DEPARTMENT OF THE INTERIOR
FRANKLIN K. LANE, Secretary

UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, Director

WATER-SUPPLY PAPER 372

ATER-POWER RECONNAISSANCE IN SOUTH-CENTRAL ALASKA

BY

C. E. ELLSWORTH AND R. W. DAVENPORT

WITH

A SECTION ON SOUTHEASTERN ALASKA

BY

J. C. HOYT

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PREFACE.

By Alfred H. Brooks.

A study of the water supply of parts of Alaska has been carried on by the United States Geological Survey for several years. At first the work was confined to Seward Peninsula; later it was extended to the Yukon-Tanana region. In each of the most important mining districts of these two provinces stream gaging records were obtained covering three to five years, and the results have been published in summary form.[1] It is unfortunate that the demands of other investigations have not permitted the allotment of additional funds for the continuation of this work to the end that longer records of stream flow might be obtained and other inland districts examined.

This volume is devoted to water investigations in another field. The rapid development in the region tributary to Copper River, Prince William Sound, and the lower Susitna has led to much search for water powers, and for this reason a preliminary examination of the province was undertaken in 1913. Measurements of stream volumes made during only one season can not, of course, be relied upon for estimating average flows, but this study has yielded much information on the topography of drainage basins, reservoirs, and power sites, and incidentally water measurements were made. These field data, together with compilations of the Weather Bureau's records of precipitation, are here brought together in convenient form and will, it is believed, serve as a general guide to the engineer, who will be the first to realize that it must be supplemented by surveys and measurements before any water-power project is seriously considered. This volume will at least serve to show that water powers available throughout the year are not so abundant in this part of Alaska as has sometimes been assumed.

The general province here discussed contains valuable mineral deposits. In its eastern part lies the Bering River coal field, with its high-grade fuels, and also the Katalla oil field. In the Copper River basin and in the Prince William Sound region, to the west, there are

[1] Henshaw, F. F., and Parker, G. L., Surface water supply of Seward Peninsula: U. S. Geol. Survey Water-Supply Paper 314, 1912. Ellsworth, C. E., and Davenport, R. W., The surface water supply of the Yukon-Tanana region: U. S. Geol. Survey Water-Supply Paper 342, 1914.

valuable gold and copper deposits. The gold deposits of the Willow Creek district of the Kenai Peninsula also lie in the province investigated, and the Matanuska coal field, with its valuable fuels, is close at hand. Take it all in all, this is one of the richest mineral districts in Alaska and it contains also arable lands. Moreover, it embraces two of the most important gateways into inland Alaska—the Copper River and Susitna valleys. Any power development in this field must be undertaken with full recognition of possible competition with the mineral fuels noted above. Coal and oil now command high prices but when the local fields are opened can doubtless be supplied at much lower rates.

This report is essentially the work of Mr. Ellsworth and Mr. Davenport, who deserve great credit for having collected so much information in a single field season in a region which is in large part difficult of access. Appended to the main report is a reprint of an article by John C. Hoyt on the water powers of southeastern Alaska. There is thus brought together all the available information concerning the water powers along the Pacific coast of Alaska as far west as Cook Inlet. These investigations should be followed by studies of stream flow extending through a period of years sufficiently long to afford data for accurate generalizations on stream volume. This work will be begun as soon as circumstances permit. For the present it must be deferred, as the annual grant of funds must be used for what are believed to be more important surveys and investigations.

A WATER-POWER RECONNAISSANCE IN SOUTH-CENTRAL ALASKA.

By C. E. Ellsworth and R. W. Davenport.

INTRODUCTION.

This report, which presents the results of the first systematic study of the water powers of south-central Alaska, has been compiled from observations made by the writers during the field season beginning May 5, 1913, and ending November 25, 1913, supplemented by information obtained from numerous reports and maps prepared by other members of the Survey and from records furnished by the Weather Bureau.

The areas investigated (see Pl. I) were the Bering River basin in the Controller Bay region; the basin of Lower Copper River and its principal tributary, the Chitina; numerous localities in the Prince William Sound region; the Willow Creek district; and the eastern part of Kenai Peninsula. Most of the larger streams in the vicinity of commercial centers and mining camps were visited, but this report should not be considered a complete inventory of the streams on which power may be developed within the areas discussed.

Southern Alaska is generally understood to afford many opportunities for large water-power development. Its water powers are sometimes spoken of as "unlimited," a term which, of course, is never literally correct as applied to water powers and which is not at all applicable to the area covered by this report. The coastal regions of south-central Alaska are, however, particularly favored with many small undeveloped water powers having capacities of less than 200 or 300 horsepower, and there are perhaps a few sites where plants of 1,000 or 2,000 or possibly as much as 5,000 horsepower could be operated throughout the year.

It is impracticable to estimate even approximately the power that could be continuously developed on many of the streams investigated, for no previous records of flow have been kept on streams in this region, and the data obtained during this reconnaissance represent only that part of the year when the streams are at or above their average stage. Even during that period daily records were obtained on only a few streams. It would be necessary to make daily observations for a year at least in order to estimate with reasonable accuracy the mean yearly discharge. Another reason, of nearly equal importance, is the lack of information regarding the capacity of the various reservoir sites. If water power is to be developed continuously throughout the year, the value of storage reservoirs—in which the excess flow in the summer and fall can be conserved for use during the winter—can not be too strongly emphasized.

Willing assistance and information were given to the writers by many residents of the country during the progress of the field work, and it is regretted that individual recognition can not be accorded. For gage readings and special services particular acknowledgment is due to G. L. Banta; the Copper River & Northwestern Railway; W. A. Dickey, manager Three Man Mining Co., of Landlocked Bay; Ellamar Mining Co.; Gold Bullion Mining Co.; Free Gold Mining Co.; S. M. Graff, manager Seward Light & Power Co.; Charles G. Hubbard, manager Kenai Dredging Co.; Kennicott Mines Co.; A. R. Ohman; C. I. Olsen; Herman Schmesar; and L. W. Storm, mining engineer, Valdez.

METHODS OF INVESTIGATION.

The two controlling features of a stream basin with respect to its water power capacity are (1) the run-off and its variation throughout the year and (2) the head under which the water can be utilized at the wheels. A third feature, however, that will frequently determine the practicability of the project on Alaska streams is the storage capacity that can be created above the point of diversion.

To determine the run-off, measurements of discharge were made by a current meter, and where practicable gages were installed from which the elevation of the water surface was read at various intervals of time depending on the proximity of the observer. After measurements of discharge are made at different gage heights, the discharge at any gage height can be estimated by plotting the measurements on cross-section paper, with discharges as abscissas and gage heights as ordinates, and then drawing a curve through the plotted points. A rating table is then prepared showing the discharge for various gage heights, the reliability of which depends on the accuracy of discharge measurements and gage readings, and also on the permanency of the stream channel. Where gage readings are not available the discharge is, of course, unknown except at the time of the engineer's visit, when discharge measurements were made. Such measurements are called miscellaneous and should be used with care in estimating the flow at other times, because of the rapid fluctuation that is characteristic of the streams. As previously mentioned, the records do not cover the low-water season which occurs from the late fall until about the first of May.

The head in feet obtainable at the various sites was determined either by aneroid barometer or from the following topographic maps:

Controller Bay region, scale 1:62,500, contour interval 50 feet.

Chitina (reconnaissance), scale 1:250,000, contour interval 200 feet. Published in Bulletin 374.

Nizina district, scale 1:62,500, contour interval 50 feet. Published in Bulletin 448.

Valdez Bay and vicinity, scale 1:62,500, contour interval 50 feet.

Ellamar and vicinity, scale 1:62,500, contour interval 100 feet.

Kenai Peninsula (reconnaissance), scale 1:250,000, contour interval 200 feet.

Willow Creek district, scale 1:62,500, contour interval 100 feet.

It was entirely beyond the scope of this reconnaissance to determine the capacity of the reservoir sites. Lakes that might furnish natural storage were measured on existing maps wherever possible, and the areas of lakes situated in unsurveyed districts were estimated merely by inspection and, of course, statements based on such methods can be considered only roughly approximate. No attempt was made to estimate the capacity of reservoirs that would be created by the construction of dams.

In the course of the reconnaissance the topography and rock formation at the outlet of lakes and other basins where it might be desirable to create storage reservoirs were hastily examined with reference to the possibilities of constructing dams. Distances were measured by pacing where the sites were easily accessible; where not, they were estimated. Elevations were either determined by hand level, aneroid barometer, or by estimation.

Statement of other physical features of the basins, such as forests, glaciers, general topography, and soil covering in this report, are based either on field observations by the writers or on information obtained from reports and maps prepared by other members of the Survey.

DEFINITION OF TERMS.

The volume of water flowing in a stream—the "run-off" or "discharge"—is expressed in various terms, each of which has become associated with a certain class of work. These terms may be divided into two groups—(1) those which represent a rate of flow, as second-feet, gallons per minute, miner's inches, and discharge in second-feet per square mile, and (2) those which represent the actual quantity of water, as run-off in depth in inches and acre-feet. The units used in this report are second-feet, second-feet per square mile, run-off depth in inches and acre-feet. They may be defined as follows:

"Second-foot" is an abbreviation for cubic foot per second and is the unit for the rate of discharge of water flowing in a stream 1 foot wide, 1 foot deep, at a rate of 1 foot per second. It is generally used as a fundamental unit from which others are computed by the use of the factors given in the following table of equivalents.

"Second-feet per square mile" is the average number of cubic feet of water flowing per second from each square mile of area drained, on the assumption that the run-off is distributed uniformly both as regards time and area.

"Run-off, depth in inches," is the depth to which the drainage area would be covered if all the water flowing from it in a given period were conserved and uniformly distributed on the surface. It is used for comparing run-off with rainfall, which is usually expressed in depth in inches.

An "acre-foot" is equivalent to 43,560 cubic feet and is the quantity required to cover an acre to the depth of 1 foot. The term is commonly used in connection with storage for irrigation work.

In the tables, "accuracy" shows the probable reliability of the record of the mean monthly flow. "A" indicating that the record is probably accurate within 5 per cent; "B," within 10 per cent; "C," within 15 per cent; "D," within 25 per cent. Special conditions are covered by footnotes.

CONVENIENT EQUIVALENTS.

The following is a list of convenient equivalents for use in hydraulic computation:

1 second-foot equals 40 California miner's inches (law of Mar. 23, 1901).
1 second-foot equals 38.4 Colorado miner's inches.
1 second-foot equals 40 Arizona miner's inches.
1 second-foot equals 7.48 United States gallons per second; equals 448.8 gallons per minute; equals 646,317 gallons per day.
1 second-foot for one year covers 1 square mile 1.131 feet or 13.572 inches deep.
1 second-foot for one year equals 31,536,000 cubic feet.
1 second-foot for one day equals 86,400 cubic feet.
1,000,000 United States gallons per day equals 1.55 second-feet.
1 acre-foot equals 325,850 gallons.
1 foot equals 0.3048 meter.
1 mile equals 1.60935 kilometers.
1 mile equals 5,280 feet.
1 acre equals 43,560 square feet.
1 acre equals 209 feet square, nearly.
1 cubic foot of water weighs 62.5 pounds.
1 foot head of water equals 0.434 pounds per square inch pressure.
1 horsepower equals 550 foot-pounds per second.
1 horsepower equals 746 watts.
1 horsepower equals 1 second-foot falling 8.80 feet.
1⅓ horsepower equals about 1 kilowatt.

To calculate water power quickly: $\frac{\text{Sec.-ft.} \times \text{fall in feet}}{12.57}$ = net horsepower on water wheel realizing 70 per cent of theoretical power.

WATER-POWER RIGHTS.

Water-power sites on public lands in Alaska within the national forests are under the jurisdiction of the Department of Agriculture; those outside the national forests are under the jurisdiction of the Department of the Interior. An act of Congress approved February 15, 1901 (31 Stat., 790), provides for permits for rights of way for power plants and transmission lines on the public lands. Regulations concerning the acquisition of rights of way under this act have been issued by both the above departments and can be obtained on application. On the ground of the inapplicability of general land laws to lands in Alaska, a question as to this act was submitted to the Department of Justice, and on June 29, 1915, the Attorney General decided that this act is applicable to Alaska. In national forests in Alaska it has been possible to provide for water-power development through special-use permits under the act of June 4, 1897 (30 Stat., 11), which authorizes the Secretary of Agriculture to regulate the occupancy and use of national forests.

It is believed that the only rights to the use of either land or water for the development of water power in Alaska have been acquired by special-use permits issued by the Secretary of Agriculture, by the posting of a notice of appropriation at the points of diversion and use, or by squatting. In the event of conflicting claims it is presumed that the relative rights of the claimants could be established in court.

CLIMATE.

GENERAL CONDITIONS.

The diversity of the climate of Alaska in its different parts and the consequent widely varying accounts thereof have given rise to much popular misconception. As a basis for the true conception it is necessary to comprehend the extent of the Territory and the many physical influences to which it is subject. The Territory (not including the Aleutian Islands) is limited in longitude by meridians 130° west and 168° west and in latitude by parallels 54° 40′ north and 71° 30′ north. Its southern shores are washed by the warm waters of the Pacific and its northern by the cold waters of the Arctic, which are open to navigation but a small part of the year.

Meteorologic observations in Alaska were undertaken to a limited extent by the Russians. Since the purchase of the Territory by the United States, observations have been made by the United States Army, the Signal Service, regular Weather Bureau observers, and voluntary observers under the supervision of the Weather Bureau and United States Geological Survey. As the Territory has become more thickly settled, the means for obtaining data have increased until at the present time the results of a large amount of climatic observations may be found at the United States Weather Bureau, where most of the original records are filed. The records prior to 1878 have been summarized by Dall and Baker [1] and by C. A. Schott.[2] Abbe [3] has treated on the climate of Alaska in a comprehensive manner and has included the records from 1867 to the end of 1902. Henshaw and Parker [4] have summarized the meteorologic data of Seward Peninsula to 1910 and the authors [5] that of the Yukon-Tanana region to 1912.

Abbe, in the report to which reference is made above, divides Alaska into eight climatic provinces, as follows: Pacific coast, Alaska Peninsula, Aleutian Islands, Bering Sea islands, Arctic coast, the interior, and the Copper River Plateau. The boundaries between these provinces do not seem everywhere well defined, and it is probable that as more information becomes available the classification may need revision. The area treated in this report is included in the Pacific coast and Copper River Plateau provinces. Precipitation data are also given for stations on the Alaska Peninsula and the Aleutian Islands.

The Pacific coast province comprises the area extending from Dixon Entrance to Kodiak Island and includes all the islands and the region lying between the ocean and the first range of mountain along the coast from Cross Sound to the beginning of the Alaska Peninsula. Data at hand seem to indicate that the so-called Copper River Plateau province comprises the area bounded on the south by the Chugach Mountains and on the north by the Alaska Range and Nutzotin Mountains. The boundaries of these two provinces are by no means closely defined at all places.

The stations for which data are given in this report are listed in the following table, together with reference numbers by which they may be found on Plate I, their latitude and longitude, and the limiting dates and length of the record.

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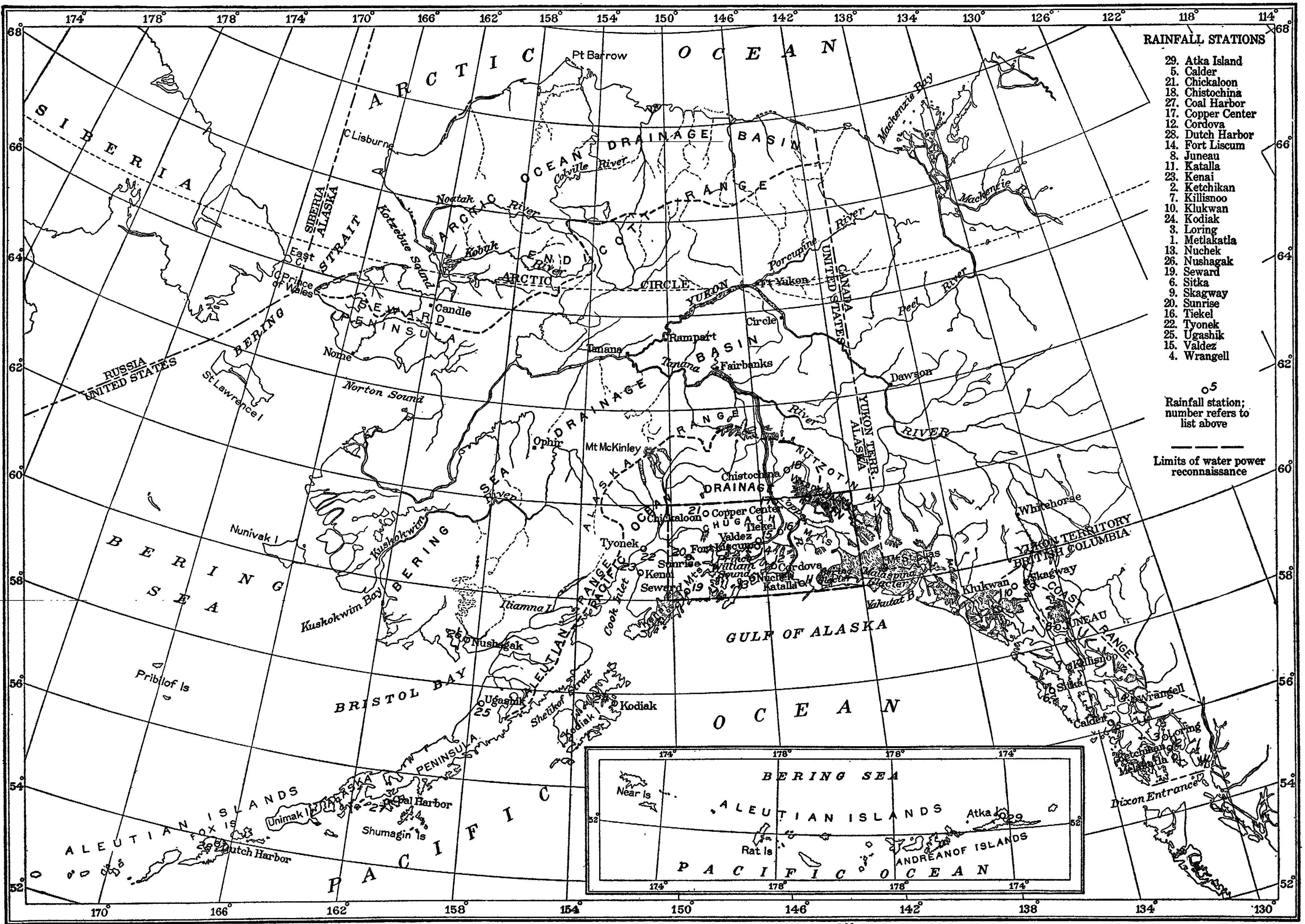
[1] Dall, W. H., and Baker, M., Pacific Coast Pilot, Coast and islands of Alaska, Appendix 1, Meteorology and Bibliography, 2d series, Washington, 1879.

[2] Schott, Charles A., Tables, distribution, and variations of the atmospheric temperature in the United States, etc.: Smithsonian Contrib. Knowl., vol. 21, No. 277, pp. 10, 11, 124, Washington, 1876. Tables and results of the precipitation of rain and snow in the United States, etc.: Idem, vol. 24, No. 353, pp. 11, 113, 2d edition, Washington, 1881.

[3] Brooks, A. H., Geography and geology of Alaska: U. S. Geol. Survey Prof. Paper 45, pp. 133-200, 1906.

[4] Henshaw, F. F., and Parker, G. L., U. S. Geol. Survey Water-Supply Paper 314, pp. 15-32, 1913.

[5] Ellsworth, C. E., and Davenport, R. W., U. S. Geol. Survey Water-Supply Paper 342, pp. 18-41, 1915.



MAP SHOWING LOCATION OF RAINFALL STATIONS IN SOUTHERN ALASKA.

Location and length of record of Weather Bureau stations in southern Alaska.

No. on Pl. I.	Station.	Latitude.	Longitude.[a]	Length of record.			
				Limiting dates.		Years.[b]	Months.[c]
		° ′	° ′				
29	Atka Island	52 15	174 15	May, 1879	August, 1886	3	14
d	Bering Island	52 12	165 55	June, 1882	April, 1886	3	11
5	Calder	56 10	133 28	April, 1908	December, 1913	4	19
21	Chickaloon	61 47	148 30	March, 1910	August, 1911	0	18
18	Chistochina	62 35	144 41	August, 1904	October, 1907	1	21
27	Coal Harbor	55 20	160 38	December, 1893	October, 1909	12	34
17	Copper Center	61 58	145 20	August, 1902	November, 1913	9	25
12	Cordova	60 32	145 46	October, 1899	December, 1913	4	74
28	Dutch Harbor [e]	53 53	166 32	September, 1878	December, 1912	8	65
14	Fort Liscum	61 05	146 20	January, 1901	December, 1913	11	22
8	Juneau	58 19	134 28	July, 1881	November, 1913	12	96
11	Katalla	60 17	144 32	April, 1907	September, 1908	0	18
23	Kenai	60 32	151 19	November, 1882	March, 1908	9	36
2	Ketchikan	55 21	131 39	June, 1902	December, 1913	0	32
7	Killisnoo	57 22	134 29	June, 1881	December, 1910	16	111
10	Kluckwan	59 23	135 54	March, 1908	December, 1913	4	16
24	Kodiak	57 48	152 25	April, 1869	November, 1913	12	140
3	Loring	55 36	131 38	March, 1904	November, 1913	7	32
1	Metlakatla	55 08	131 35	November, 1891	July, 1894	2	9
13	Nuchek	60 23	146 40	May, 1883	August, 1884	0	16
26	Nushagak	58 57	158 21	August, 1881	July, 1905	2	35
19	Seward	60 06	149 27	February, 1908	October, 1913	3	31
6	Sitka	57 03	135 19	May, 1842	December, 1913	42	123
9	Skagway	59 28	135 20	January, 1883	August, 1913	8	95
20	Sunrise	60 53	149 26	October, 1903	November, 1913	7	36
16	Tiekel	61 19	145 21	March, 1904	September, 1907	2	19
22	Tyonek	61 03	151 10	November, 1898	April, 1909	5	44
25	Ugashik	57 35	157 50	January, 1884	December, 1885	2	0
15	Valdez	61 07	146 16	October, 1909	December, 1913	4	3
4	Wrangell	56 28	132 20	June, 1868	January, 1909	0	51

[a] West except on Bering Island, which lies outside the area mapped.
[b] Complete records.
[c] Months of scattered records.
[d] Lies outside of the area mapped.
[e] Records at Udatka and Unalaska combined under Dutch Harbor.

The longest record is that at Sitka, where observations were begun by the Russian Government in March, 1842, and continued until October, 1867. The observatory was on the eastern end of the low, flat Japonski Island. The United States Government has continued the observations since October, 1867, with occasional lapses.

In this report only those aspects of the climate will be considered that bear directly on the water supply. Of those, precipitation and temperature and the agencies which they include are the most important.

PRECIPITATION.

The discharge of streams depends primarily on precipitation, for all water on the earth's surface originally fell as rain or snow. The proportion of the rainfall which passes down the stream, and the sensitiveness of the stream fluctuations to the effect of rainfall depend on other factors. The steep slopes and impervious soil of much of the region along the coast makes this sensitiveness unusually great, and a knowledge of the precipitation along the Alaska coast therefore becomes especially valuable in the absence of actual measurements or as an aid in interpreting stream flow data already obtained.

Most of the important data concerning the precipitation along the Alaska coast are summarized in the following tables, which show the mean monthly precipitation at the various stations, the monthly precipitation at many of these stations since 1900, and the daily precipitation at representative stations for 1913. The annual precipitation at Sitka for the years of complete record is shown graphically in figure 1, and the mean monthly precipitation at all the stations is

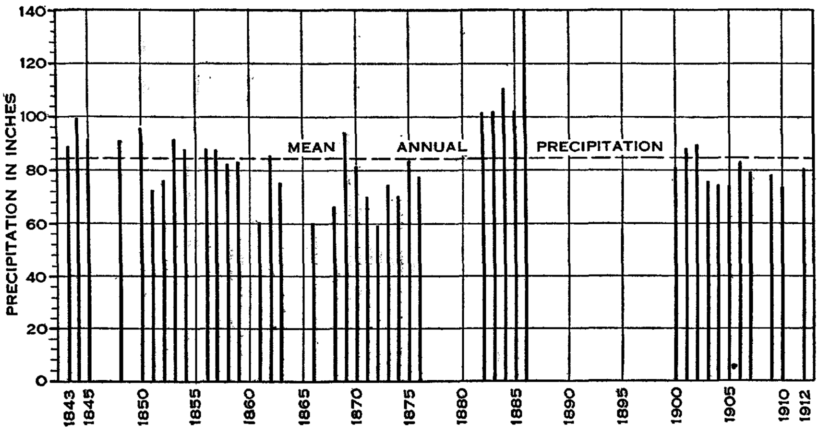


FIGURE 1.—Diagram showing annual precipitation at Sitka, Alaska, 1843–1912.

shown in figure 2. In all these records snowfall is supposed to have been reduced to its equivalent rainfall.

Mean monthly precipitation at Weather Bureau stations in southern Alaska.

Station.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Atka Island	9.05	6.47	5.22	6.66	6.55	5.63	5.28	5.67	9.02	10.32	11.59	7.77	89.23
Bering Island	.70	1.59	.91	1.13	.96	1.69	2.46	2.09	2.50	2.60	2.96	1.62	21.21
Calder	8.54	6.59	7.63	8.32	5.57	4.14	5.37	6.38	7.29	16.99	12.18	17.18	106.18
Chickaloon	.84	2.47	.59	.02	.01	.55	1.92	.61	1.46	.07	.03	.05	8.62
Chistochina	.16	.27	.39	0	.16	1.07	2.60	1.82	2.40	1.51	.26	.92	11.56
Coal Harbor	3.72	4.22	3.61	5.56	3.46	2.55	3.31	3.78	4.74	4.80	5.21	4.21	49.27
Copper Center	.57	.46	.17	.07	.39	.86	1.56	1.12	1.13	.96	.70	.75	8.74
Cordova	9.86	9.23	8.82	9.80	9.84	6.67	6.30	11.69	19.91	20.21	11.47	13.97	137.77
Dutch Harbor	10.02	6.81	5.74	5.80	5.42	3.60	2.80	3.26	7.70	10.89	8.74	8.33	79.11
Fort Liscum	7.01	5.08	6.00	3.58	4.12	2.45	5.03	7.83	9.29	9.06	6.01	8.36	73.82
Juneau	6.44	4.41	4.69	4.70	5.31	3.79	4.75	6.86	10.36	9.88	7.55	7.00	75.74
Katalla	11.88	3.94	4.54	7.75	6.30	6.26	11.30	9.67	15.36	25.62	12.44	11.48	126.54
Kenai	.66	.70	.75	.47	.85	.92	2.31	3.61	3.06	2.03	1.07	.87	17.29
Ketchikan	12.48	7.80	12.00	11.99	6.68	5.34	8.98	13.05	14.52	24.80	16.82	19.36	153.82
Killisnoo	4.75	2.14	2.96	3.00	2.80	2.19	3.45	4.21	6.85	7.76	5.64	5.12	50.87
Kluckwan	1.25	1.24	1.32	.55	.73	.89	.68	1.32	3.02	3.60	2.22	2.64	19.46
Kodiak	5.09	4.50	3.73	3.96	5.77	4.45	3.55	4.99	5.71	7.23	6.74	6.76	62.48
Loring	8.26	9.97	10.05	13.07	8.67	6.43	7.54	8.41	17.03	21.03	20.94	16.05	147.45
Metlakatla	12.59	10.48	7.59	6.83	7.32	3.10	6.63	8.12	8.24	15.78	11.23	14.61	132.50
Nuchek	27.07	9.15	18.02	16.92	18.92	4.18	9.93	14.14	22.96	21.50	10.51	16.81	190.11
Nushagak	2.91	1.15	2.53	1.42	2.45	2.10	3.70	4.59	4.82	1.93	2.28	1.20	31.08
Seward	2.01	4.92	3.34	3.70	3.53	1.83	2.66	5.33	7.18	8.62	7.54	8.13	58.79
Sitka	7.65	6.58	5.77	5.54	4.10	3.40	4.29	7.05	10.09	11.84	9.33	8.78	84.42
Skagway	1.68	2.91	1.67	1.39	.79	.94	1.22	1.65	3.08	4.31	4.10	3.51	27.25
Sunrise	2.44	2.70	1.78	2.74	1.95	1.04	2.00	2.98	3.34	4.67	4.30	4.21	34.15
Tiekel	1.28	.84	.95	.36	.36	.92	3.37	1.44	1.11	2.40	3.11	1.88	18.02
Tyonek	1.68	.94	.91	.98	.46	1.05	3.03	5.04	3.43	3.22	1.26	1.21	23.21
Ugashik	1.44	.50	1.04	1.14	1.50	1.14	2.90	3.52	5.52	2.70	1.42	1.62	24.44
Valdez	4.16	6.03	5.49	2.21	3.60	1.75	3.72	4.32	9.08	5.59	2.69	8.99	57.63
Wrangell	5.68	8.11	2.89	4.11	3.58	3.33	3.55	2.97	10.82	8.02	12.92	10.41	76.39

Mean monthly precipitation at stations in southern Alaska since 1900.

