the surface conditions at the site of the damage. For example, the great earthquake of 1964 was so destructive in Anchorage partly because much of the city was built on glacial outwash overlying clay. The city of Valdez is built on an alluvial fan that slumped. This is not to say that the seismic shock did not cause much damage, but certainly most of the destruction was due to slumping, high water, and compaction and landsliding both above and below water (Grantz, Plafker, Kachadoorian, 1964).

The region around Huslia is very sparsely inhabited, otherwise severe damage would have been caused by the earthquake of April 7, 1958, on the Koyukuk River. At that location, underlying saturated silt and sand is overlain by stabilized dry sand dunes (Davis, 1960). Apparently,

Figure 5. Designations of geologic and soils units on different maps of area. Read from left to right.

Geol. Age / Map	Fairbanks I-455	Fairbanks D-1 GQ-124	Fairbanks D-2 GQ-110	Fairbanks D-3 I-340	Big Delta D-6 I-297	Chena Hot Springs Road BPR	Soil Series Developed on Formation S.C.S. 1959, No. 25	Bull 872 (U.S.G.S.)
RECENT	Flood Plain Alluvium (1) gravelly, (2) silty (Qa)	Flood Plain Alluvium (Qal) Swale & slough deposits (Qs)	Flood Plain Alluvium (Qal) Swale & slough deposits (Qs)	Flood Plain Alluvium (Qal) Swale & slough deposits (Qs)	Flood Plain Alluvium (Qal) Swale & slough deposits (Qs)	Alluvial sand and gravel	Alluv. land; Chena Salchacket; Tanana Bradway	Alluv. deposits (Qal)
	Swamp deposits (Qs) Landslide debris (Ql) Reworked creek gravel (Qg)	Reworked creek gravel (Qg)	Reworked creek gravel (Qg)	Reworked creek gravel (Qg)	Creek gravel (Qg)	Not mapped	Mine tailings	Alluvial deposits (Qal)
WISCONSIN AND RECENT		Terrace Alluv. (Qts)	Not mapped	Not mapped	Terrace Alluv. (Qts)	Not mapped		Alluvial deposits (Qal)
	Abandoned Flood Plain alluvium (1) gravelly (2) silty (Qab)	None in area	None in area	None in area	None in area	None in area	Tanana	Not mapped
	Alluvial fan deposits (Qaf)	None in area	None in area	None in area	None in area	None in area	None in area	Not mapped
	Dune sand, reworked (Qdr)	None in area	None in area	None in area	None in area	None in area	None in area	None in area
WISCONSIN	Riley Cr, glac. Moraine (Qrm) Outwash (Qro)	None in area	None in area	None in area	None in area	None in area	None in area	Glacial deposits (Qm)
ILLINOISAN TO RECENT	Torrential fan deposits (Qtf)	None in area	None in area	None in area	None in area	None in area	None in area	None in area
	Fairbanks loess (Qf)	Fairbanks loess (Qf)	Fairbanks loess (Qf)	Fairbanks loess (Qf)	Fairbanks loess (Qf)		Fairbanks, Gilmore, Ester	
	Perennially frozen silt, undif. (Qsu)	Perennially froz. silt, undif. (Qsu) Alluv. fan silt (Qsf)	Perennially frozen silt, undif. (Qsu) Alluv. fan silt (Qsf) Org silt (Qso) Peat (Qp)	Perennially froz. silt, undif. (Qsu) Alluv. fan silt (Qsf)	Perennially froz. silt, undif. (Qsu) Alluv. fan silt (Qsf)	Alluv. fan silt Thaw lakes & muskeg veg.	Minto, Ester, Saulich, Goldstream Goldstream, Lemeta	Alluvial deposits (Qal)
	Dune sand (Qd)	None in area	None in area	None in area	None in area	None in area	None in area	None in area
Illinoisan	Glacial deposits Healy, Dry Creek Browne	None in area	None in area	None in area	None in area	None in area	None in area	None in area
Tertiary	Basalt (Tb)	Basalt (Tb)	None in area	None in area	None in area	None in area	None in area	Undif lavas (TQv) Quartz monz (TQm) Rhyolite & dacite(Tev)
Mesozoic	Intrusive rocks (Mzi)	Alt dike rock (ad)	Alt dike rock (ad) Granite (Gr) Quartz diorite(qd)	Alt dike rock (ad)				
Paleozoic							Gilmore, Ester	Granite & quartz diorite (grd) Ultrabas. & basic rks (Dbi) Undif pre Mid Ord. rks (p0)
Precambrian	Birch Creek Schist (P€bc)	Birch Creek Schist (P€bc)	Birch Creek Schist (P€bc)	Birch Creek Schist (P€bc)	Birch Creek Schist (P€bc)	Not mapped	Gilmore, Ester	Birch Creek Schist (p€)

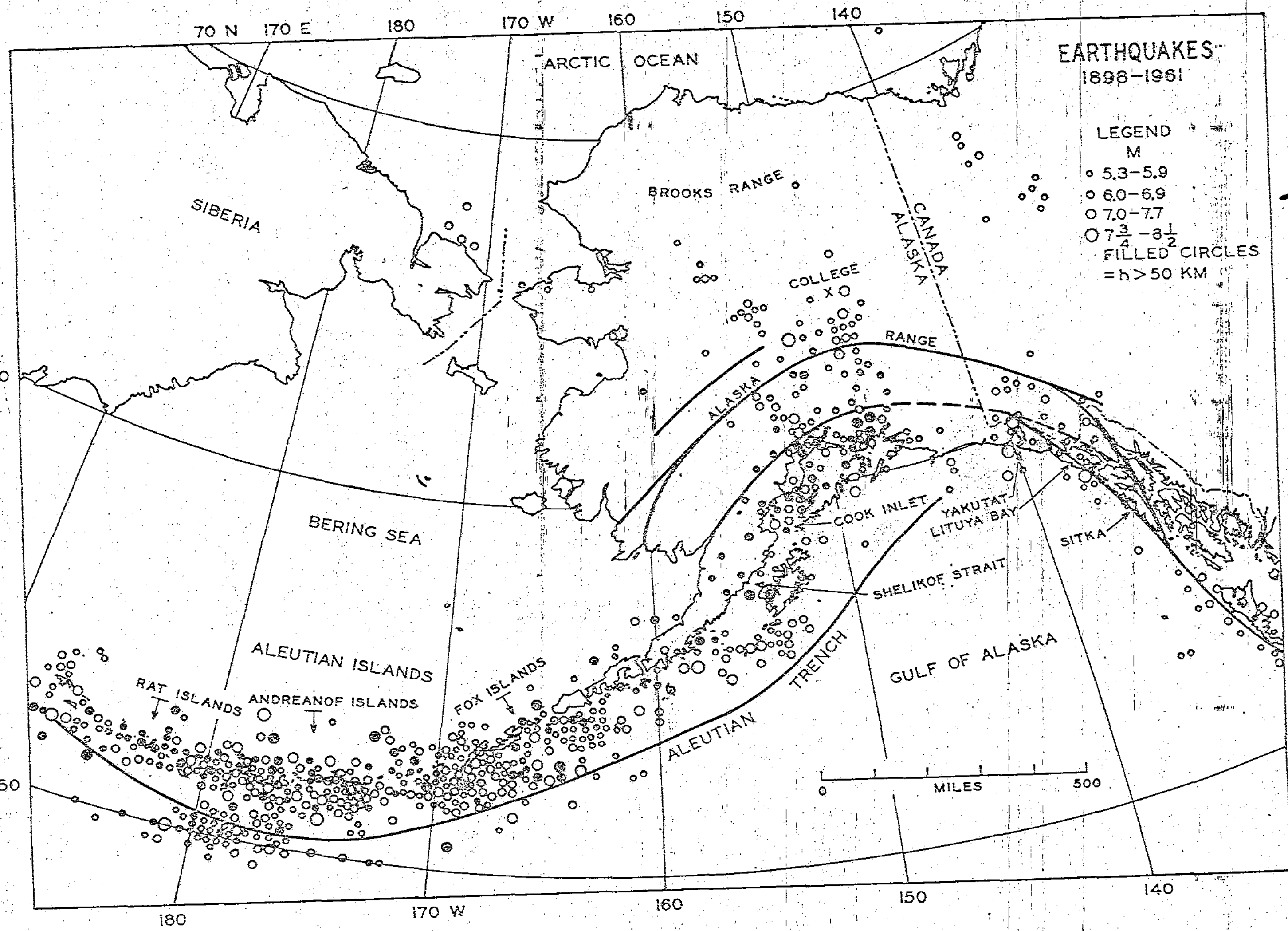

Fig. 6. Distribution of earthquakes in Alaska.

spontaneous liquefaction of the underlying material allowed it to be forced from fissures in the sand dunes during the shaking. This resulted in sand flows and slumping. There was also slumping toward the river. The only large areas of dune sand overlying alluvium near the Borough are on the Tanana River above Big Delta and near the Teklanika River west of Nenana. Before any structures are placed on stabilized dunes, drilling should be done to determine if they are underlain by saturated sand or silt.

The potential danger of earthquake damage to structures in the Borough is very real and difficult to assess. The largest magnitude estimated for a quake in historical times is 8.4 for the Anchorage quake of 1964. The strongest in Interior Alaska occurred in the Kantishna area, about 120 miles from Fairbanks. It had an intensity of 7.75. The most severe ever felt in Fairbanks was on January 29, 1929, which was caused by a quake near the head of the Tatlanika River, 60 miles away. The closest epicenter positively located was about 30 miles southeast of Fairbanks (July 22, 1937). Small quakes, recorded at the College Seismological Station, may have originated as close as 10 miles from the city.

Considering the seismic history of the area, future construction should be of an earthquake-proof type. Special attention should be paid to picking a location where landslides are not likely to be triggered by their shocks. Fairbanks and most of the inhabited parts of the Borough are located in stable areas. Situations that might be dangerous are where alluvial fans of coarse dry material cover saturated sand or silt, or where a building is located too close to a steep river bank. The normal Tanana floodplain provides a good earthquake-resistant foundation. During the shock of October 16, 1947, which did minor damage in Fairbanks, two-story concrete block walls that had been erected at Ladd Field (now Fort Wainwright) lacked the support that the enclosing frame structures later provided. As far as is known, no major damage was done to the finished buildings. Over longer periods the distinct possibility exists that central Alaska may experience a stronger shock (or one closer). Either of these conditions could produce greater earthquake damage than has been experienced recently.