Station.	Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Calder	1908	......	......	......	12.35	5.00	2.77	5.20	6.62	18.83	15.43	11.74	......	......
	1909	......	......	10.50	3.58	5.01	6.25	10.36	12.68	17.98	16.90	4.77	3.85	......
	1910	8.35	6.20	9.70	9.20	5.17	4.65	3.75	4.80	7.79	21.35	9.24	14.05	104.25
	1911	10.15	3.00	6.22	8.25	3.23	2.62	2.05	2.70	6.90	10.35	12.55	16.80	84.82
	1912	5.25	11.85	3.30	6.25	6.00	4.23	3.55	4.01	9.80	21.55	14.85	17.72	108.36
	1913	10.40	5.30	8.45	10.30	8.43	4.31	7.30	7.50	20.75	16.35	19.95	15.60	134.64
Chickaloon	1910	......	......	.03	.02	.01	1.02	1.42	.05	1.46	.07	.03	.05	......
	1911	.84	2.47	1.15	.02	.01	.08	2.41	1.17	......	......	......	......	......
Chistochina	1904	......	......	......	......	......	......	......	.40	2.01	......	......	.20	......
	1905	.05	.02	.08	0	.48	.90	3.19	3.20	3.11	1.68	.03	.75	13.49
	1906	.26	.60	.30	Tr.	0	.81	1.78	1.48	......	......	.50	1.80	......
	1907	......	.20	.80	......	Tr.	1.50	2.82	2.21	2.07	1.34	......	......	......
Coal Harbor	1901	3.95	6.57	1.99	3.55	.67	2.21	1.64	1.63	2.80	7.45	3.54	8.87	44.87
	1902	6.54	4.64	5.34	4.77	2.98	.33	1.70	3.05	5.88	4.74	6.87	1.20	48.04
	1903	3.90	7.32	1.90	2.26	2.77	2.05	3.66	3.64	5.29	2.52	2.52	4.69	45.52
	1904	2.00	.12	.66	1.89	1.83	1.23	4.22	4.17	3.73	2.07	2.82	2.00	26.74
	1905	.17	9.05	1.20	18.92	6.76	4.44	1.75	2.20	2.95	3.03	9.25	4.64	64.36
	1906	2.33	5.43	6.46	......	3.27	1.01	3.18	4.28	3.42	4.44	3.52	2.87	......
	1907	5.65	2.00	1.43	6.72	4.59	1.88	4.71	4.90	5.84	5.83	......	......	......
	1908	6.06	4.49	4.20	1.97	6.47	3.57	3.66	......	......	......	......	......	......
	1909	......	......	......	......	3.91	1.56	3.08	......	4.37	1.28	......	......	......
Copper Center.	1902	......	......	......	......	......	......	......	1.08	.73	2.02	1.50	.20	......
	1903	.05	.05	.04	Tr.	.60	1.38	.99	1.16	1.34	1.71	.20	.75	8.63
	1904	.67	.22	Tr.	.24	.92	1.11	1.80	2.09	.73	.48	.36	.68	9.30
	1905	.29	1.01	.20	Tr.	.48	.50	1.35	.72	1.94	.97	.94	.97	9.37
	1906	1.14	.19	.69	.36	.43	1.19	2.14	.69	.37	.84	.99	.35	9.38
	1907	......	.60	.30	0	.36	1.14	.97	.71	.25	1.35	.80	.35	......
	1908	.45	.25	.05	.10	.13	.27	1.83	.65	.78	1.15	.10	.70	6.46
	1909	.70	......	......	......	.88	.72	3.43	1.27	.52	.40	.20	.60	......
	1910	1.25	.33	.21	Tr.	Tr.	.48	1.66	.50	.85	1.02	.31	.30	6.91
	1911	.10	1.43	.09	.04	.18	.20	1.12	2.72	1.85	.74	.65	1.94	11.06
	1912	.20	.24	.11	0	.16	1.60	.56	.82	3.79	.65	0	1.61	9.74
	1913	.83	.27	0	0	.15	.89	1.30	.99	1.36	.25	2.35	.55	8.94
Cordova	1901	16.17	1.21	16.91	......	......	......	......	......	26.36	24.71	8.02	9.75	......
	1902	12.02	8.05	.60	......	......	......	......	......	......	35.56	11.10	11.40	......
	1903	16.74	16.60	......	......	......	......	......	10.75	16.67	17.70	13.24	23.44	......
	1904	11.69	......	.72	13.55	......	......	......	......	9.12	27.76	9.66	19.05	......
	1905	8.20	11.56	12.51	9.10	10.48	6.51	4.42	12.99	......	15.57	29.64	12.81	......
	1906	10.63	.94	5.34	7.54	......	......	......	......	......	......	17.08	8.56	......
	1907	3.26	8.48	2.15	......	......	......	......	......	......	29.15	13.16	15.55	......
	1908	13.24	13.09	7.68	......	......	......	......	......	......	......	......	......	......
	1909	......	......	......	......	6.09	14.63	4.95	8.86	19.17	9.04	1.69	19.22	......
	1910	8.89	7.50	16.18	5.34	6.21	5.82	7.51	6.39	12.61	19.70	6.37	9.33	111.85
	1911	4.91	13.69	8.07	14.79	8.42	8.74	4.37	......	11.27	15.90	9.80	......	......
	1912	10.00	12.21	16.79	4.02	20.29	5.66	4.99	23.16	49.63	24.88	5.83	13.47	188.92
	1913	2.68	7.58	3.98	7.72	3.66	.74	12.77	8.46	19.08	15.09	17.19	16.02	114.97
Dutch Harbor.	1906	3.09	9.46	12.19	3.07	6.82	1.14	3.56	3.10	2.29	7.91	5.38	5.76	63.77
	1907	8.76	2.49	2.93	2.97	5.39	1.27	2.11	3.25	......	7.79	10.82	7.27	......
	1908	8.01	4.80	1.85	3.87	3.69	2.67	2.71	5.59	6.85	8.40	9.70	8.74	66.88
	1909	5.30	4.60	2.56	3.95	4.20	1.35	1.39	5.33	9.07	20.20	1.59	3.70	63.24
	1910	7.29	4.61	2.39	2.95	6.23	4.18	.46	......	17.43	11.10	7.86	2.19	......
	1911	6.88	10.53	4.94	6.10	5.74	......	5.91	2.92	2.35	8.26	8.56	5.62	......
	1912	4.20	5.12	8.22	5.74	6.72	4.56	3.70	1.52	6.80	10.82	8.26	4.14	69.80
Fort Liscum	1901	9.40	.80	6.38	6.20	1.45	1.13	4.77	16.20	12.72	10.31	6.28	7.47	83.11
	1902	9.94	1.28	4.70	2.80	3.08	.24	3.65	8.56	15.72	18.20	6.98	4.43	79.58
	1903	10.42	13.60	4.72	3.87	2.23	3.24	4.29	6.44	8.62	6.62	5.62	9.61	79.28
	1904	6.80	.52	.10	4.50	.68	2.26	5.61	12.45	7.96	9.16	2.20	3.99	56.23
	1905	3.63	5.73	7.17	2.96	7.02	3.83	3.49	9.85		6.06	10.37	7.75	......
	1906	12.53	1.83	7.54	4.20	1.36	4.01	7.12	8.46	4.11	8.61	7.50	6.75	74.02
	1907	1.75	10.14	6.04	.82	4.05	2.83	11.25	10.61	11.98	16.77	7.94	7.13	91.13
	1908	16.58	7.22	6.58	3.56	......	.79	2.19	3.35	6.00	8.56	8.72	11.09	......
	1909	2.29	2.57	5.80	6.94	6.28	6.14	5.78	6.65	6.40	2.83	.59	18.02	70.29
	1910	8.79	6.45	9.80	2.19	5.94	2.68	2.69	4.35	8.90	9.07	1.20	2.93	64.99
	1911	1.98	5.11	4.27	5.08	1.35	2.99	5.60	2.59	5.71	8.01	2.21	6.22	51.12
	1912	2.76	3.93	9.68	.81	5.89	1.01	4.96	6.06	16.64	7.71	6.13	9.75	75.33
	1913	4.26	6.85	5.19	2.57	10.11	.70	4.03	6.19	6.71	5.87	12.37	13.53	78.38
Juneau	1901	9.57	6.32	8.19	8.19	3.47	2.13	1.98	14.04	11.41	16.50	3.52	13.33	98.65
	1902	12.76	2.08	5.64	4.34	3.99	2.41	7.60	12.10	14.24	6.57	7.38	4.26	83.37
	1903	11.31	7.29	3.09	3.74	6.74	1.44	2.26	5.45	6.94	......	......	......	......
	1904	......	......	......	7.84	6.50	10.40	8.15	4.04	9.20	9.34	8.36	8.80	......
	1905	2.83	3.08	5.90	4.96	1.58	2.96	1.93	7.85	......	12.74	15.49	10.32	......
	1906	4.35	1.57	.56	3.03	......	1.34	3.58	3.21	3.68	12.30	12.27	2.17	......
	1907	.48	8.88	2.74	3.10	3.93	2.45	3.40	6.88	17.03	11.19	4.58	.25	66.46
	1908	.39	3.87	6.50	0	4.88	2.45	2.80	3.85	17.00	8.40	1.82	5.32	63.32

Mean monthly precipitation at stations in southern Alaska since 1900—Continued.

Station.	Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Juneau	1909	.59	3.78	9.22	4.44	5.67	5.77	7.69	11.96	13.68	6.05	2.79	1.97	73.61
	1910	3.08	.88	3.15	4.53	10.17	2.70	9.94	1.55	1.19	2.13	.98	3.58	44.60
	1911	1.34	1.56	1.44	2.51	1.65	2.24	.91	2.20	2.15	7.66	4.09	7.99	35.74
	1912	.54	7.16	2.72	2.93	3.14	5.53	a 3.60	6.50	9.60	14.80	7.94	13.25	......
	1913	5.21	4.43	4.20	3.67	4.73	.72	6.50	8.39	12.14	14.58	7.76	......	......
Katalla	1907	......	......	......	7.50	4.85	8.29	13.96	11.41	12.34	25.62	12.44	11.48	......
	1908	11.88	3.94	4.54	8.00	7.75	4.22	8.20	7.93	18.38	......	......	......	......
Kenai	1901	.64	.07	.32	.85	.30	.06	1.66	4.85	2.23	1.69	.64	.19	13.50
	1902	.84	.44	.50	1.03	.42	.59	1.71	2.92	4.69	2.73	.86	1.55	18.28
	1903	.83	2.18	.44	.67	.54	1.16	2.48	3.78	2.72	.77	.78	.18	16.53
	1904	.46	.29	.02	.34	Tr.	.87	2.44	3.50	4.01	1.71	.48	.66	14.78
	1905	.29	.92	.57	.46	.84	.84	1.06	6.26	.78	2.92	2.16	1.41	18.51
	1906	.30	.10	1.24	.17	.29	.57	4.41	2.95	1.41	1.74	.39	1.16	14.73
	1907	.68	.61	.67	.04	1.24	2.31	5.49	......	10.00	1.66	......	......	......
	1908	.50	.11	.11	......	......	......	......	......	......	......	......	......	......
Ketchikan	1910	......	......	......	......	......	......	......	......	7.44	28.92	11.88	18.37	......
	1911	8.51	7.24	8.96	11.99	2.26	6.43	......	......	......	......	......	......	......
	1912	......	......	......	......	7.15	6.65	5.60	4.89	16.44	27.78	18.47	21.23	......
	1913	16.46	8.35	15.04	......	10.62	4.97	15.73	11.87	19.67	17.69	20.12	18.47	......
Killisnoo	1901	6.95	6.05	5.40	1.15	4.00	1.60	1.40	5.95	5.50	9.10	3.55	5.30	55.95
	1902	......	2.65	1.50	2.10	4.70	1.60	3.80	4.80	7.20	4.60	2.75	2.90	......
	1903	4.05	2.40	.20	6.15	2.55	.75	1.15	2.30	3.10	12.45	3.65	5.00	43.75
	1904	4.30	1.25	1.20	1.35	1.75	3.35	4.60	2.30	7.70	8.20	9.20	8.55	53.75
	1905	1.90	2.80	2.60	2.20	......	1.20	1.60	4.30	......	4.10	8.40	7.75	......
	1906	6.90	2.70	.90	5.15	1.25	2.85	3.80	4.90	4.70	8.40	9.55	2.50	53.60
	1907	1.40	9.55	1.70	1.35	1.60	3.85	3.05	4.65	6.85	8.57	......	......	......
	1908	......	3.94	.64	2.28	1.55	.97	2.29	2.54	8.95	7.90	6.50	1.86	......
	1909	1.00	1.80	1.13	......	......	.55	3.20	4.50	12.10	7.60	1.35	1.60	......
	1910	3.50	.81	1.50	1.65	1.20	2.30	4.45	2.15	4.85	8.25	.62	2.35	33.63
Kluckwan	1908	......	......	.66	.58	......	......	......	......	......	2.38	3.06	1.79	......
	1909	.20	.35	2.43	Tr.	.79	.92	2.36	1.62	5.24	2.65	.61	1.10	18.27
	1910	1.75	.81	3.13	1.24	.67	.76	2.70	......	1.75	2.71	1.89	1.85	......
	1911	1.09	2.32	1.06	.39	1.46	.72	1.07	.76	1.72	5.07	3.83	3.12	22.61
	1912	1.55	2.07	0	.11	.66	1.28	.93	1.06	2.52	4.71	1.02	3.79	19.70
	1913	1.67	.63	.63	1.01	.06	.76	1.35	1.83	3.89	4.05	2.88	4.22	22.98
Kodiak	1901	2.62	.30	3.85	......	3.45	4.50	3.56	5.13	5.98	8.95	4.82	11.10	......
	1902	3.89	6.29	4.33	3.26	5.55	1.55	1.87	6.15	......	......	......	......	......
	1903	6.74	8.10	.39	4.61	4.92	7.80	4.38	4.79	7.95	6.27	3.40	8.29	67.64
	1904	3.63	......	Tr.	2.68	3.35	2.26	1.36	4.89	4.63	5.54	5.20	3.24	......
	1905	4.80	4.90	2.60	1.70	2.70	3.10	2.10	......	1.80	......	8.00	2.42	......
	1906	2.50	8.60	3.50	3.80	5.10	......	4.70	......	1.50	6.70	5.10	3.20	......
	1907	1.00	4.00	Tr.	.61	6.30	5.20	3.50	3.70	9.00	8.70	7.70	6.50	30.36
	1908	4.57	5.65	2.91	4.87	6.05	1.63	6.64	7.04	3.82	6.91	14.11	7.15	71.35
	1909	1.33	1.53	3.92	5.41	4.97	7.25	2.92	5.12	4.64	4.45	1.42	5.47	48.43
	1910	2.68	5.36	4.90	7.40	4.54	3.68	5.23	......	3.62	8.18	5.38	6.73	......
	1911	2.00	2.98	3.24	4.44	3.01	7.57	1.78	3.53	2.77	9.85	9.32	4.71	55.20
	1912	12.92	8.16	5.28	6.67	14.59	......	......	......	......	......	......	......	......
	1913	......	......	3.13	2.97	8.69	2.73	3.62	4.79	5.38	5.22	2.71	......	......
Loring	1904	......	......	2.05	7.27	15.80	9.68	7.97	1.15	20.20	26.01	31.90	20.01	......
	1905	5.18	13.19	16.53	11.65	9.46	.84	5.26	12.71	14.07	17.94	28.49	25.92	161.24
	1906	21.66	6.08	8.56	24.52	5.59	10.09	4.99	15.21	17.28	20.49	21.57	8.41	164.45
	1907	.53	13.03	4.98	7.76	4.30	5.23	3.73	9.75	10.14	20.09	24.55	16.28	120.37
	1908	14.68	6.56	9.55	14.94	8.99	5.34	6.52	5.09	24.89	19.50	......	9.30	......
	1909	5.72	7.55	14.54	5.63	7.77	4.98	17.46	16.47	28.94	24.68	12.61	5.46	151.81
	1910	5.63	11.38	11.77	18.09	9.21	9.30	6.79	5.33	10.92	28.76	13.60	18.11	148.89
	1911	3.71	12.28	13.44	17.53	6.90	7.13	6.28	2.63	8.02	12.49	14.28	21.72	126.41
	1912	8.26	13.93	4.41	8.55	6.01	7.53	4.91	5.38	11.89	21.23	20.59	19.19	131.88
	1913	8.96	5.74	14.64	14.70	12.70	4.18	11.46	10.38	23.97	19.07	20.88	......	......
Seward	1908	......	10.43	2.35	4.00	1.63	.45	3.35	6.34	4.29	9.73	20.99	12.38	......
	1909	.52	.47	3.72	3.03	4.47	4.39	.72	3.71	3.66	8.92	.37	12.80	46.78
	1910	3.32	4.52	2.50	.55	1.43	2.59	2.15	2.45	7.12	5.72	1.55	4.31	38.21
	1911	1.45	5.67	2.30	4.12	2.66	2.95	1.89	2.55	3.28	9.30	4.96	1.29	42.42
	1912	......	......	5.77	4.29	8.33	.53	3.10	14.04	12.91	9.29	9.84	9.89	......
	1913	2.76	3.52	3.37	6.24	2.68	.05	4.82	2.90	10.83	8.78	......	......	......
Sitka	1901	9.33	6.38	7.80	7.17	4.86	1.26	.45	10.03	8.82	15.59	6.16	10.18	88.03
	1902	11.92	2.25	5.39	4.93	6.10	1.87	7.35	14.96	13.43	8.25	6.19	5.93	88.57
	1903	6.61	8.68	2.57	4.25	3.65	.90	2.85	3.90	5.80	14.52	6.50	14.97	75.20
	1904	10.36	.43	3.04	3.39	3.80	3.22	5.95	3.74	12.27	10.38	8.78	8.13	74.49
	1905	3.82	4.78	4.21	7.52	2.44	2.25	2.83	7.38	8.80	7.03	11.37	11.21	73.64
	1906	7.25	1.89	1.58	10.64	3.46	3.34	7.45	4.66	5.78	15.22	15.59	6.61	83.47
	1907	2.36	3.55	1.75	2.16	3.87	3.66	4.66	12.60	15.75	11.77	12.13	4.81	79.07

a July 7–31.

Mean monthly precipitation at stations in southern Alaska since 1900—Continued.

Station.	Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Sitka	1908	7.54	6.57	4.74	9.58	3.82	1.39	3.45	7.52	15.85	10.65	7.20	......	......
	1909	1.49	2.43	12.97	4.67	4.47	3.29	5.14	6.62	16.98	10.46	3.83	5.45	77.80
	1910	10.06	5.17	6.51	6.13	3.44	3.47	3.74	3.35	8.04	7.34	3.87	11.48	72.60
	1911	9.39	8.37	8.65	5.98	3.21	2.76	2.84	2.30	5.96	10.98	8.36	......	......
	1912	3.18	5.90	5.01	2.67	3.66	3.49	3.84	9.07	8.27	15.13	9.92	19.87	80.01
	1913	......	......	......	......	3.98	.75	2.81	9.07	9.30	16.58	11.88	5.67	......
Skagway.....	1901	......	......	......	......	......	......	......	......	......	4.92	......	......	......
	1902	......	......	......	......	.13	.30	2.89	3.03	1.66	1.75	1.24	2.06	......
	1903	2.08	1.44	.43	.48	1.10	.56	.02	2.08	1.41	9.99	1.60	3.35	24.54
	1904	1.44	Tr.	.33	2.31	.84	.97	1.07	.18	2.80	5.35	6.28	......	......
	1905	......	1.14	1.14	1.27	1.11	.10	.16	2.14	2.67	2.17	3.25	2.21	......
	1906	......	1.16	.57	3.55	.37	2.63	2.11	2.26	1.30	5.58	6.47	.33	......
	1907	.46	4.85	.47	1.08	.92	.39	.91	1.98	2.47	5.87	4.23	2.99	26.62
	1908	1.42	1.70	.23	.80	.70	.11	.48	.49	4.18	2.46	3.16	1.83	17.56
	1909	......	.15	2.15	Tr.	.70	.68	2.43	......	6.41	3.63	......	......	......
	1910	2.80	1.40	4.80	1.38	.46	1.80	2.30	1.71	1.21	4.31	......	......	......
	1911	.07	1.42	......	......	......	......	......	......	......	......	......	......	......
	1912	.15	2.00	......	......	......	......	......	......	......	......	......	......	......
	1913	.15	.75	.35	.65	.25	.30	......	3.65	......	......	......	......	......
Sunrise......	1903	......	......	......	......	......	......	......	......	......	2.61	3.37	3.70	......
	1904	1.69	.13	.28	5.08	1.01	1.36	1.05	5.02	2.33	9.35	2.37	8.31	37.98
	1905	2.12	1.93	1.64	3.41	.84	.69	1.40	4.46	1.86	4.36	9.47	8.48	40.66
	1906	2.18	.29	3.63	1.17	2.35	2.46	1.84	3.70	1.54	6.67	3.87	2.30	32.00
	1907	2.05	1.93	......	1.41	1.30	.74	4.62	2.29	4.45	6.03	7.32	6.78	......
	1908	7.03	4.68	2.00	3.37	2.63	.21	2.28	2.91	5.00	2.59	4.49	3.37	40.56
	1909	.54	1.05	2.71	.68	2.27	1.96	1.79	3.06	2.64	2.56	.40	3.36	23.02
	1910	3.22	4.39	1.66	1.55	.86	1.44	1.79	1.74	2.80	4.34	2.29	4.06	30.14
	1911	1.20	6.01	2.44	4.74	1.34	.89	1.61	1.40	3.59	5.20	3.64	3.25	35.31
	1912	3.41	5.24	1.20	2.86	6.12	.63	......	3.13	5.44	5.90	8.80	5.40	......
	1913	.96	1.37	.45	3.17	.78	.07	1.64	2.04	3.70	4.35	4.67	......	......
Tiekel.......	1904	......	......	.05	.75	.40	.79	1.53	2.00	1.21	2.82	.90	2.95	......
	1905	.98	.49	1.31	.04	Tr.	.80	1.05	1.02	1.41	1.48	4.90	2.34	15.82
	1906	2.50	.20	1.87	.58	.25	1.39	2.70	.72	.62	2.90	3.52	.36	17.61
	1907	.37	1.81	.56	.07	.80	.68	8.20	2.00	1.20	......	......	......	......
Tyonek......	1901	1.55	.05	.62	1.00	.04	.53	2.68	5.77	3.16	4.42	.45	1.13	21.55
	1902	3.08	.52	1.09	.71	.38	0	2.93	5.40	6.56	4.96	.94	1.72	28.29
	1903	1.95	3.91	.45	1.01	.69	1.59	2.62	5.69	2.76	1.15	.64	.53	22.99
	1904	1.07	.26	......	......	......	......	......	......	......	......	......	......	......
	1905	......	......	......	......	......	1.27	.92	4.75	.92	3.19	3.10	1.24	......
	1906	.65	.49	1.32	.77	.39	1.00	2.96	2.95	1.67	......	1.04	1.38	......
	1907	1.96	1.08	1.66	.24	......	2.86	6.39	3.05	5.76	3.48	2.18	.57	......
	1908	1.98	.99	......	......	.39	.25	......	......	......	1.30	1.21	1.86	......
	1909	.58	.53	.99	2.38	......	......	......	......	......	......	......	......	......
Valdez.......	1909	......	......	......	......	......	......	......	......	......	3.81	.32	14.90	......
	1910	6.78	3.08	3.47	.79	4.43	2.68	2.60	2.94	8.09	8.73	1.47	3.00	48.06
	1911	2.82	7.43	6.08	4.52	2.72	2.46	2.81	1.07	2.52	3.75	3.00	9.27	48.34
	1912	3.04	4.97	10.97	.71	5.45	1.23	5.10	7.05	18.74	6.99	2.47	9.14	75.86
	1913	4.00	8.63	1.43	2.82	1.78	.64	4.38	6.20	6.95	4.66	6.20	8.63	56.32

Daily precipitation, in inches, at various stations in south-central Alaska for 1913.

Copper Center.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.[a]	Annual.
1											1.08		
2													
3													
4													
5							0.22				.22		
6													
7													
8													
9													
10		0.13											
11							.27						
12						0.33		0.35					
13					0.09						.35		
14													
15													
16													
17													
18										0.25	.70		
19													
20													
21													
22							.19						
23									0.80				
24						.20			.37				
25													
26	0.83						.22						
27		.14			.06		.32		.09				
28							.08	.35					
29						.36		.29					
30													
31													

[a] Total for December 0.55 inch.

Cordova.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1	0.68	0.53		0.65				0.16		1.45	3.45	0.85	
2							0.15	.01	1.15		2.80	.17	
3							.02		.10	.14	.63	.46	
4			0.39	.10			Tr.	.01	.03	.80		.43	
5				.16				.18		.17		.70	
6						0.02		.26				.78	
7			.10				.08	.06				.27	
8			1.35				.01	1.08				1.10	
9			.56			.38	Tr.	2.02				.18	
10	.20	.12	.65	.20		.12			.10			.16	
11		.23	.01						.12		.85	.59	
12		.30			0.12				2.07		4.23	.25	
13			.05	.67	.48				.57	.11	.31	2.05	
14			.02						1.78		.78	1.46	
15		.49		.40			.20		1.71		.11	.05	
16		.65		.65			.33	.01	.09				
17		.43		.42	.22	.03	.73		.01		.18		
18		3.88		.22	.48		1.55		.16	.60	1.03	.25	
19		.30		.50	.53		2.15		.53	2.26		.66	
20		.12		.96			2.03	.02	.12	.08	.02	.04	
21				.20				.05		.74	.63	.09	
22	.12				.48		.75		1.91	2.38	.60		
23	.04			.37	.43	Tr.	.54		2.03	.74	.40	.53	
24	.05		.25	.48	.08	.12		.35	2.22	.74	.06	.51	
25	.28		.15			.07	.07		.78	.36		.27	
26	.60						.38	.91	.13		.05		
27			.30				.07	2.40	.12			.34	
28	.08	.53	.05				1.00	.90	.37		.15	1.38	
29				.98		.28	.83	.04	.56	1.30	.23	.85	
30				.76		.76	1.63		2.42	2.20	.68	1.46	
31	.72		.10				.25			1.02		.14	

Daily precipitation, in inches, at various stations in south-central Alaska for 1913—Continued.

Juneau.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1	0.20	0.28	0.15	0.11	0.08		0.25			1.00	0.10		
2	.19	.11	.02	.14	.22		.24	0.04		.03	.16		
3	.04		.25	.03	.25			Tr.	0.02		.46		
4	.07		.20	.31	.02		.01	.53	.16	.03			
5	.31		.37			0.18	.17	.40	.13	.46	.01		
6	.90		.60	.04				1.30	.03	.04	.03		
7	.15			.03			.07	.31	.72	.25	.35		
8		.14	.18			.11	1.08	.08	.06	.40	.46		
9			.21	.14		.02		.40	.40	.20	1.10		
10	.21		.10	.15			.06		.11	.01	.52		
11		.48				.08	.80		.90	.05	.06		
12		.30		.08	.15	.10			.61	.16	.13		
13		.50		.38	.27	.10			.44	.40	.31		
14		.57	.12	.15				.02	.92	.16	.66		
15		.45	.20	.05			.22		.78	.40	.70		
16		.25		.34	.01		.10		.46	.73	.02		
17		.12		.08			.22		.09	.55			
18	Tr.	.48		.42			.63			.82	.80		
19	.11	.10		.03	.71		.15		.65	3.50			
20	.36	Tr.		.05	.07				.77	.97			
21	.11	.22		.03	.11				1.45	.90	.25		
22	.43			.21	.30	.03			.65	.76	.25		
23	.58			.19	.18			.05	.35	.60	.12		
24	.09				.04			.67		1.15	.01		
25	.19	Tr.	.50	.02	.25			.90		1.10			
26	.24		.57	.04	.06		.42	.34	.01	.15			
27	.25	Tr.	.13	.07	.12		.72	1.80	.03		.36		
28	.30	.43	.12		.36	.10		1.55	.90		.38		
29	.04				.63		.68	Tr.	1.30	.10	.01		
30	.40		.25	.58	.43		.37	Tr.	.20		.51		
31	.04		.23		.53		.31			.22			

Seward.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1		0.70	0.13	0.25	0.15					0.37			
2		.20	.18				Tr.						
3										.77			
4	0.35		.30							.83			
5	.20		.60						0.05	.07			
6				.02					.12				
7			.09										
8			.97					1.00					
9	.25		.03	.12		0.02		.20					
10		.10	.10			Tr.							
11					Tr.								
12		.10		.55			Tr.						
13				.10					.18				
14		.12		.48			Tr.						
15		.25		.48			0.10		Tr.				
16		.30		1.10			.11	Tr.					
17		.42		.33	1.00		.12						
18					.18		.45		.20	Tr.			
19	.05	1.00		.63	Tr.		.81	.08	1.22	1.48			
20		.20		.18	.03		.91	.10	Tr.				
21				.30				.04		.14			
22				.28	.30		.44	.05	.86	1.05			
23				.22	.22	.03			1.98	.14			
24			.20	.20	Tr.			.02	2.40				
25	.17		.53				.27		2.45	.18			
26	.10		.05				.27	.54	.10				
27	.37	.13						.87	.05				
28			.12	.15			.46		Tr.	.24			
29				.62	.15		.68		.15	.38			
30	.47			.23	.05		.20		1.07	2.58			
31	.80		.07		.60		Tr.			.55			

Daily precipitation, in inches, at various stations in south-central Alaska for 1913—Continued.

Sunrise.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1	0.02	0.49	Tr.	0.28	0.08					0.38	1.49		
2	.01	.25	Tr.		.02					.19	2.13		
3	.13	.02			Tr.					Tr.	Tr.		
4	.07		0.12	.03				Tr.		.33	Tr.		
5	.01		.15	.09	Tr.			Tr.	0.01	.29			
6	Tr.		.01		Tr.			0.01	Tr.	.02	.06		
7			.03					Tr.		.10	Tr.		
8			Tr.				Tr.	.10		.06			
9	.18		.02	.06			0.06	.06		.02			
10	Tr.		.04					.39			Tr.		
11	.04				Tr.						.11		
12	Tr.			.02	Tr.		Tr.				.14		
13	.01	Tr.	Tr.	.11					.04		.09		
14		Tr.		.01					.01		Tr.		
15		.02		.26			.21		.06				
16		.01		.04			.25	.13	.03				
17		.01		.05	.22		.02		.08		.14		
18		.16			.08		.04	Tr.	.07	.32	.09		
19	.17	.01		.98			.06	.07	.03	.38			
20	Tr.	.09		.41	.04		.24	.03		Tr.	.02		
21	Tr.			.52	.01		Tr.	.01		.12	.37		
22				.03	.09		.17		.26	.31	Tr.		
23				.09		0.04	.02		.24	.30	.01		
24	.05		.01	.03				Tr.	.99	.03	.01		
25	.02		Tr.				.13	.01	1.46	.09			
26	.18		.02				.10	.15	Tr.				
27	.01	.02	.03		Tr.		.01	1.03	.02				
28	.01	.29	.01	Tr.	.13		.27	.05	.23	Tr.	.01		
29	.02			.07	.04	.03	.01		.05	.07			
30	Tr.			.09	.05		.05		.12	1.25			
31	.03		.01		.02					.09			

Valdez.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1		1.39	Tr.	0.02	0.13			Tr.		0.18	1.45	0.26	
2	Tr.	.13			.14		0.07		0.04	.05	.33	1.01	
3	0.04	Tr.					.03			.06	.38	.39	
4	.09		0.11				.01	0.01		.50	.04	.29	
5	.60		.24					.01		.52		.39	
6	.06						.02	.46		.01		.20	
7			.13	Tr.			.02	.02		.03		.23	
8			.54	.02			.06	.56				.81	
9	Tr.		.13			0.22		.45				.03	
10						.09	.01	.02	.09			.02	
11	.04	.14	Tr.				.10	Tr.	.01			.02	
12	Tr.	.12		.03	.31			.01	.24		1.22		
13			Tr.	.24	.37			.01	.43	Tr.	.33	1.32	
14				.02					.41		.10	.17	
15		1.17		Tr.			.16		.34			.11	
16		.43			Tr.		.02	.02	.01				
17		1.14			.06		.15		.02		.31		
18		1.47		.22	.12		.35		Tr.	.15	1.13	.04	
19	.03	.54		.12	.39		.35	Tr.	.15	.61		Tr.	
20	Tr.	.42		.90			.75	.10		.20	.03		
21		.08		.07	.02		.01	.07		.13	.21		
22				.16	.07		.35	Tr.	1.13	.60	.31	.07	
23	.08			.17	.08	.02	.12		2.00	.06	.22	.28	
24	.10	.04		.04			Tr.	.03	1.12	.10	.04	.08	
25	.89		.27	Tr.		.29	.16	.05	.39	.21			
26	.22		Tr.			Tr.	.56	.45	.11				
27	.61	.23	Tr.			Tr.	.06	2.95	.01			.08	
28	.25	1.33		.03			.44	.65	.11		.06	.50	
29	.46			.33	.04	.02	.41	.07	.14	.29	.01	.85	
30	.39			.45	.03		.12	.26	.20	.78	.03	.88	
31	.14		.01		.02		.05	Tr.		.18		Tr.	

The records vary widely and indicate some very pronounced characteristics of areal distribution. The greatest annual precipitation in the Territory apparently occurs in the southern part of the Alexander Archipelago, at Loring, Ketchikan, and Metlakatla, the average being 144 inches. To the north there is an evident decrease, for at Calder and Sitka the records are 106 inches and 84 inches, respectively. At Killisnoo and Juneau, which are somewhat protected from oceanic influences, the records are 51 and 76 inches. At Skagway and Klukwan, which lie considerably inland from the open ocean, the average precipitation is 23 inches.

To the west the first point at which observations have been made is Katalla. The records there and at Nuchek and Cordova indicate another region of remarkably heavy precipitation. The maximum is recorded at Nuchek, but the record was so short that probably less reliance should be placed on it than on the longer records at Katalla and Cordova, of which the average is 132 inches.

Fort Liscum and Valdez are at the upper end of Port Valdez and somewhat protected from the ocean might be expected to receive less rainfall than places more exposed. At Fort Liscum the record is 74 inches, whereas across the bay it is 58 inches, a rather marked variation for so short a distance—4 miles. The fact that Fort Liscum is situated at the base of a steep mountain slope and Valdez on a broad, low delta, 1½ miles from the foot of the nearest mountain, account for the phenomenon. (See p. 89.)

Marked differences in the precipitation at the different stations are found also on Kenai Peninsula. From Seward, where the recorded precipitation is 59 inches, the amount decreases to 34 inches at Sunrise on the north, and to 17 inches at Kenai. Conditions similar to those at Kenai apparently prevail at Tyonek, which is situated a few miles north of Kenai and across Cook Inlet, the mean annual precipitation at that point being 23 inches.

The annual precipitation at Kodiak—62 inches—is not very different from that at Seward. On the eastern shore of the Alaska Peninsula there is a record of 49 inches at Coal Harbor, but on the western coast a smaller precipitation is indicated by the records of 24 and 31 inches at Ugashik and Nushagak, respectively.

Farther west the precipitation apparently increases, for at Dutch Harbor the mean is 79 inches, and still farther west, at Atka Island, it is 89 inches. The most western station at which records have been obtained is Bering Island, where the mean is 21 inches.

North of the Chugach Mountains there is a very marked decrease in rainfall. Tiekel, situated in the northern foothills of these mountains, has a record of 18 inches. At Chickaloon, Copper Center, and Chistochina conditions of precipitation appear approximately the same, the average being 10 inches per year and indicating a region of low precipitation including a large part of the Chitina, upper Copper, and Matanuska valleys. This does not mean, however, that the precipitation on the mountains in this region may not be much higher than that at the station affording the data.

Neither the object of this paper nor the information at hand justifies a very comprehensive discussion of the meteorology of the region, but it seems advisable to call attention to certain influences that produce the wide variation of precipitation in Alaska noted in the foregoing paragraphs.

The cooling of air to the point at which the moisture it carries is precipitated as rain or snow may be caused by various conditions, but the cause most active along the Alaska coast is the passage of the relatively warm southerly winds, laden nearly to the point of saturation with moisture that has been collected by evaporation from the Pacific Ocean, over the cool land areas.

The exposure of the locality to the ocean winds and its position with respect to surrounding topographic features probably explain many of the variations in precipitation found in the coastal province. At the foot of a high, steep mountain side exposed to the moisture-laden winds the rainfall will be heavier than at a place similarly situated on the leeward side, and it will also be greater than at a place exposed to the same winds but lacking the mountain background, since the cool mountain air is very effective in precipitating the moisture. Thus an area that is protected from the prevailing winds by mountains, islands, or projections of mainland would receive less precipitation than an area not so protected.

The great mountain systems lying across the course of the prevailing winds also serve as effective obstructions to the passage of moisture to the interior. The moisture-laden southwesterly air currents passing up the mountain sides become increasingly cooler and continue to deposit their excess moisture, and at the summit their moisture content represents the capacity of the air at that temperature. As they descend on the other side they usually enter a warmer region, and there tend to retain their moisture until they are cooled below the temperature prevailing at the mountain summit over which they have passed.

This phenomenon explains some of the peculiarities of the distribution through the year. The diagram, figure 2, shows clearly that along the coast, owing to the lowering of the land temperature and to other physical causes, precipitation is heaviest during September, October, November, and December.

Across the Chugach Mountains the annual rainfall is greatly reduced and the period of heaviest rainfall apparently begins in midsummer. In the interior[1] rainfall is heaviest in June, July, and August, the warmest season of the year, the reason being that the higher tem-

[1] Ellsworth, C. E., and Davenport, R. W., U. S. Geol. Survey Water-Supply Paper 342, p. 41, 1915.

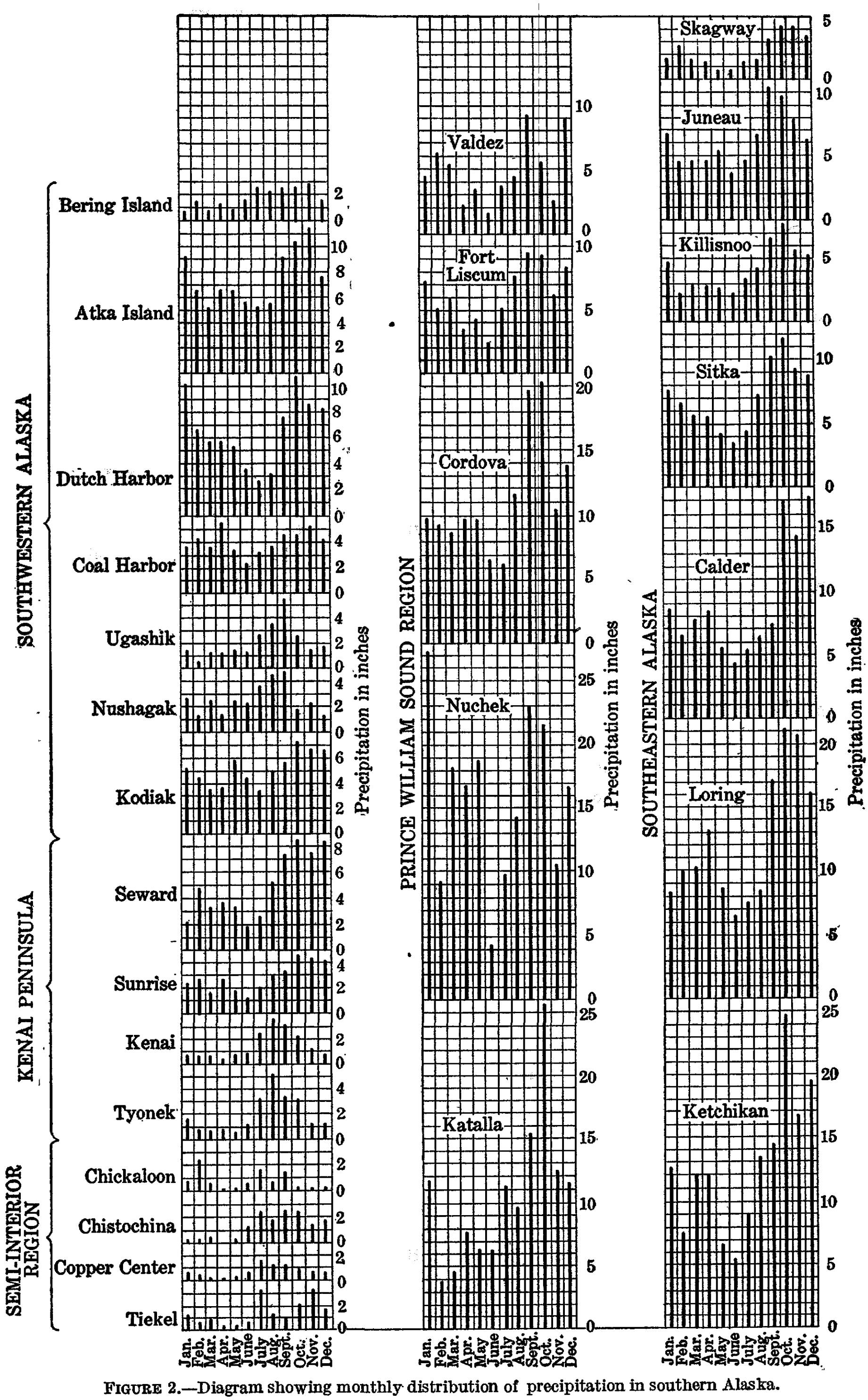


FIGURE 2.—Diagram showing monthly distribution of precipitation in southern Alaska.

peratures on the coast and at the mountain summits during the summer allow the passing winds to carry more moisture into the interior.

The effect of altitude on precipitation is undoubtedly very pronounced in this region. The evidences do not seem conclusive that the increase is continuous from the coast to the summits of the mountains, for the maximum precipitative effect of the land temperature acting on the warm sea air might be at some place below the summit. After the air has been unburdened of much of its moisture at the first mountain summits and has attained a more uniform humidity, the tendency is toward increase in precipitation where the lower temperatures prevail. Decrease in temperature and therefore increase in precipitation usually accompanies increase in elevation. This fact has an important bearing on the water supply of some of the inland area.

The effect of elevation on precipitation is well illustrated in the Cook Inlet country. At Kenai the mean annual precipitation is 17 inches, at Tyonek 23 inches, and at Chickaloon 9 inches. The last-named station lies within the region of low precipitation already noted. About 30 miles west of Chickaloon is the Craigie Creek drainage area, most of which lies at elevations between 2,000 and 4,000 feet, whereas the altitude of Chickaloon is about 900 feet. The run-off from Craigie Creek at the Gold Bullion mill is shown on page 145, and for the months of June, July, August, and September the total is 32.52 inches. The size of the drainage area has been very accurately determined. The season of 1913 was considered exceptionally dry throughout the Cook Inlet country.

A topographic party of the United States Geological Survey, working throughout the summer of 1913 at the head of the Susitna River on the south slope of the Alaska Range, noted some of the characteristics of precipitation in that area. The season was comparatively dry to July 10, but thereafter until September 1 it was estimated that rain and fog prevailed more than two-thirds of the time. The same period in the lower Susitna Valley and Cook Inlet region was practically rainless. Moreover the natives at the head of the Susitna were reported as saying that the season was not abnormally rainy. These comparisons indicate a large increase of precipitation with increase in altitude in the interior region during the summer.

The maximum rainfall in 24 hours very rarely reaches 7 inches, but frequently exceeds 3 inches at the wettest places. The maximum is somewhat greater in the eastern part of the coast province than in the western, and it decreases rapidly toward the interior. At Copper Center a 24-hour rainfall in excess of 1 inch is very unusual.

At some of the stations in southeastern Alaska a rainfall in excess of one-hundredth of an inch occurs on more than 200 days of the year. In the western part the number of rainy days decreases to about 150. At the more inland areas, such as on Upper Lynn Canal and the Cook Inlet region, the number of rainy days does not much exceed 90 per year. The average number of rainy days per year at Copper Center is 63. Thus the maximum rainfall in a 24-hour period and the number of rainy days in a year are seen to bear a well-defined relation to the quantity of annual rainfall.

A study of the water supply of a region obviously involves the question of snowfall. The principal factors determining the amount of snowfall are the quantity of precipitation and the temperature at which such precipitation occurs. In southeastern Alaska, because of the relatively high winter temperature, there is little snow at sea level, but at higher elevations it is very heavy. At White Pass the winter snowfall is about 25 to 30 feet, but on the Chilkat summit it is said to be less than 4 feet. Farther west, owing to the lower winter temperature, the snowfall is heavier. The total at Seward is reported as about 6 feet, at Valdez 12 feet, and at Cordova about 10 feet. At Thompson's Pass 15 feet is reported. These figures are approximate and vary considerably from year to year.

On May 6, 1913, 5 feet of snow was measured on the extensive flat area back of the town of Valdez. A few days later, on May 16, the depth on this flat had decreased to 2.5 feet, with a water equivalent of 26 per cent.

On May 9, 1913, a trench was observed which had been dug through the snow for a considerable distance alongside of Solomon Gulch for the purpose of installing a pipe line for a hydroelectric development. The locality is on the south side of Port Valdez, 500 or 600 feet above sea level. The snow at that time varied in depth from 6 to 18 feet and probably had been considerably greater earlier in the spring.

The snowfall higher in the mountains is undoubtedly enormous, as is indicated by the early date at which the snow line commenced to descend the mountain side, and the fact that perennial snow and glaciers are not uncommon. This heavy snowfall is of considerable practical significance in its effect on run-off, and also because of its tendency to produce great snowslides in the winter and especially in the spring when the masses of snow commence to thaw on the precipitous mountain slopes. Owing to their wide prevalence they threaten the stability of any structure lying in their path and present a serious obstacle to mining, railroad, or water-power development.

In the Kenai Valley at the elevation of Kenai Lake the annual snowfall is about 6 feet. On December 16, 1913, a depth of 4 feet was reported in this region as being an exceptionally heavy fall for that season. Farther north, in the regions of lower precipitation, the snowfall is less. The transition from coast to interior conditions is well illustrated along the Copper River. On the Copper River Flats there is a fall of 15 to 30 feet. The Copper River & Northwestern Railway has found the difficulty of keeping the track clear of snow by their rotary plows much greater below the mouth of Tiekel River at mile 101 than above. At Chitina there are 3 to 4 feet of snow, about 4 feet are reported at Kennicott, and 3 feet at Copper Center. On May 22, 1913, there was about 5 feet of snow at the delta of the Copper, with a gradual decrease northward until at Chitina, 100 miles to the north, the ground was bare up to an elevation of over 2,000 feet.

The average depth of accumulated snow near Miles Glacier during 1907 and 1909 is shown in the following table. The observations were kept by the Copper River & Northwestern Railway during the construction of the road:

Average depth of snow, in feet, near Miles Glacier for 1907–1909.

Day.	Oct.	Nov.	Dec.	Day.	Oct.	Nov.	Dec.	Day.	Oct.	Nov.	Dec.
1907.											
1	......	0.6	3.2	11	......	2.0	3.6	21	.9	2.0	3.9
2	......	.6	3.1	12	0.0	2.0	3.8	22	.8	2.5	4.0
3	......	.6	3.1	13	.8	1.9	4.0	23	.7	2.5	4.0
4	......	.7	3.0	14	1.1	1.9	4.0	24	.6	2.5	4.0
5	......	1.0	3.0	15	1.3	1.9	4.0	25	.5	2.5	4.0
6	......	1.5	3.0	16	1.5	1.9	4.0	26	.5	2.6	4.0
7	......	1.8	3.0	17	1.3	1.9	3.9	27	.4	3.0	4.0
8	......	2.0	3.1	18	1.2	1.9	3.9	28	.3	3.2	4.0
9	......	2.0	3.3	19	1.1	1.9	3.9	29	.3	3.2	4.0
10	......	2.0	3.5	20	1.0	1.9	3.9	30	.5	3.2	4.0
								31	.6	......	4.2

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	Oct.	Nov.	Dec.
1908.									
1	4.5	8.0	9.6	9.1	9.8	2.6	....	0.1	0.4
2	4.8	8.0	9.5	9.2	9.7	2.5	....	.1	.4
3	5.2	8.0	9.5	9.3	9.6	2.3	....	.2	.3
4	5.6	8.0	9.4	9.4	9.5	2.0	....	1.0	.2
5	5.9	8.0	9.4	9.5	9.4	1.7	....	1.5	.1
6	6.4	7.9	9.3	9.5	9.3	1.5	....	1.6	.1
7	6.6	7.9	9.3	9.6	9.2	1.4	....	1.7	.1
8	6.7	7.9	9.3	9.7	9.0	1.2	....	1.0	.2
9	6.9	8.0	9.3	9.8	8.7	1.0	....	.2	.8
10	7.0	8.1	9.2	9.9	8.5	.8	....	0.0	.4
11	7.1	8.0	9.1	10.1	8.3	.6	....	0	.8
12	7.1	8.0	9.1	10.3	8.1	.5	....	0	.8
13	7.0	8.2	9.1	10.5	7.7	.3	....	.2	.8
14	7.0	8.5	9.0	10.7	7.5	.2	....	Trace.	.9
15	7.0	9.0	9.0	10.9	7.3	0.0	....	Trace.	.8
16	7.0	9.4	9.0	11.1	7.0	....	....	Trace.	.8
17	7.0	10.0	9.0	11.3	6.7	....	....	Trace.	.7
18	7.1	10.0	9.0	11.4	6.5	....	0.0	Trace.	.6
19	7.1	10.0	9.0	11.5	6.2	....	.2	Trace.	.8
20	7.2	9.9	8.9	11.4	6.0	....	.2	Trace.	1.2
21	7.2	9.9	8.9	11.3	5.7	....	.2	Trace.	1.6
22	7.2	9.8	8.9	11.1	5.4	....	.3	Trace.	1.6
23	7.2	9.8	8.9	11.0	5.0	....	.7	Trace.	2.8
24	7.3	9.8	9.0	10.8	4.7	....	.7	Trace.	3.6
25	7.5	9.7	9.0	10.6	4.5	....	.1	Trace.	3.9
26	7.6	9.7	9.0	10.3	4.2	....	.1	.1	4.0
27	7.7	9.7	9.0	10.2	3.8	....	.2	.4	4.0
28	7.8	9.6	9.0	10.0	3.6	....	.1	.4	4.0
29	7.9	9.6	9.0	9.9	3.3	....	.1	.3	4.0
30	8.0	....	9.0	9.8	3.0	....	.1	.4	4.0
31	8.0	....	9.1	....	2.8	....	.1	....	4.0

Average depth of snow, in feet, near Miles Glacier for 1907–1909—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	Oct.	Nov.	Dec.
1909.								
1	4.0	6.5	6.9	6.7	3.9	0.1	0.2	0.2
2	3.8	6.5	6.9	6.6	3.8	.3	.3	.3
3	3.7	6.5	6.9	6.5	3.7	.5	.4	.6
4	3.6	6.5	6.9	6.5	3.6	.6	.5	.9
5	3.4	6.5	7.0	6.4	3.5	.7	.6	1.1
6	3.2	6.5	7.0	6 3	3.4	.7	.6	1.2
7	3.0	6.5	7.0	6.2	3.3	.7	.6	1.1
8	2.8	6.6	7.0	6.1	3.2	.7	.6	1.1
9	2.7	6.6	7.0	6.0	3.1	.6	.5	1.1
10	2.5	6.7	7.0	5.9	3.0	.5	.5	1.4
11	2.4	6.7	7.0	5.8	2.9	.3	.5	2.0
12	2.2	6.7	7.0	5.7	2.7	.2	.4	2.1
13	2.1	6.7	7.0	5.6	2.6	.1	.4	2.0
14	2.0	6.7	7.0	5.5	2.5	0	.4	1.6
15	1.8	6.7	7.0	5.4	2.3	0	.4	1.5
16	2.0	6.8	6.9	5.4	2.2	0	.3	1.4
17	2.2	6.8	6.9	5.3	2.1	0	.3	1.3
18	2.6	6.8	6.9	5.2	1.9	0	.3	1.2
19	3.0	6.7	6.9	5.1	1.8	0	.3	1.1
20	3.2	6.7	6.9	5.0	1.7	0	.3	1.0
21	3.4	6.7	7.0	4.9	1.5	0	.3	1.1
22	3.6	6.7	7.0	4.8	1.3	0	.3	1.2
23	3.8	6.7	7.0	4.7	1.2	0	.3	1.2
24	4.0	6.8	7.0	4.6	1.0	0	.3	1.2
25	4.5	6.8	7.0	4.5	.9	0	.2	1.2
26	4.7	6.9	6.9	4.4	.7	0	.2	1.2
27	5.0	6.9	6.9	4.3	.6	0	.2	2.0
28	5.3	6.9	6.9	4.2	.5	0	.2	2.0
29	5.8	....	6.9	4.1	.3	0	.2	1.9
30	6.3	....	6.8	4.0	.2	0	.2	1.5
31	6.5	....	6.8	....	0	0	....	1.2

NOTE.—Records furnished by the Copper River & Northwestern Railway.

Maximum velocity of wind, in miles per hour, near Miles Glacier for 1908–9.

Day.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1908.							
1	....	12	4	6	20	60	20
2	3	12	9	20	24	50	24
3	10	8	12	10	15	52	20
4	15	7	22	9	5	48	23
5	8	20	18	12	10	60	15
6	4	12	4	20	12	30	20
7	8	11	8	20	20	24	....
8	7	10	8	8	....	24	....
9	8	20	8	30	20	24	12
10	12	15	11	5	20	20	18
11	10	6	7	7	12	12	20
12	12	16	9	20	32	12	40
13	10	14	5	13	20	12	40
14	4	13	8	4	25	19	38
15	9	9	13	20	30	20	50
16	8	5	11	24	24	22	25
17	6	8	6	40	30	36	24
18	12	12	13	10	20	24	20
19	18	18	24	10	42	37	20
20	9	8	7	45	48	32	15
21	6	11	30	24	70	36	24
22	....	16	11	20	70	40	30
23	12	4	13	20	48	34	20
24	12	10	8	36	42	12	20
25	14	8	12	30	40	8	20
26	....	12	8	24	48	24	25
27	7	10	11	24	64	12	50
28	11	5	6	20	48	20	65
29	14	6	8	0	60	12	70
30	8	8	12	40	38	12	48
31	....	9	12	....	31	....	30

Maximum velocity of wind, in miles per hour, near Miles Glacier for 1908-9—Contd.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1909.												
1	60	72	37	0	12	25	9	(a)	10	12	20	25
2	60	50	50	24	0	20	12	......	8	34	22	30
3	50	50	50	20	12	22	8	......	18	21	31	43
4	36	55	37	8	20	8	10	......	15	45	8	80
5	50	60	30	26	8	8	9	......	12	40	25	75
6	55	65	25	36	8	17	12	......	18	30	29	68
7	60	50	30	37	10	15	20	......	15	34	43	62
8	72	55	30	20	0	15	11	......	7	47	38	49
9	72	60	60	0	10	18	12	......	7	32	38	45
10	64	60	36	0	12	15	13	......	12	20	33	15
11	60	40	50	30	20	16	8	......	12	12	12	5
12	40	50	48	12	20	17	20	......	20	30	16	27
13	50	70	22	31	10	8	14	......	35	10	4	40
14	51	84	24	48	8	9	12	......	15	12	4	37
15	60	72	......	48	0	15	13	......	31	28	45	37
16	65	66	12	24	4	16	12	......	12	30	65	32
17	70	36	0	10	8	15	15	......	12	42	60	27
18	70	12	20	17	10	20	8	......	10	60	55	27
19	70	36	24	0	0	10	12	......	14	48	54	16
20	71	50	23	20	12	8	7	......	24	58	47	37
21	70	40	35	10	20	12	12	......	35	50	60	20
22	70	60	18	24	8	14	20	......	36	22	60	20
23	50	65	50	49	8	8	12	......	38	25	60	21
24	65	34	36	12	20	18	15	......	31	8	67	27
25	30	24	24	20	15	20	13	......	32	5	63	20
26	50	36	36	10	27	15	6	......	30	15	67	28
27	60	20	17	10	8	24	5	......	30	30	67	30
28	65	24	40	40	12	20	10	......	24	30	68	38
29	54	......	12	0	20	12	15	......	15	25	65	30
30	70	......	15	6	20	10	14	......	15	17	47	66
31	72	......	0	......	20	......	8	......	......	20	......	66

a No records during August.

NOTE.—Records furnished by the Copper River & Northwestern Railway.

TEMPERATURE.

Perhaps no meteorologic phenomenon in southern Alaska has a greater influence on the regimen of streams than temperature, for most of the streams head in glaciers or perennial snows, and on such streams the effect of temperature equals or exceeds that of rainfall. In the interior regions, where the temperature seldom goes above the freezing point for several months each winter, the run-off becomes entirely dependent on underground sources, whereas on the coast occasional periods of thawing weather augment the flow to an important extent.

The temperature conditions at various representative stations in southern Alaska are summarized in the following table:

Summary of temperature records at various Weather Bureau stations in southern Alaska.

Copper Center.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Maximum	49	49	49	64	80	96	87	87	80	66	49	50	......
Minimum	—74	—55	—48	—26	18	22	22	20	3	—26	—46	—53	......
Mean	—10.8	2.3	14.3	29.0	44.1	53.1	55.4	52.4	42.9	27.7	4.6	3.3	27.1

Summary of temperature records at various Weather Bureau stations in southern Alaska—Continued.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Cordova.													
Maximum	47	58	61	70	72	80	86	80	84	72	60	49	......
Minimum	2	4	1	15	28	34	33	40	31	26	11	5	......
Mean	27.8	30.3	31.6	37.0	44.8	50.9	56.2	55.4	48.7	43.9	33.2	29.7	38.9
Fort Liscum.													
Maximum	45	45	54	53	71	79	82	80	84	57	47	45	......
Minimum	−14	−12	− 8	2	25	30	32	30	17	10	0	−13	......
Mean	20.7	21.8	26.1	27.8	41.8	49.8	52.0	50.1	44.9	35.8	29.1	23.9	35.2
Juneau.													
Maximum	50	51	61	63	80	84	88	82	74	68	60	60	......
Minimum	−10	− 4	− 5	13	24	31	38	36	23	20	− 1	1	......
Mean	26.9	29.2	34.7	41.0	48.4	54.8	58.1	55.4	49.6	43.6	34.7	31.9	42.6
Killisnoo.													
Maximum	52	50	53	63	76	83	84	81	69	65	65	54	......
Minimum	− 7	−10	− 2	15	44	31	38	36	27	10	1	1	......
Mean	27.4	26.9	32.8	38.6	45.8	51.3	55.2	54.4	48.0	41.7	33.8	31.1	43.1
Kodiak.													
Maximum	53	58	65	61	74	82	82	85	77	66	54	61	......
Minimum	− 8	− 3	2	5	20	30	32	34	26	16	9	−12	......
Mean	29.4	22.7	33.7	36.1	43.4	50.3	54.1	59.4	46.9	41.6	29.8	30.5	40.5
Loring.													
Maximum	47	52	63	67	93	91	87	85	83	67	58	54	......
Minimum	−20	−23	−10	9	25	32	36	35	30	15	5	4	......
Mean	23.2	29.8	34.0	39.5	48.5	53.0	57.3	57.1	51.2	43.9	36.4	32.1	42.8
Seward.													
Maximum	43	44	49	65	75	84	83	85	84	64	49	45	......
Minimum	−11	−12	− 7	10	26	32	40	33	27	11	9	−10	......
Mean	19.0	27.0	31.3	36.5	43.5	45.8	54.1	54.4	48.7	39.0	31.1	25.8	39.5
Sitka.													
Maximum	56	58	65	70	80	84	87	83	80	70	60	59	......
Minimum	− 4	− 3	− 1	15	28	30	34	30	28	22	1	5	......
Mean	31.7	33.5	36.5	41.3	46.7	51.2	54.7	57.2	51.8	45.7	38.0	35.6	43.8
Skagway.													
Maximum	47	49	63	62	94	90	92	89	77	63	56	57	......
Minimum	−21	− 9	−10	9	25	29	37	31	26	12	− 6	− 4	......
Mean	18.4	24.0	30.2	40.0	49.5	56.0	58.2	54.3	49.6	40.8	31.2	26.9	39.6

Summary of temperature records at various Weather Bureau stations in southern Alaska—Continued.

Sunrise.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Maximum	44	57	58	60	76	79	76	78	72	59	51	48	......
Minimum	−29	−27	−23	− 4	23	27	34	28	17	2	−15	−26	......
Mean	10.4	19.4	24.9	33.0	43.1	49.8	53.6	51.6	44.3	34.1	22.6	17.7	33.5

Tyonek.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Maximum	38	49	58	59	74	91	82	76	79	61	47	49	......
Minimum	−27	−25	− 9	− 1	22	33	38	31	22	5	− 3	−21	......
Mean	11.5	18.6	25.3	35.2	45.2	53.4	57.0	58.3	48.9	36.2	25.2	18.5	36.1

Valdez.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Maximum	44	47	52	63	78	78	84	84	82	62	53	45	......
Minimum	− 2	−17	− 6	4	18	30	37	29	30	12	1	− 6	......
Mean	19.2	22.4	26.7	34.4	43.5	50.0	53.9	52.7	47.8	40.5	26.4	22.3	35.8

As would be expected from its position north of the coast range, the greatest range in temperature occurs at Copper Center, whereas all the other stations are within the Pacific coast province. At that point there is a variation of 170°, ranging from a maximum of 96° in June to a minimum of —74° in January. A mean annual temperature of 27.1 shows clearly the rigorous climatic conditions.

An interesting relation between the coast stations is the narrow range in the mean annual temperature. The extreme difference is only 10.3°, the maximum of 43.8 occurring at Sitka and the minimum 33.5 at Sunrise.

Temperatures below zero have been recorded at all the stations except Cordova, where 1° is the minimum. At that station the minimum yearly range of 85° also occurs. The most uniform mean monthly temperatures occur at Sitka, ranging from 31.7° for January to 57.2° in August.

CONTROLLER BAY REGION.

GENERAL FEATURES.

The Controller Bay region occupies an area about 500 square miles in extent, bounded by the Chugach Mountains on the north, Bering Glacier on the east, the Pacific Ocean to the south, and the Copper River delta on the west.

The topographic features of the region are exceedingly varied, including southern spurs from the Chugach Mountains, isolated peaks to the south ranging in height from 1,000 to 3,000 feet, with intervening low swampy areas and numerous lakes.

Katalla, the post office and commercial center of the region, is on the north shore of Katalla Bay about 10 miles east of Controller Bay. Supplies are landed by small launches from ocean-going vessels, which anchor about half a mile from the shore. Katalla is a proposed outlet for the Bering River coal field which lies 20 to 30 miles northeast of the town.[1]

Little information is available regarding the climate of this region. (See p. 15.) The average yearly precipitation probably exceeds 100 inches and snowfall is rather heavy. The summers are cool and cloudy and the winters are moderate.

Spruce and hemlock, the principal trees, grow in heavy stands and reach diameters of 2 to 3 feet. The best timber grows along the foothills below an elevation of 1,000 feet. The United States Forest Service estimates the stands on the Ragged Mountains and in the vicinity of Martin River and Bering Lake at approximately 2,130,000,000 feet board measure.

MEASURING POINTS.

The points at which discharge measurements were made in 1913 in the Controller Bay region are listed below. Records of daily flow are not available for streams in this region. The numbers in the list correspond to numbers on Plate II.

Measuring points in Controller Bay region, 1913.

1. Bering River above Stillwater Creek.
2. Canyon Creek at mouth.
3. Stillwater Creek 1 mile above mouth.
4. Trout Creek one-fourth mile above mouth.
5. Clear Creek at Cunningham's camp.
6. Clear Creek near Katalla.

BERING RIVER DRAINAGE BASIN.

GENERAL FEATURES.

Bering River drains the eastern part of the Controller Bay region, of which it is the principal stream. Its water is derived mainly from Bering Glacier, though Martin River Glacier contributes considerable water through Canyon, Stillwater, and Shepherd creeks. As in most glacial streams the volume of discharge bears little relation to the area of the drainage basin, which is indeterminate because of uncertainty as to how much of Bering and Martin River glaciers drains through Bering River.

Bering River rises in First Berg Lake (see Pl. II), the first of a series of five lakes on the northeast margin of Bering Glacier. It flows

[1] The Bering River coal field is described by G. C. Martin, Geology and mineral resources of the Controller Bay Region, Alaska: U. S. Geol. Survey Bull. 335, pp. 65-112, 1908. The Controller Bay oil field is described in the same bulletin, pp. 112-120.

southwestward about 23 miles and enters the northern part of Controller Bay about 10 miles west of Katalla. The areas of the lakes from first to fifth are 2.2, 0.08, 0.27, 0.58, and 1.8 square miles, respectively. These lakes have been described by Martin[1] as follows:

Marginal lakes.—The five Berg Lakes, situated on the margin of Bering Glacier, near the northeast corner of the region under discussion, present some interesting features. These lakes are bordered on their landward sides by steep banks, which are in general barren of vegetation and which are covered chiefly with glacial débris. These banks extend to an elevation of about 1,000 feet above tide, or about 200 feet above the level of the lakes. They are cut and built into well-developed terraces, which mark former stages in the elevation of the lakes. The lower terraces are entirely barren of vegetation, but the upper ones have a scant growth of grass, herbs, and small bushes, which are only a few years old.

The surface of the four western lakes is known to be at the same altitude (about 810 feet in 1905), and Fifth Lake probably is at the same level.

These lakes are certainly connected by water channels through the crevasses of the glacier, and possibly by open spaces under the ice. The surface of the ice is level, except where it rests against the land on the points between the lakes. The identity in the altitude of the lakes, the level surface of the ice between the lakes, and the way in which bergs break off on the margin of First Lake show that this arm of the glacier is floating in one large lake, of which the five Berg Lakes are only open areas. The surface of the glacier, after a gentle slope, descends in a low, crevassed icefall to its floating level.

The level of the lake is oscillating. The absence of vegetation on the lower terraces shows that it has fallen in recent years. In June, 1905, it was rising several inches per day. The outlet of the lake, which is beneath the ice at the end of the long point south of First Lake, becomes choked with débris at irregular intervals. The water then rises until the pressure clears the outlet or till the water can flow on the surface around the end of the point, when the lake is emptied, causing severe floods in the valley of Bering River.