All in all, this survey of local geology revealed additional information about the economic difficulties in the local physical environment. Several major problems and questions were exposed. They are --

(1) The geological conditions identified in and near Fairbanks are a striking contrast to that found near urban areas elsewhere. As a consequence, more than the "typical" insight into the local geology is necessary in urban planning and on behalf of residents.

(2) Widespread conditions of permafrost, ice wedges and frost-susceptible ground definitely limit the type of "reasonable" land uses. The amount and accessibility of "buildable" land is much more scarce than commonly believed, a matter duscussed in greater detail later.

(3) The present stock of commercial and residential buildings is exposed to natural conditions which cause rapid physical wear and tear.

That is, physical depreciation in these structures occurs rapidly in this climate. In addition, a good many of the present dwellings were constructed on unsuitable foundation materials or were inadequately designed for this climate (Haring, 1966a).

Chapters III and IV have established a background for a discussion of two additional natural resource factors. They are soils and water, and comprise the principal subject matter of Chapter V.

V

SOILS AND WATER

This chapter is concerned principally with the existing soil and water conditions which prevail in the Borough and the ways in which they affect economic activity. To a large extent, the soil and water conditions are dictated by the local weather and geologic features discussed at length in Chpaters III and IV. In particular, the purposes of this chapter are--

(1) To identify basic soil and water conditions and their locational incidence;

(2) To estimate, in a preliminary fashion, water supply conditions in and near the Borough's urbanized areas; and

(3) To identify areas in terms of buildability and analyze likely interpretations and uses of this type of land classification.

Soils

(Note: The following discussion has been taken largely from S.C.S. Series, 1959, No. 25, Soil Survey, Fairbanks Area, Alaska. Since part of the descriptions are taken almost verbatim, particular acknowledgement is hereby given to the source.)

Definitions

The following terms apply to various segments of this chapter. They are defined below--

Soil profile - The vertical sequence of natural layers in a soil, extending from the surface to the underlying material that has not been changed by leaching or by plant roots.

Soil series - Soils that have profiles almost alike, except for a different texture of the surface layer. Named for a town or other geographic feature. Example: Fairbanks loess.

Soil type - A subdivision of a series. Within a series, all soils having the same texture for the surface layer belong to a type. Example: Fairbanks silt loam.

Soil phase - A subdivision of a soil type. The name is descriptive of some feature that affects management. Example: Fairbanks silt loam, 3 to 7 percent grade.

Mapping unit - Area shown on a soils map. There are three types of soils maps: Detailed, reconnaissance, and detailed-reconnaissance. On a detailed map, soil types or phases are mapped as units except for very small isolated areas. Each map unit therefore is nearly equivalent to a type or phase. On a reconnaissance map, several types or even series may be lumped into one mapping unit. These maps are suitable for appraising land for uses such as agricultural, forestry and recreational. The detailed-reconnaissance map is partly detailed, partly reconnaissance.

Soils group - A broad geographic group of soils. In the Fairbanks area there are two: soils of the uplands, and soils of the alluvial plains.

Texture - The fabric of the mineral component of the soil mass resulting from the relative proportions of the three particle size separates--sands, silt and clay.

Structure - The aggregation of the textural units of the soil mass into variously shaped and sized larger particles. In other words, it is the relationship of the textured particles to each other, including the amount of pore space.

Capability group - A grouping of soils that shows, in a general way, how suitable they are for most types of farming. It is a practical grouping based on limitations of the soils, i.e., the risk of damage when they are used, and the way they respond to treatment. Three levels or bases of subdivision are: (1) capability class, (2) capability subclass, (3) capability unit. There are eight classes, numbered from I to VIII in order of decreasing usefulness for crops. Classes I and V are not represented in the Fairbanks area. Subclasses indicate major limitations: e = erosion, w = wet, s = shallow, droughty or stoney, c = too cold or too dry. The capability units are called management groups and include all soils sufficiently similar to render them suitable for the same crops and management practices. They are given numbers that are assigned locally. There are 23 local management groups.

Descriptions of Soil Series

Soils of the uplands. These soils have developed in loess or in loess which has moved downslope incorporating organic material in it (muck). Thus, it forms chiefly in the geologic formations Fairbanks loess (Qf) or perennially frozen silt, undifferentiated (Qsu). From the distribution of these soils, it is probable that some of them have developed on Birch Creek Schist, a parent material that should yield soils similar to those formed on loess. Since mass wasting is more effective on south facing slopes, the lower parts of these slopes generally have more gentle gradients than the corresponding north facing slopes. The soils of south facing slopes have developed under forests of white spruce, paper birch and quaking aspen. They are usually well drained and free from permafrost. On north facing slopes, the vegetation is spindly black spruce and thick moss. The boundary between the soils on north and south facing slopes is abrupt at the ridgetops.

The following soils are found on the uplands:

(1) Ester Series: They develop on poorly drained, perennially frozen shallow deposits of micaceous silt on north facing slopes of high ridges. The natural cover consists of spindly black spruce and scattered alder and willow, and a few areas support paper birch. The surface is generally covered with moss, lichen and shrubs and the depth to schist bedrock is usually less than 24 inches. Near the tops of steep ridges, the transition to Gilmore, or less commonly Fairbanks soil is abrupt. On the less steep parts of north-facing slopes, Ester soils grade into Saulich soils. Ester soils occur on Fairbanks loess (Qf), Perennially frozen silt, undifferentiated (Qsu), and Birch Creek Schist (P€bc). Some of the soil situated in the higher parts of the Fairbanks loess may not be frozen.

(2) Fairbanks Series: These soils, the most extensive of the uplands, are well drained and found in moderately deep micaceous silt. They occur mainly near the middle of long, south facing slopes and on lower hills near the alluvial plain. These soils support paper birch and white spruce. Where cleared or burned, aspen or alder appear. They develop on Fairbanks loess (Qf) and are susceptible to erosion when cleared.

(3) Gilmore Series: They are also extensive in the area coverage. Soils are found on south facing slopes of high ridges in shallow to very shallow micaceous silt. They readily support paper birch, white spruce and aspen. When cut over, quaking aspen and alder will appear. They are found covering Fairbanks loess and Birch Creek Schist (Qf and P€bc).

(4) Goldstream Series: Poorly drained, silty soils with perennially frozen subsoil that occur in broad, low areas of the alluvial plain along principal rivers and in relatively narrow strips along upland drainage-ways. Vegetation is a dense growth of shrubs and a few clumps of spindly black spruce, tamarack and willow with sedge tussocks. Its depth usually is 10 to 24 inches to permafrost. These soils occur on alluvial plains slightly lower than the Tanana soils. They are more poorly drained and finer textured than Tanana soils, and are situated on perennially frozen silt, undifferentiated (Qsu) and organic silt (Qso).

(5) Minto Series: Occur on nearly level to moderately sloping, moderately well drained areas at the bases of hills that are dominated by the well-drained Fairbanks soils. They support white spruce, paper birch and quaking aspen. Some areas are covered with black spruce. The forest floor is covered with some moss, grass and horsetail. In many places, the Minto soils are underlain by permafrost and ground ice; if thermokarst pits or hummocks develop, the land may be spoiled for agriculture. They may grade into Tanana or Goldstream series on their lower boundaries and occur in Perennially frozen silt, undifferentiated (Qsu).

(6) Saulich Series: Poorly drained soils on lower parts of north facing slopes in fairly thick deposits of silty material. Vegetation consists of a thick mat of moss and a dense growth of low shrubs with sparse stands of black spruce and scattered alders and willows. The subsoil is perennially frozen and ranges in depth 12 to 30 inches to permafrost. The soil is always saturated in the natural state above permafrost and develops on Perennially frozen silt, undifferentiated (Qsu).

Among the five soil series of the uplands, the Fairbanks and Minto soils are the best for agriculture. They are erodible, and the Minto soils may be subject to thermokarst pitting. The soils of north-facing slopes and upland drainages are generally too wet, but they may be stripped and drained.

Soils of the alluvial plains. These soils occur on silty or sandy alluvium of the Tanana floodplain and are underlain by gravel at depths of from one to more than 50 feet. Close to the major streams, the soils are sandy and permafrost is deep or absent. Those removed from major streams are silty and have a high permafrost table.

(1) Alluvial land Series: Occur on frequently flooded areas adjacent to the rivers and sloughs, only at slightly higher than the normal level of streams. They are usually dissected by many small channels. The soil is mainly loose, coarse sand and gravel, covered in places by a thin mantle of gray silty material. Vegetation is a fairly dense cover of shrubs, moss, sedges and black spruce. This situation is found on floodplain alluvium (Qal).

(2) Bradway Series: Poorly drained, sandy soils (less than 100 feet to more than a mile in width), occupying old channels and other poorly drained areas near rivers. They are perennially frozen below 3 or 4 feet and always wet above the permafrost level. They are covered with grass and sedge, low shrubs and clumps of black spruce. Found on floodplain swale and slough deposits (QS).

(3) Chena Series: Very shallow, excessively drained sandy soils formed on recently deposited material along the Tanana River. They are 3 to 10 inches thick over gravel. Permafrost is deep or absent. They are dry, but support forests of white spruce, paper birch and quaking aspen. Found on floodplain alluvium (Qal).

(4) Gravel pits: On the alluvial plain and less commonly along the roads in the uplands. Most of them extend several feet below the water table.

(5) Lemeta Series: Peat soils that have formed in depressions in the alluvial plain. They consist of mostly undecomposed sphagnum moss with some slightly decomposed sedge. They are perennially frozen at shallow depth, with free water and ground ice just below the surface. This classification is the same as peat (Qp) of the geologic maps.

(6) Mine Tailings: Consists of gravel with no soil and a very irregular rough surface. Provides excellent foundations and supply of coarse rubble. Occupies stream valleys that have been dredged for gold. Some tailings are as much as a mile wide and several are 1/2 mile wide. Scrub willows and alders are beginning to grow on them.

(7) Salchaket Series: Develops on nearly level, well drained material recently deposited along the Chena and Tanana Rivers. It is dominantly sandy but commonly contains layers of silty material. Usually underlain by coarse sand and gravel. The depth to the gravelly material ranges from 10 inches to 6 feet or more. A silty layer as thick as 12 inches may be present on the surface, but this is absent in certain places. Vegetation consists of white spruce, paper birch and quaking aspen with some balsam poplar near the streams. This soil forms on the floodplain alluvium (Qal).

(8) Tanana Series: Nearly level, imperfectly drained soils which occur on silty materials that are situated farther from the streams and slightly higher than the Salchaket soil. It is perennially frozen at a depth of 30 inches or less and may border Minto soils at the foot of slopes.

Lenses of very fine sandy loam or fine sand are common, and gravel underlies most areas at a depth of 4 to 10 feet. Its native vegetation consists of black and white spruce, paper birch, tamarack and willow, with a mat of moss and low shrubs. These soils develop on floodplain alluvium (Qal) and abandoned floodplain alluvium (Qab).

Among the soils of the alluvial plains, the Salchaket and Tanana soils are best suited to agriculture. The Salchaket soils tend to be especially droughty in dry years because of their coarse texture. Water perched above the Tanana soils may prevent use of the land the first year, but the ground rapidly drains as the permafrost table recedes.

Almost all the soil series described above are subdivided into types and phases in the detailed map portion of the Fairbanks area survey. Some of the series are lumped together into associations in the reconnaissance map portion. One useful product of the soil survey is identification of the soils in management groups. As noted earlier, there are 23 groups in the Fairbanks area. (See definitions section of this chapter.)

Soil Classification

The soil series, described previously, represents one of several methods of classifying land area. Other possible classifications are designed for agricultural evaluation (as noted) and as an index of building conditions. In this project, a general classification of land area is established for its "buildability." Several additional comments about buildability are appropriate at this point.

With sufficient investment any particular land area in the Borough is technically buildable. The index refers to "buildable" with prevailing physical conditions and reasonable costs. Thus, organic silt areas are listed as "unbuildable." Obviously, organic silt is much less buildable than swampy floodplain. The latter areas often are easily drained and filled. Establishing buildable categories also abstracts away from other major economic considerations. They are--

(1) accessibility, i.e., proximity to traveled roads;

(2) technological changes in building design and construction costs;

(3) terrain; and

(4) non-monetary or psychic considerations.

In this report, it is noted that much of the non-urban area in the Borough is relatively inaccessible for purposes of commercial and residential construction. No general shortage of accessible and buildable land exists at present. However, much of the area which might be used remains uncleared and undrained, a significant factor affecting the timing and cost of construction. In a very few years technological changes may seriously affect the locations where buildings might be reasonably situated. Thermal piles, refrigerating the ground beneath structures and similar innovations might become widely used on lands presently considered unbuildable.

A widespread preference of local residents to "live out in the country," on ridgetops, et cetera, is not considered material to this discussion except in noting the particular geology, weather and water conditions one might expect at these kinds of locations. The consensus of contractors is that terrain as a consideration represents no serious barrier to construction for most purposes.

A summary of buildability conditions in and near the Fairbanks urban area is shown in Table 4. In the existing urban area, which is designated area number 1 in the table, approximately 25 percent of the

TABLE 4

ESTIMATED SQUARE MILES AND PERCENT OF SELECTED FAIRBANKS-NORTH STAR BOROUGH AREAS CLASSIFIED ACCORDING TO SOIL TYPE AND BUILDABILITY

Soil Classification	Area #1*		Area #2*+		Area #3+	
	Sq. Mi.	Percent	Sq. Mi.	Percent	Sq. Mi.	Percent
Buildable						
1. Floodplain, (except swamp floodplain)	19.0	67.8	18.0	36.7	37.0	48.1
2. Fairbanks Loess	2.1	7.5	10.4	21.2	12.5	16.2
3. Birch Creek Schist	0.3	1.1	1.2	2.4	1.5	1.9
Total Buildable	21.4	76.4	29.6	60.3	51.0	66.2
Unbuildable						
4. Swamp Floodplain+*	1.0	3.6	2.0	4.1	3.0	3.9
5. Silt:						
Silt, n.e.c.	2.0	7.1	15.0	31.0	17.0	22.2
Frozen	0.2	0.7	1.3	2.8	1.5	1.9
Organic	2.8	10.0	0.7	1.4	3.5	4.5
6. Peat	0.6	2.1	0.4	0.8	1.0	1.3
Total Unbuildable	6.6	23.5	19.4	40.1	26.0	33.8
Total All Classifications	28.0	99.9	49.0	100.4	77.0	100.0

* Area #1 is bounded by the northwest corner of (T1N, R1W, section 32), the northeast corner of (T1N, R1E, section 32), the southwest corner of (T1S, R1W, section 17), and the southeast corner of (T1S, R1E, section 17).

\+ Area #3 is bounded by the northwest corner of (T1N, R2W, section 24), the northeast corner of (T1N, R1E, section 22), the southwest corner of (T1S, R2W, section 24), and the southeast corner of (T1S, R1E, section 22).

*+ Area #2 = Area #3 - Area #1.

+* The (swamp) floodplain area is included in unbuildable land. Given sufficient investment (drainage and fill), it can be converted readily to a floodplain class.

SOURCE: Authors' computations from Geologic Map of the Fairbanks (D-2) Quadrangle, Alaska. Troy L. Péwé, 1958.

land is unbuildable. Area 2 represents land adjacent to the urban designation, i.e., urbanizing locations on which new construction is likely to occur. Roughly 40 percent of this neighboring acreage is classified unbuildable. That is, acreage immediately surrounding existing commercial and residential areas is generally of progressively poorer quality. High quality land for building purposes is even more scarce than apparent from Table 4 when one considers the following additional factors--

(1) Significant portions of areas 1 and 2 are in public domain, e.g., Fort Wainwright, University lands. Interestingly, University lands include sizeable swamp and peat areas.

(2) Much of the buildable land classified floodplain probably is also

a) very inaccessible, and

b) exposed to high risk of seasonal flooding.

(3) Specific exceptions will occur in areas generally classified as buildable, i.e., water quantity and quality problems are well established in specific residential areas on the floodplain. These water supply conditions are discussed at greater length later in this chapter.

Water

Surface water is available in ample quantities from the Chena River (including Chena Slough) which has an average discharge of 1344 cfs. Utilization of this source of water would require a large pipeline and treatment plant which would not freeze. Apparently the use of this surface water has not been seriously considered. Instead, the principal source is groundwater, and the following discussion is concerned exclusively with it.

Groundwater of the Tanana Floodplain

The City of Fairbanks is situated on a great aquifer fed by runoff from the north side of the Alaska Range, as well as by local streams. A knowledge of the geology is essential to the successful development of wells because problems of both quality and quantity are widespread. The differences between the uplands and the Tanana River lowland become of great economic importance when water supply conditions are considered.

The Tanana "flats," in the longitude of Fairbanks, has already been described as being about 40 miles wide and more than 100 miles long. The depth of unconsolidated alluvium in this structural basin is not known. Wells at any appreciable distance from the valley sides have not penetrated through to the bedrock. Those close to bedrock bluffs (as at the University of Alaska) were drilled 90 feet or more before striking bedrock. Seismic methods of estimation have indicated a depth of 250 meters (810 feet) from the surface to bedrock, approximately 2 miles south of Fairbanks (Barnes, 1961, p. 257). The upper 150-200 feet of material that fills this vast basin is fairly well identified by drilling. It is about two-thirds fine sandy material and one-third gravelly material. The materials present were reported as--

> (C)omplex system of alternating lenses of sand, gravel and silt ... 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. (Cederstrom, 1963, p. 17).

There is very little muck on the floodplain. The alluvium is directly recharged by rain and snow. In addition, water from dozens of tributaries in the Alaskan Range contributes to this process. One authority describes this situation as follows:

> (It) constitutes a groundwater reservoir of almost limitless capacity. In so far as present and foreseeable needs are concerned, in the area around Fairbanks and Fort Wainwright, the limitations that might be encountered in any well developed 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 yields is at best of only academic interest.
>
> Practically every well that has been drilled on the floodplain 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 static, or nonpumping, water level ordinarily is about 10 or 12 feet below the land surface, and it is not known to be more than 16 feet below the land surface anywhere. (Cederstrom, 1963, p. 37-38.)

Typical water yields for 2 inch wells from the floodplain (Cederstrom, 1963, p. 42) range from 30 gpm to as much as 50 gpm. In good highly permeable aquifers, properly developed 6 inch wells can deliver 150 gpm with 22 feet of drawdown. An 18 inch diameter well, owned by the Fairbanks Municipal Utilities, has yielded 3400 gpm. Specific capacities (gpm per foot of drawdown) of 300 and 600 have been reported.

These water supply conditions do not extend completely across the Tanana basin. In the gravel of the outwash plains, bordering the mountains to the south, the water table is deeper. Péwé (1955, p. 129-130) states that the quality of water is good (and presumably better than that of the floodplain) and abundant. It issues from springs at the north end of the plains near Big Delta; however, detailed information is lacking. For example--

> (D)epth to the water table increases upslope at the rate of 15 feet per mile to as much as 200 feet half way up the outwash plain.
>
> No data are available concerning groundwater conditions in the alluvial plains south of the Tanana River. Conditions probably are similar to those in the glacial outwash plains.

It would seem reasonable, however, that conditions in the "Abandoned alluvium" unit (See map I-455) would be more like those in the present floodplain or at least transitional.

Obviously, the quantity of groundwater in the floodplain is not a pressing problem. There are, however, two factors that introduce serious qualitative difficulties. They are (1) permafrost and (2) poor water quality. Where the permafrost table is below the water table, domestic water can be obtained from shallow wells, although the supply might be somewhat more limited, i.e., as on a perched water table. These sources of water are quite susceptible to contamination. If the level of the water table is only a short distance above permafrost, the potential public health problems are accentuated.

Generally, permafrost is present on the floodplain except near streams or recently abandoned stream channels. Where undisturbed, the depth to the permafrost table ranges from 2 to more than 4 feet. Where the cover has been cleared for many years, the frost table may have receded to considerable depths. Well records given by Cederstrom (1963, p. 63) show the top of permafrost as deep as 55 feet. Considering the time since the area was cleared and the city located, it seems rather deep for the permafrost to have thawed. Péwé (1954, p. 325) states that there are thawed areas of intercalated unfrozen gravel, "connected with the unfrozen layer to comprise irregular unfrozen passages throughout the permafrost of the floodplain." Cederstrom apparently believes that--where alternating frozen and thawed layers are found in a well, it represents interfingering along a steeply inclined or a vertical contact. An instance of a lens of dry gravel in a solidly frozen saturated mass is recorded (Cederstrom, 1963, p. 18).