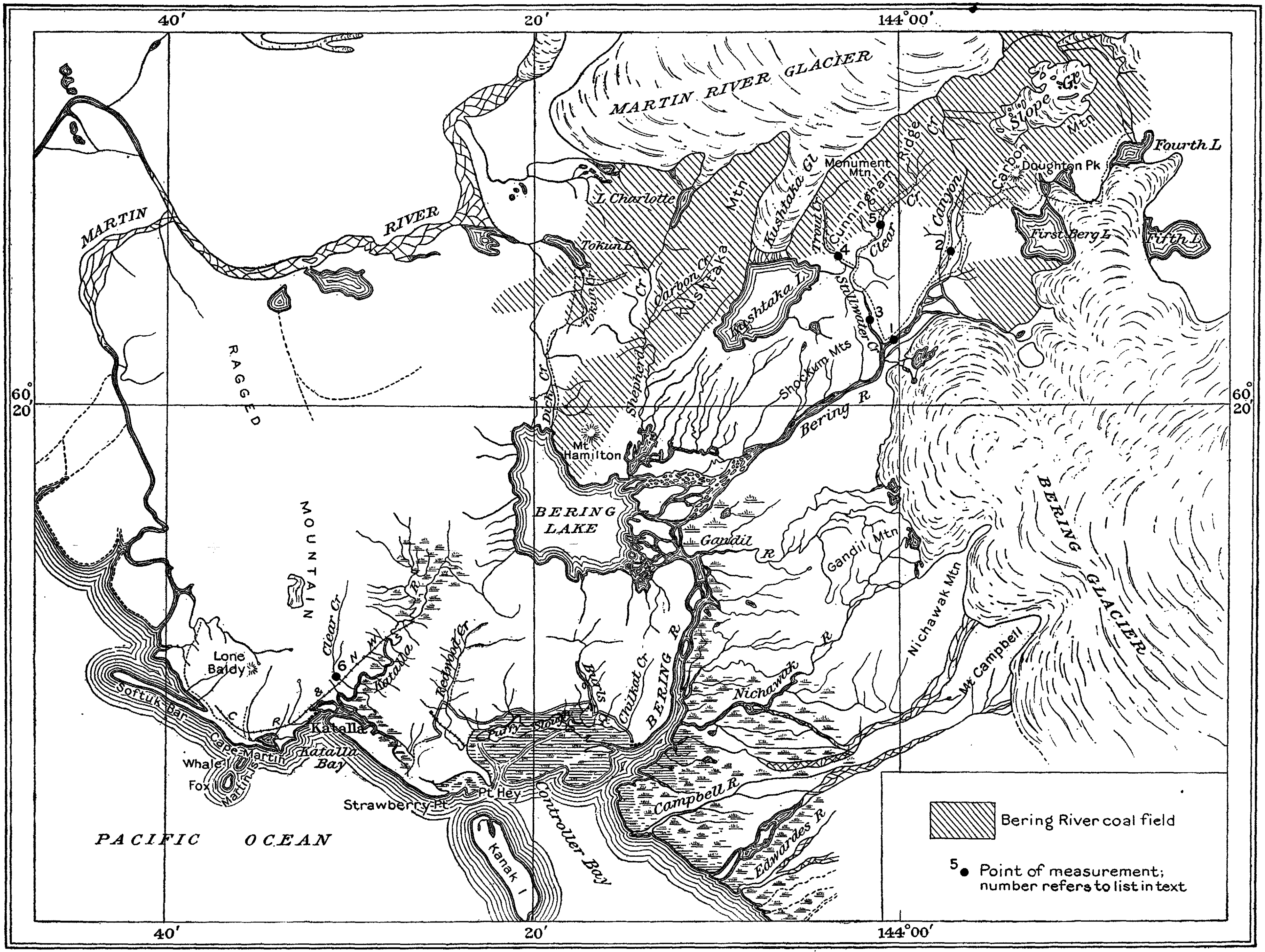
The principal tributaries of Bering River from the north are Canyon, Stillwater, and Shepherd creeks. Gandil and Nichawak rivers flow from Bering Glacier through a low swampy country and enter Bering River from the east below Bering Lake.

Bering Lake, which lies about 5 miles north of Controller Bay, covers an area of about 12 square miles and is said to be very shallow. It is connected with Bering River by several channels, though most of the river water passes by without entering the lake. The level of the lake is raised from 1 to 3 feet by tides.

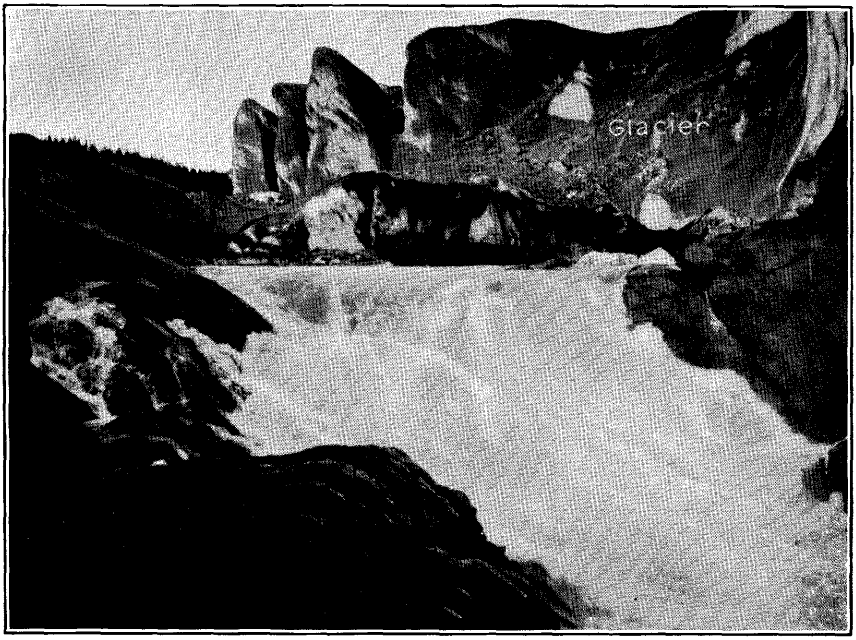
Bering River is navigable for small launches during high and medium stages as far as the mouth of Stillwater Creek, a distance of 16 miles. It flows over a bed of glacial sand and silt with constantly changing channels.

First Berg Lake lies at an elevation of about 800 feet. About 2 miles below the lake, at an elevation of about 750 feet, the river commences to fall rapidly (see Pl. III, *A*) and in a distance of less than a mile it drops over 600 feet. Power could be developed by

[1] Martin, G. C., Geology and mineral resources of the Controller Bay region, Alaska: U. S. Geol. Survey Bull. 335, pp. 47–48, 1908.

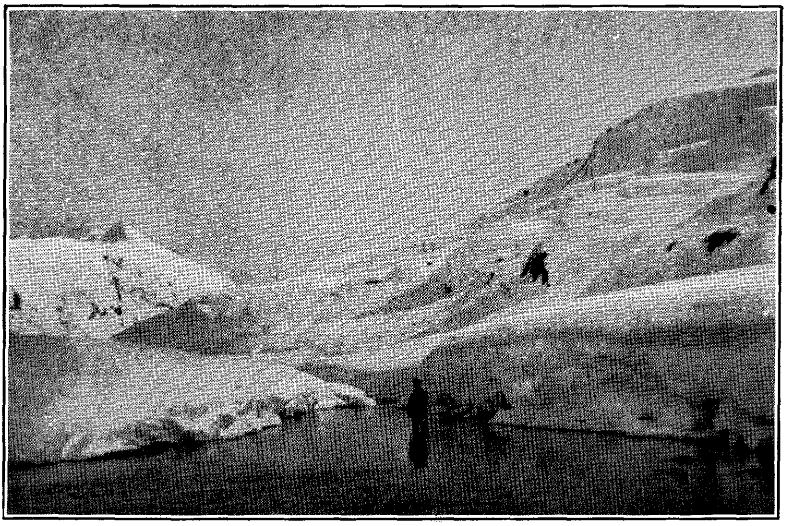


MAP OF CONTROLLER BAY REGION SHOWING LOCATION OF MEASURING POINTS.



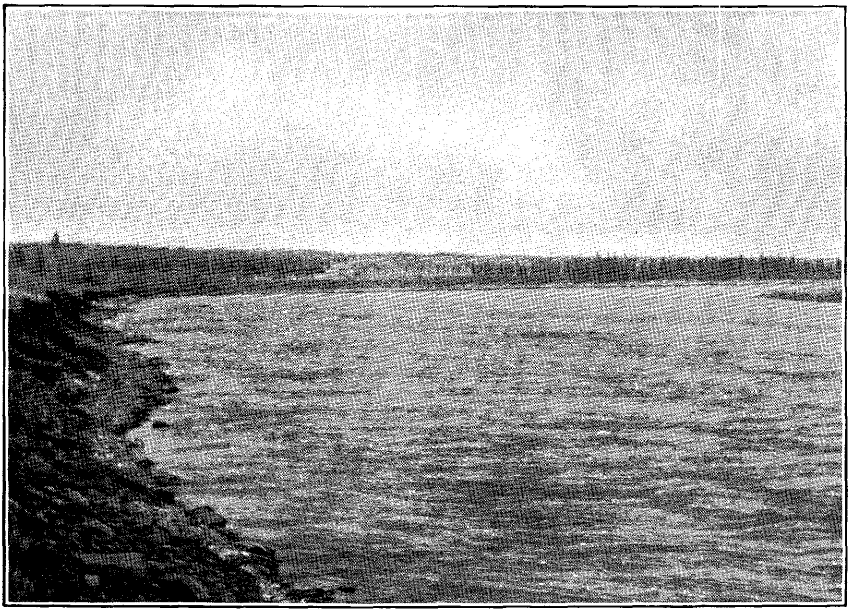
A. FALLS ON BERING RIVER NEAR OUTLET OF FIRST BERG LAKE.

Ice cliff from Bering Glacier in background.

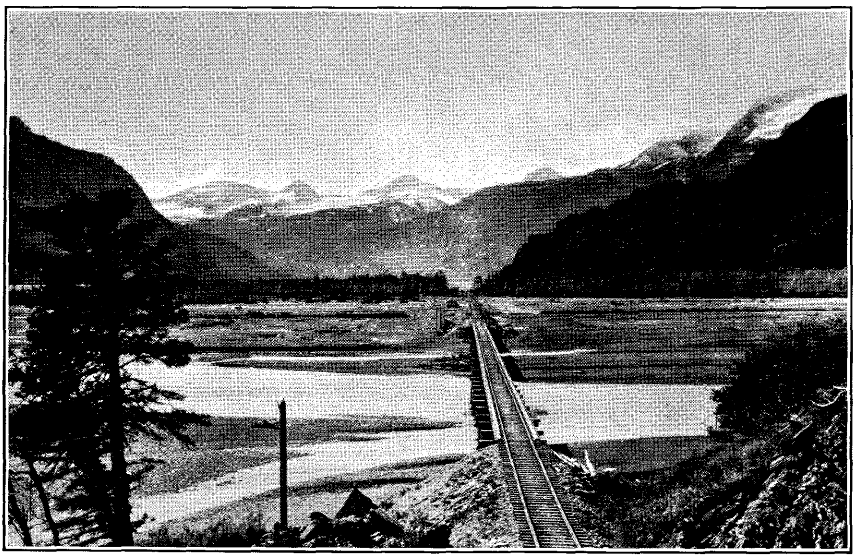


B. SOLOMON GULCH, MAY 9, 1913.

Elevation, about 600 feet.



A. COPPER RIVER 1 MILE ABOVE COPPER CENTER.



B. COPPER RIVER VALLEY.

Tiekel River in foreground.

carrying water from First Berg Lake through Carbon Mountain to Canyon Creek valley, where a head of about 650 feet could be obtained. A tunnel about 1 mile long would be required. It would not be possible to raise the level of the lake by a dam because of the glacier which obstructs the outlet, but substorage could be obtained by placing the intake below the low-water level of the lake. According to Martin the lake is subject to changes in level, due to obstructing of the outlet by débris. He also states that it has fallen in recent years.

Careful observations of the lake level should be taken at frequent intervals for a year or more before beginning the construction of a tunnel or other form of conduit to divert the water from the lake.

On July 10, 1913, the lake was still frozen over from the previous winter. It is reported that it has been known to remain frozen throughout the summer.

A measurement of Bering River made just above Stillwater Creek on July 11, 1913, gave a discharge of 3,950 second-feet. A simultaneous measurement of Canyon Creek showed a discharge of 179 second-feet. The inflow between Canyon Creek and the lake outlet appears to be rather small. It is believed that an estimate of 3,000 second-feet discharge at the lake outlet on the above date is conservative, though it is open to question because of the possibility that considerable inflow that could not be seen may reach the river below the lake.

A flow of 3,000 second-feet under a head of 650 feet, would develop over 155,000 horsepower with an efficiency of 70 per cent at the wheel. The measurement was made in the season of maximum run-off, and as no winter records are available it is difficult to estimate the amount of power that could be developed during that season; but since with the head available (650 feet) over 5,000 horsepower could be produced for every 100 second-feet of discharge, it seems conservative to predict, considering the feasibility of drawing on storage from the lakes, that at least from 5,000 to 10,000 horsepower could be produced throughout the year.

CANYON CREEK.

Canyon Creek rises in Martin River Glacier, flows southward about 6 miles, and enters Bering River 6 miles below First Berg Lake. The creek falls 900 feet, thus having an average grade of about 150 feet per mile.

The first 3 miles of its course is through a narrow, steep-walled valley, which becomes wider with approach to Bering River and at the junction reaches a maximum of more than a mile.

A measurement made July 11, 1913, gave a discharge of 179 second-feet.

STILLWATER CREEK.

GENERAL FEATURES.

Stillwater Creek rises in Kushtaka Lake, flows southeastward about 4 miles, and enters Bering River about 2½ miles below Canyon Creek. Its total fall is approximately 60 feet. For the last mile of its course the current is rendered very sluggish by backwater from Bering River.

Its principal tributaries are Trout and Clear creeks, clear-water streams that flow from Cunningham Ridge and enter from the north about 1 mile below Kushtaka Lake.

Kushtaka Lake is nearly 4 miles in maximum length, trends northeast-southwest, and covers an area of 4.7 square miles. Practically the entire inflow is from Kushtaka Glacier, which is a southern arm of Martin River Glacier. The lake acts as a settling basin, thus giving a much clearer outflow than the ordinary glacial stream.

The level of the lake could be raised 20 to 30 feet by a dam of moderate length, thus obtaining a storage of 60,000 to 90,000 acre-feet. A fall of at least 35 feet below the normal lake level could be obtained by carrying the water in a pressure pipe for a distance of about 1 mile. Under that head, with an efficiency of 70 per cent, about 275 horsepower could be realized at the wheel for every 100 second-feet of discharge. The only data regarding the flow is one discharge measurement listed below. Considering the storage that could be created it is estimated that from 500 to 1,000 horsepower could be developed at minimum flow in the winter and from 1,000 to 2,000 horsepower from May until October.

The lake is confined by morainic material deposited by Martin River Glacier when at its maximum extension. The nature of the foundation that could be obtained for a dam at the outlet is unknown. The material at the surface resembles heavy glacial till. A solid rock foundation might be obtained at a moderate depth.

DISCHARGE MEASUREMENTS.

The following miscellaneous measurements were made in Stillwater Creek drainage basin in 1913:

Miscellaneous measurements in Stillwater Creek drainage basin in 1913.

Date.	Stream.	Tributary to—	Locality.	Discharge.	Drainage area.	Discharge per square mile.
				Second-feet.	*Square miles.*	*Second-feet.*
July 11	Stillwater Creek	Bering River	1 mile above mouth	858		
11	Trout Creek	Stillwater Creek	¼ mile above mouth	12.6	2.3	5.48
11	Clear Creek	do	Cunningham's camp	37	6.3	5.87

KATALLA RIVER.

Katalla River drains an area of 38 square miles west of Bering Lake. It is about 8 miles long and flows in a southeasterly direction, entering Katalla Bay at the town of Katalla. The valley is low and swampy and is more than a mile in average width. The headwaters are separated from Bering Lake by a divide less than 100 feet in elevation. The natural railroad route from Katalla to the coal fields lies up the Katalla River valley and over the divide to Bering River.

Clear Creek, the principal tributary of Katalla River, joins it from the north about a mile from Katalla. It is about 4 miles long and drains an area of 7.5 square miles. It occupies a narrow, V-shaped valley and flows through a succession of pools and rapids over a bed of gravel and bowlders, with a grade of about 150 feet per mile.

The following measurement was made 1 mile above the mouth:

July 13, 1914: Discharge, 151 second-feet; drainage area, 6.8 square miles; discharge, per square mile, 22.1 second-feet.

WATER-POWER SITES.

The principal water-power sites in the Controller Bay region are on Bering River at the outlet of First Berg Lake (p. 36), and on Stillwater Creek at Kushtaka Lake outlet (p. 38). Some of the smaller streams might furnish a few hundred horsepower for 5 or 6 months in the year, but it is doubtful whether storage could be provided for the development of more than very small power in the winter.

The only market that can be foreseen for these powers is the energy that will eventually be required in connection with the mining of the coal beds of the area. Coal of good quality will then be available at comparatively low cost, and the poorer qualities unsuited for the open market will offer a fuel for local power development so cheap that water power will have to be produced in the most economical manner to become a successful competitor.

COPPER RIVER DRAINAGE BASIN.

GENERAL FEATURES.

The Copper River drainage basin occupies an area comprising about 23,000 square miles in the southeastern part of the main body of Alaska. It may be divided into four physiographic divisions—the Chugach Mountains on the south, the Wrangell Mountains on the east, the Alaska Range to the north, and the Copper River Plateau to the west.

The topography of the basin is of the most varied character. The Wrangell Mountains, occupying the northeastern section, form the most conspicuous feature. They have been described by Moffit and Capps [1] as follows:

The Wrangell Mountains, although a more or less distinct group, merge into the St. Elias Range on the southeast and are not there sharply defined from them. They are limited on the south and west and partly on the north by the valleys of Chitina and Copper rivers, and are separated from the Nutzotin Mountains on the northeast by a depression extending from the head of Copper River to the head of White River. The group trends in a northwest-southeast direction and its length is approximately double its width. Its greatest diameter is about 100 miles. Half a dozen or more peaks of unusual beauty and size, ranging in height from 12,000 to 16,200 feet, rise above the rugged snow-covered mass about them, and from one of these, Mount Wrangell, the group received its name. The Wrangell Mountains were formed by the erosion of a great mass of Tertiary and Recent lavas piled up on an older surface of very considerable relief and having its greatest development in the neighborhood of Mount Wrangell and Mount Sanford. The southeastern limit of these younger flows is probably somewhere in the vicinity of Skolai Pass and Chitistone River, although it is possible that they may extend still farther to the east. Thus the Wrangell Mountains consist essentially of lava flows and are distinct in their origin from the other mountains about them, all of which are made up principally of deformed sedimentary beds.

The most prominent summits are Mount Sanford (16,208 feet), Mount Blackburn (16,140 feet), Mount Wrangell (14,005 feet), Mount Regal (13,400 feet), and Mount Drum (12,000 feet).

The range is covered with a connected system of glaciers whose tentacle-like arms spread out from the various peaks and reach down at numerous points to elevations of 2,000 to 4,000 feet, from which flow many important streams. Kennicott Glacier terminates at an elevation of about 1,500 feet, the lowest elevation reached by any of the ice sheets draining to the Chitina River or the Copper above the Chitina.

The Copper River Plateau has been described by Brooks [2] as follows:

A broad gravel and silt floored basin stretches north from the inland slope of the Chugach Mountains to the foothills of the Alaska Range. It is bounded on the east by the Wrangell Mountains and the Copper River, and extends westward to the Susitna basin by a depressed area lying between Talkeetna Mountains and the Alaska Range. The basin has a monotonous lack of relief which contrasts strongly with the rugged mountains encircling it. [See Pl. IV, *A*, p. 37.] At the escarpment on its eastern margin where it falls off to the Copper River it stands about 2,000 feet above sea level, but it rises gently to the west to an altitude of about 3,000 feet at the divide. This topographic feature is, in fact, a plateau built up largely of Pleistocene deposits, deeply dissected near its margins and called the "Copper River Plateau," by Mendenhall,[3] who was the first to describe it. While it is usually an almost unbroken plain, it is varied in places by hills and small groups of mountains and is dotted with small lakes.

[1] Moffit, F. H., and Capps, S. R., Geology and mineral resources of the Nizina district, Alaska: U. S. Geol. Survey Bull. 448, p. 10, 1911.

[2] Brooks, A. H., Geography and geology of Alaska: U. S. Geol. Survey Prof. Paper 45, p. 54, 1906.

[3] Mendenhall, W. C., A reconnaissance from Resurrection Bay to the Tanana River, Alaska: U. S. Geol. Survey Twentieth Ann. Rept., pt. 7, p. 297, 1900.

The Copper River Plateau lies entirely within the Pacific mountain system, and though of low relief includes three important watersheds. Its eastern drainage falls into the Copper, its western into the Susitna and Matanuska, and a small area in the north drains to the Tanana through the Delta River.

Within the plateau region the Copper River and its tributaries have cut deep channels varying from a few feet up to 500 or 600 feet below the general plateau level. (See Pl. IV, *A*, p. 37.) The formation is made up largely of sand, gravel, and clay, and it is not likely that many solid rock canyons occur except possibly near the headwaters of the stream flowing from the Wrangell Mountains.

Copper River rises in Copper Glacier on the north slope of Wrangell Mountain and enters the Pacific about 150 miles (in an air line) south. Mount Sanford (elevation 16,208 feet), the highest peak of the Wrangell Range, lies about 10 miles to the west of the Copper Glacier outlet. Nabesna Glacier, situated about 30 miles farther east, is one of the sources of the Tanana River. Copper River flows in a northerly direction for about 40 miles to its junction with the Slana, a large tributary from the north. Batzulnetas is situated at the mouth of Tanada Creek, 10 miles above the Slana. After receiving the Slana, the Copper makes a right-angle turn to the west, gradually bending to the south, and then, bearing toward the east, it is joined from the east by its largest branch, the Chitina, about 150 miles below its head. It has then nearly encircled the western end of the Wrangell Mountains. The town of Chitina is on the west side of the Copper opposite the mouth of the Chitina River.

Below Chitina the Copper enters the Chugach Range and thence to its mouth its flood plain reaches to steep mountain slopes on either side, broken only by some of its larger branches from the east and west, which, heavily laden with glacial sand and gravel, have built up terraces at their mouths. (See Pl. IV, *B*.) Between Chitina and Tasnuna rivers the flood plain is seldom over a mile in width and averages much less than that. At Wood Canyon, beginning about 6 miles below Chitina, the river passes between narrow rock walls for about 3 miles. At several points the canyon is of the "box" type, with nearly vertical sides rising 50 feet or more above the water surface. This canyon offers probably the most natural site for power development on Copper River. Below the Tasnuna the valley floor widens and for much of the remainder of its course to the delta is 1 to 4 miles wide.

Abercrombie Rapids are situated along the northern part of the terminal moraine from Miles Glacier. It is estimated that in a distance of about 2.5 miles the river falls through a height of about 40 feet. The rapids were probably formed by the former encroachment of the glacier upon the river channel. The carrying power of the river above the glacier was thereby decreased, and heavy deposits of glacial sediment were laid down, forming a lower stream-gradient for several miles above. When the glacier began to recede it left large bodies of heavy till, through which the river is now slowly cutting its way. The river has been pushed well over toward the west side of the valley and hugs the base of steep rocky slopes for the first 2 miles of the rapids. It then makes a nearly right-angle turn to the east and about one-half mile farther on enters an expanded section of the river at the base of Miles Glacier, known as Miles Glacier Lake.

Abercrombie Rapids offer the fundamental requirements for the development of power, a large volume of water and a concentrated fall. The economic value of a water power, however, depends on the market for the power and the cost of development. The latter factor alone would probably put this site out of the class that would be economically feasible at the present time and probably far into the future. The principal difficulty would be the construction of a diversion dam. A rock foundation probably could not be obtained at a reasonable depth. The east end of the dam would be in a high glacial moraine which is probably underlain with ice. (See Pl. V, *A*.) The track of the Copper River & Northwestern Railway follows the west bank of the river past the rapids. To carry water from the head of the rapids to a power house at the foot, nearly 2 miles of tunnel would have to be built through the rock slope on the west side of the river in order to avoid the railway track. The eastern slope, which is flanked by the moraine, would offer a distinctly unstable foundation for a conduit even though the water could be successfully diverted.

Copper River carries large quantities of frazil during October and November when it is freezing. In the spring, beginning about the first of May, the break-up occurs, during which time there is an immense flow of heavy cakes of ice that would be difficult to pass over a dam. The large quantities of glacial débris that are carried by the river would also present a serious problem if power development should be undertaken.

Twenty-five miles below the Slana Copper River is joined by Chistochina River, which rises in the Alaska Range on the south slope of Mount Kimball and flows south about 50 miles. Here Copper River emerges from the valley between the Alaska Range and the Wrangell Mountains and flows along the eastern margin of the Copper River Plateau until it approaches the Chitina. Between the Chistochina and the Chitina the principal tributaries of the Copper in downstream order from the north and west are the Gakona, Gulkana, Tazlina, Klutina, and Tonsina rivers; from the east it receives the Sanford, Klawasi, Nadina, Dadina, Chetaslina, Cheshnina, and Kotsina rivers, which drain the westward slope of the Wrangell Mountains.

A. COPPER RIVER, LOOKING DOWNSTREAM TO HEAD OF ABERCROMBIE RAPIDS.

Moraine from Miles Glacier on the left. Copper River & Northwestern Railway follows right bank.

B. VIEW UP COPPER RIVER. MILES GLACIER IN THE BACKGROUND.

Below Chitina the principal tributaries are Tasnuna and Tiekel rivers from the west and the Bremner from the east.

The delta begins about 10 miles below Miles Glacier, 30 miles from salt water. Alaganik Slough, the westernmost channel, enters salt water about 12 miles southeast of Cordova. Eastward many channels reach the ocean for a distance of over 20 miles.

"The lower course of the Copper seems once to have been a wide embayment reaching back into the Chugach Mountains, but this has been filled in by vast quantities of sediment brought down by the river, and the broad delta is the result of their deposition."[1]

Nearly all the tributaries of the Copper head in glaciers and carry heavy deposits of glacial silt (see table, p. 46), particularly during the warmer months, when they are especially active. Only two "live" glaciers—Miles and Childs—reach the main river. They are situated about 30 miles from salt water. Miles Glacier is on the east bank just above the crossing of the Copper River & Northwestern Railway (see Pl. V, *B*), and Childs Glacier is just below on the opposite side. Large quantities of ice break from the face of these glaciers into the river during warm weather. Childs Glacier appears the more active of the two. Each presents a face of about 2 miles along the river's edge, in some places rising vertically more than 300 feet above the water's surface.

Before the construction of the Copper River & Northwestern Railway from Cordova to Chitina and Kennicott small boats were used quite extensively on the Copper and some of its larger tributaries, and light-draft steamboats have navigated from the Tasnuna to Copper Center and from Chitina to the Nizina River on the Chitina. Since the railroad has been in operation little boating has been done on the Copper, and the construction of roads and trails and a fuller knowledge of the tributary areas has lessened the advantage of using the minor stream for boating.

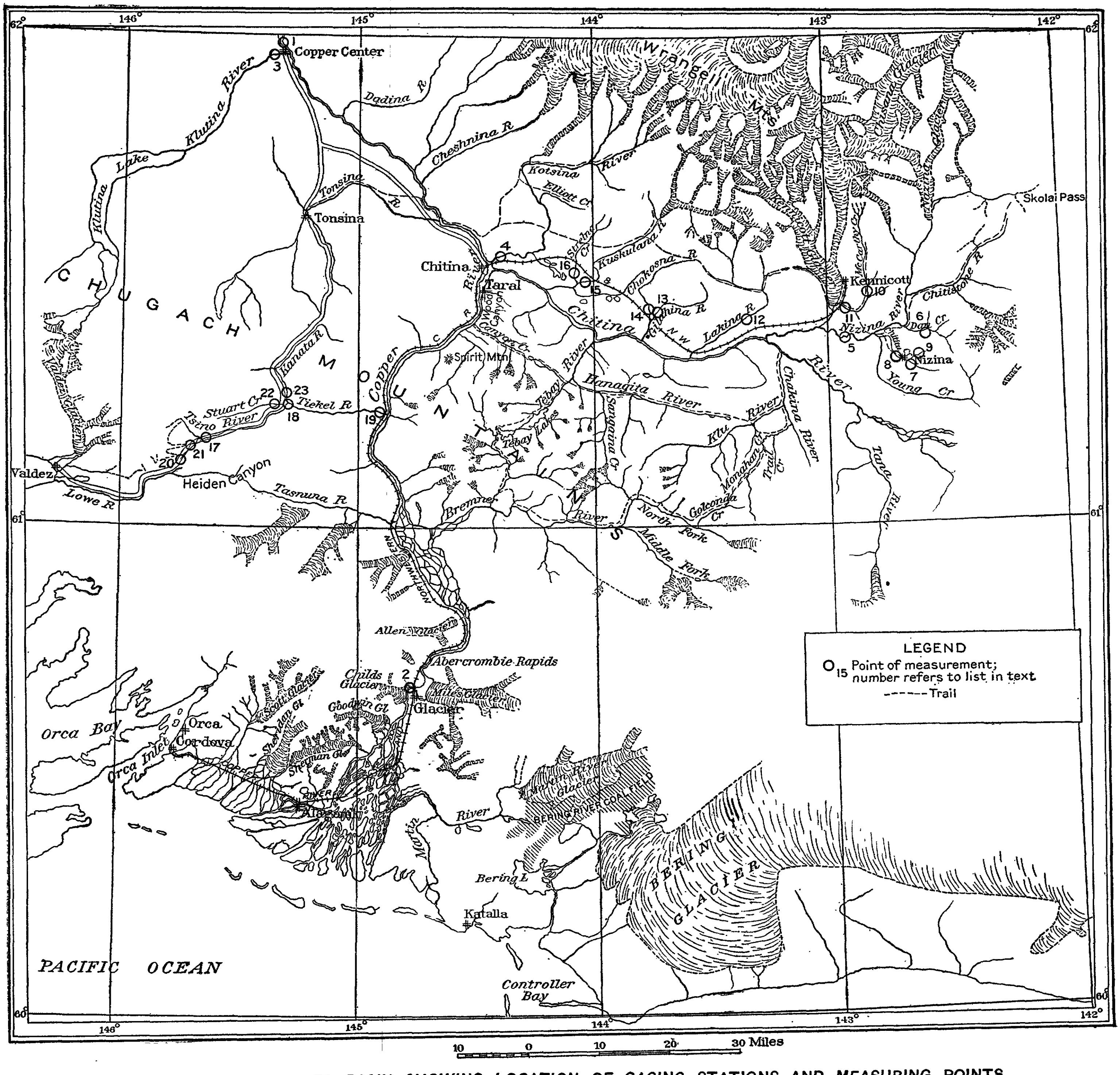
Copper River rises at an elevation of about 3,600 feet, making an average gradient of about 12 feet per mile. From Copper Center to the ocean there is a total fall of 1,000 feet, giving a mean fall in that distance of about 6.7 feet per mile.

MINERAL RESOURCES.

The principal mineral resources of the Copper River basin are copper and gold. The most important copper deposits are those of the Kotsina-Chitina[2] belt, extending along the southern slope of the Wrangell

[1] Schrader, F. C., and Spencer, A. C., Geology and mineral resources of a portion of the Copper River district, Alaska: U. S. Geol. Survey special reports on Alaska, p. 27, 1901.

[2] Described by Moffit, F. H., and Maddren, A. G., Mineral resources of the Kotsina-Chitina region, Alaska: U. S. Geol. Survey Bull. 374, pp. 42-92, 1909; Moffit, F. H., and Capps, S. R., Geology and mineral resources of the Nizina district, Alaska: U. S. Geol. Survey Bull. 448, pp. 77-97, 1911. See also Moffit, F. H., Mining in Chitina Valley: U. S. Geol. Survey Bull. 542, pp. 81-85, 1913.



MAP OF COPPER RIVER BASIN SHOWING LOCATION OF GAGING STATIONS AND MEASURING POINTS.

From Chitina eastward the Kennicott extension of the railway traverses a gravel bench standing 300 to 500 feet above the river level, and this is covered with a similar type of vegetation to that of the Copper River Plateau. The trees are mostly stunted and have no value except for fuel. There are some patches of good timber in the river bottoms along the Lakina and other streams.

GAGING STATIONS AND MEASURING POINTS.

The points at which gaging stations were maintained or discharge measurements made in 1913, in the Copper River basin, are listed in the following table. The numbers correspond to those used on Plate VI.

Gaging stations and measuring points in Copper River basin in 1913.