There are a variety of reasons why it may be necessary to penetrate permafrost: (1) there may not be any ground water above the frost, or too little of it, or (2) to find better water at a greater depth although there is no assurance that better water will be found. The thickness of permafrost varies greatly on the floodplain, and depths of 265 feet may be penetrated (Péwé, 1954, p. 325). Water from such a well rises to the piezometric surface. If the frost layer is thick, wells will almost always freeze within a week when left idle. In addition to using the well continually, it may be necessary to instigate anti-freezing procedures, such as pouring hot water down the well periodically. Once frozen, the well must be thawed by steam. Apparently this steam treatment thaws the permafrost around the well enough to inhibit further freezing. Normally freezing does not damage a well.

Without a heated basement, wells in unthawed areas may freeze in the winter. This occurs as ground beneath the house freezes inward until the well is surrounded by frost. Usually this happens in late winter after freezing temperatures have prevailed for several months. Remedial and preventive measures are the same as for wells in permafrost, except that in some cases thawing may be instigated by pouring salt down the casing.

Winter frost is also troublesome to public water systems. The City of Fairbanks, the Public Health Service, the State Department of Health and Welfare, and the local Military installations all have experienced difficulties with water distribution in cold regions. The City of Fairbanks has solved the freezing problem in the following way: (1) by forcing water to circulate slowly from the main lines into each building and back to the main line stream of water and (2) introducing heat into the water supply. At Fairbanks, the velocity in the main line is 3 feet/sec. and in distribution lines 0.2 feet/sec. (Hubbs, 1963, p. 428). Water mains are buried about 6 feet deep. This water system might be extended (or installed in other communities). Routing the mains behind houses, or at least away from the centers of roads and streets, should be considered. For example, snow clearing from streets and sidewalks allows winter frost to penetrate to much greater depths than where the undisturbed snow is allowed to pile up. Many engineering problems are encountered in installing and operating water and sewage systems in cold climates. An extensive bibliography on these matters comprises Appendix A to this report.

Poor water quality also is a major problem in the Tanana floodplain. For example, all the water in the Fairbanks area is useable for irrigation and livestock. The quality of water pumped from the Tanana alluvium varies greatly within a short distance, i.e., 50 feet. This condition is due to the irregular arrangement of lenses of silt, sand and gravel. The Tanana River basin was filled with alluvium under conditions similar to those prevailing today. That is, the meandering of the channels and large amounts of vegetative debris have been incorporated into the alluvial fill, i.e., organic material will be found at almost any depth. For example, a well drilled several years ago, just downstream from the Cushman Street bridge on the right side of the Chena, had to be abandoned at a depth in excess of 150 feet. A log had been struck that completely stopped drilling progress (Clarence Procise, personal communication). Abandoned slough channels and swales on the surface contain large amounts of other organic material, e.g., decayed grass, moss, and even animal remains. One might encounter this kind of organic matter at any practical depth.

The quality of water from the floodplain is described by Cederstrom (1963, p. 45) as follows:

> 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 the 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 the wells rarely is less than 100 ppm and more commonly ranges from 100 to 300 ppm. Only a little of the hardness is of the non-carbonate ('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 non-carbonate type.
>
> Most groundwater from the floor of the Tanana Valley in Fairbanks and the 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.

A critique of the general chemistry of local groundwater is presented as follows. Organic material in the ground produces a reducing environment and deoxygenates the groundwater. Reduction of sulfate, and direct oxidation of carbonaceous material produce free CO_2 which makes the water corrosive. Iron bearing minerals are dissolved and iron comes into solution as iron bicarbonate. At the same time, iron carbonate is dissolved, and as the water becomes harder, the solution of iron is inhibited. One authority reported that--"Hence the iron content, although objectionably high for ordinary uses, remains relatively low with reference to the total amount of dissolved solids," (Cederstrom, 1963, p. 47). There is no consensus about the form in which the iron is in solution, other than as an organic complex. Similarly, the precipitation of iron may be due to bacteria. The association of iron with organic material is illustrated by the fact that logs exhumed from the alluvium, after drying, are noted to be rust colored. Rain striking such logs washes the color off and often rusty streaks are found downslope from the logs.

The low temperature of the groundwater (about 34°) allows more CO_2 to be dissolved than reported for other urban regions. This may contribute to the high CO_2 and iron content of the local water. However, the quality of the local surface water is similar to that reported from certain rivers in the contiguous states (Cederstrom, 1963, p. 48). This comparison suggests that action of organic material, rather than low temperature, is the proximate cause for the relatively iron-high, carbonate-low sulfate condition.

Although the water hardness is a troublesome aspect of local groundwater supplies, the iron-high content really makes the Fairbanks-type water objectionable. Of course, the presence of H_2S and organic scum, present in some places, are personally objectionable also. "Average" water on the floodplain is reported at 2 - 6 ppm. Water from bedrock sources, though hard, contains amounts of iron sufficiently low to be acceptable under this standard. As might be expected, wells situated on muck or silt areas of the floodplain contain exceptionally "poor" water, as indicated by the KFAR well. Given 0.3 ppm as a permissible maximum standard, iron contents as high as 43 ppm (at KFAR transmitter) were recorded in Fairbanks.

With heavy and prolonged pumping, a well in a moderate-sized lens of gravel (with relatively good water) gradually exhausts the immediate water supply and draws in water from neighboring silty high-organic areas. In this way, the quality of water from wells deteriorates with use. It is conceivable that water quality might improve, but instances of this were not reported. Gravel pits dug in materials penetrated by old wells indicate that iron oxides had precipitated on the surrounding gravel. The clogging of aquifers by iron oxides also was reported by Cederstrom (1963, p. 42) for a large capacity industrial well. Its yield dropped from 1800 to 800 gpm. In addition, the high iron content of local water damages wells by rusting, and may partially or completely clog internal screens.

Groundwater of the Uplands

The quality and quantity of groundwater away from the floodplain varies greatly. In the main, well yields are much lower than found on the floodplain. No wells are found operating in the Fairbanks loess (Qf) and in the muck. Perennially frozen silt, undifferentiated (Qsu), very low permeability, high organic content, and permafrost render the

Qsu useless as an aquifer (Cederstrom, 1963, p. 37). In places where bedrock is overlain by silt or muck, circulation is restricted. Water obtained from this bedrock is poorer in quality than that obtained from the alluvium. In other places, iron and organic contents may be low, but total hardness is high.

Almost all of the wells drilled in the upland obtain their water from bedrock, even where bedrock is buried beneath a hundred feet or more of muck or silt. Often the Schist bedrock is deeply weathered, and it is necessary to drill through the weathered zone or depend on crevices in brittle rock. Where the rock is not brittle, there may be water available. However, the clayey products of decomposition tend to clog the well under these circumstances. Artesian conditions exist on many of the middle slopes, with permafrost forming the cap.

Cederstrom (1963, p. 35) speculates that yields in excess of a hundred gallons per minute may be taken from buried alluvium of the upland valleys along Farmer's Loop and the Steele Creek Roads. Because of the great accumulations of loess and muck in the area, an old stream valley, that contains gravel, may be difficult to locate. Little is known of local wells that might have been drilled on the floodplains of the major streams--the Chena, Salcha and Chatanika Rivers and Goldstream Creek. Judging from experience gained in placer mining, however, much of the shallower parts of the stream valleys probably are frozen to bedrock. Near the streams, of course, shallow ground water can be obtained. Where the depth of alluvium is more than say 100 feet, there is a good possibility of obtaining large water yields from gravel.

Yields from bedrock sources are much smaller than from alluvium. A great many residential wells yield so little that large storage tanks are maintained inside the homes, whereas a number of wells produce 10-15 gpm. One well on Columbia Creek produces 57 gpm, but Cederstrom (1963, p. 33) maintained that gravelly material from above was recharging the bedrock. The University of Alaska has obtained its water from sources in the schist bedrock by drilling collector holes laterally from sumps. The sum of these bedrock sources, including 8 wells, yield about 35-40 gpm. The University is the largest local user of groundwater from bedrock sources. However, its demands have outstripped supply, and water from the alluvium now is mixed with that from the bedrock. As water consumption expands, this trend will continue. In view of the limited supply and uncertain quality of bedrock water sources, additional large-scale water needs must be satisfied from the floodplain alluvium.

Publicly Owned Water Systems

The community's demand for water is readily divisible into market segments served by different supply systems. An overview of these relations is presented in Table 5.

TABLE 5

OVERVIEW OF CLASSES OF WATER USERS AND ALTERNATE SOURCES OF SUPPLY IN FAIRBANKS, 1967

Users	Supply
1. Households	1. (a) municipal utility system 1. (b) individual wells
2. Commercial and Industrial Enterprises, including University	2. (a) municipal utility system 2. (b) individual wells
3. Military Establishments	3. individual wells

The preceding discussion of water supply conditions mostly concerned drilling individual wells outside the present city boundaries. Additional insight and supporting evidence into water supply conditions are supplied by operation of these other water systems (Haring, 1967a). For example, the annual water requirement of Fort Wainwright is approximately 650 million gallons. This requirement is satisfied by the operation of two independent wells of approximately 150 feet in depth. Although the water table there begins at 15 to 20 feet below surface, its quality is unacceptable. Consequently, water is taken from 100 foot levels. Prior to treatment, the water quality is 9.5 parts iron per million, well in excess of the 0.3 standard.

The municipal utility system, nearly parallel to city boundaries, is adequately described by several published reports (Haring, 1967a).

Quality Problems for Businesses and Households

The business and household sectors of the community face special restrictive water supply conditions, most of which are quality in nature. For summary purposes, these problems are listed for two areas: (1) areas served by the Municipal Utility System, (2) areas served by individual wells, if at all.

Business and residences situated on the MUS system are at a distinct advantage in most instances. The drawbacks of city water supply are relatively few, namely (a) discoloration which would affect few industrial uses and (b) taste and odor generally considered less desirable than University or Pioneer Wells quality, but well within minimum public health standards. In addition, whether residents have public sewer available or not, City water is general insurance against the risks of serious and harmful contamination. In certain areas, especially Hamilton Acres, selected individual wells provide water of a higher quality than available from the City. Under these circumstances, mandatory connections regulations initially seem to contradict good sense. For the most part, the benefits of a mandatory utility connections rule far outweigh individual injuries in special circumstances. However, the geographic availability of utility connections today is nowhere close to providing service to the majority of local residents, a matter discussed in the following section.

Outside of the city limits water supply problems are more severe. (See Tables 4 and 5.) An increasing number of commercial enterprises is located in this area, and the largest amount of new residential construction occurs in it. Recent studies indicated major problems, several of which are listed as follows--

(1) A high proportion of households, in acquiring a water source were forced to purchase (a) a well of unknown depth in being drilled, (b) make several attempts at locating water, (c) a well with poor or unsuitable water flow or quality. For example, houses constructed prior to locating adequate water often utilized external corridors from a second well to the residence. Many homes remain without an individual operating well of any type. Approximately one-half of the households visited recently reported serious cost difficulties of the above three types.

(2) Water supply problems represent a serious barrier to real estate financing. Without an "adequate" well and its required water quality,

long term real estate financing is prohibited, i.e., FHA financing. In one recent instance, a home was built on a construction loan according to the FHA design and specifications, but a trace of detergent appeared in the well which forbade permanent financing. In many instances, residences are sold by escrow (personal mortgage) simply because the real estate could not be sold at a reasonable price under any other terms. Still worse, several homes visited, which were FHA financed, probably could not be refinanced at any later time unless public utility services are extended greatly.

(3) The public health and personal risks in utilizing a private domestic well are potentially quite serious. The very soil and underground conditions which limit water flow and quality also control the discharge of human wastes. Shallow groundwater wells, frequent in certain established sections of Fairbanks, are particularly exposed to these risks. Additional building and the continuation of the present situation almost certainly will lead to a progressively worsening situation. Urban growth, normally associated with higher population density per acre, will aggravate these conditions. An offsetting factor, which reduces population density, is wide incidence of unbuildable land.

Taken together, the above situation clearly constitutes a major public policy problem for local government. The direct economic implications alone constitute a critical factor inhibiting the growth of this urban area.

Economic Implications

The prevailing soils and water conditions constitute a major area of concern. They vitally affect individual households as homeowners and renters. They are a major problem to attracting new industry. Local governmental agencies are directly concerned in terms of offering public utility services, maintaining public health standards and in urban planning. Taken altogether the situation represents a prima facie case for public planning, and outright intervention into local construction markets, far greater than normally practiced. This is especially appropriate in governing water supplies and waste disposal. In that particular area, individuals are fully capable of directly affecting the water supply of neighbors and potentially causing grievous health risks to their family and the community at large. Worse yet, these very conditions are not a situation with which a "reasonable person" (e.g., migrant worker, local resident) is expected to be familiar.

The implications of this segment of the report are several. They are--

(1) Soil and water conditions increase construction costs outside city boundaries materially.

(2) Unusual financial risks are borne by those who construct residences, i.e., likelihood of not locating water, acquiring poor quality water and subsequent difficulties in financing.

(3) Significant amounts of land within the Fairbanks urban area are unbuildable at present. Land so classified corresponds closely

with the areas in which water supplies are ample, but likely of poor quality.

(4) The developing and urbanizing portions of the borough contain a larger proportion of unbuildable land than the present urban area. An indirect "benefit" of this phenomenon is the necessarily high geographic dispersion of homes as residential areas expand.

(5) Many areas of the Borough might be "upgraded" in terms of buildability. The first major step in this direction is land clearing and draining. These activities should precede construction by several years. (See also the section on local geology.)

VI

CRITIQUE OF NATURAL RESOURCE-BASED INDUSTRIES

Introduction

The physical conditions which exist in the Borough area, and presented in the preceding three chapters, have affected the growth of "basic" industry. These natural resource-based industries are very important and represent businesses which export most of their products to other areas. In the case of coal production, the immediate Borough area is an important market.

The attraction of new industry to Fairbanks is one way of stimulating the local economic base. However, considering the matters already discussed, several restrictive questions might be asked--What types of industry complement and aggravate the problems of air, soil and water conditions? What industries, given conditions of demand for its products, would diversify and strengthen the region's economic base for longer term growth? Considering natural resource scarcity and demand conditions, what industries appear likely to prosper or be attracted to Fairbanks?

Answers to these questions comprise the content of this chapter. The specific purposes of the chapter are--

(1) To indicate the types of natural resource-based industries which are likely to prosper, and

(2) To examine how these industries would contribute to an expanding economic base in the Borough.

The region's economy, once principally dependent upon gold mining, has changed dramatically in its dependence upon basic industry (Eels, 1966). For purposes of this report, business conditions and opportunities in mining, agriculture, forestry and fisheries will be discussed.

Mining

Alaskan Production

Recent Mineral Yearbooks (Malone and Holdsworth, 1964, p. 2) report a steady rise in total mineral production since 1944 for Alaska. For example, from $22 million of output in 1960, it rose to about $83 million in 1965. The effect of this increase on the Borough is more apparent with a breakdown of production into the following categories. (See Table 6.)

TABLE 6

VALUE OF MINERAL PRODUCTION IN ALASKA BY MAJOR COMMODITY GROUP, 1960 AND 1965 (in millions of dollars)

	1965	1960	Change in Value	Percent Change
Metals, Stone, Misc.	$ 7,911	$ 8,565	$ -654	- 7.6
Coal	5,878	6,318	-440	- 7.0
Oil and Gas	36,775	1,496	+35,279	+2300.0
Sand, Gravel	33,925	5,483	+28,442	+ 500.0
	$84,489	$21,862		

Increases were registered in oil and gas, and sand and gravel production, while metals and coal output decreased in value. The economy of Interior Alaska has not been directly influenced by oil and gas. (Exploration activity on the Arctic Slope, of course, is felt indirectly in Fairbanks.) Sand and gravel mining is directly derived from public works and private construction. Sand and gravel are not "exportable" commodities and their production often is considered as creating no new mineral wealth, i.e., it should be considered as part of the construction industry. Likewise, coal production, averaging $5 to $6 million annually, is a commodity which is presently non-exportable (Connor, 1965). Conceivably, experiments in coke blending might improve the resource position of this relatively small industry. Up to the present time, the outlook for this technological breakthrough remains bleak. With increasing price and service competition from oil and natural gas for heating, and atomic minerals for energy over longer periods, coal production will become less feasible. Existing coal deposits represent an important resource, and every effort should be made to stimulate production immediately and to locate new uses and markets.

Sources of Information and Organization of Mining Districts

Several systems of defining mining districts and indexing information about them have been devised (Ransome and Kerns, 1954, p. 1; and Wolff, 1964, p. 358-364). The three chief systems are based on--

(1) U. S. Geological Survey regions and districts,

(2) U. S. Geological Survey quadrangle map system, and

(3) U. S. Bureau of Mines regions, districts and subdistricts.

The U. S. Geological Survey system is not used as extensively as the others. Its use is chiefly in describing Survey activities. The Bureau of Mines system is defined by Ransome and Kerns in U. S. Bureau of Mines Information Circular 7679, and is based on historical classifications set up by the miners and the courts. The quadrangle system is a method of referring all mines and prospects to the maps of particular quadrangles.

The local region has long been known as the Fairbanks mining district. There are four separate areas within this district.

(1) The largest and most important consists of the lodes and placers distributed around Pedro Dome and along the Chatanika River, and around Ester Dome near Fairbanks.

(2) The upper Chena.

(3) The upper Salcha.

(4) The Richardson or Tenderfoot district which is near the Richardson Roadhouse 60 miles south of Fairbanks. The last three are placer districts with histories of small sporadic production.

All of these districts are located partially within the Borough. In the U. S. Bureau of Mines system, the Borough is in the Fairbanks district of the Yukon River region. The Fairbanks and upper Chena mines are in the Fairbanks subdistrict. The Salcha and Richardson mines are in the Salcha subdistrict. In the quadrangle system, mines are located chiefly in the Fairbanks, Livengood, with a few in Circle and Big Delta quadrangles.

The U. S. Geological Survey maintains the most extensive bibliography on the mineral deposits of Alaska. Both the Survey and the State Division of Mines and Minerals have compiled extensive inventory information about deposits. All of these references are indexed by quadrangle, and accordingly it is necessary to know the quadrangle in which a deposit is located in order to use this literature.

Alaskan location maps and lists of Geologic Survey publications include deposits of chromite, cobalt, nickel, and platinum; copper, lead and zinc; molybdenum, tin and tungsten; antimony, bismuth and mercury; lode gold and silver, placer gold; iron; and industrial and construction minerals. These are issued as mineral resource maps (MR Series). For an extensive bibliography, see Handbook for the Alaskan Prospector (Wolff, 1964, p. 379-406) and the bibliography segment of this report.

Overview of Metallic Operations

Placer Gold. Nearby gold deposits discovered in 1902, led directly to the creation of Fairbanks as a city. The mining district has produced about 7,500,000 to 8,000,000 ounces of placer gold, which represents approximately 37 percent of the total production of Alaska. The value of this gold in today's prices is well in excess of $200 million.

The Fairbanks mining district developed slowly because the placers in many places were buried under thick blankets of muck. Thus, mining soon became an activity for well-financed individuals or companies. Correspondingly, it was not for poorly equipped and financed "stampeders." Primarily, underground methods were employed in placer gold production. During the summer of 1903, the output was $40,000. Annual production reached a peak of approximately 517,000 ounces in 1909, then declined about 17,000 ounces in 1927. A new dredging program resulted in a steady increase in production. By 1940, production of placer gold was about $7,000,000 (or about 200,000 ounces). After World War II, production climbed until in 1950, a production of about $3,600,000 was achieved ($10,125,000 for all of Alaska). This gradually declined, until with the shutting down of the last dredge, placer gold production in the Fairbanks District became a matter of what 5 or 6 small mines could produce. The U.S.S.R.&M. Co. still maintains an office in Fairbanks to support its two dredges in the Koyukuk and in the Fortymile districts. At present, there are 6 small placer gold mines operating near Fairbanks and one on the Upper Chena. Annual production probably is less than one-quarter of a million dollars.

Without an increase in the selling price of gold (or an outright subsidy), the outlook for gold placer mining in the Fairbanks district is bleak. There are placers of unknown magnitude which might justify the resumption of 2 or 3 dredges and several dragline operations. At higher selling prices an annual production of placer gold of 1 to 2 million dollars easily could result. Much of the reserves of the area are deeply buried under muck, and this condition requires extensive hydraulic stripping. To stimulate production, suitable stripping regulations, low taxes, and building standards will be required. Conflicting land uses, such as by homesites, must be considered in assessing the value of its resurrection.

<u>Lode Gold</u>. Soon after the placers were discovered in the mining district, a search began for the lode source of the gold. Activity

increased rapidly and reached a climax about 1913. Many of the ventures were ill-advised, thereby causing a temporary decline of local gold production. However, output did generally increase until 1938. At that time there were 11 mines operating, employing a total of 110 men (Territorial Division of Mines Annual Report, 1938). By 1940, there were only 7 operating mines, employing 84 men.