1. **Copper River near Copper Center.**
2. **Copper River at Miles Glacier.**
3. **Klutina River at Copper Center.**
4. Kotsina River near mouth.
5. Nizina River above Kennicott River.
6. Dan Creek above hydraulic plant.
7. White Creek above Jolly Gulch.
8. Chititu Creek below Rex Creek.
9. Rex Creek above hydraulic plant.
10. McCarthy Creek above Nikolai Creek.
11. **McCarthy Creek near McCarthy.**
12. Lakina River at railroad crossing.
13. Gilahina River at railroad crossing.
14. Chokosna River at railroad crossing.
15. Kuskulana River at railroad crossing.
16. Strelna Creek at railroad crossing.
17. Tsina River below Ptarmigan Creek.
18. Tsina River at mouth.
19. Tiekel River at mouth.
20. Ptarmigan Creek at upper canyon.
21. Ptarmigan Creek at lower canyon.
22. Stuart Creek at mouth.
23. Kanata River at mouth.

NOTE.—Black-faced type indicates regular gaging stations; light-faced type points of miscellaneous measurements.

COPPER RIVER NEAR COPPER CENTER.

A temporary gage was installed on Copper River at the Indian School about 1½ miles above Copper Center June 18, 1913.

Two readings of stage and one of turbidity were taken each day from June 18 to November 30. No means were available for making discharge measurements, but it would be possible to stretch a light cable across the river at Copper Center in holding in place a boat from which soundings and velocity measurements could be made. On September 27, 1913, the river at the suggested measuring section was 330 feet wide, and a measurement made by dropping floats across the section at intervals of 25 feet gave a mean surface velocity of 6.43 feet per second.

Daily gage height, in feet, of Copper River near Copper Center for 1908.

[Chas. W. H. Heideman, observer.]

Day.	May.	June.	July.	Aug.	Day.	May.	June.	July.	Aug.
1	2.0	3.2	5.1	3.6	16	1.6	3.6	5.2	3.1
2	2.0	4.0	5.1	3.9	17	3.0	....	5.0	3.0
3	2.0	4.4	5.0	4.0	18	5.2	4.0	4.9	2.9
4	[a] 4.1	4.7	4.8	4.0	19	5.6	4.0	4.9	3.0
5	4.9	4.2	4.8	4.0	20	5.9	5.0	5.1	3.0
6	5.0	3.5	4.8	4.0	21	6.4	5.1	5.1	3.1
7	5.6	3.7	4.7	4.0	22	5.9	5.1	5.0	3.2
8	6.0	3.3	4.6	3.8	23	....	5.1	5.0	3.3
9	6.1	2.9	4.7	3.7	24	4.6	5.2	5.0	3.2
10	[a] 4.2	3.2	4.9	3.6	25	4.1	5.1	5.0	3.2
11	.8	3.2	5.2	3.5	26	3.9	5.1	3.7	3.0
12	.8	3.1	5.7	3.2	27	3.3	5.1	3.6	2.9
13	.8	3.0	5.4	3.2	28	3.4	5.2	3.8	3.0
14	.6	3.5	5.2	3.3	29	3.1	5.1	3.8	3.3
15	[b] 2.0	3.6	5.0	3.2	30	3.0	5.0	3.5	3.5
					31	2.4	....	3.5	....

[a] Ice jammed below gage from May 4 to 10. Ice went out 1 p. m. May 10.
[b] Ice running.

NOTE.—Records furnished by Mr. Heideman, who was in charge of the Government experiment farm. The exact location of the gage is not known but was probably near the one installed in 1913. Ice went out May 5, 1907.

Daily gage height, in feet, and turbidity, in parts per million,[a] of Copper River near Copper Center, Alaska, in 1913.

[L. A. Jones, observer.]

Day.	June.	July.		August.		September.		October.		November.	
	Gage height.	Gage height.	Turbidity.	Gage height.	Turbidity.	Gage height.	Turbidity.	Gage height.	Turbidity.	Gage height.	Turbidity.
1	....	17.6	....	19.5	1,500	15.2	350	14.3	150	13.0	120
2	....	17.4	....	18.7	1,500	15.0	250	14.3	110	13.0	130
3	....	17.4	....	18.1	1,500	15.0	180	14.2	150	13.0	130
4	....	17.6	....	17.6	800	14.8	200	14.2	110	12.8	130
5	....	18.0	....	17.4	800	14.7	200	14.1	130	12.8	120
6	....	18.6	1,500	17.3	500	14.6	180	14.0	130	12.8	120
7	....	18.5	900	17.2	800	14.5	180	14.0	130	12.8	110
8	....	18.4	800	17.0	800	14.4	200	13.8	130	12.7	110
9	....	18.1	600	16.8	600	14.3	180	13.6	130	12.6	110
10	....	17.8	600	16.7	500	14.2	180	13.6	130	12.6	110
11	....	17.8	600	16.6	800	14.1	180	13.4	110	12.6	100
12	....	17.6	500	16.3	500	14.0	180	13.3	110	12.6	100
13	....	17.4	350	16.2	500	14.0	180	13.4	110	12.6	85
14	....	17.3	400	16.2	500	13.9	180	13.6	130	12.7	95
15	....	17.3	400	16.1	800	13.9	110	14.0	130	12.8	85
16	....	17.4	500	15.9	600	13.9	100	13.8	150	12.7	85
17	....	17.2	500	15.8	500	13.8	110	13.7	150	12.6	100
18	16.7	17.0	500	15.6	500	13.8	110	13.6	150	12.8	95
19	17.0	16.9	350	15.6	500	13.7	130	13.4	150	12.6	100
20	17.0	16.5	300	15.8	350	13.7	100	13.6	150	12.5	95
21	16.8	16.5	400	16.0	500	13.7	100	13.5	150	12.5	95
22	16.7	16.4	300	16.1	800	13.7	100	13.5	130	12.5	80
23	17.0	16.6	350	16.0	800	13.7	120	13.5	130	12.5	85
24	17.8	16.8	350	16.2	800	14.0	110	13.4	130	12.6	80
25	18.1	17.3	400	16.5	800	14.4	150	13.2	130	12.6	85
26	18.0	18.4	1,500	16.7	800	14.5	250	13.3	120	12.5	85
27	18.1	19.0	3,000	16.6	600	14.4	200	13.2	120	12.6	80
28	17.7	19.8	3,000	16.5	500	14.4	110	13.0	120	12.8	75
29	17.9	20.4	3,000	16.1	500	14.4	200	13.0	120	12.8	90
30	17.8	20.2	3,000	15.8	350	14.3	150	12.9	120	13.0	95
31	....	20.1	3,000	15.6	250	....	....	13.0	150	....	....

[a] Silica standard; determinations made with U. S. Geol. Survey turbidity rod.

COPPER RIVER AT MILES GLACIER.

Gage-height records were kept on Copper River by the Copper River & Northwestern Railway Co. from 1907 to 1910. The exact location of the gage is not known, but it was probably near the site of the bridge constructed during that period between Childs and Miles glaciers, 49 miles from Cordova and about 40 miles from the Pacific Ocean. (See Pl. V, *B*.) The datum plane of the gage was at an elevation equal to mean low-tide level at Cordova. To reduce the following gage heights that were taken at that point to their actual elevation above the datum plane, add 100 feet. Readings taken after about the 1st of November of each year may have been affected by ice, but no definite information is available regarding such conditions. No discharge measurements were made previous to 1913. It is not thought advisable to estimate discharges for 1907–1910 because of uncertainties regarding changes in channel since that period.

On June 29, 1913, a chain gage was installed by the Geological Survey on the railroad bridge on the guard timber on the upstream side of the center panel of the third span from the east bank. The gage datum was 85.3 feet below the base of the rails, or 93 feet above mean low-tide level at Cordova.

Discharge measurements were made from the upstream side of the bridge.

The channel at the bridge is composed of gravel and bowlders and is believed to be fairly permanent. The control for the section at the bridge is not well defined and the gage heights may have been affected at times by the action of ice breaking from the face of Childs Glacier, which would not only tend to contract the section and back up the water but also might change the condition of the bed of the river at the control.

Discharge measurements of Copper River at Miles Glacier in 1913.

Date.	Width.	Area of section.	Mean velocity	Gage height.	Discharge.	Date.	Width.	Area of section.	Mean velocity	Gage height.	Discharge.
	Feet.	*Sq. ft.*	*Feet per sec.*	*Feet.*	*Sec.-ft.*		*Feet.*	*Sq. ft.*	*Feet per sec.*	*Feet.*	*Sec.-ft.*
June 30	1,440	13,400	15.52	40.5	208,000	Nov. 12	990	6,250	2.78	[a]27.6	17,400
Sept. 13	1,007	7,330	5.47	28.0	40,100						

[a] Backwater from ice on riffle below section.

Daily gage height, in feet, of Copper River at Miles Glacier for 1907–1910.

[A. O. Johnson, observer. Records furnished by the Copper River & Northwestern Railway.]

Day.	Aug.	Sept.	Oct.	Nov.	Day.	Aug.	Sept.	Oct.	Nov.
1907.					1907.				
1	....	24.0	20.8	16.4	16	28.0	22.7	20.0	18.4
2	....	23.8	21.2	16.3	17	28.0	23.5	19.5	18.4
3	29.2	23.5	22.0	16.2	18	28.0	24.2	19.9	18.5
4	29.0	23.2	22.6	16.1	19	27.9	25.0	20.2	18.6
5	28.8	23.0	23.0	16.0	20	27.7	25.8	20.3	18.7
6	28.5	22.8	23.0	16.2	21	27.4	26.5	20.3	18.9
7	28.4	22.5	23.0	16.4	22	27.2	26.7	20.2	19.0
8	28.3	22.2	23.0	16.8	23	27.0	26.2	20.1	19.0
9	28.1	22.0	22.8	17.2	24	26.9	25.9	20.0	19.0
10	28.0	21.9	22.7	17.5	25	26.5	25.0	19.7	19.1
11	27.8	21.7	22.4	17.7	26	26.0	24.0	19.4	19.2
12	27.6	21.5	22.0	17.9	27	25.5	23.0	19.0	*a* 19.2
13	27.5	21.9	21.6	18.1	28	25.1	21.9	18.6	....
14	27.5	22.1	21.0	18.3	29	24.8	21.0	17.9	....
15	27.7	22.4	20.5	18.4	30	24.6	20.5	17.0	....
					31	24.4	20.4	16.5	....

a River frozen after Nov. 27.

Day.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Day.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1908.								1908.							
1	*a*23.0	31.7	28.2	25.9	19.0	18.8	18.3	16	25.7	28.8	27.7	22.0	18.4	19.0	18.2
2	22.8	31.5	28.5	26.0	19.4	19.7	18.4	17	25.8	29.0	27.0	23.9	18.4	19.0	18.5
3	23.1	31.0	27.8	26.4	19.7	20.1	18.3	18	26.0	29.7	26.5	23.8	18.6	19.0	18.6
4	23.2	30.5	27.3	26.7	19.9	20.2	18.4	19	26.5	29.2	26.7	23.4	18.6	19.3	18.7
5	23.1	29.9	27.2	26.8	19.5	20.3	18.4	20	28.0	29.0	26.9	23.0	18.6	19.4	18.7
6	23.0	29.1	27.0	25.8	19.3	20.4	18.4	21	28.7	28.9	26.8	22.0	18.5	19.3	18.7
7	23.0	28.6	27.0	25.0	19.0	20.5	18.4	22	29.4	28.4	26.5	21.4	18.0	19.1	18.6
8	23.0	28.0	27.3	23.6	19.0	20.5	18.4	23	30.0	28.0	26.0	20.9	17.4	19.0	18.6
9	23.0	27.5	28.0	23.0	19.0	20.3	18.3	24	30.7	27.5	26.0	20.7	17.1	18.9	18.7
10	23.2	27.5	28.5	22.5	19.0	20.2	18.5	25	31.6	27.2	26.0	20.2	17.0	18.8	18.8
11	23.8	28.3	28.0	22.2	19.0	20.0	18.5	26	32.0	27.0	25.8	19.8	17.5	18.7	18.8
12	24.0	30.2	28.2	22.0	19.0	19.6	18.3	27	31.4	26.8	25.8	19.4	17.8	18.8	18.9
13	24.4	31.0	28.6	21.6	19.0	19.5	18.3	28	31.0	26.8	25.8	19.2	18.0	18.5	18.8
14	24.7	30.0	28.3	21.3	18.8	19.2	18.4	29	30.7	27.0	25.8	19.2	18.2	18.3	18.6
15	25.0	29.1	28.0	21.3	18.6	19.0	18.2	30	31.2	27.4	25.5	19.3	18.4	18.3	18.5
								31	......	28.0	25.5	......	18.6	......	18.5

a Ice in river broke up June 1.

Daily gage height, in feet, of Copper River at Miles Glacier for 1907–1910—Continued.

Day.	Jan.	Feb.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1909.									
1	18.6	....	....	22.9	30.0	30.8	26.0	19.9	19.3
2	18.6	....	....	22.6	31.0	30.7	25.2	19.7	19.4
3	18.6	....	....	22.2	30.1	29.8	24.9	19.1	19.4
4	18.5	....	....	22.0	29.1	29.4	24.6	18.9	19.6
5	18.5	....	22.0	22.0	29.0	29.7	24.7	18.5	19.7
6	18.5	....	22.1	21.8	28.1	29.7	25.7	18.3	19.7
7	....	....	22.3	21.7	28.1	29.5	24.9	18.1	19.8
8	....	20.5	22.9	22.3	28.0	29.3	24.7	18.1	19.8
9	....	21.0	23.0	23.2	28.0	29.4	24.5	17.9	19.9
10	....	28.5	23.2	22.5	29.0	29.5	24.1	17.7	19.9
11	....	34.5	23.4	22.7	29.0	30.1	24.3	18.0	20.7
12	....	37.3	23.2	22.7	29.0	31.2	24.0	23.8	20.7
13	....	38.9	23.5	22.5	28.1	30.9	23.7	23.5	20.6
14	....	40.0	23.7	22.3	29.0	30.4	23.5	21.9	20.6
15	....	32.5	23.6	22.2	28.9	29.2	23.1	21.1	20.6
16	....	23.5	23.6	22.4	29.0	28.3	23.1	20.8	20.5
17	....	21.5	24.0	23.3	29.0	28.6	22.7	20.2	20.5
18	....	20.6	24.5	23.3	29.6	28.0	22.5	19.7	....
19	....	20.1	24.0	23.5	30.2	27.9	22.7	19.7	....
20	....	20.1	23.7	23.0	30.2	28.6	23.4	19.7	....
21	....	....	23.5	22.6	30.2	28.6	22.0	419.2	....
22	....	....	23.0	22.4	30.3	28.4	21.4	18.9	....
23	....	....	22.7	22.7	30.1	26.9	21.0	18.6	....
24	....	....	22.0	23.5	30.3	27.1	20.9	19.1	....
25	....	....	22.0	23.9	30.6	27.5	20.4	19.4	....
26	....	....	22.0	24.5	30.9	27.8	20.2	19.6	....
27	....	....	22.4	25.0	30.3	28.0	19.8	19.3	....
28	....	....	22.7	26.6	31.5	27.9	19.7	19.2	....
29	....	....	22.7	28.0	31.5	26.0	19.7	19.2	....
30	....	....	22.8	29.6	31.6	26.2	20.0	19.2	....
31	....	....	22.9	....	31.5	26.3	....	19.3	....

NOTE.—River frozen over Jan. 6. Ice broke up Feb. 8, caused by lake in Miles Glacier breaking loose. River frozen over Feb. 20. River broke up May 5. River frozen over after Nov. 17.

[H. A. Brown, observer.]

Day.	May.	June.	Day.	May.	June.	Day.	May.	June.
1910.			1910.			1910.		
1	....	24.5	11	....	22.0	21	....	24.4
2	....	24.1	12	....	21.8	22	....	26.5
3	....	24.2	13	....	21.6	23	28.9	26.8
4	....	24.1	14	....	22.0	24	28.8	27.1
5	....	23.3	15	....	22.4	25	28.5	27.9
6	....	23.3	16	....	22.6	26	31.1	28.7
7	....	22.8	17	....	22.9	27	32.3	29.0
8	....	22.5	18	....	23.0	28	29.5	27.4
9	....	22.4	19	....	23.6	29	26.3	27.0
10	....	22.2	20	....	23.7	30	25.8	28.4
						31	25.5	....

NOTE.—Ice broke up May 23. Gage heights during May affected by ice.

Daily gage height, in feet, and discharge, in second-feet, of Copper River at Miles Glacier for 1913.

[Drainage area, 21,800 square miles. Andrew Beck, observer.]

Day.	June.		July.		August.		September.		October.		November.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
1			39.2	186,000	36.4	142,000			28.0	40,100		
2							31.2	70,400				
3			39.8	197,000								
4									26.0	27,500		
5												
6			38.7	179,000	33.9	106,000	29.2	50,000				
7									26.0	27,500		
8			39.9	198,000								
9							28.0	40,100				
10			38.6	178,000								
11					34.4	113,000						
12												17,400
13												
14												
15			39.5	192,000	32.2	82,600						
16			41.0	216,000	31.9	78,700						
17							28.5	44,000				
18												
19					31.2	70,400	28.4	43,200				
20			35.5	128,000								
21							28.9	47,200				
22			35.4	127,000								
23			34.7	117,000	33.4	98,600	34.5	114,000				
24												
25							36.2	139,000				
26			36.4	142,000								
27			37.0	152,000	38.4	174,000						
28												
29	40.3	205,000	38.6	178,000			33.9	106,000				
30	40.5	208,000										
31					32.4	82,600						

NOTE.—Discharge determined from a rating curve based on two discharge measurements; may be 15 per cent in error.

KLUTINA RIVER BASIN.

GENERAL FEATURES.

The Klutina River basin comprises an area of approximately 1,040 square miles, bounded on the north and west by the Tazlina River basin and on the east by that of the Tonsina. The area to the south drains into Port Valdez.

Klutina River rises in Klutina Glacier on the north slope of the Chugach Mountains, flows northeastward and joins Copper River at Copper Center. About 15 miles below its source it enters Klutina Lake, and thence to its mouth, a distance of about 25 miles, it passes first through a region of mountains 3,000 to 4,000 feet high and then through the Copper River Plateau, in which its valley is incised between steep gravel walls to a depth of 400 to 500 feet. (See Pl. VII, *A*.) In its lower course through the plateau, a distance of about 13 miles, it falls 400 feet.

A KLUTINA RIVER NEAR COPPER CENTER, LOOKING UPSTREAM.

B. McCARTHY CREEK.

Klutina Lake is about 22 miles long, 4 miles in maximum width, 51 square miles in area. Much of the water of the river is derived from glaciers, but the lake acts as a settling basin and at its mouth the river is comparatively clear for a glacial stream. It carries only the finer material and shows little evidence of its glacial origin. The lake also regulates the flow of the river (see fig. 3), preventing extremely high rates of run-off during the summer, when the glaciers and snowbanks in the mountains are melting rapidly, and sudden decrease in flow in the fall when the glaciers become less productive.

Klutina Glacier is a northern arm of Valdez Glacier. In 1898 the Klutina Valley was the route of travel for many gold seekers on their way to the interior of Alaska and the Klondike region. The trail started from Valdez and followed the Valdez Glacier to the summit of the range and then down the Klutina Glacier to Klutina River, whose valley it followed to Copper Center. The following year the military trail was built over Thompson Pass and the Klutina route abandoned.

The discharge of 1,050 feet on October 31, 1913, which was probably the minimum since the beginning of the open season in May would be sufficient to produce about 80 horsepower for each foot of fall with an efficiency of 70 per cent at the wheel.

KLUTINA RIVER AT COPPER CENTER.

A gaging station was established June 17, 1913, at the crossing of the Government wagon road, and gage readings were taken night and morning each day until October 31, when ice rendered gage readings valueless as an indication of the discharge. The river flows in two channels at the road crossing. A vertical staff gage was installed on a pier of each bridge. Readings from the gage in the left or main channel were used in estimating the entire flow, as that channel seemed to be more permanent than the right, which shifted considerably.

Discharge measurements of Klutina River at Copper Center, in 1913.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*		*Feet.*	*Sec.-ft.*
June 18	8.73	4,650	Sept. 26	7.50	2,070

Daily gage height, in feet, of Klutina River at Copper Center for 1908.

[Chas. W. H. Heideman, observer.]

Day.	May.[a]	June.	July.	Aug.	Day.	May.[a]	June.	July.	Aug.
1	....	3.8	5.5	4.5	16	....	4.2	5.2	4.1
2	....	4.2	5.5	4.5	17	....	4.5	5.1	....
3	....	4.0	5.4	4.6	18	(a)	4.8	5.0	....
4	....	3.8	5.4	4.6	19	3.3	5.0	5.0	4.2
5	....	4.2	5.3	4.6	20	4.3	5.1	5.0	4.1
6	....	4.5	5.1	4.5	21	4.2	5.1	5.1	3.7
7	....	4.8	5.1	4.5	22	3.3	5.2	5.0	3.5
8	....	4.0	5.0	4.5	23	....	5.3	5.0	3.0
9	....	3.7	4.8	4.4	24	4.4	5.3	4.9	3.0
10	....	4.1	4.6	4.4	25	3.8	5.4	4.8	3.0
11	....	4.2	4.9	4.3	26	3.4	5.5	4.8	2.9
12	....	4.3	5.0	4.2	27	3.0	5.5	4.8	2.9
13	....	4.1	5.0	4.0	28	3.4	5.6	4.7	3.0
14	....	4.0	5.1	4.0	29	3.3	5.5	4.6	2.9
15	....	4.2	5.2	4.1	30	3.4	5.4	4.6	2.9
					31	3.6	....	4.6	2.9

[a] Ice went out May 18.

NOTE.—Records furnished by Mr. Heideman, who was in charge of the Government experiment farm. Gage was on the middle pier of the bridge, about one-half mile from Copper River.

Daily gage height, in feet, and discharge, in second-feet, of Klutina River at Copper Center for 1913.

[Drainage area, 1,040 square miles. Chas. Morris, observer.]

Day.	June.		July.		August.		September.		October.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
1	....	....	9.4	7,300	8.5	3,960	8.15	3,160	7.5	2,070
2	....	....	9.35	7,060	8.5	3,960	8.0	2,860	7.5	2,070
3	....	....	9.35	7,060	8.4	3,720	7.95	2,770	7.45	2,010
4	....	....	9.3	6,820	8.4	3,720	7.8	2,510	7.4	1,950
5	....	....	9.3	6,820	8.4	3,720	7.75	2,430	7.4	1,950
6	....	....	9.3	6,820	8.4	3,720	7.65	2,280	7.3	1,830
7	....	....	9.3	6,820	8.4	3,720	7.6	2,200	7.2	1,720
8	....	....	9.4	7,300	8.4	3,720	7.5	2,070	7.2	1,720
9	....	....	9.4	7,300	8.35	3,600	7.4	1,950	7.05	1,580
10	....	....	9.3	6,820	8.4	3,720	7.3	1,830	6.9	1,440
11	....	....	9.3	6,820	8.4	3,720	7.3	1,830	6.8	1,350
12	....	....	9.3	6,820	8.45	3,840	7.25	1,780	6.8	1,350
13	....	....	9.3	6,820	8.45	3,840	7.2	1,720	6.75	1,310
14	....	....	9.3	6,820	8.4	3,720	7.1	1,620	6.7	1,270
15	....	....	9.3	6,820	8.4	3,720	7.1	1,620	6.6	1,200
16	....	....	9.25	6,600	8.3	3,490	7.05	1,580	6.55	1,170
17	8.75	4,660	9.2	6,370	8.2	3,270	7.0	1,530	6.55	1,170
18	8.75	4,660	9.15	6,160	8.15	3,160	6.95	1,480	6.5	1,140
19	8.8	4,820	9.05	5,750	8.1	3,060	6.95	1,480	6.5	1,140
20	8.85	5,000	9.0	5,550	8.1	3,060	6.9	1,440	6.5	1,140
21	8.85	5,000	8.95	5,360	8.1	3,060	6.85	1,400	6.5	1,140
22	8.85	5,000	8.9	5,170	8.1	3,060	6.8	1,350	6.5	1,140
23	8.9	5,170	8.85	5,000	8.1	3,060	7.1	1,620	6.5	1,140
24	8.9	5,170	8.8	4,820	8.2	3,270	7.3	1,830	6.5	1,140
25	9.0	5,550	8.8	4,820	8.25	3,380	7.35	1,890	6.5	1,140
26	9.1	5,950	8.8	4,820	8.3	3,490	7.5	2,070	6.5	1,140
27	9.3	6,820	8.8	4,820	8.3	3,490	7.5	2,070	6.5	1,140
28	9.35	7,060	8.8	4,820	8.35	3,600	7.55	2,140	6.5	1,140
29	9.4	7,300	8.7	4,510	8.3	3,490	7.55	2,140	6.45	1,110
30	9.4	7,300	8.55	4,090	8.3	3,490	7.55	2,140	6.4	1,080
31	....	....	8.5	3,960	8.25	3,380	....	....	6.35	1,050
Mean discharge		5,680		6,030		3,520		1,960		1,390
Second-feet per square mile		5.46		5.80		3.39		1.88		1.34
Run-off, depth in inches		2.84		6.69		3.91		2.10		1.54
Maximum		7,300		7,300		3,960		3,160		2,070
Minimum		4,660		3,960		3,060		1,350		1,050
Accuracy		C.		C.		C.		C.		D.

KOTSINA RIVER BASIN.

Kotsina River heads in large glaciers on the southwestern slope of the Wrangell Mountains, between Kuskulana and Chesnina rivers. It follows a very irregular course with a general southeasterly trend, is about 40 miles long, and joins Copper River from the east just above the mouth of the Chitina. The basin covers an area of 447 square miles. Its topographic features, like those of most of the tributaries of the upper Copper River, are exceedingly diverse. The upper 20 miles of its valley lies between high rugged mountains. Its course below the mountain is through the southeastern corner of the Copper River Plateau, in which it has cut a deep canyon, in some places through hard rock, in others through gravel and conglomerate.

Through the summer the river carries a large volume of water with the usual amount of débris that would be expected of a stream whose source is mainly from glaciers. Peacock, Roaring, Rock, Copper, and Elliott creeks are the principal tributaries from the south and east. They are all without glacial source except one minor glacier near the head of Rock Creek. The Great Northern Development Co. has installed a hydroelectric plant of 17 kilowatts capacity on Roaring Creek for use in the development of copper properties. Roaring Creek drains an area of 10.1 square miles. There is said to be a good site for a small water-power plant on Peacock Creek. It drains an area of 6.3 square miles. From the topographic map Elliott Creek shows a fall of 1,000 feet in the lower 2 miles of its course. It is 8 miles long and drains an area of 16.9 square miles. From the north the tributaries of the Kotsina nearly all have glacial origin. Kluvesna Creek, one of the largest of the northern branches, heads in Kluvesna Glacier. Falls Creek, a tributary of the Kluvesna, has a heavy grade and is said to offer a good opportunity for the development of water power in the summer.

No daily records of flow in the Kotsina basin have been kept by the Survey.

A measurement was made near the mouth of the Kotsina, as follows:

November 9, 1913: Discharge, 200 second-feet; drainage area, 447 square miles; discharge per square mile, 0.45 second-foot.

CHITINA RIVER BASIN.

GENERAL FEATURES.

Chitina River, the largest tributary of Copper River, drains an area of 6,260 square miles. It rises in the St. Elias Range near the international boundary and flows northwestward for more than 100 miles to the Copper. It occupies a broad valley of gravel deposits, through which it has cut a deep trench in the lower 50 or 60 miles of its course.

Near the mouth of the Nizina the valley attains a width of nearly 15 miles. Below that point the valley is somewhat narrower and is broken by many small isolated peaks and rolling hills.

Much of the valley is imperfectly drained, and depressions resulting from glacial action are filled with water, forming many lakes and ponds and considerable areas of swamp land. The flood plain of the river is a mile or more in width at many places and shows all the characteristics of a plain formed by glacial stream.

The most important tributaries of the Chitina are from the north and emanate principally from the south slope of the Wrangell Mountains; in order downstream they are Nizina, Lakina, Gilahina, and Kuskulana rivers. From the south the main affluents are the Tana, Chakina, and Tebay rivers, which rise in the Chugach Mountains.

Tana River heads in Tana Glacier, a long westward arm of the massive ice sheet that surrounds Mount St. Elias and that eastward drains into the Alsek River in Yukon Territory. Tebay River, which joins the Chitina about 20 miles above the Copper, drains the Hanagita Valley and receives through its more southerly branches the discharge from a few minor glaciers. Between the Hanagita Valley and the Chitina, a distance of about 6 miles, the Tebay falls over 1,000 feet. There are several lakes in the headwaters which might possibly be made to afford considerable storage.

The flow of the streams during the summer depends largely on the melting of the glaciers, and in so far as that factor prevails the variations bear a direct relation to the temperature. The precipitation at the lower levels is rather low, probably not exceeding 18 inches per year, with only a moderate snowfall. At the higher levels the precipitation is believed to be much greater. Deep snow banks remaining late into the summer help keep up the flow on many of the streams. Summer rains can not be depended on, but they occasionally cause high water and, when accompanied by warm winds, are likely to cause excessive floods. The winter flow depends almost entirely on underground sources. Many of the smaller streams are said to go dry for several months, whereas others draining much smaller basins maintain a considerable flow throughout the winter, the difference being due to the character of the underlying formations on which the circulation of water and its escape to the surface depend. The geology of the northern portion of the Chitina basin is outlined by Moffit and Maddren [1] as follows:

Both sedimentary and igneous rocks are encountered. Four principal formations, including the unnamed Triassic shales and limestones, occupy most of the area and appear throughout its length from east to west. These formations, in order from oldest to youngest, are the Nikolai greenstone, the Chitistone limestone, the Triassic

[1] Moffit, F. H., and Maddren, A. G., Mineral resources of the Kotsina-Chitina region, Alaska: U. S. Geol. Survey Bull. 374, p. 21, 1909.

limestones and shales, and the Kennicott formation. The rocks have been folded and faulted, but the metamorphism is not great. It is most noticeable in the greenstone but has hardly affected the Kennicott formation.

The limestone, because of its solubility, should offer favorable conditions for underground storage, and the folded and faulted condition of the greenstones and shales is also favorable for underground storage and circulation of deep-seated waters. The foregoing statements are at best only general and should not be construed to mean that a large winter run-off would be the rule. Any statement of stream-flow conditions in this northern latitude is hardly worth considering unless based on actual observation.

NIZINA RIVER BASIN.

GENERAL FEATURES.

Nizina River, the largest branch of the Chitina, heads in Nizina Glacier, flows southward about 16 miles to a point near the mouth of Dan Creek, where it takes an easterly course, which it follows for about 22 miles to its union with the Chitina. It drains an area of 1,240 square miles and is nearly as large as the Chitina at their junction.

For the first 20 miles of its course it flows over a gravel flood plain from one-half to 2 miles wide, bordered by steep-sloped mountains 6,000 to 8,000 feet in height. At low water it follows one or more constantly shifting channels. At medium stage the number of channels increases, and finally at flood height the entire flood plain becomes covered from bank to bank with swift-flowing, muddy water carrying large quantities of sand and gravel. Below Young Creek the bordering mountains are separated by a wider valley in which the river has cut a deep trench through the gravel and shale formations; finally, for the last 2 or 3 miles of its course, the river flows between walls of solid rock, forming a box canyon for much of the distance. Small boats have been taken down through the canyon but always with considerable danger. The river has an average grade of about 30 feet per mile. Several thousand horsepower could be developed during the summer months by constructing a dam at the canyon, but probably the difficulties and expense of passing the immense quantities of sand and gravel that would be brought down against a dam would be so great as to render such a project impracticable.

Chitistone River rises in Russell Glacier near Skolai Pass, about 25 miles northeast from its confluence with the Nizina. Its course lies in a narrow valley with steep-sloped mountains 8,000 to 9,000 feet high on either side. It is reported that in some sections it passes through narrow, rock-walled canyons for short distances.

Dan and Chititu creeks are small streams that enter the Nizina from the southeast about 6 miles and 8 miles, respectively, below Chitistone

River. They flow past important gold placer claims, and their waters are particularly valuable for hydraulic mining. The basin of Dan Creek comprises 42 square miles and that of Chititu Creek 27 square miles.

Young Creek, which enters the Nizina about 1 mile below Chititu Creek, is about 30 miles long and drains an area of 104 square miles. Its lower course parallels that of Chititu Creek, about which its headwaters turn, interlocking with those of Dan Creek. Neither Dan, Chititu, nor Young creek receives much, if any, glacial water. They carry large quantities of silt from the shale formation in which they have cut their channels, besides much gravel and sand from the overlying formation.