Lode gold production was about 164,000 ounces in 1937. Figures for the five years or so during which mining continued prior to World War II are not readily available. However, 50,000 ounces to 100,000 ounces a year is a reasonable production estimate. Gold lode mines were shut down by law during World War II and did not re-open locally or nationally. There have been a few new small partner-operated ventures that have been short lived, and insignificant in terms of stimulating the Borough economy.

Presently, there is some interest in lode gold mining. For example, the Keystone Mining Company has consolidated a group of claims extending along a belt about 5 miles long in the Pedro Dome area. One small mine is in operation there, and the ore is being treated at the Cleary Hill mill.

A research project by the U. S. Bureau of Mines and the University of Alaska concerns the design of a mining and milling system suitably adapted to the Fairbanks gold lodes. The purpose of this project is to arrive at an approximate cost per ton relative to conventional methods of production. The project will outline an efficient mining and milling system; and potential operators might estimate the approximate minimum scale necessary for profitable mining. The preliminary estimate of this cost is about $40 to $75 per ton, depending upon the size of operation. It is unlikely that sufficient ore, of the necessary grade, can be developed for any sustained operation. That is, an increase in the price of gold probably will be necessary before moderately large production could begin. Assuming that sufficient ore could be extracted, it is entirely possible that several small mines could supply a mill with a capacity of 150 tons per day. Such a mill (operated 250 days per year) would manufacture an annual output of 37,500 tons at an estimated value of $1,875,000. A large group of existing-sized claims must be assembled in order for an industry with this technology to operate. In addition, existing plant and equipment must be scrapped in starting a new company of this type.

So far, only gold mining in the Borough itself has been considered. Fairbanks is the trade center for several gold mining camps in the Interior. A change in mining activity in these districts is quickly felt in Fairbanks. In the order of their economic ties to Fairbanks (but not in their order of production), these camps are situated at the following locations: Tolovana (Livengood), Circle, Chandalar, Koyukuk, Hughes, Manley Hot Springs, Rampart, Melozitna, Chistochina, Fortymile, Eagle, Ruby, Bonnifield, Chisana, McGrath, Innoko, and Iditarod. The future importance of these mining districts is almost impossible to assess. They depend upon the price and cost situation in the years ahead. Under favorable conditions, including a rise in selling price, 2 to 3 million dollars per year might be produced. For example, the Chandalar district, which contains undeveloped gold lodes, may begin new production without a rise in price and could easily produce $250,000 per year for several years.

Silver, Lead. There are a number of nearby lead-silver and antimony prospects along a belt several miles long. (See Plate 1.) Production from them has been sporadic and small. At present, two new prospective operations are being explored. Very likely, these would have to be selectively mined in order to develop. In the event that prospecting reveals that a larger body of ore exists, then only a small production on a sustained basis would be forthcoming. The price of silver is expected to increase in 1968. This probably will lead to an increase in prospecting activity.

Tungsten. Tungsten has been produced occasionally in Interior Alaska when the selling price was high. Production from the Fairbanks district has been about 4000 units (20 pounds each) of WO_3. It is expected that only small reserves might be found with additional prospecting, and it is doubtful if this industry could be revived.

Antimony. Antimony is associated with certain gold lodes and deposits of the lead-silver belt. Total production of antimony ore from the Fairbanks district has been about 2,500 tons. The Stampede Mine in the Kantishna district has produced slightly more. Total reserves for both districts are estimated at only 100 tons of high-grade ore and 10,000 tons of low-grade, or submarginal material.

Copper. There are no significant copper prospects within the Borough. The deposit at Bornite on the Kobuk River is too distant to generate significant economic effects in the Borough. There are at least two copper deposits under investigation in the Valdez Creek district in the Alaskan Range south of Fairbanks. It is too early to estimate the feasibility of production. However, almost certainly, copper will be mined near the Borough if the current price and demand outlook for copper continues.

Non-metallic Products

Sand, gravel and crushed stone are extracted in various grades in the local area. They are used chiefly for road construction and concrete structures. The annual production varies directly with the volume of contract construction (Beasley and Haring, 1965), and these local supplies are not sufficiently high grade to justify shipment to distant construction sites in Alaska. A small deposit of white marble at Fox has been quarried occasionally for ornamental stone. Skarn at Moose Bluff has been used in some new buildings at the University of Alaska. Also, very small amounts of Birch Creek Schist and some slate units of the pre-Ordovician rocks have been used.

Exploration and Government Agencies

In spite of the low level current production, the dormant mining industry of the Interior draws considerable trade to Fairbanks. In 1965, approximately 6600 claims in the State were "retained" by annual work at an estimated value of $100 per claim. In Central Alaska, about $180,000 was expended by private industry for exploration (Division of Mines and Minerals Annual Report for 1965, p. 17). Statewide, the U. S. Geological Survey spent about $3,000,000 for exploration, the U. S. Bureau of Mines $470,000 and the State Division of Mines and Minerals $388,000.

General Observations on Future of the Mineral Industry

The following recapitulation represents something between a realistic and optimistic view. (See Table 7.)

TABLE 7

ESTIMATED RANGE OF ANNUAL MINING PRODUCTION FOR INTERIOR ALASKA, AS OF 1966

Commodity Group	Annual Production (in 000 dollars) Minimum Realistic Projection	Optimistic Estimate
Placer Gold	200	2,000
Lode Gold	50	2,000
Silver, Lead, Antimony	0	1,000
Tungsten	0	100
Oil and Gas	None known in Interior. Some chance for discoveries, may bring in a few million dollars annually eventually.	
Coal	4,000	5,000
	Declining after natural gas becomes available. Mines are outside the Borough, but almost entire output goes to Borough.	
Sand and Gravel	8,000	10,000
	Annually, but depends on construction spending, chiefly for roads.	
Copper	Very speculative; may range from 0 to 1,000.	
TOTAL - ALL CATEGORIES	12,250	

Agriculture

Production Situation

To a large extent the growth of an agricultural base in Alaska has been restricted by public land policies. During the early years of mining and settlement, acquiring title to public lands proved especially difficult (Cooley, 1966). Homesteading increased available agricultural land very slowly, and farm units soon proved too small and scattered for effective farm management (Loll, 1965). In the entire State, approximately one hundred enterprises might be called "commercial" farms in 1966, and this group accounted for over 90 percent of marketed agricultural output. Overall production is divided into selected product groups by the Bureau of Census and shown in Table 8.

The position of agriculture in the immediate Borough area is complicated by several factors. They are--

(1) Competing uses of land, i.e., sale of Creamer's Dairy for commercial and residential uses.

(2) Shortage of cleared and accessible contiguous land classified as "suitable" for agricultural purposes. (See Chapter 5.)

(3) Sharp seasonal growing seasons which limit production, and the corresponding wide practice of farmers holding other jobs, e.g., farming part-time. (See Chapter 3.)

(4) Unfavorable cost conditions, especially pertaining to land prices and wages, and less extensively to transportation (Haring, 1965).

TABLE 8

Selected Farm Characteristics for Alaska, 1959 and 1964

Category	1964	1959	Change
1. Number, acreage, value			
a. No. of farms	382	367	-15
b. Average size farm (acres)	5,129	2,420	+2,709
c. Value per acre ($)	9.17	24.82	-13.55
2. Type of farms (No.)			
a. Field crops	34	35	- 1
b. Vegetable	5	10	- 5
c. Poultry	16	19	- 3
d. Dairy	62	73	-11
e. Livestock	45	28	+17
3. Value of products sold ($)			
a. Field crops	790,398	581,273	+209,125
b. Vegetables	118,150	187,975	- 69,825
c. Poultry	266,072	317,266	- 51,194
d. Dairy	2,040,519	1,634,700	+405,819
e. Livestock	426,685	415,255	+ 11,430
4. Farms by annual sales class			
$40,000 & more	33	20	+13
20,000 - 39,999	28	36	- 8
10,000 - 19,999	30	44	-14
under 10,000	122	85	+37
	213	185	+28

Source: Bureau of Census, 1964 Census of Agriculture.

Trends Affecting Growth

The survival of an agricultural sector in the Borough is economically desirable in many respects. Most important is the income-spending effect of Alaskans purchasing locally-produced products. The money income stream, otherwise directed to other areas, is contained locally. That is, successful selling of local agricultural products represents a substitute for importing comparable goods.

Several factors and trends probably will dictate the pace at which this industry will prosper or decline. These are--

(1) The degree to which public lands are made available to private acquisition, i.e., transfer of federal lands to State and local government and individuals.

(2) Improved transportation modes and rates, i.e., recently inaugurated Sea-Land service to Alaska facilitates more buying from "outside."

(3) Adaptation of farms to selling products enjoying comparative cost advantages, e.g., in value/weight, perishability, consumer preferences.

(4) Continued expansion of Alaskan markets, i.e., favorable business conditions.

(5) Sufficient low-cost financing.

Forestry

Current Situation

Commercial forestry in Alaska has evolved slowly from the Southeastern region (Haring and Massie, 1966). By 1966, middle-sized sawmills were operating at Haines, and were being revived in the Susitna area near Anchorage. The wood products industry of Interior Alaska remained very small, a condition apparent in Tables 9 and 10. The Borough area contains several conventional sawmills and houselog operations, a few of which operate during the winter months. The total employment factor is expanding, but currently less than 100 persons are on an annual rate basis.

TABLE 9

VOLUME OF LOGS CONSUMED IN ALASKA ACCORDING TO PLANT LOCATION AND TREE SPECIES
1961

Geographic Location And Plant Type	Volume of Production		Species Distribution of Production+ (in percent)	
	M cu. ft.	M bd. ft.	Western Hemlock	Sitka Spruce
Coastal-total	66,352	394,022	53	46
Pulpmills	53,010	314,791	52	28
Sawmills	13,342	79,231	1.0	18
Interior-total	686	4,071	*	*
Sawmills	656	3,894	*	*
Houselogs	30	177	*	*
State Wide	67,039	398,093	53	46

* Not Applicable
+One percent of "other" minor species not included.

SOURCE: Northern Forest Experiment Station, Wood Processing in Alaska - 1961.