Kennicott River carries the flow from Kennicott Glacier to the Nizina River, a distance of about 4 miles. It is subject to extreme floods, usually one or more each year, which are caused by the clogging of the subglacial channels that open up with an immense flow after enough water has accumulated to produce sufficient pressure to force out the obstruction. The flood discharge sometimes lasts several days.

McCarthy Creek (Pl. VII, *B*, p. 50) rises in small glaciers on the south slope of the Wrangell Mountains and for about 13 miles flows southward, paralleling Kennicott Glacier, which lies 3 to 4 miles to the west. The dividing ridge is a southern spur from the Wrangell Mountains and ranges from 6,000 to 7,000 feet in height. McCarthy Creek then gradually bends toward the west, and for the last 3 miles flows about northwest. Its total length is about 20 miles, and it enters Kennicott River at the town of McCarthy. The basin comprises 72 square miles. The principal tributaries are from the east and are the East Fork and Nikolai Creek, which enter about 10 miles and 12 miles, respectively, below the head. Below the East Fork the stream flows between high gravel banks, meeting here and there ledges of shale and porphyry through which it has cut its way, forming small canyons. About 3 miles from its mouth, as it enters the valley of the Kennicott, the flood plain broadens and averages nearly one-fourth of a mile in width. McCarthy Creek has a rather uniform grade of about 100 feet per mile. Considerable power could be developed from about the middle of May until the middle of October; for the remainder of the year extreme cold greatly reduces the flow (see fig. 3) and causes excessive formation of ice. Water could be diverted to a flume or pressure pipe and carried down the valley until a sufficient head could be obtained. A pressure pipe would probably be cheaper in the long run than a flume. A pipe line could be cheaply laid along the valley bottom without much danger from high water. The valley slopes are composed largely of steep gravel banks that would offer rather unstable support for a flume. The only engineering

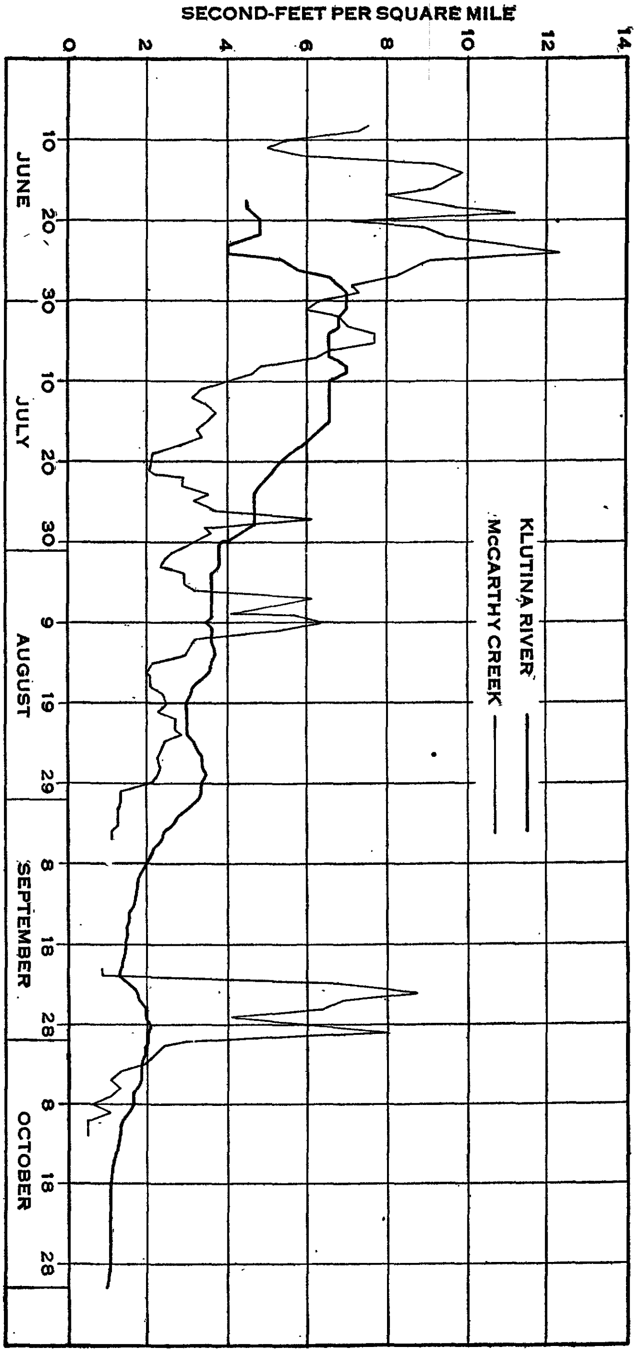


FIGURE 3.—Diagram showing discharge, in second-feet per square mile, of Klutina River and McCarthy Creek, for 1913.

difficulty that would be encountered would be the designing of headworks that would effectively divert the water into a flume or pipe line and at the same time withstand the effect of flood pressures and prevent the entrance of sand and gravel into the conduit. On October 12, 1913, there was a discharge of 37 second-feet, which it is probably safe to assume was the minimum flow since the beginning of the open season in May. That amount of water would produce nearly 300 horsepower for every hundred feet of fall, with an efficiency of 70 per cent at the wheel.

Miscellaneous measurements were made at several points in the Nizina River basin in 1913, and a regular gaging station was established on McCarthy Creek near its mouth.

McCARTHY CREEK NEAR McCARTHY.

This station was established June 8, 1913. The gage is a vertical staff on the right bank of the creek about three-quarters of a mile above the mouth.

Measurements were made from a car and cable at high water and by wading at low and medium stages.

The bed of the stream is composed of sand, gravel, and bowlders. The control at the gage did not change appreciably during 1913 and is believed to be fairly permanent except during flood stages, when radical changes might take place.

This station was established and records were obtained in cooperation with the Kennicott Mines Co.

Discharge measurements of McCarthy Creek near McCarthy in 1913.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*		*Feet.*	*Sec.-ft.*
May 29	3.85	191	Nov. 3	3.00	37
June 8	4.63	540	5	3.50	[a] 24
Sept. 21	3.29	61			

[a] Backwater caused by anchor ice.

Daily gage height, in feet, and discharge, in second-feet, of McCarthy Creek near McCarthy for 1913.

[Drainage area, 71 square miles. A. V. Doze, observer.]

Day.	June.		July.		August.		September.		October.		November.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
1	......	......	4.40	427	3.80	170	3.49	91	3.80	170	......	......
2	......	......	4.52	485	3.81	174	3.48	90	......	154	......	......
3	......	......	4.54	495	3.90	210	3.49	91	3.70	139	3.00	37
4	......	......	4.64	544	3.90	210	3.45	84	3.50	93	......	......
5	......	......	4.64	544	3.94	226	3.44	83	3.40	76	......	24
6	......	......	4.48	465	4.42	437	......	......	3.49	91	......	......
7	......	......	4.42	437	4.26	362	......	......	3.40	76	......	......
8	4.63	539	4.22	344	4.38	418	......	......	3.10	44	......	......
9	4.59	519	4.18	326	4.45	451	......	......	3.40	76	......	......
10	4.32	389	4.08	282	4.30	380	......	......	3.00	37	......	......
11	4.24	353	4.00	250	3.94	226	......	......	......	37	......	......
12	4.38	418	3.92	218	3.92	218	......	......	3.00	37	......	......
13	4.86	654	3.98	242	3.90	210	......	......	......	......	......	......
14	4.95	700	4.04	266	3.75	154	......	......	......	......	......	......
15	4.92	684	4.01	254	3.72	145	......	......	......	......	......	......
16	4.86	654	3.95	230	3.74	151	......	......	......	......	......	......
17	4.68	564	3.97	238	3.74	151	......	......	......	......	......	......
18	4.88	664	3.88	202	3.80	170	......	......	......	......	......	......
19	5.14	798	3.74	151	3.81	174	......	......	......	......	......	......
20	4.56	504	3.68	134	3.76	158	......	......	......	......	......	......
21	4.82	634	3.72	145	3.84	186	3.29	61	......	......	......	......
22	4.89	669	3.89	206	3.84	186	3.31	63	......	......	......	......
23	5.10	777	3.89	206	3.88	202	4.51	480	......	......	......	......
24	5.29	876	4.00	250	3.80	170	4.80	624	......	......	......	......
25	4.84	644	3.94	226	3.79	167	4.52	485	......	......	......	......
26	4.77	609	4.02	258	3.76	158	4.45	451	......	......	......	......
27	4.70	574	4.42	437	3.77	161	4.10	290	......	......	......	......
28	4.56	504	3.98	242	3.76	158	......	......	......	......	......	......
29	4.59	519	3.99	246	3.74	151	4.70	574	......	......	......	......
30	4.44	446	3.94	226	3.52	97	3.90	210	......	......	......	......
31	......	......	3.84	186	3.52	97	......	......	......	......	......	......
Mean discharge		595		296		211		....		85.8		....
Second-feet per square mile		8.38		4.17		2.97		....		1.21		....
Run-off, depth in inches		7.17		4.81		3.42		....		.54		....
Maximum		876		544		451		....		170		....
Minimum		353		134		97		....		37		....
Accuracy		A.		A.		A.		....		A.		....

MISCELLANEOUS MEASUREMENTS.

The following table shows the results of miscellaneous discharge measurements made in the Nizina River basin in 1913:

Miscellaneous measurements in Nizina River drainage basin in 1913.

Date.	Stream.	Tributary to—	Locality.	Discharge.	Drainage area.	Discharge per square mile.
				Sec.-ft.	*Sq. m.*	*Sec.-ft.*
Nov. 4	Nizina River	Chitina River	5 miles above Kennicott River.	492	865	0.45
May 31	Dan Creek	Nizina River	Above hydraulic plant	37	40	.92
June 1	White Creek	Chititu Creek	Above Jolly Gulch	14.1	9.4	1.50
3	Chititu Creek	Nizina River	Below junction White and Rex creeks.	53	24	2.21
3	Rex Creek	Chititu Creek	Above hydraulic plant	18.4	9.5	1.94
Nov. 5	McCarthy Creek	Kennicott River	Above Nikolai Creek	21	48	.44

LAKINA RIVER BASIN.

GENERAL FEATURES.

Lakina River, the first important tributary of Chitina River below the Nizina, rises in small glaciers between Kennicott Glacier on the east, Kuskulana Glacier on the north, and Gilahina River on the west. Castle Peak (elevation 10,514) is the highest point in the basin. The topography of the headwaters is rugged, but the basin does not extend as far north as the axis of the Wrangell Range. The river carries less glacial débris than the Nizina or the Kuskulana. The summer flow is probably derived to a considerable extent from melting snow in the higher peaks and depends on glacial flow to a less extent than any of the northern tributaries of the Chitina except the Gilahina.

One of the best stands of spruce in the Chitina basin is found along the banks of the Lakina as it leaves the mountains and starts across the Chitina Valley. The trees are not large, probably but few are over 18 inches in diameter, but they are said to be of fair quality. A small portable sawmill was in operation near the railroad crossing during the summer of 1913. The lumber was used largely for building at McCarthy. At the present rate of consumption the supply large enough for saw logs will become exhausted in a few seasons.

The Lakina is about 28 miles long, and its average grade is 70 feet per mile. There are no natural dam sites or storage sites so far as known on the river, but considerable power could be developed for about six months in the year by carrying the water along the side of the valley, either in an open conduit or a pipe, until sufficient head was obtained. On October 31, 1913, there was a discharge of 99 second-feet at the railroad crossing, which was probably the minimum flow since the beginning of the open season in May. That amount of water would produce 787 horsepower per 100 feet of fall with an efficiency of 70 per cent at the wheel. The relatively small amount of sediment carried by the river makes it more desirable for power development than many streams that in other respects are superior.

A gage was installed on the creek near the railroad crossing on June 9, 1913, but no daily readings were obtained.

MISCELLANEOUS MEASUREMENTS.

The results of miscellaneous discharge measurements made in the Lakina River basin are shown in the following table:

Miscellaneous measurements in Lakina River drainage basin in 1913.

Date.	Stream.	Locality.	Gage height.	Discharge.	Drainage area.	Discharge per square mile.
			Feet.	*Sec.-ft.*	*Sq. miles.*	*Sec.-ft.*
June 9	Lakina River	Railroad crossing	4.09	[a] 1,750	124	14.11
Oct. 3	.....do	.....do	2.24	224	124	1.81
31	.....do	.....do	[b] 2.50	99	124	.80

[a] Float measurement. [b] Gage height affected by ice.

GILAHINA RIVER BASIN.

GENERAL FEATURES.

Gilahina River rises in mountains 6,000 to 7,000 feet high between Lakina River on the east and Kuskulana River on the west. It is about 12 miles long and joins the Chitina 9 miles below the Lakina. Three miles from the Chitina it forks. The west branch, which is called the Chokosna, drains an area of 50 square miles and is nearly as large as the main stream above the forks. The upper 6 miles of the Gilahina in its course through the mountains has a grade of about 150 feet per mile. As it approaches the Chitina Valley the grade increases, and for the lower 6 miles the average grade is about 200 feet per mile.

There are no glaciers in the basin, and at normal stages the water is clear and free from sediment. The valley floor is made up of gravel, bowlders, sand, and clay, and at high stages the stream transports considerable material, causing marked changes in the channel.

Gages were installed on the Gilahina and the Chokosna near the railroad crossing on June 10, 1913, and frequent readings were taken during the summer by employees of the Copper River & Northwestern Railway, but because of insufficient discharge measurements and various uncertainties regarding the readings it is not thought desirable to estimate daily discharges.

MISCELLANEOUS MEASUREMENTS.

The results of discharge measurements made in the Gilahina basin are shown in the following table:

Miscellaneous measurements in Gilahina River drainage basin in 1913.

Date.	Stream.	Locality.	Gage height.	Discharge.	Drainage area.	Discharge per square mile.
			Feet.	*Sec.-ft.*	*Sq. mi.*	*Sec.-ft.*
June 10	Gilahina River	Railroad crossing	5.08	212	56	3.79
Oct. 2	.....do	.....do	4.54	81	56	1.45
June 10	Chokosna River	.....do	3.25	241	43	5.62
11	.....do	.....do	3.06	172	43	4.00
Oct. 1	.....do	.....do	2.58	69	43	1.60

KUSKULANA RIVER BASIN.

GENERAL FEATURES.

Kuskulana River has its source in Kuskulana Glacier at an elevation of about 2,200 feet. It flows southwestward for about 21 miles and joins Chitina River about 10 miles above the Copper at an elevation of approximately 600 feet, thus having an average grade of a little over 75 feet per mile. The main body of Kuskulana Glacier is about 11 miles long and slopes from east to west with an average width of about one-third mile. It receives four northern branches that emanate from the south and west slopes of Mount Blackburn. The basin above the Chitina Valley is exceedingly rugged. The snowfall in the higher mountains is said to be heavy, accumulating in massive drifts in the gulches and sheltered spots and in some places lasting throughout the summer. The river derives its main supply from Kuskulana Glacier and is heavily laden with glacial silt and sand.

In the upper 10 miles of its course the river passes through a broad gravel-filled flat, with high mountains on either side; its lower course of 11 miles across the Chitina Valley lies for much of the way through a steep rock-walled canyon. At the railroad crossing the rails are about 220 feet above the water surface, and the canyon within rock walls is about 170 feet deep. The width at the water surface, about 200 feet below the bridge, measured 70 feet, and the width at the top was estimated to be about 150 feet. The canyon affords many excellent dam sites. Below Strelna Creek it is in many places particularly narrow and its walls are nearly vertical. The river is said to get very low in the winter and goes dry at places in the upper basin above the canyon, where the underlying formation is composed of loose material. There is no opportunity for large storage in the basin, but the river offers opportunity for the development of a thousand horsepower or more for five or six months during the year by the construction of a dam at the canyon; but the winter flow is undoubtedly too low to warrant the operation of such a plant, even though ice difficulties could be overcome.

Extensive copper prospects in the upper basin indicate a possible future need of considerable power. The tributary streams above the canyon are all small. Nugget Creek, which is the largest, enters the main stream from the west just below the glacier. It drains an area of 12.1 square miles and falls about 800 feet in the lower 2 miles. Several other minor streams in the upper basin have heavy grades, and during warm weather, when their flow would be maintained by melting snow, they would probably produce sufficient power for small mining operations. An examination in the winter might show sufficient flow for small power plants on some of the side streams fed by springs with sufficient thermal properties to prevent the excessive formation of ice.

Strelna Creek, the most important tributary of the Kuskulana, heads in the ridge south of the Kotsina River, at an elevation of 6,000 to 7,000 feet, and enters the Kuskulana between 4 and 5 miles from the Chitina. It is about 12 miles long. The lower 6 miles of its course lie across the Chitina Valley plateau, with a grade of about 200 feet per mile. There are no glaciers in its basin, and the summer flow depends on rainfall and melting snow in the headwaters. Some winters it is said to go dry; in others there is a small flow even during the coldest weather.

No record of daily flow has been obtained in the Kuskulana basin. A gage was installed on the Kuskulana below the railroad bridge May 24, 1913, and was read every few days until about the middle of June, when the gage was washed out by high water; but an extremely shifting channel and insufficient measurements to determine the nature of such changes make it undesirable to attempt to estimate discharges from gage heights. A gage was also installed on Strelna Creek, at Strelna, on May 26, 1913, and a few gage readings were made, but the channel shifted so badly that without frequent measurements of discharge the gage heights would give little indication of the flow.

MISCELLANEOUS MEASUREMENTS.

The measurements that were made in the Kuskulana basin in 1913 are shown in the following table:

Miscellaneous measurements in Kuskulana River drainage basin in 1913.

Date.	Stream.	Locality.	Gage height.	Discharge.	Drainage area.	Discharge per square mile.
			Feet.	*Sec.-ft.*	*Sq. mi.*	*Sec.-ft.*
May 23	Kuskulana River	Railroad crossing	0.99	145	221	0.66
June 11	....do	....do	2.04	603	221	2.73
Oct. 1	....do	....do		[a] 500	221	2.26
Nov. 7	....do	....do		130	221	.59
June 11	Strelna Creek	....do	3.05	46	25	1.84
27	....do	....do	3.40	55	25	2.20
Sept. 30	....do	....do	2.83	24	25	.96
Nov. 6	....do	....do	[b] 3.10	3.3	25	.13

[a] Estimated. [b] Backwater from heavy accumulation of anchor ice.

TIEKEL RIVER BASIN.

GENERAL FEATURES.

Tiekel River is formed by the union of the Tsina River from the southwest and Kanata River from the north. It flows eastward about 15 miles and joins Copper River at mile 101 on the Copper River & Northwestern Railway, about 70 miles from the ocean. (See Pl. IV, *B*, p. 37.) Its course lies in a narrow valley bounded by high mountains on either side. The basin comprises an area of about 400 square miles, lying in the heart of the Chugach Range.

Between the forks and Copper River the Tiekel falls about 750 feet—an average of 50 feet per mile. About midway in its course through the mountains there is reported to be a cataract variously estimated at 20 to 50 feet in height, and narrow box canyons furnishing natural dam sites are also reported. It is not likely that any good storage sites exist, and the steep rock bluffs that flank the river bottom on each side would not offer favorable opportunity for the construction of a conduit.

During the summer the run-off is exceedingly heavy (see p. 66), and for at least five or six months the minimum flow would probably be sufficient to produce from 50 to 100 horsepower per foot of fall, but for several months during the winter the flow is doubtless very small, and without storage it would probably not be practicable to attempt to operate throughout the winter. Prediction of the effect of the formation of ice is difficult. The distance of the stream from the coast indicates that protracted periods of relatively cold weather should be expected.

There is but little timber in the main Tiekel River valley of size suitable for saw logs. Along the river banks and up to an elevation of about 2,000 feet, where it is not too rocky and steep, a dense growth of willows and alders is everywhere present. There are also a few scattered birch and spruce, but all are rather stunted. Just below the mouth of the Tiekel, along Copper River, there are a few large cottonwoods. Above Ptarmigan Drop the Tsina basin is barren of all timber except small brush. Below Ptarmigan Drop there are small clumps of spruce and cottonwood which have answered the local needs for fuel and cabin logs, but they are too small for saw logs. The Kanata River valley is somewhat better supplied with timber but would soon become exhausted if it was called upon to furnish logs for milling or fuel for power development.

Tsina River rises in glaciers lying in an unmapped area to the east of Valdez Glacier, from which they are probably eastward extensions. It is a typical glacial stream, flowing for the first 6 to 8 miles of its course in many constantly changing channels, which finally merge into one. (See Pl. VIII, *B*.) About 2 miles below Ptarmigan Drop

A. CANYON ON TSINA RIVER ABOUT 3½ MILES ABOVE BEAVER DAM ROAD HOUSE.

B. VIEW UP TSINA RIVER 4½ MILES ABOVE BEAVER DAM ROAD HOUSE.

A. VIEW UP POWER CREEK FROM HEAD OF FALLS.

Snowslide across creek in the foreground.

B. POWER CREEK BASIN FROM EYAK LAKE.

road house the valley narrows, and much of the way for the next 6 miles the river flows between rock walls that in some places rise 100 feet or more above the river bottom. The canyon affords several excellent dam sites. At a point about 3.5 miles above Beaver Dam road house the canyon is more than 100 feet deep. (See Pl. VIII, *A*.) The width was estimated to be 20 feet at the bottom and 100 feet at the top. The river has an average grade of about 50 feet per mile. It carries immense quantities of glacial débris during warm weather, but after about the 1st of September the water becomes clearer during normal flow. Tsina River, like many other glacial streams, is subject to extreme floods caused by the release of water that has been stored in the glaciers. On October 16, 1913, the river was discharging at least 1,500 second-feet, but two days later, without appreciable change in the weather, the flow had decreased to 87 second-feet. People living along the stream stated that the river commenced to rise rapidly on October 14.

About 1 mile above the Beaver Dam road house the valley suddenly broadens and the flood plain reaches a maximum width of a half mile or more. Passing through this enlarged section a distance of 3 or 4 miles, the river again enters a narrow valley in which it has cut a rock-walled canyon much of the way for 2 or 3 miles. On leaving the canyon it enters a big basin in which Kanata Creek enters from the north and the main Tiekel breaks through to the east. Stewart Creek joins the Tsina from the west less than a mile from the Tiekel. Kanata Creek is a clear-water stream and is about 15 miles long. It heads in a low divide near Ernestine road house.

Ptarmigan Creek, the largest southern tributary of the Tsina, heads in Thompson Pass (elevation about 2,690 feet) 18 miles east of Valdez. The basin occupies an area of about 18 square miles. The valley is broadly U-shaped, trends northeasterly, and is flanked by mountains 5,000 to 6,000 feet in elevation. The basin is narrow and precipitous on the east. To the west it is much wider and rises more gradually, and it is from this side that the greater part of the stream flow is derived. There are two glaciers on the west. Worthington Glacier, the northernmost and much the larger, extends well down toward the valley bottom and lies between the upper and lower canyons. On the east side of the basin several small glaciers lie high among the mountain peaks. The Government wagon road follows the west side of the creek until near the head of the lower canyon, where it crosses and soon enters the Tsina River valley. The creek is about 6 miles long and falls about 1,000 feet. About 500 feet of the fall is concentrated in two rock canyons. The upper canyon begins about 2 miles below Thompson Pass. A fall of about 200 feet occurs in a distance of approximately one-half mile. The lower canyon is near the mouth of the creek and through it the stream falls nearly 300 feet in a horizontal distance of about 1½ miles. Water could be easily diverted at the head of the upper or lower canyon and carried cheaply along either slope in a conduit of pipe or a combination of pipe and flume. With an efficiency of 70 per cent at the wheel about 16 and 24 horsepower could be developed at the upper and lower canyons, respectively, for each second-foot of discharge.

Ptarmigan Creek basin is barren of all trees except willows and alders, and if any of the several gold prospects that are now being developed in the basin should become mines, these water powers would become particularly valuable because of the absence of fuel. Water would probably not be available for the development of power before the last part of May, and by late November the diminished flow and heavy formation of ice would likely prohibit the operation of a plant until the following season.

MISCELLANEOUS MEASUREMENTS.

No daily records of stream flow have been kept in the Tiekel Basin, but miscellaneous measurements were made during 1913 and are listed in the following table:

Miscellaneous measurements in Tiekel River drainage basin in 1913.

Date.	Stream.	Tributary to—	Locality.	Discharge.	Drainage area.	Discharge per square mile.
				Sec.-ft.	*Sq. mi.*	*Sec.-ft.*
Oct. 20	Tsina River	Tiekel River	Below Ptarmigan Creek	87		
Nov. 9	do	do	do	50		
10	do	do	Mouth	134	161	0.83
June 13	Tiekel River	Copper River	do	5,820	408	14.3
July 1	do	do	do	8,480	408	20.8
Sept. 10	do	do	do	819	408	2.01
Oct. 17	Ptarmigan Creek	Tsina River	Below lake at head of upper canyon.	11.9	7.7	1.55
Nov. 8	do	do	do	2.8	7.7	.36
Oct. 18	do	do	2 miles above mouth at head of lower canyon.	22	16	1.38
Nov. 11	do	do	do	23	16	1.44
Oct. 19	Stuart Creek	do	At mouth	14.8		
Nov. 10	do	do	do	8.0		
Oct. 19	Kanata River	Tiekel River	do	146	175	.83
Nov. 10	do	do	do	69	175	.39

WATER-POWER SITES.

The topography of the Copper River basin is in many respects favorable for water-power development. The Wrangell and Chugach mountains give a heavy grade and many waterfalls to the streams emanating from them and contribute a heavy summer flow derived from the melting of glaciers and of snow banks accumulated during the previous winter. Natural storage sites in the form of lakes and ponds or opportunities for the creation of large storage basins by dams, features second only in importance to the discharge and grade of the streams, are, however, not particularly favorable.

In the winter the run-off becomes very low, and it is doubtful if the development of water power will be found practicable during that season north of the Chugach Range. Without more data it is difficult to make even an approximate statement regarding the period during which the flow of the streams and the temperature conditions would permit the operation of a plant in that region, but from the best information available it appears that the extreme limits of time for the successful operation of such plants would be from about the 1st of May until the 1st of December. The same limits of operating time would also probably apply to the tributaries of the lower Copper unless considerable storage could be obtained.

The most natural sites for power development on the main Copper River are at Wood Canyon, about 6 miles below the Chitina, and at Abercrombie Rapids, about 10 miles above the delta. (See pp. 41–42.) A head of 40 to 50 feet could probably be obtained at each locality, thus affording opportunity for producing between 4,500 and 5,700 theoretical horsepower for each thousand second-feet of flow. The lowest flow measured in 1913 at the gaging station at Miles Glacier bridge was 17,400 second-feet on November 12. That probably represented the minimum flow since about the middle of May of that year. The discharge at Wood Canyon on the above date was probably about 15,000 second-feet, since the drainage area is about 15 per cent less than at the measuring section. The only inflow of consequence between Abercrombie Rapids and the measuring section is that from Miles Glacier. Both sites would be expensive to develop, and silt and ice would introduce serious operating problems. At the latter site the river is flanked on the east side by a moraine which might render the construction of stable headworks particularly difficult.

Numerous power sites of smaller capacity occur on the Nizina River, McCarthy Creek, Lakina, Kuskulana, and Tebay rivers, and many other tributaries of the Chitina. The Kotsina and other branches of the Copper that head in the Wrangell Mountains also afford favorable opportunities for power development. Of the lower Copper River tributaries the Tiekel is perhaps the principal power stream. There are also many smaller branches that flow from the Chugach Mountains on which considerable power could be developed. Such data as are available regarding these sites are included in the descriptions of the basins in which they occur.

In the mountainous regions the transmission of electricity would be very difficult and expensive because of the heavy snowfall and steep rocky slopes. High winds prevail in the lower Copper River valley (see table, pp. 31–32) and through many of the tributary valleys in that section during much of the winter.

Most of the tributaries of the Copper head in glaciers and carry large quantities of sand and silt during the summer.

At the present time, with coal costing $10 or more per ton at the coast and crude oil at $2 per barrel, hydroelectric power would probably be much cheaper than steam, even though the plant could be operated but six or seven months a year (see pp. 153–155), but in view of the many difficulties in the way of water-power development, such as short season and consequent necessity for auxiliary steam power, great variation in stream flow, transmission costs, and silt and ice conditions, it does not seem probable that large water-power plants will have much advantage over steam plants if fuel costs are reduced to as reasonable a figure as should be expected when the Bering River coal fields are opened up. In inaccessible regions where transportation costs would make fuel unduly expensive the small water powers will no doubt be of considerable value if energy is there needed for mining or other purposes.

McKINLEY LAKE DISTRICT.

The McKinley Lake district is important because of the occurrence of gold quartz veins,[1] although no mines have as yet been developed.

McKinley Lake lies west of the Copper River delta, about 20 miles east from Cordova and about 2 miles north of the railroad at Alaganik. It is about 1½ miles long and drains into Alaganik Slough. The surface of the lake is but little above mean tide level.

Salmon Creek is the largest stream in the district. It rises in several small glaciers in high rugged mountains south of Sherman Glacier and flows in a southerly direction for about 5 miles. Its valley lies north and east of McKinley Lake, from which it is separated by a low narrow ridge, which disappears gradually as the south end of the lake is approached. Salmon Creek waters are said to flood their banks at high stages and mingle with those of the lake near its southern end. At low stages the river is said to enter Alaganik Slough by a channel entirely independent of that from the lake. About 1 mile below its source the creek forks; the main stream leaves its glacier at an elevation of about 675 feet; the minor branch enters at an elevation of about 350 feet, and on July 26, 1913, its discharge was estimated to be nearly as much as the main branch. For about 1½ miles below the forks the gradient is about 125 feet per mile. In that section the stream is confined to a flood plain averaging roughly from 400 to 500 feet in width, with a floor of glacial débris through

[1] See Chapin, Theodore, The McKinley Lake district: U. S. Geol. Survey Bull. 542, pp. 78–80, 1912.

which the stream meanders from bank to bank, usually confined to one channel at low and medium stages. The conditions along the valley show evidence of the movement of immense quantities of sand and gravel during flood stages.

A float measurement was made just below the fork (No. 1, Pl. X, p. 72) on July 26, 1913, at what appeared to be about a normal stage for that time of the year. A discharge of 119 second-feet was obtained. Considerable power could be developed during warm weather by diverting the water at the forks and carrying it in a conduit along the side of the valley for about 1½ miles, where a head of 150 to 200 feet could be obtained. From 10 to 15 horsepower could thus be produced for each second-foot of discharge. There is said to be a considerable flow throughout the winter, but it is not believed that it would be sufficient to warrant the operation of a plant for several months during the coldest weather. There are no sites along the creek where storage reservoirs could be provided.

The district is favored with an excellent stand of timber that would furnish cheap fuel for the development of steam power, and it seems likely that it would successfully compete with hydroelectric power, considering the rather unfavorable conditions for the development of the latter. The nearness of the railroad would permit the transportation of coal to the mines at a low cost.

POWER CREEK DRAINAGE BASIN.

GENERAL FEATURES.

Power Creek rises in Shepherd Glacier east of Orca Inlet and flows southwestward for about 5 miles, entering a northern arm of Eyak Lake about 4 miles northeast of the town of Cordova (Pl. IX, *B*, p. 65).

Eyak Lake is an irregular-shaped body of water lying east of Cordova. It is separated from Orca Inlet at Cordova by narrow lowlands, rising only a few feet above high-tide level and connecting a southern spur of Chugach Mountains with a small isolated range, to the south 3,000 to 4,000 feet high. The greatest dimension of the lake is from Cordova on the west to its outlet on the east, a distance of 4 or 5 miles. Its average width in a north-and-south direction is about 1 mile. It drains south through Eyak River to the Pacific Ocean, a distance of 5 or 6 miles across tidal swamps which border the coast and extend eastward to the Copper River delta. The level of the lake is raised a few inches by high tide backing up Eyak River. The Copper River & Northwestern Railway follows along the south shore of the lake.

Power Creek is bordered on both sides by high rugged mountains. The first 2 or 3 miles of its course is through a U-shaped glacial valley whose average width is about one-fourth mile. (See Pl. IX, *A*.)

Extending across the lower end of the valley is a ridge 300 to 400 feet high, through which the creek has cut a narrow gorge at its eastern end, and there falls more than 175 feet in a horizontal distance of about 500 feet. Below the falls the creek drops more than 150 feet in $1\frac{1}{2}$ miles. It is proposed by the parties who now claim water rights to divert water just above the falls and carry it through the ridge in a tunnel, thence along the west side of the valley for about $1\frac{1}{2}$ miles below to a power house, where a fall of over 300 feet would be available. It is reported that about 800 feet of tunnel would be required. On September 10, 1913, about 60 feet of 4 by 6 foot tunnel had been driven. The formation was of soft rock which could be broken down with a pick without the assistance of explosives. The rock disintegrated rapidly on exposure to the air and it was found necessary to timber the tunnel as the work progressed. This work had been accomplished almost entirely by the efforts of one man.

Power Creek basin above the falls is steep and barren, furnishing but little ground storage near the surface, though the considerable flow that it is said to have throughout the winter indicates that the rock formation of the basin must offer considerable underground storage. After heavy rains the creek rises rapidly and floods frequently occur. The lower valley is thickly covered with spruce and hemlock trees, some of which reach a diameter of over 3 feet.

Power Creek offers a better opportunity for the development of power than any other stream near Cordova. It was originally considered as a source of power for lighting the town, but an agreement could not be reached between the power company and those who claimed water rights and a plant was installed on Humpback Creek instead.

Stream flow data are insufficient to make an accurate estimate of the amount of power that could be developed. But from the best data available it is estimated that the minimum flow for six months in the year would not be less than 75 second-feet. That flow would produce about 1,800 horsepower with an efficiency of 70 per cent at the wheel. During the remaining six months of the year the capacity might become 50 to 75 per cent less. Some storage could be obtained by a dam at the upper end of the gorge, which would increase the minimum capacity of the plant over that afforded by the natural minimum flow.

POWER CREEK NEAR CORDOVA.

This station was established July 25, 1913. The gage is a vertical staff on the right bank of the creek, about 300 feet above Ohman's cabin, $1\frac{1}{2}$ miles from Eyak Lake, and about 6 miles from Cordova. (See No. 2, Pl. X, p. 72.)

Measurements were made by wading at a section just below the gage.

The discharge at the proposed point of diversion for power development, which is about 1½ miles above the gage, was about 25 per cent less than at the regular measuring section on September 10, 1913, as determined by measurement. The actual difference in run-off at the two sections was probably somewhat less, as the bed of the creek at the upper section appeared to be more porous, thus affording a greater opportunity for underground flow.

Discharge measurements of Power Creek near Cordova, Alaska, in 1913.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*		*Feet.*	*Sec.-ft.*
July 25	6.90	518	Oct. 6	6.25	262
Sept. 10	5.83	137	Nov. 15	5.76	140
10		[a] 109			

[a] This measurement was made above the falls to determine the difference in discharge at the two sections.

Daily gage height, in feet, and discharge, in second-feet, of Power Creek near Cordova, Alaska, for 1913.

[A. R. Ohman, observer.]

Day.	July.		August.		September.		October.		November.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
1										
2										
3										
4										
5										
6										
7			6.70	433						
8			7.07	698						
9			7.87	[a] 1,030			5.99	187		
10			7.14	633	5.83	147	5.86	154	5.57	96
11			6.85	496	5.83	147	5.84	149	5.63	106
12			6.74	450	6.17	240	5.80	140	6.51	359
13			6.72	441	6.39	314				
14			6.98	656	7.11	617			6.01	193
15					7.15	638			5.76	132
16										
17										
18										
19			6.38	311						
20			6.42	325						
21			6.45	336						
22			6.52	363						
23			6.49	351						
24			6.58	385						
25	6.90	418	6.60	393						
26	7.02	674	6.92	427						
27			9.88	[a] 2,360						
28										
29										
30	6.85	496								
31	6.90	418								

[a] Approximate.

NOTE.—Daily discharge computed from a rating curve fairly well defined below 700 second-feet.

PRINCE WILLIAM SOUND REGION.

GENERAL FEATURES.

Prince William Sound is an irregular-shaped bay reaching northward from the head of the Gulf of Alaska. (See Pl. X.) It extends from Cordova on the east to the head of Passage Canal on the west, a distance of 102 miles. In a north-and-south direction it reaches from the head of College Fiord to the lower end of Montague Island, a distance of 104 miles. The entrance to the sound lies between Hinchinbrook and Montague islands. The shore line is broken by a succession of fiords, bays, and inlets, and many islands break the continuity of the sound, particularly in its western part.

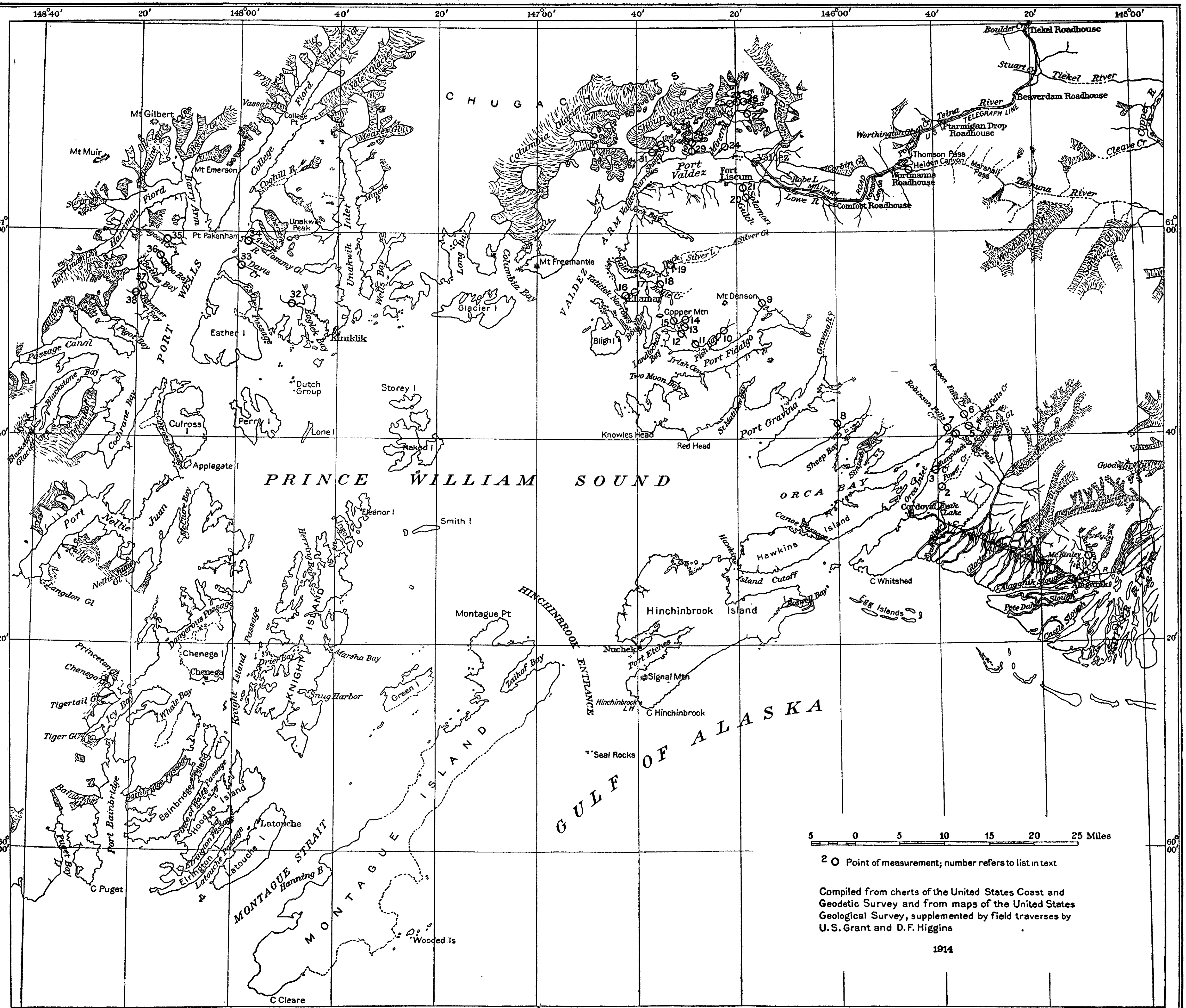
The topographic features of the mainland are particularly rugged. The coast is rocky and precipitous and rises rapidly to the summit of the Chugach Mountains, which nearly encircle the sound. Most of the higher valleys are occupied by glaciers, many of which extend down to sea level. The majority of the peaks near the coast are from 2,000 to 5,000 feet in elevation. Farther north, toward the axis of the range, they reach altitudes of over 10,000 feet.

Grant and Higgins [1] state that "the topography of Prince William Sound is that of a maturely eroded mountainous district, with the forms of river erosion modified by ice erosion. Into such a district the sea has come, filling the main basin of the sound and extending far up the valleys that lead into it."

The streams entering the sound drain small areas, and most of them are 1 to 5 miles in length. Lowe River is nearly if not the largest. It is 30 miles long and drains an area of probably less than 200 square miles. Practically without exception they all have their source in snow fields and glaciers. Their flow is subject to wide variation from summer to winter. The rapid meeting of the glaciers and snow banks, together with a heavy rainfall in the summer, produces excessive rates of run-off. In the fall and winter the flow from the accumulated ice and snow in the mountains rapidly decreases and the precipitation comes mostly in the form of snow. There is some rainfall and melting of snow during the winter, but the flow probably depends largely on the draining of underground channels. The prevailing rock formation is slate and graywacke, with only a thin covering of soil and other loose material. The opportunity for underground storage is therefore likely to be limited, and such sources would, as a rule, become quickly exhausted as soon as the inflow from the surface was cut off by low temperatures.

Valdez and Cordova are the principal towns in the Prince William Sound region. Valdez, which is situated at the head of Port Valdez,

[1] Grant, U. S., and Higgins, D. F., Reconnaissance of the geology and mineral resources of Prince William Sound, Alaska: U. S. Geol. Survey Bull. 443, p. 15, 1910.



MAP OF PRINCE WILLIAM SOUND SHOWING LOCATION OF GAGING STATIONS AND MEASURING POINTS.

is the supply point for the Valdez mining district and adjacent territory and is the headquarters for the Alaska Road Commission and the military telegraph line through the Copper River valley to Fairbanks and the Yukon Valley. It is also the terminal for the Valdez-Fairbanks wagon road. The population according to the 1910 census was 810.[1] Cordova, which stands near the southeast corner of the sound, had a population of 1,152 in 1910, but that was during the construction of the Copper River & Northwestern Railway, which brought here a population much larger than the present population of the town. The commercial life of the town now depends on its being the transfer point between ocean-going boats and the railroad leading to the Copper River valley. Other settlements in this region are Orca, Landlock, Ellamar, Fort Liscum, Golden, and Latouche.

MINERAL RESOURCES.

The mineral resources of Prince William Sound region lie mainly in its gold and copper ores.[2] Regular shipments of copper ore are made from the Beatson-Bonanza, mine on Latouche Island, and from the Ellamar mine, at Ellamar.[3] Small quantities of ore have also been shipped from various other properties, notably those near Landlocked Bay and Port Fidalgo. Copper prospects are widely distributed throughout the region and considerable development work has been done, but the productive mines are so far limited to those mentioned above.

The auriferous quartz veins so far discovered lie principally in the area surrounding Port Valdez,[4] and since 1910 prospecting has been actively carried on. The Cliff mine has been worked almost continuously since the installation of the first mill, in April, 1910. The present mill has six 1,450-pound Nissen stamps and is the only mill that is being operated uninterruptedly. Several small mills have recently been installed in the district, and reports indicate that further development work will be continued. Though there is sufficient reason to believe that the gold lodes of this district will furnish ore for the successful operation of many small mills, development work has not yet assured the hope of any large mines. Gold-quartz veins have also been discovered near Port Wells,[5] and for the past year considerable excitement has prevailed in that section, but up to the present time all the properties are in the development stage.

[1] This includes only the incorporated town; with the adjacent settlement its population is now probably 1,200 to 1,500.

[2] Grant, U. S., and Higgins, D. F., Reconnaissance of the geology and mineral resources of Prince William Sound, Alaska: U. S. Geol. Survey Bull. 443, 1910.

[3] See Capps, S. R., and Johnson, B. L., The Ellamar district, Alaska: U. S. Geol. Survey Bull. 605, 1915.

[4] Brooks, A. H., Gold deposits near Valdez: U. S. Geol. Survey Bull. 520, pp. 108–130, 1912.

[5] Johnson, B. L., The Port Wells gold-lode district: U. S. Geol. Survey Bull. 592, pp. 195–236, 1914.

TIMBER.

The mainland shores and most of the islands of Prince William Sound are generally covered with a thick growth of trees up to an elevation of 1,000 feet or more. Spruce is the prevailing growth, and some of it is of a size and quality to produce a good grade of sawed lumber. Much of it, however, is stunted and of an inferior quality. The United States Forest Service estimates that there is nearly 3.5 billion feet board measure of timber in the Prince William Sound region.

The timber resources of this region will probably be used chiefly for the production of wood pulp. These timbers are said to be suitable for such uses, and the possibilities for the successful introduction of the pulp industry have been more or less considered, but so far as is known no steps have yet been taken toward the construction of mills. The manufacture of wood pulp was recently commenced in southeastern Alaska. One small mill was being erected in the summer of 1913, but it is reported that this project was abandoned and that no immediate development of the wood-pulp industry is in prospect.

The forests of Prince William Sound are all included in the Chugach National Forest Reserve, which is under the control of the Forest Service of the United States Department of Agriculture. The local administration of this reserve is under the charge of the forest supervisor at Ketchikan, who has a suboffice at Cordova. Such timber as it is considered advisable to cut within the reserve will be sold by the Forest Service at a price not less than the appraised value. Lots exceeding $100 in value must be advertised for 30 days and sold to the highest bidder.

GAGING STATIONS AND MEASURING POINTS.

Points at which gaging stations were maintained or discharge measurements made on streams tributary to Prince William Sound in 1913, are listed below. The numbers correspond to those given on Plate X.

1. Salmon Creek below forks.[1]
2. **Power Creek near Cordova.**[2]
3. **Humpback Creek near Cordova.**
4. Snyder Falls Creek at mouth.
5. Wesley Falls Creek at elevation 600 feet.
6. Parsons Falls Creek at mouth.
7. Robinson Falls Creek at mouth.
8. Unnamed stream tributary to Sheep Bay.
9. Unnamed stream tributary to Port Fidalgo.
10. Unnamed stream tributary to Fish Bay.
11. Unnamed stream tributary to Fish Bay.
12. Chisna Creek at mouth.
13. Horsetail Falls Creek at mouth.
14. Lagoon Creek at mouth.

[1] This stream enters the Pacific Ocean east of Prince William Sound through Alaganik Slough.

[2] This stream enters the Pacific Ocean east of Prince William Sound through Eyak Lake and Eyak River.

15. Reynolds Creek at elevation 250 feet.
16. **Gladhaugh Creek at elevation 250 feet.**
17. Gladhaugh Creek at elevation 125 feet.
18. **Bottle Creek at mouth.**
19. **Duck River at mouth.**
20. Solomon Gulch above upper dam.
21. Solomon Gulch at mouth.
22. Lowe River at lower end Heiden Canyon.
23. Mineral Creek between Brevier and Glacier creeks.
24. Mineral Creek at lower canyon.
25. Brevier Creek at elevation 150 feet above mouth.
26. Glacier Creek at elevation 100 feet above mouth.
27. East Fork of Mineral Creek at elevation 900 feet above mouth.
28. **Gold Creek above falls.**
29. Gold Creek at mouth.
30. **Uno Creek at mouth.**
31. McAlister Creek at mouth.
32. Unnamed creek tributary to Eaglek Bay.
33. **Davis Creek at Golden.**
34. **Avery River near Golden.**
35. Lagoon Creek at lake outlet.
36. **Hobo Creek at mouth.**
37. Hummer Creek at mouth.
38. Unnamed creek tributary to Hummer Bay.

NOTE.—Black-faced type indicates regular gaging stations; light-faced type points of miscellaneous measurements.

ORCA BAY.

GENERAL FEATURES.

Orca Bay is the easternmost arm of Prince William Sound. Near its head a passage known as Orca Inlet leads southward to the Gulf of Alaska. The town of Cordova is on the east shore of Orca Inlet about 5½ miles from Orca Bay. Ocean-going vessels reach the harbor of Cordova by way of Orca Bay and Orca Inlet. Orca post office and cannery is situated about 3 miles above Cordova on the same side of the inlet.

Humpback Creek enters Orca Inlet from the east about 5 miles north of Cordova. It heads in rugged mountains 3,000 to 4,000 feet high and falls rapidly to sea level. The hydroelectric plant of the Cordova Power Co. is situated at the mouth of the creek. (See pp. 105–106.)

Orca Bay terminates at its head in a gravel and silt flat 2 to 3 miles long and a mile or more in width, known as Nelson Townsite. The flats have been formed by glacial wash brought down and deposited by Rude River.[1]

Rude River is said to head in a large glacier 8 or 10 miles from tide water, and occupies a broad silt-floored valley throughout its course. It is reported that the glacier from which it takes its source reaches well down into the main valley, precluding any opportunity for power

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[1] Called also Cordova River.

development. Three streams, Snyder Falls, Wesley Falls, and Parsons Falls creeks, enter Rude River within 3 miles of tidewater.

Snyder Falls Creek enters from the east near Cooper's cabin just above high-tide level. It has its source in small hanging glaciers and deep snow banks at an elevation of over 1,000 feet above sea level. Most of the flow is collected in a small cirque at an elevation of about 800 feet. The creek has cut a deep channel near the cirque outlet, and thence to Rude River valley, a distance of less than a mile, it flows in a series of falls and rapids through a rock-walled canyon most of the way. At several points along its course the water could be easily diverted to a pressure pipe and carried to the mouth of the creek.

Wesley Falls Creek enters Rude River about 1 mile above Snyder Falls Creek and from the same side. Its headwaters, like those of Snyder Falls Creek, are among rugged, steep-sloped mountains, with but little soil or vegetation to regulate the run-off. Water could be easily diverted at an elevation of about 600 feet. The south side of the valley offers a fair opportunity for the construction of a pipe line leading to the mouth of the creek, a distance estimated to be less than a mile.

Parsons Falls Creek joins Rude River from the west about 1 mile above Wesley Falls Creek. It drains a somewhat larger area than either Snyder Falls Creek or Wesley Falls Creek. Its headwater region is less rugged and barren. Timber line extends to a higher altitude and there are probably no glaciers in the basin. It is formed by the union of several branches, below which it falls rapidly through a distance of several hundred feet and then takes a moderate grade to Rude River.

Robinson Falls Creek is a small stream from the west, about opposite Snyder Falls Creek.

There is no opportunity to develop storage on any of the streams entering Orca Inlet, except possibly small reservoirs that might be of sufficient capacity to equalize the daily flow.

HUMPBACK CREEK NEAR CORDOVA.

This station was established May 20, 1913. The gage is located at the spillway of the Cordova Power Co.'s dam.

Measurements of discharge were made in the spillway, which is located on the left side of the dam. It is 7 feet deep and 20 feet wide and is of sufficient capacity to carry the flow of the creek at all times except at extreme flood stages, when the excess flow passes over the crest of the dam. The average quantity of water diverted through the base of the dam to the pipe line for the operation of the wheel was approximately determined by taking the mean of several measurements made just below the tailrace.

Discharge measurements of Humpback Creek near Cordova, Alaska, in 1913.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*		*Feet.*	*Sec.-ft.*
May 20	1.28	44	Sept. 9	0.83	10.0
May 21	1.28	38	Oct. 7		[a] 30
July 28	1.34	46	Nov. 16		[a] 17.7
July 30	1.80	97			

[a] These measurements were made in the creek below the dam. All other measurements were made at the spillway.

Discharge measurements below tailrace of Cordova Power Co.'s plant in 1913.

Date.	Discharge.	Date.	Discharge.
	Sec.-ft.		*Sec.-ft.*
May 21	4.5	Sept. 9	6.3
July 28	3.5	Oct. 7	4.0

Daily gage height, in feet, and discharge, in second-feet, of Humpback Creek near Cordova Alaska, for 1913.

[Chas. Cochran, observer.]

Day.	May.		June.		July.		August.		September.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
1										
2			1.56	70						
3					1.65	80	1.35	[a] 48		
4										
5							1.38	50		
6					1.78	[a] 96				
7			1.56	70						
8					1.65	80				
9							2.00	122	0.83	10.0
10										
11					1.56	70				
12										
13			1.55	68			1.21	35		
14										
15										
16					1.75	91	1.10	26		
17										
18							1.10	26		
19			1.57	[a] 71	2.32	164				
20	1.28	[a] 41			2.60	[a] 200				
21	1.28	[a] 41					1.10	26		
22										
23			1.56	70						
24					1.80	97				
25							1.10	26		
26							1.42	54		
27	1.67	82					5.85			
28			1.56	70	1.33	46				
29	1.62	[a] 76			2.00	122	1.70	85		
30					1.85	103				
31										

[a] Entire flow passing over spillway. To obtain the natural flow of the creek on other days add 4.6 second-feet, which is the average flow diverted through base of dam for use at power plant.

NOTE.—Discharge computed from a rating curve that is fairly well defined below 120 second-feet.

MISCELLANEOUS MEASUREMENTS.

The results of discharge measurements made at miscellaneous points on streams near Orca Bay are shown in the following table:

Miscellaneous measurements on streams near Orca Bay in 1913.

Date.	Stream.	Tributary to—	Locality.	Discharge.
				Sec.-ft.
July 29	Snyder Falls Creek	Rude River	Mouth	99
28	Wesley Falls Creek	....do	Elevation 600 feet	79
29	Parsons Falls Creek	....do	Mouth	a 150
29	Robinson Falls Creek	....do	....do	8.3

a Estimated.

SHEEP BAY.

Sheep Bay is a northern arm of Orca Bay. It is about 8 miles long and is situated between Simpson Bay on the east and Port Gravina on the west. Entering it from the west about midway of its length is a small unnamed creek that would offer a favorable site for a small power plant. At an elevation of about 700 feet is a lake with an estimated area of about 100 acres. The outlet is through a narrow rock canyon, where a dam could be easily constructed that would raise the lake level 15 or 20 feet. The lake is nearly surrounded by high rock walls rising 1,000 to 2,000 feet to the summit of the ridge. Below the lake the creek falls about 300 feet in a distance of about one-half mile; it then takes a moderate grade through a meadow-like part of the basin for a distance of probably less than one-half mile, and thence to the bay, a distance estimated to be about 1,000 feet, it falls nearly 250 feet. Just before entering salt water it has a sheer drop of over 150 feet. The discharge at the outlet of the lake on July 30, 1913, was estimated to be between 70 and 80 second-feet.

PORT FIDALGO.

Port Fidalgo is a large eastward arm of Prince William Sound, lying between Port Gravina and Valdez Arm. From Porcupine Point to the extreme head of Port Fidalgo the distance is about 25 miles, and the average width about 3 miles. The streams from the south, as far east as Whalen Bay, are small and would probably not be worth considering as sources of power. Beyond Whalen Bay to the east the streams were not visited, though there are said to be several that carry considerable water, but no information is available regarding their value for power development.

About 6 miles from the extreme head of Port Fidalgo an unnamed stream enters from the north. Its lower course for 3 or 4 miles is through a broad glacial valley, and its wide flood plain of overwash silt and sand and the muddy appearance of the water give evidence of a glacial source. It heads east of Mount Denson ("Rooster Comb"), and as seen from the mouth appears to come from the mountains in a narrow, precipitous valley, though glaciers may reach well down to the level of the enlarged valley leading to salt water. A measurement made near the mouth on August 2, 1913, gave a discharge of 205 second-feet.

Fish Bay is a small northern projection from Port Fidalgo opposite Irish Cove. It has two tributary streams of importance. The larger of the two enters at its extreme upper end. It is sometimes called Falls Creek, for appropriate reasons, but that name is not well established and it is generally considered an unnamed stream. About 1½ miles from the mouth it forks. The eastern fork is the larger of the two, and on August 2, 1913, the discharge was estimated to be about twice that from the west. A measurement made just below the forks on the above date showed a discharge of 70 second-feet. As seen from the spur between the two branches, each appears to head in large glacial cirques that may perhaps contain small lakes. On leaving the cirques both streams fall nearly vertically through a height variously estimated from 1,000 to 2,000 feet. The streams unite about a mile below the foot of the escarpment. Because of the immense fall the east fork is locally considered to afford an exceptional opportunity for water-power development. This opinion would be justified if a sufficient flow could be maintained, but it is doubtful if the discharge during the winter or even for much of the remainder of the year would be nearly as great as at the time of the above measurement, which was made during the season when the melting of ice and snow in the mountains would naturally be at a maximum.

How much less the discharge at the head of the falls would be than at the forks can be determined only by actual measurements. Even though the difference was but little during warm weather it might become considerable in the winter, when the lower temperatures at the higher altitudes might reasonably be expected to cut off almost entirely the flow to the upper basin, while at an elevation of 1,500 feet or more below, because of the increased possibilities for inflow from deep-seated underground sources, the supply might be sufficient to warrant power development.

The valley below the falls is heavily timbered and very difficult to travel through. The creek has a moderate grade for a coastal stream, but it flows through rock canyons at several points and there are a few falls and rapids that prohibit travel along the creek except at low water and then only with considerable difficulty. In some places the valley is narrow with steep slopes; in others it widens with benchlike formations at varying elevations above the water level.

The next stream enters Fish Bay near the extreme southeast corner. It heads in a ridge about 2,000 feet high southeast of Landlocked Bay, at a distance estimated to be about 3 miles from its mouth.

The topography is less rugged than that typical of most coastal streams. There are no glaciers in the basin. The flow is dependent on rainfall and melting snow and is probably very low for much of the year. There is a small lake at an elevation of about 950 feet that could be made to furnish storage that would be very important for a small water-power plant. Below an elevation of about 900 feet there is evidence of but little inflow.

A measurement made at the above elevation on August 1, 1913, gave a discharge of 3.7 second-feet.

LANDLOCKED BAY.

GENERAL FEATURES.

Landlocked Bay is a northern arm of Fidalgo Bay between Fish Bay on the east and Boulder Bay on the west. Four small streams—Chisna, Horsetail Falls, Lagoon, and Reynolds creeks—enter Landlocked Bay.

Chisna Creek rises on the north slope of Billygoat Mountain at an elevation of about 2,200 feet. It is about 1½ miles long and flows north, entering directly opposite the Three Man Mining Co.'s camp. The Chisna Consolidated Mines Co. installed a small water-power plant at the mouth of the creek several years ago. (See p. 107.)

Horsetail Falls Creek enters Landlocked Bay about one-half mile east of Chisna Creek. It falls nearly vertically through a height of about 500 feet just before entering the bay. There is a small pond at an elevation between 900 and 1,000 feet. The discharge of the creek becomes very low in the fall after the beginning of cold weather, and probably during much of the winter it is practically dry. On October 8 and also on November 18 the flow of the creek was observed by the writers to be very low, probably less than 1 second-foot on each of the above dates.

Lagoon Creek is the largest stream tributary to the coast between Fish Bay and Galena Bay. It heads opposite Bottle Creek and flows southeastward, entering the head of Landlocked Bay through the Lagoon. For the first mile above the mouth the creek flows through a narrow, steep-sloped valley and in that distance falls about 450 feet. It is made up of a series of cataracts, rapids, and small gravel-filled basins. Above, the valley broadens considerably and the creek has a more moderate grade. At low and medium stages the water is clear and is probably derived from rain and melting snow. It is said that there are no glaciers within the basin. The development of power would be dependent on the daily flow of streams, as there is but little opportunity for storage. Several measurements of discharge were made at the mouth (see table, p. 81), where the flow would naturally be somewhat greater than at a higher altitude where a diversion would be made for power development. On October 8, 1913, the discharge at an elevation of about 450 feet was estimated to be 25 per cent less than at the mouth.

Reynolds Creek rises at an elevation of about 2,500 feet and flows southward, entering Landlocked Bay about one-fourth mile northeast of the camp of the Three Man Mining Co. The basin is nearly circular and covers an area of 1.4 square miles. It is a clear-water stream and fluctuates rapidly during rainy periods and in warm weather when there is snow in the headwaters. It has been considered as a source of power by the Three Man Mining Co. Water would be diverted at an elevation of about 240 feet and carried along the west side of the valley in a flume 1,500 feet long. About 400 feet of pipe would be required to convey the water from the flume to a power house at the beach. A gage was installed on the creek on July 31, 1913, at an elevation of about 250 feet, and several readings were made during the summer by W. A. Dickey, but because of shifting channels and insufficient measurements to determine time and amount of the various changes, it is not considered advisable to publish estimates of flow except at times of measurements. The least discharge measured was 2.4 second-feet, on November 18. Under a head of 240 feet that rate of flow would develop 46 horsepower at an efficiency of 70 per cent. It is not unlikely that a lower stage was reached for short periods during the summer and fall between rains. What the flow would be during the winter can only be determined by frequent measurements.

MISCELLANEOUS MEASUREMENTS.

The only records of flow on streams tributary to Landlocked Bay are the following miscellaneous measurements:

Miscellaneous measurements near Landlocked Bay in 1913.

Date.	Stream.	Tributary to—	Locality.	Discharge.	Drainage area.	Discharge per square mile.
				Sec.-ft.	*Sq. miles*	*Sec.-ft.*
Aug. 1	Chisna Creek	Landlocked Bay	Mouth	4.2	0.9	4.67
1	Horsetail Falls Creek	do	do	4.2	.7	6.00
July 31	Lagoon Creek	do	do	67		
Oct. 8	do	do	do	20		
Nov. 18	do	do	do	14.4		
July 31	Reynolds Creek	do	Elevation 250 feet	12.7	1.2	10.58
Oct. 8	do	do	do	3.3	1.2	2.75
Nov. 18	do	do	do	2.4	1.2	2.00

GLADHAUGH CREEK.

GENERAL FEATURES.

Gladhaugh Creek enters Virgin Bay about one-fourth mile north of Ellamar. The basin occupies a circular area 1.6 square miles in extent and reaches its highest point on Ellamar Mount (elevation 2,700 feet) to the north. In its upper part the bounding ridge rises precipitously and the flow reaches the main stream in many ill-defined channels from a cirquelike basin.

At the lower end of the cirque there is a nearly vertical fall of about 40 feet. From the foot of the falls to the mouth, a distance of about 1 mile, the creek falls about 200 feet. After about the middle of June, when the snow has left the basin, the flow is dependent on the rainfall, and reaches a very low stage much of the time.

The Ellamar Mining Co. diverts water from Gladhaugh Creek about one-half mile from the mine, at an elevation of about 125 feet. It is carried to the camp in an iron pipe and there used for domestic and boiler purposes.

The stream has been considered as a possible auxiliary source of power for use at the Ellamar mine. Such records as have been obtained show that for much of the time the flow would be insufficient to warrant the installation of a plant.

GLADHAUGH CREEK AT ELEVATION 250 FEET.

On May 14, 1913, a gage was installed on the left bank of Gladhaugh Creek, about 150 feet above the falls, and at an elevation of 250 feet.

Discharge measurements of Gladhaugh Creek at elevation 250 feet in 1913.

[Drainage area, 0.6 square mile.]

Date.	Gage height.	Discharge.	Discharge per square mile.
	Feet.	*Sec.-feet.*	*Sec.-feet.*
May 14	1.74	9.7	16.17
Aug. 2	1.44	2.4	4.00
Oct. 8	1.52	2.0	3.33

Daily gage height and estimated discharge of Gladhaugh Creek at elevation 250 feet in 1913.

[Observer L. W. Storm.]

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Sec.-feet.*		*Feet.*	*Sec.-feet.*
May 14	1.75	10.2	June 19	1.74	9.8
May 16	1.78	11.3	July 13	1.53	4.0
May 20	1.72	9.0	July 26	1.73	9.4
May 24	1.75	10.2	Aug. 2	1.44	2.4
May 31	1.83	13.3	Oct. 8	1.52	2.0
June 6	1.85	14.1			

GLADHAUGH CREEK AT ELEVATION 125 FEET.