TABLE 10
SUMMARY OF FOREST RESOURCE CHARACTERISTICS IN INTERIOR
ALASKA AS OF 1965

Resource Characteristic	Copper River Valley	Tanana River Valley	Yukon River Valley	Kuskokwim River Valley	Total Interior Alaska*
Ownership of Forest Land	Mainly Federal B.L.M., some State and private	Primarily state easily accessible private; Federal - B.L.M. in non-accessible places	Federal - B.L.M.	Federal - B.L.M.	---- ----
Commercial Forest Land	Approximately 1 mil. acres	Valley - 2 mil. acres Readily accessible - 1 mil. acres	Unknown, estimated at 10,000 sq. mi. forest area	100,000 acres plus adjacent to river approx. 68,000 acres	Unknown, but estimated at over 3.1 mil. acres
Species Composition	Mainly White Spruce	White Spruce 60% Hardwood 40%	Mainly White Spruce	Primarily White Spruce; some Birch, Aspen and Cottonwood	----
Commercial Timber Volume (bil. bd. ft.)	1	Valley 7 Readily accessible 4	Unknown (estimated potential ± 10)	Valley .780 Adjacent to river .365	Unknown, but estimated in excess of 18.78
Estimated Allowable annual Cut (mil. b. ft.)	15	Valley 90 Readily accessible 45	Unknown	Valley 6 1/2 adjacent to river 4	Unknown, but estimated in excess of 111.5

* Based on major river valleys only

SOURCES: U. S. Forest Service, U. S. Bureau of Land Management and Alaska State Division of Lands.

Stage of Development

Forestry in Interior Alaska will expand. The critical questions are--where, producing what, and how rapidly? Certainly the sawmill-houselog operators will continue to expand operations. New operators, such as community sponsored manufacturing (Kearns and Kozely, 1965) will enter the market. Local price and demand conditions remain favorable.

Moreover, this forest-based industry could expand significantly in a relatively short time with the aid of the following conditions--

(1) New access roads to merchantable timber stands,

(2) Innovations in river transportation and riverside logging,

(3) Attraction of a large producer to cut timber from public lands, e.g., a pulp mill.

Continued growth of forest products manufacturing is especially desirable in Interior Alaska. The purchase of locally manufactured products obviously stimulates expansion of the Borough economic base. Moreover, many forestry operations, e.g., logging, might be scheduled contra-seasonally. Winter employment of this type would tend to counteract the violent seasonal pattern of local income receipts and employment.

Fisheries

Commercial fishing in and near the Borough is difficult to assess. A small volume of this output is sold through the larger supermarkets, and most fresh fish are sold at small fish camps or ordered directly from remote fishing sites. A significant volume of salmon, sheefish and arctic char are air freighted to Fairbanks from western and northern

Alaskan communities. The major buyers are supermarkets and restaurants.

With the continued introduction of freezer processing barges along Interior waterways, the fishery situation is gradually changing. During 1965-1966, Fairbanks-based barges operated in the lower Yukon River, and this type of operation could be expanded profitably. The natural resource position so grossly exceeds the present marketable harvest that substantial advances in commercial fishing and processing could be instituted in the near future.

Land Policy Implications

This chapter examined the present and potential scope of industrial operations which harvest the region's natural resources. Several areas of conflicting interests are bound to arise. The major issues are summarized as follows--

(1) Intensive mineral exploration and increased forest utilization require relatively large investment in access roads and/or research. These efforts must be compared with alternate uses of public funds.

(2) Presently feasible methods of mining tend to compete with neighboring recreation activities and residential construction.

(3) Water quality regulations of the State tend to restrict the type of resource utilization and increase costs of production.

For the most part, expansion of most resource-using industries in the Borough is entirely possible. However, it can only be accomplished by dramatic and forceful public land policy which will favor their development. In particular, State selection and sale of desirable lands, and federal investment in roads, exploration and other research represent actions which would attract these industries.

APPENDIX A

Special Bibliography on Cold Climate Water Supply and Waste Disposal

(Taken from G. L. Hubbs, Water Supply Systems in Permafrost Areas; in Proceedings Permafrost International Conference: Nat. Acad. Sci.-Nat. Res. Council, Publ. No. 1287).

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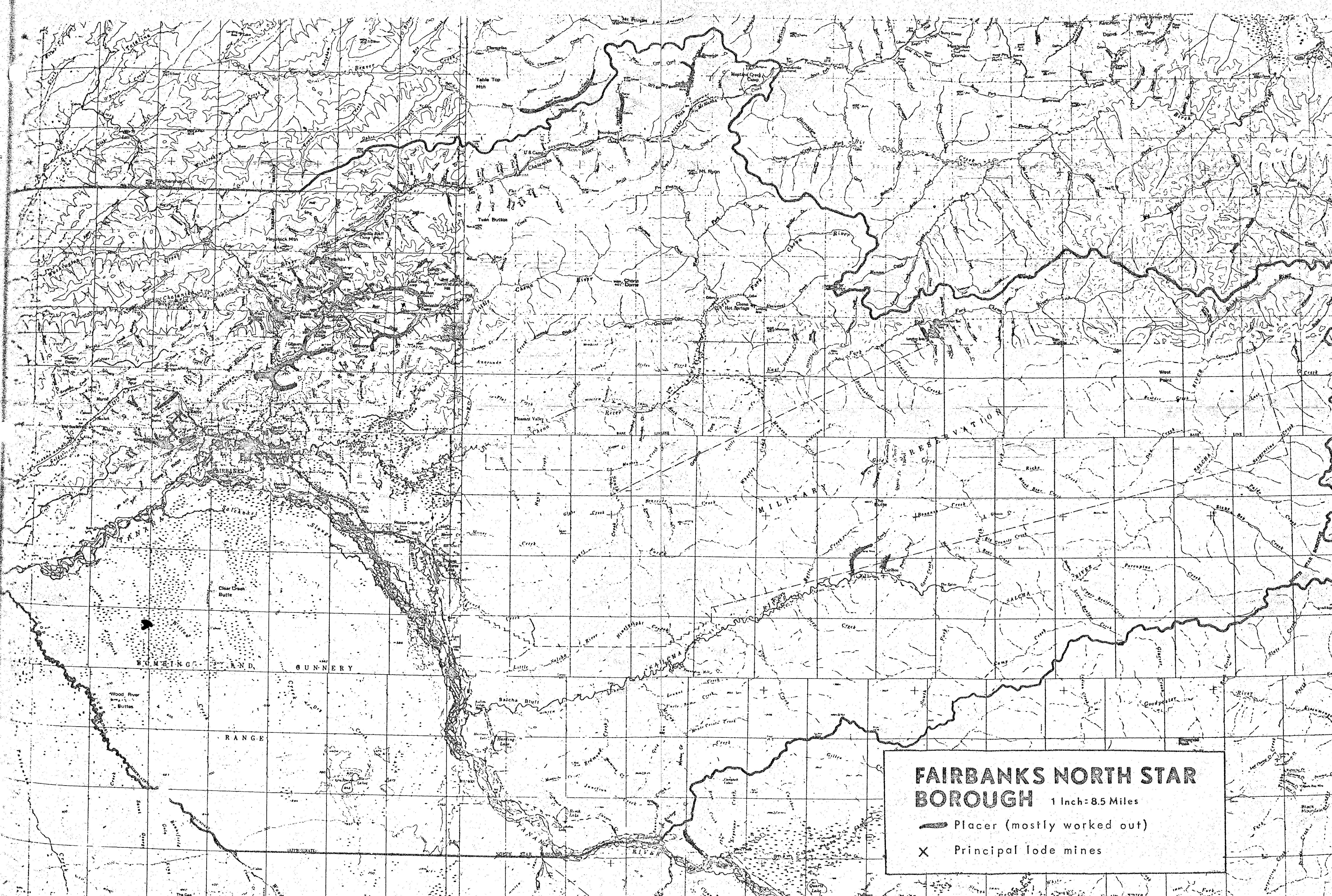

FAIRBANKS NORTH STAR BOROUGH
1 Inch: 8.5 Miles
Placer (mostly worked out)
Principal lode mines
FAIRBANKS
Table Top Mtn
Twin Buttes
Haystack Mtn
Mt. Ryan
Chena Dome
Chena Hot Springs
West Point
Clear Creek Butte
Wood River Buttes
Salcha Bluff
Harding Lake
Black Mountain
MILITARY RESERVATION
BOMBING AND GUNNERY RANGE
TANANA
SALCHA
Goodpaster
Chena River
NORTH STAR BOROUGH

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(Note: ** indicates publication of prime importance.
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Organization of Bibliography

A number of agencies and organizations have issued publications on the geology and mineral resources of the area included in the Borough. For a discussion of these different agencies, see Wolff (1964, p. 370-406).

The following bibliography, although not complete, covers the major publications that might be consulted for planning in the Borough. Important works are annotated. The types of publications are cited as follows:

U. S. Geological Survey

Professional Papers	(P.)
Bulletins	(Bull.)
Water Supply Papers	(W.S.)
Circulars	(Circ.)
Open File Reports	(O. F.)
Geologic Quadrangle Maps	(G. Q.)
Mineral Investigation Maps	(M. R.)
Misc. Geologic Investigations	(I)
Annual Reports (no longer issued)	(Ann. Rept.)
Special Publications	(Spec. Pub.)
Topographic Maps	

Topographic maps at a scale of 1:250,000 or about 1" = 4 miles have been made for the whole State. Those that cover the Borough are Fairbanks, Livengood, Circle, and Big Delta. A very small part of the Borough is included in the Eagle quadrangle. These maps cover one degree of latitude and three degrees of longitude each, and may be obtained in simple contour or shaded relief. Each quadrangle is divided into 24 similar smaller quadrangles, lettered A to D from bottom to top, and numbered 1 to 6 from right to left. Hence, the upper right quadrangle is D-1 and the lower left, A-6. The smaller maps have a scale of 1:63,360 or 1" = 1 mile.

U. S. Bureau of Mines

Minerals Yearbooks

Bulletins	(Bull.)
Reports of Investigations	(R. I.)
Information Circulars	(I. C.)

Alaska Division of Mines and Minerals
(formerly Territorial Dept. of Mines)

Annual Reports

Pamphlets

Information Circulars

Maps

Geochemical Reports

Geological Reports

General

In addition to these publications, the bibliography lists books, magazine articles, theses reports, and other sources of information under a "general" category.

U. S. Geological Survey Publications

Professional Papers

P. 192**. Areal geology of Alaska, Smith, 1939, 100 p. + 5 maps and one correlation chart.

The only comprehensive survey of geology of Alaska, now, unfortunately, old. Describes rocks, system by system with each system taken up by region. Large chart shows correlation from region to region. Maps of geology, glaciation, permafrost, regions, and publications for different areas. All these maps are now superceded.

P. 264*. Permafrost and Groundwater in Alaska: Middle Tanana Valley, Péwé, 1955, p. 125-130.

Describes that part of the Tanana Valley between Big Delta and Nenana. Contains sections on physiography, climate and vegetation, geology, permafrost, and groundwater. Deals directly with problems encountered at Fairbanks. No data on alluvial plains south of the river, but suggests they may be similar to glacial outwash plains which have better water than the Fairbanks area.

P. 293. Quaternary and engineering geology in the central part of the Alaskan Range, Wahrhaftig, 1958, 118 p.

Part I gives a detailed chronology of Quaternary glacial activity in the Nenana River area. Should be useful to anyone working with the Quaternary deposits south of the Borough.

Part II describes engineering materials along the railroad with size distribution data for sediments, the engineering aspects of permafrost, slumps and earthflows, rockslide and rockfalls, frost heaving and settling, icings, individual landslides between miles 349.1 and 357.5. There are also sections on industrial sites. These descriptions are applicable to parts of the Borough.

P. 400-B. Geological Survey research, 1960.

Sec. 49. Geochemical Exploration in Alaska, Chapman and Shacklette, 1960, p. 104-107.

Sec. 63. Some thermal effects of a roadway on permafrost, Greene, Lachenbruch, Brewer, 1960, p. 141-144.

Sec. 154. Surficial deposits of Alaska, Karlstrom, p. 333-335.

Sec. 186. Thermal contraction cracks and ice-wedges in permafrost, Lachenbruch, p. 404-406.

Sec. 187. Contraction crack polygons, Lachenbruch, p. 406-409.

P. 424-D. Geological Survey research 1961.

Sec. 383. Gravity low at Minto Flats, Alaska, Barnes, 1961, p. D254-257.

Sec. 419*. Engineering geology problems in the Yukon-Koyukuk lowland, Alaska, Weber, Péwé, p. 371-373.

This short article contains description of 6 surficial map units easily identified, and their engineering geology characteristics. Some of these units are present on the Tanana flats within the Borough.

P. 475-B. Geological Survey research, 1963. Art. 38. Influence of snow cover on frost penetration, Krinsley, 1963, p. 144-147.

Six inches appears to be the "critical thickness;" the insulating value goes up sharply after exceeding this depth.

P. 482**. Physiographic divisions of Alaska, Wahrhaftig, 1965, 52 p. plus maps.

The latest and most complete analysis of the physiography of Alaska.

Bulletins

Bull. 251. The gold placers of the Fortymile, Birch Creek, and the Fairbanks regions, Alaska, Prindle, 1905, 89 p.
Very early description of reconnaissance geology and placers.

Bull. 295. The Yukon-Tanana region, Alaska, Prindle, 1906, 27 p. plus bibliography.
Old description of geology and placer mining districts known at that time, excluding Fairbanks, but including Salcha and Tenderfoot.

Bull. 337. The Fairbanks and Rampart quadrangles, Yukon-Tanana Region, Alaska, Prindle, with a section on the Rampart Placers, by F. L. Hess and on water supply of the Fairbanks region by C. C. Covert, 1908, 102 p.
Reconnaissance geology and brief description of placers and mining methods. Contains early stream discharge data.

Some of the bulletins 345 through 692 have letters following the number. These are parts of bulletins titled: "Mineral resources of Alaska, report of investigations in (year)." They are progress reports and contain short articles which were later expanded into full bulletins. Generally, they do not contain any information not stated in more detail in some later bulletin.

Bull. 345-D. Occurrence of gold in the Yukon-Tanana region, Prindle, 1908, p. 179-186.
Short general discussion of the district.

Bull. 345-F. Water supply of the Fairbanks district, 1907, Covert, 1908, p. 198-205.
Contains discharge data for several streams in the district.

Bull. 379-D. The Fairbanks gold placer region, Prindle and Katz, 1908, p. 181-200.
Short description of method and costs.

Bull. 379-E. Water supply of the Yukon-Tanana regions, 1907-1908, Covert and Ellsworth, 1908, p. 201-228.
Stream discharge data and discussion of potential.

Bull. 442-F. Sketch of the geology of the northeastern part of the Fairbanks quadrangle, Prindle, 1910, p. 203-209; Auriferous quartz veins in the Fairbanks district, p. 210-229, Prindle; Placer mining in the Yukon-Tanana Region, Ellsworth, p. 230-245; Water supply of the Yukon-Tanana Region, 1909, Ellsworth, p. 251-283.

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Bull. 520-H. Placer mining in the Fairbanks and the Circle districts, p. 240-245; Water supply of Fairbanks, Salchaket, and Circle districts, p. 246-270, Ellsworth, 1912.

Bull. 525*. A geological reconnaissance of the Fairbanks quadrangle, Alaska, with a detailed description of the Fairbanks district and an account of lode mining near Fairbanks, Prindle, Smith, Katz, 1913, 220 p. plus topographic and geological maps of the region and district.

Although old, some of the rock descriptions in this bulletin are still of great value to geologists. The descriptions of placer mining methods are chiefly of historical value, but the tables of thickness and width of the gold occurrences are pertinent. There is a section on water supply. Most of the information on lodes is superceded by Bulletin 849 but is still useful for locations and descriptions.

Bull. 538. A geologic reconnaissance of the Circle quadrangle, Alaska, Prindle, 1913, 82 p. plus maps.

Early reconnaissance report covering much of the area between the Yukon and the Tanana Rivers. Describes all phases of geography, and has detailed descriptions of all the rocks, including glacial deposits and alluvial deposits. Placers of the Circle district are described and other placers of the area, excluding the Fairbanks district.

Bull. 542-F. Lode mining near Fairbanks; placer mining in the Yukon-Tanana region; Water supply of the Yukon-Tanana region, 1912, Smith, Ellsworth, and Davenport, 1913, p. 137-278.

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Bull. 649*. Antimony deposits of Alaska, Brooks, 1916, 67 p.

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Bull. 664*. The Nenana coal field, Alaska, Martin, 1919, 54 p.

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The last section describes the Liberty Bell lode mine and the placer mines of the Nenana coal fields, 60 miles south-west of Fairbanks.

Bull. 849-B**. Lode deposits of the Fairbanks district, Alaska, in Investigations in the Alaska Railroad Belt, 1931, Hill, 1933, p. 29-163.

This report is part of a larger volume reporting on investigations designed to stimulate mining and hence provide hauling for the Alaska Railroad. It is probably the most detailed and comprehensive paper on the Fairbanks lodes. About 175 claims are listed and descriptions of the more important ones are given. There are short sections on tungsten and stibnite deposits. Cost data are out of date but the geology and mine maps are still valuable.

Bull. 872**. The Yukon-Tanana region, Alaska, 276 p. plus topographic and geologic maps, Mertie, 1937.

Now 30 years old, this is still the most comprehensive report on the region lying between the Yukon and the Tanana Rivers. The geologic map is the only one that shows the whole region. Contains geography, descriptive geology of all the rock units, and a comprehensive discussion of economic geology. It must be remembered that details of this work have been superceded and made out of date.

Bull. 907*. Geology of the Alaska Railroad, Capps, 1940.

Geography and geology of the following provinces: Chugiak-Kenai, Talkeetna, Cook Inlet-Kuskokwim, and the Yukon-Tanana. The geologic maps covering the Yukon-Tanana area includes the mining districts of Fairbanks. This is a slight updating of Mertie's work (Bull. 872).

Bull. 926-C*. Occurrences of molybdenum minerals in Alaska, Smith, 1942.

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Bull. 989-F**. Effect of permafrost on cultivated fields, Fairbanks area, Alaska, Péwé, 1954, p. 315-349.

Descriptions and definitions of permafrost phenomena and distribution of permafrost in the area. Much of what is said regarding the effect of permafrost on cultivated fields is applicable to engineering geology in general. Contains a table listing fields in the area that show effects.

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Describes geology of all known and possible petroleum provinces. Separate volume of maps and sections.

Bull. 1111-I**. Frost Heaving of piles with an example from Fairbanks, Alaska, Péwé and Paige, 1963, p. 334-407.

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Comprehensive index by quadrangle.

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Descriptions for prospects all over Alaska.

Water Supply Papers

W. S. 218. Water Supply investigations in Alaska, 1906-07, Nome, Kougarok, Fairbanks, Henshaw and Covert, 1908, 156 p.

W. S. 228. Water Supply investigations in the Yukon-Tanana Region, Alaska, 1907-08, Fairbanks, Circle, Rampart, Covert and Ellsworth, 1909, 108 p.

W. S. 418. Mineral Springs of Alaska, Waring, Dole, Chambers, 1917, 113 p.

Descriptions of occurrences; some analyses.

W. S. 992*. Bibliography and index of publications relating to the groundwater prepared by the Geological Survey and cooperating agencies, Waring and Meinzer, 1947, 412 p.

W. S. 1372. Compilation of records of quantity and quality of surface waters of Alaska through 1950, Wells and Love, 1957.

W. S. 1460-A. Chemical character of public water supplies of the larger cities of Alaska, Hawaii, and Puerto Rico, 1954, Lohr, 1962, p. 6.

W. S. 1466. Quantity and quality of surface waters of Alaska, October, 1950 to September, 1953, Wells and Love, 1958, p. 185-201.

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W. S. 1492*. Bibliography of publications on ground water, 1964-65, Vorhis, 1957.

W. S. 1500. Quantity and quality of surface waters of Alaska, 1957, Wells and Love, 1960, p. 73-80.

W. S. 1546*. Annotated bibliography on hydrology and sedimentation of the United States and Canada, 1955-58, Riggs, 1962.

W. S. 1539-B**. Jet drilling in the Fairbanks area, Alaska, Cederstrom and Tibbits, 1961, 28 p.

Description of construction and operations of simple rapid drilling equipment which proved itself in the Fairbanks area.

W. S. 1570. Quantity and quality of surface waters of Alaska, 1958, Wells and Love, 1960, p. 85-101.

W. S. 1590**. Groundwater resources of the Fairbanks area, Alaska, Cederstrom, 1963, 84 p.

Contains sketch of geology, occurrence of groundwater, yields of well in different aquifers, water quality and records, logs, and analyses of wells. Best single reference.

W. S. 1640. Surface water supply of Alaska, 1959, Wells and Love, 1961, p. 86-96.

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W. S. 1760. Groundwater levels in the United States, 1956-60, Northwestern States, Hackett, 1963.

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General discussion of problems.

W. S. 1809-E*. Galleries and their use for development of shallow groundwater supplies with special reference to Alaska, Fuelner, 1964, 16 p.

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