In order to determine the relation between the run-off at elevation 250 feet and at elevation 125 feet a gage was installed at the lower elevation on August 2, 1913, but as daily records at the point were not kept the only days on which the flow at the two stations can be compared are August 2 and October 8, when the discharge was measured at each station. The measurements show that on those dates the discharge at the lower gage was 45 per cent greater than at the upper.

Discharge of Gladhaugh Creek at elevation 125 feet in 1913.

[Drainage area, 1 square mile.]

Date.	Discharge.	Discharge per square mile.
	Sec.-feet.	*Sec.-feet.*
Aug. 2	3.5	3.50
Oct. 8	2.9	2.90
Nov. 18	2.0	2.00

GALENA BAY.

GENERAL FEATURES.

Galena Bay is an eastward projection of Valdez Arm, lying between Jack Bay on the north and Tatitlek Narrows on the south. It is about 6 miles long, with an average width of about 1 mile. The only streams of importance entering the bay are Bottle Creek and Duck River.

BOTTLE CREEK.

GENERAL FEATURES.

Bottle Creek drains an area comprising approximately 12 square miles north of Landlocked Bay. It enters Galena Bay near its extreme southeast corner at the Galena Bay Mining Co.'s camp. The bounding ridges are steep and rugged, but much of the inclosed area is of low relief and swampy. Between Gumboot Basin and the bay the creek falls more than 150 feet. Gumboot Basin is a flat expanse beginning about 1 mile from the bay and extending eastward along the creek for a distance of 2 to 3 miles, varying in width from one-half mile to 1 mile. The main tributaries are from the south. Copper Creek, which joins Bottle Creek near the upper end of Gumboot Basin, rises in Copper Lake about $1\frac{1}{2}$ miles from the main stream, at an elevation of about 750 feet. Copper Lake covers an area of about 100 acres and receives its inflow mainly from the northeast slope of Copper Mountain (elevation 3,946 feet). East of Copper Creek valley is Vesuvius Valley, which drains into Bottle Creek near the lower end of Gumboot Basin. Mallard Lake is situated near the lower end of Vesuvius Valley at an elevation of about 200 feet. The Galena Bay Mining Co., which has copper prospects at the upper end of the valley, has installed a hydroelectric plant on Bottle Creek. (See p. 107.)

BOTTLE CREEK AT GALENA BAY.

This station was established May 13, 1913. The gage was located near the mouth of the creek on the left bank. It was read at or near time of low tide. At high tide the readings were affected by backwater from the bay. Measurements of discharge were made by wading below the gage. The channel remained permanent during the period covered by the records.

Discharge measurements of Bottle Creek at Galena Bay in 1913.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*		*Feet.*	*Sec.-ft.*
May 13	1.93	155	Oct. 11	1.14	30
Aug. 3	1.41	61			

Daily gage height, in feet, and discharge, in second-feet, of Bottle Creek at Galena Bay for 1913.

[Drainage area, 12 square miles; G. L. Banta, observer.]

Day.	May.		June.		July.		August.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
1			1.80	127	1.90	148	1.56	84
2			1.78	123	1.87	142	1.52	77
3			1.85	138	1.88	144	1.41	60
4			2.05	181	1.90	148	1.38	56
5			2.20	215	1.92	152	1.36	54
6			2.30	238	1.86	140	1.45	66
7			2.15	204	1.82	131	1.40	59
8			2.18	210	1.80	127	1.36	54
9			2.42	267	1.76	119	1.45	66
10			2.30	238	1.70	108	1.60	90
11			2.05	181	1.65	99	1.40	59
12			1.95	159	1.65	99	1.35	52
13	1.93	155	2.38	257	1.65	99	1.30	46
14	1.86	140	2.40	262	1.60	90	1.20	35
15	1.84	135	2.35	250	1.60	90	1.14	30
16	2.04	179	2.33	245	1.70	108	1.05	24
17	1.98	166	2.25	226	1.75	118	1.00	20
18	2.18	210	2.20	215	1.85	138	.98	19
19	2.04	179	2.05	181	2.05	181	1.02	21
20	1.80	127	2.16	206	2.80	362	1.00	20
21	1.85	138	2.05	181	2.45	274	1.03	22
22	1.92	152	2.18	210	2.10	192	1.10	27
23	2.05	181	2.10	192	1.95	159	1.20	35
24	1.90	148	2.05	181	1.85	138	1.10	27
25	1.80	127		178	1.74	116	1.12	29
26	1.74	116		174	1.70	108	2.20	215
27	2.20	215	2.00	170	1.67	103	3.20	462
28	2.16	206	2.03	177	1.65	99	2.80	362
29	2.05	181	1.95	159	1.62	94	1.70	108
30	1.85	138	1.90	148	1.58	87	1.30	46
31	1.80	127			1.55	82	1.25	40
Mean discharge		159		196		135		76.3
Second-feet per square mile		13.3		16.3		11.2		6.36
Run-off (depth in inches on drainage area)		9.40		18.2		12.9		7.33
Maximum		215		267		362		462
Minimum		116		123		82		19
Accuracy		B.		B.		B.		B.

NOTE.—Discharges computed from a rating curve fairly well defined below 200 second-feet.

A. DAM SITE AT OUTLET OF SILVER LAKE.

B. FALLS ON DUCK RIVER NEAR SILVER LAKE.

PORT VALDEZ, LOOKING NORTH.

Shoup Bay near center.

DUCK RIVER.

GENERAL FEATURES.

Duck River has its source in Silver Lake at an elevation of about 250 feet above sea level. (See Pl. XI, *A*.) It is estimated to be about 2 miles long and enters Galena Bay at the northeastern corner through the Lagoon. The river has a uniformly steep grade with several very beautiful waterfalls near the lake. (See Pl. XI, *B*.) It is bounded on the north by a steep-sloped ridge, which reaches an altitude of about 4,000 feet opposite the lake outlet and increases in elevation eastward. To the south the topography adjacent to the river is irregular, with a more gradual ascent to the summit. The valley is densely timbered except a few small meadow-like openings on the south which are swampy and usually contain small ponds.

Duck River and Silver Lake offer the most favorable opportunity for water-power development in the Prince William Sound region, so far as is known by the writers. Silver Lake is estimated to be between 3 and 5 miles long and to have an average width of about 1 mile. The shore rises abruptly on all sides and the water is said to be deep even a few feet from the edge. The lake, as seen from the outlet, is surrounded on all sides by high mountains that reach their greatest elevations near the head, where they are particularly rugged and precipitous. Some distance from the outlet the lake bends to the south, cutting from view its upper part. The lake lies beyond the area mapped and it is impossible to estimate the extent of its drainage with reasonable accuracy, but the run-off, as shown by the measurements listed below (also see fig. 4), is much greater than would be expected from the available information concerning the general limits of the basin. The waters of Duck River were quite turbid at the time of each measurement, though undoubtedly much less so than they would have been without the settling effect from the lake. The appearance of the water and the apparent high run-off leads to the conclusion that a considerable proportion of the inflow must be from active glaciers that are reported to exist in the upper part of the basin.

The topography at the outlet of the lake is favorable for the construction of a dam up to a height of 100 feet or more. (See Pl. XI, *A*.) The lake level could be raised 30 feet by a dam about 60 feet long. Bedrock lies near the surface and a solid foundation for a dam is probably obtainable. Considerable substorage could be obtained if desired by placing the intake pipe below the normal lake level.

It is reported that water could be conducted from the lake outlet to a power house at sea level on the lagoon, about one-half mile south of the mouth of Duck River by a pipe line about 1½ miles long.

Parties who claim water rights on the river state that from a knowledge obtained by weir measurements made during the spring

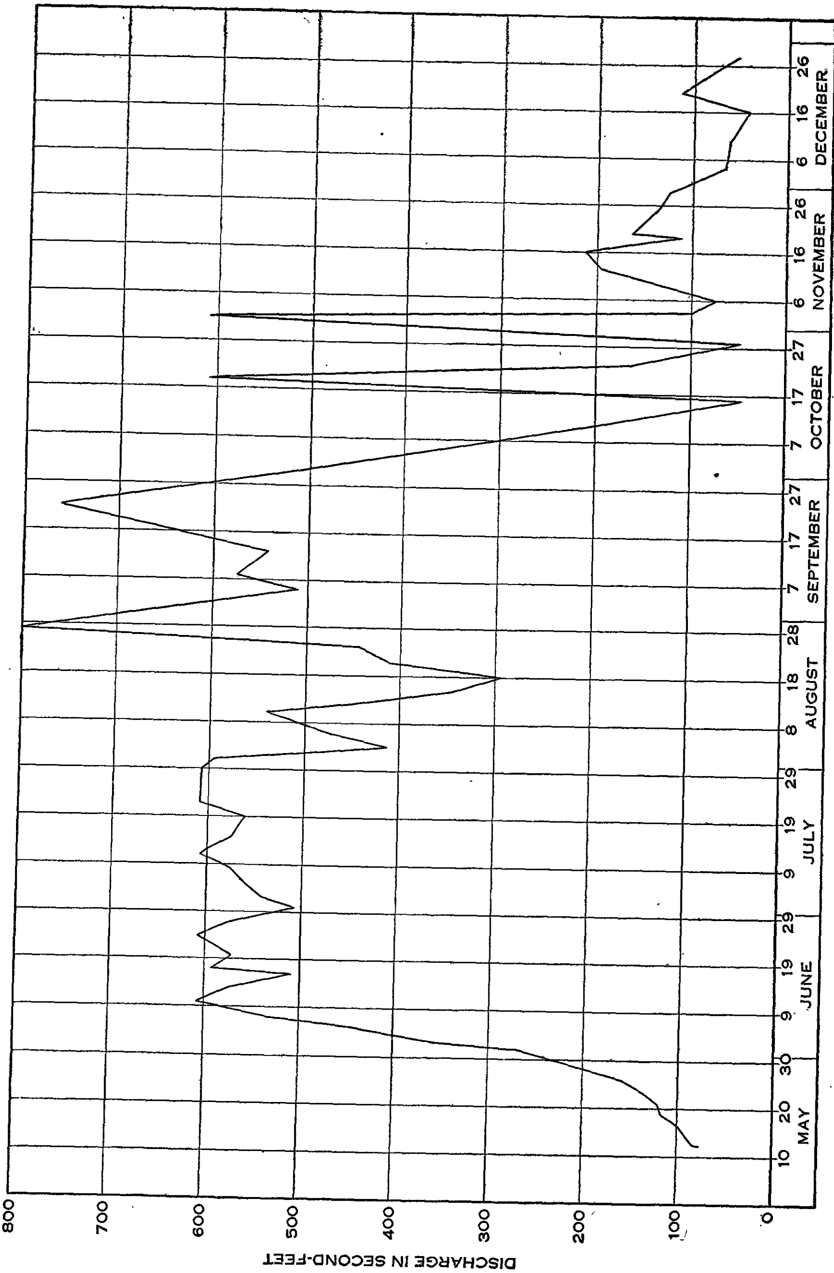


FIGURE 4.—Hydrograph of Duck River.

of 1913, together with general observations at different seasons of the year, they have estimated the minimum flow to be not less than 30 second-feet.

The average yearly flow of Duck River, as determined from the following records and an assumed flow of 30 second-feet for the remainder of the year, is about 240 second-feet. The facilities for storage are believed to be sufficient to maintain a uniform flow at the above rate. With an efficiency of 70 per cent at the wheel, 240 second-feet of water under a head of 250 feet would produce nearly 4,800 horsepower. More records should be procured, particularly during the winter months, on which to base final plans for development.

DUCK RIVER AT GALENA BAY.

This station was established May 13, 1913, on the right bank of the creek about 600 feet above the mouth. Gage readings were made at intervals of four or five days for the remainder of the year.

Measurements were made by wading at low and medium stages and from a boat at high stages. The channel remained permanent during the period covered by the records.

The difference in discharge of the river at the outlet of the lake and at the measuring section near the mouth was not determined by actual measurements, but there was no evidence of much inflow between these points.

Discharge measurements of Duck River at Galena Bay in 1913.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*		*Feet.*	*Sec.-ft.*
May 12	1.55	76	Oct. 12	1.90	149
13	1.61	82	Nov. 19	1.73	112
Aug. 3	2.54	409			

Daily gage height, in feet, of Duck River at Galena Bay for 1913.

[G. L. Banta, observer.]

Day.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1		2.25					2.85	
2		2.42	2.75		2.85			
3				2.54			1.70	
4						2.50		1.45
5		2.60	2.78		2.70			
6				2.65			1.50	
7		2.74						
8			2.80		2.80			
9								
10		2.85		2.75				1.40
11			2.85					
12	1.55		2.84	2.60		1.90	2.05	
13	1.61	2.80			2.75			
14								
15			2.80	2.40				
16	1.68	2.70				1.10	2.10	1.10
17		2.83						
18				2.30				
19	1.78		2.78			2.85	1.73	
20		2.80					1.95	1.75
21	1.80			2.54				
22			2.85		3.05			
23	1.85					1.95		
24		2.85		2.60				
25			2.85				1.85	
26	1.94							
27		2.80		3.10				
28	2.05					1.20		1.30
29			2.85				1.80	
30		2.70			2.70			
31			2.83					

NOTE.—Discharge computed from a rating curve well defined between 60 and 500 second-feet.

Daily discharge, in second-feet, of Duck River at Galena Bay for 1913.

Day.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1		272					608	
2		350	540		608			
3				412			100	
4						390		64
5		445	560		507			
6				476			70	
7		533						
8			573		573			
9								
10		608		540				59
11			608					
12	76		601	445		149	196	
13	85	573			540			
14								
15			573	340				
16	97	507				40	212	40
17		594						
18				293				
19	118		560			608	107	
20		573					164	111
21	122			412				
22			608		760			
23	136					164		
24		608		445				
25			608				136	
26	161							
27		573		800				
28	196					44		50
29			608				122	
30		507			507			
31			594					

PORT VALDEZ.

GENERAL FEATURES.

Port Valdez is a northeastern fiord of Prince William Sound. It is about 14 miles long and about 3 miles in average width. It trends east and west, bending to the south at the western end, and terminates in Valdez Narrows, with a minimum width of about 1 mile. The fiord is 600 to 800 feet in average depth, with but little shallow water except at the head, where large glacial streams are building up their delta. Port Valdez is surrounded by high, rugged mountains (see Pl. XII, p. 85), the main Chugach Range to the north and a spur of it to the south. On the north the mountains have steep slopes and have many sharp rocky peaks, some reaching altitudes of nearly 7,000 feet. The mountains south of the bay are not so high, ranging from 3,000 to 5,400 feet in elevation. Many of the higher valleys on the north are filled with glaciers. Valdez Glacier is the largest body of ice in the region. It is more than 15 miles long, nearly 2 miles in average width, and terminates about 3½ miles northeast of the town of Valdez at an elevation of 250 feet above sea level. The only glacier reaching tidewater is Shoup Glacier at the head of Shoup Bay. There are a few small glaciers among the higher of the peaks to the south.

The principal streams tributary to Port Valdez are Solomon Gulch from the south, Lowe River and Valdez Glacier streams at the head, and Mineral Creek, Gold Creek, and Uno Creek from the north. There are many other streams entering the bay, but they drain small areas and carry sufficient water for power development only during the spring and early summer, when the snow in the mountains is rapidly melting, or at times of heavy rains. (See p. 97 for list of miscellaneous measurements.)

SOLOMON GULCH.

Solomon Gulch offers a more natural if not a greater opportunity for the development of water power than any stream entering Port Valdez. It has its source in glaciers 6 or 8 miles from the bay and occupies a broad, gravel-filled basin for most of its length. About three-fourths of a mile from the mouth of the creek the basin is contracted by a spur from the east, and the stream for the remainder of its course flows through a rock-walled canyon in a series of falls with a drop of over 500 feet. This power is now being utilized by two companies who have installed hydroelectric plants and transmit current to Valdez. These plants are described on pages 107–108. The basin is without forests except a few small scattered spruce. The snowfall is very heavy in the upper basin and the summer run-off is likely to be excessively high. (See Pl. III, *B*, p. 36.) The minimum flow probably occurs during March and April, though the run-off probably becomes very low by the 1st of February. Several miscellaneous measurements were made on the creek and are listed in the table on page 97. The lowest flow measured was 12.7 second-feet on May 7, 1913, but this, owing to melting snow, was undoubtedly greater than the minimum for the winter. A conservative estimate of the minimum would be less than 10 second-feet. It is estimated that if all the storage that it would be practical to provide was utilized, possibly 1,000 horsepower could be developed at all seasons. The topography at the head of the canyon is favorable for the construction of a dam, and a reservoir with a capacity of 5,000 to 10,000 acre-feet could probably be created.

LOWE RIVER.

Lowe River, the largest stream in the district, rises north of Marshall Pass, flows in an easterly direction for about 30 miles, and enters the bay at its southeast corner about 2 miles from Valdez. Its flow is derived largely from glacial sources and is subject to great variation. Excessive floods occur during the summer, whereas in the winter the discharge is said to reach a very low stage, though no measurements have been made later than October 17. About 3 miles below Marshall Pass the river enters Heiden Canyon and is confined between steep walls for 6.5 miles. At the lower end of the canyon, about 1.5 miles above Wortman's, it occupies a broad gravel-filled valley through which it flows in many constantly shifting channels for 4.5 miles to Keystone Canyon. There the mountains close in and for a distance of 3 miles the walls of the canyon are for much of the way of solid rock and at points rise nearly vertically above the stream for a height of several hundred feet. Between Keystone Canyon and the bay, a distance of about 12 miles, the valley is from 1 to 2 miles wide.

Lowe River falls 1,854 feet between Marshall Pass and Port Valdez, a distance of about 26 miles, making an average grade of about 71 feet per mile.

Power could be developed at both Heiden and Keystone canyons. At the latter the head would have to be developed by a dam across the canyon. Such construction might be warranted if the flow was sufficient to operate a plant of large capacity, but during the winter it becomes very low and there is but little opportunity for storage. Lowe River carries immense quantities of sand and gravel during the summer. The feasibility of constructing high dams on rivers of that type is open to question. Such a project would involve the relocation of the Government wagon road, which now follows the right bank of the river through the canyon.

Heiden Canyon offers perhaps a more favorable opportunity for power development. Water could be diverted near the head of the canyon to a conduit on the north bank and carried along the bench above the canyon for about 6.3 miles. In that way a head of more than 900 feet could be obtained. The drainage area above the canyon is about 30 square miles and ranges in elevation from 1,500 to about 7,000 feet. It lies in an area of heavy snowfall, and the winter temperatures, though modified by the warmer coastal air current, are probably sufficiently low to prevent much surface run-off during that season. So far as is known there is no opportunity for storage. From about the middle of May until October several thousand horsepower could no doubt be developed, but the high elevation of the basin might cause such a small run-off and low temperatures as to render the operation of the plant impracticable during the winter. On October 17, 1913, there was considerable slush ice running in the river at the foot of Heiden Canyon, large masses of anchor ice had formed on the river bottom, and solid ice extended several feet from each edge.

MINERAL CREEK.

Mineral Creek has its source in a glacier at an elevation of about 1,000 feet. It is about 8 miles long and flows southward until about 1 mile from its mouth, when it turns toward the west and enters the bay about 4½ miles west of Valdez. The basin covers an area of 14 square miles. The topographic features are exceedingly rough, including many sharp pinnacles and narrow spurs. Many of the peaks exceed 6,000 feet in altitude and large glaciers occupy the upper parts of the tributary valleys. The main valley is bounded by precipitous slopes on both sides, with a U-shaped cross section. For the first 3 miles the valley is narrow and there are a few solid-rock canyons; below this stretch the river has built up a broad flood plain averaging about one-fourth mile in width. About 1½ miles from the mouth, as the stream leaves the mountains and approaches the tidal flats, a ridge 200 to 300 feet high crosses the valley. The creek has cut its way through this ridge at the east end, forming a narrow rock canyon, where a dam 50 to 60 feet high could easily be constructed.

Brevier Creek heads in a large glacier about a mile west of Mineral Creek and falls more than 1,000 feet in its course. During warm weather it is a torrential stream, but the discharge rapidly decreases on the approach of cold weather, and the bed of the stream near the mouth is said to be dry in the winter, though in its upper course there is a small surface flow.

Glacier Creek enters Mineral Creek just below Brevier Creek, and is similar in character, but its flow is considerably smaller.

The East Fork of Mineral Creek enters the major stream about 1 mile below Glacier Creek. It is less than 2 miles long and rises in a glacier about 2,000 feet above the level of Mineral Creek. Nearly a thousand-foot fall occurs in the lower half mile of its course. It would probably furnish 200 to 300 horsepower for 4 or 5 months in the summer, and water could be easily diverted to a pressure pipe on the south side of the creek. On October 24 there was about 6 inches of snow, at an elevation of 900 feet above the mouth, and the creek was frozen over solid except where it had a vertical fall of several feet. It is doubtful if it would be feasible to attempt to develop water power on upper Mineral Creek or any of its tributaries between the early part of November and the middle of May. At the lower canyon on Mineral Creek continuous power could no doubt be developed throughout the winter, but a head of not over 75 feet could be obtained. A flow of 37 second-feet, as measured on November 24, 1913, under a head of 75 feet would produce under operating conditions only little more than 200 horsepower, which is several times greater than should be expected later in the winter. The storage obtained would probably be sufficient to equalize the flow during much of the winter, but would be of little value in caring for the accumulation of excess water in the fall.

Placer gold is said to occur in the gravels of Mineral Creek above the lower canyon, which would be flooded by the construction of a dam.

The basin is barren of all timber except a few scattered cottonwoods in the lower valley and alders on the valley sides up to an elevation of about 1,500 feet, where there is sufficient soil to support their growth.

Considerable prospecting for gold quartz is being done each summer in the headwaters of Mineral Creek,[1] and some development work has been accomplished. A small stamp mill for preliminary work was erected in the fall of 1913 at the mouth of Brevier Creek. Power for its operation will be obtained from Glacier Creek when the flow is sufficient. The plant is described on pages 108–109.

In the summer supplies can be hauled up the creek on wagons for about 4 miles, when the stage of the water will permit travel along the bars. Pack animals are used for the remainder of the distance. When the water is high everything has to be packed either from Valdez or from the boat landing near the mouth of the creek. The pack trail crosses the creek at the lower canyon and follows the west side of the valley. There are branch trails leading to the various properties. Most of the hauling is done in the winter when sleds can be used.

[1] See Brooks, A. H., Gold deposits near Valdez: U. S. Geol. Survey Bull. 520, pp. 125–127, 1912.

GOLD CREEK.

GENERAL FEATURES.

Gold Creek enters Port Valdez about 4 miles below Mineral Creek. It flows southward, is about 3 miles long, and drains an area of 10 square miles. The surrounding ridges are 4,000 to 5,000 feet high. The flow in the summer is maintained largely by glaciers which lie at elevations between 2,300 and 5,000 feet and cover about one-third of the basin. Gold Creek occupies a hanging valley that opens to the bay at an elevation of about 800 feet above and about one-half mile horizontally from tidewater. Through the falls the creek is confined in a sharp rock gorge that rises precipitously to the summit of the mountains on either side. Above the falls the valley widens into a gravel filled basin which is about one-half mile long and 1,000 feet in maximum width. Placer gold is said to occur in the gravel of this basin, and considerable work has been done preparatory to the installation of an hydraulic plant. Above this basin for a distance of about 1 mile the valley is made up of smaller basins separated by rock gorges and contracted sections of the valley, through which the stream has a decidedly increased grade.

There is no timber in the basin except alders and small brush.

Small water power could be developed in the summer at sections above the main falls, where the fall is concentrated for short stretches. In the lower section of the creek a head of over 800 feet could be obtained by a pipe line less than 1 mile long leading to a power house on the beach, where probably a thousand horsepower could be generated for 6 or 7 months in the year. The discharge, however, is subject to wide variation, and from November until May it is doubtful if it would be sufficient to warrant the operation of a plant. The basin receives a heavy snowfall, causing large snowslides which would require costly construction to protect a pipe line. A horse trail leading up the basin along the west side of the valley is dangerous to travel and at times impassable during the fall and spring, when the slides are most active. A dam could be easily constructed at the head of the falls and small storage could be obtained, but ground now claimed for placer mining would thereby be flooded.

Gold quartz prospects have been found near the head of Gold Creek, but very little development work has been done.

GOLD CREEK NEAR VALDEZ.

This station was established September 8, 1913, at the head of the falls on the left bank of the creek at an elevation of about 800 feet above sea level and just below the Budd Mining Co.'s camp. Discharge measurements were made by wading.

Discharge measurements of Gold Creek near Valdez, Alaska, in 1913.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Sec.-feet.*		*Feet.*	*Sec.-feet.*
May 8		[a] 12.1	Oct. 13	3.03	21
Aug. 10		[b] 202	23	2.95	17.6
Sept. 8	3.19	34	Nov. 24		[a] 6.5

[a] Section one-half mile below gage at mouth of creek.
[b] Section one-half mile above gage at upper end of lower basin.

Daily gage height, in feet, and discharge, in second-feet, of Gold Creek near Valdez, Alaska, for 1913.

[Drainage area, 9.5 square miles. W. R. Van Ornum, observer.]

Day.	Sept.		Oct.		Nov.		Day.	Sept.		Oct.		Nov.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.		Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
1							16	3.52	94	2.95	17.8		
2							17	3.45	78	2.95	17.8		
3			3.45	78	3.25	42	18	3.38	63	2.91	16.4		
4			3.45	78	3.05	23	19	3.40	67	2.95	17.8		
5			3.45	78	2.95	17.8	20	3.38	63				
6			3.35	58	2.95	17.8	21	3.38	63	2.95	17.8		
7			3.23	39	2.85	14.6	22	3.48	85	2.97	18.4		
8	3.20	35	3.15	30			23	5.70		2.95	17.8		
9	3.22	38	3.15	30	2.75	12.0	24			2.92	16.7		
10	3.15	30	3.13	28			25			2.85	14.6		
11	3.20	35	3.05	23			26			2.85	14.6		
12	3.30	49					27						
13	3.45	78	3.03	21			28	3.80	165	2.80	13.1		
14	3.55	101	3.02	21			29	3.75	152				
15	3.58	108	2.95	17.8			30			2.93	17.0		
							31						

NOTE.—Discharges computed from a rating curve fairly well defined between 15 and 40 second feet.

SHOUP BAY.

GENERAL FEATURES.

Shoup Bay is an arm of Port Valdez near its northwest corner. It is about 2 miles long and varies in width from one-fourth to three-fourths mile. Many of the most important gold quartz veins of the Valdez district occur near Shoup Bay.[1] The entrance to the bay is shallow, but there is a narrow channel that is sufficiently deep for small launches. The main drainage into the bay is from Shoup Glacier, which reaches down to tidewater. It discharges large quantities of silt and has built up a broad mud flat at the head of the bay.

Uno Creek discharges into the bay near the northeast corner. It drains a roughly circular-shaped area comprising 5 square miles east of Gold Creek. Uno Basin occupies the central part of the area and is not as steep sloped as the bounding ridges, which rise sharply,

[1] See Brooks, A. H., op. cit., pp. 123–125.

reaching a maximum elevation of 5,445 feet on the north. Between Uno Basin and tidewater the creek descends in a series of rapids and falls through a height of 1,000 feet in a horizontal distance of but little over one-half mile. Several hundred horsepower could be developed at the falls from May until October, but after October the flow decreases rapidly, and it is believed that there would be a period of several months in the winter and early spring when it would be too small for practical use.

Estimates of discharge were made at the mouth for part of the summer of 1913. (See table, p. 96.) The minimum discharge measured was 2.5 second-feet on November 20. At that time the creek was frozen solid for much of the way between the foot of the falls and tidewater and the snow was about 3 feet deep. Because of heavy ice and snow the only section where a measurement could be made with reasonable accuracy was just below high-tide level at time of low tide. The actual discharge may have been somewhat greater than measured because of seepage through the beach sands, over which the creek flowed for a short distance above the measuring section.

The flow of Uno Creek is derived almost entirely from rainfall and melting snow. The only glacier in the basin is small, covering an area of only about 60 acres.

McAlister Creek enters Shoup Bay from the west. It drains an area of 2.5 square miles.

There is said to be opportunity to develop water power in the summer from streams flowing to the margin of Shoup Glacier from high mountains to the north.

UNO CREEK AT SHOUP BAY.

This station was established August 5, 1913, on the right bank of the creek about 300 feet from high-tide level and just below the proposed tailrace from the Sea Coast Mining Co.'s water-power plant.

Discharge measurements of Uno Creek at Shoup Bay in 1913.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*		*Feet.*	*Sec.-ft.*
May 8		6.3	Oct. 13	2.15	8.1
Aug. 5	3.18	54	23		7.2
10	3.18	61	Nov. 20		2.5
Sept. 7	2.31	14.0			

Daily gage height, in feet, and discharge, in second-feet, of Uno Creek at Shoup Bay for 1913.

[Drainage area, 5.0 square miles. R. M. Redpath, observer.]

Day.	Aug.		Sept.		Oct.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
1			2.69	30	2.76	34
2			2.60	26	2.55	24
3			2.55	24	2.45	19.3
4			2.46	19.7	2.50	21
5	3.18	58	2.41	17.7	2.58	25
6	3.28	64	2.38	16.6	2.46	19.7
7	3.22	60	2.32	14.5	2.42	18.1
8	3.44	73	2.30	13.8	2.31	14.2
9	3.38	70	2.30	13.8	2.30	13.8
10	3.18	58	2.26	12.6	2.28	13.2
11	3.15	56	2.27	12.9	2.22	11.4
12	3.00	47	2.38	16.6	2.25	12.3
13	3.02	48	2.94	44	2.15	8.1
14	3.02	48	3.07	51		
15	2.95	44	3.03	49		
16	2.88	40	2.84	38		
17	2.88	40	2.70	30		
18	2.88	40	2.61	26		
19	2.86	39	2.62	27		
20	3.02	48	2.51	22		
21	3.08	52		30		
22	3.02	48	2.82	37		
23	2.97	45	3.55	80		
24	3.00	47	3.62	85		
25	3.00	47	3.09	52		
26		54	2.99	46		
27		62	2.66	29		
28	3.38	70	2.62	27		
29	3.05	50	2.80	36		
30	3.07	51	2.82	37		
31	2.84	38				
Mean discharge		51.7		32.1		18.0
Mean per square mile		10.3		6.42		3.60
Run-off (depth in inches on drainage area)		10.3		7.16		1.74
Accuracy		C.		C.		C.

A. OCTOBER 10, 1913.

B. AUGUST 9, 1913.

FALLS AT EAGLEK BAY.

A. DAVIS LAKE FROM POINT NEAR OUTLET.

B. FALLS ON DAVIS CREEK BELOW LAKE.

MISCELLANEOUS MEASUREMENTS.

The results of miscellaneous discharge measurements made in 1913 on streams discharging to Port Valdez are given in the following table:

Miscellaneous measurements on streams tributary to Port Valdez in 1913.

Date.	Stream.	Tributary to—	Locality.	Discharge.	Drainage area.	Discharge per square mile.
				Sec.-ft.	*Sq. mi.*	*Sec.-ft.*
May 7	Solomon Gulch	Port Valdez	Elevation 550 feet	12.7		
9	do	do	do	16.0		
Nov. 24	do	do	Mouth	[a] 35		
Oct. 17	Lowe River	do	Foot of Heiden Canyon.	92	[b] 50	1.82
24	Mineral Creek	do	Between Brevier and Glacier Creek at elevation 650 feet.	26		
May 10	do	do	At lower canyon, elevation 100 feet.	79	39	2.03
Oct. 24	do	do	do	74	39	1.90
Nov. 24	do	do	do	37	39	.95
Oct. 24	Brevier Creek	Mineral Creek	Elevation 100 feet above mouth.	4.4	4.9	.90
24	Glacier Creek	do	Elevation 150 feet above mouth.	2.0		
24	East fork of Mineral Creek.	do	Elevation 1,000 feet above mouth.	2.6	3.8	.68
May 8	McAlister Creek	Shoup Bay	Mouth	2.4	2.5	.96

[a] Estimated. [b] Approximate.

EAGLEK BAY.

Eaglek Bay lies about 12 miles east of Port Wells, between Esther Passage on the west and Unakwik Inlet on the east. About a mile from the head on the west is a small cove into which flows an unnamed stream that is locally considered to afford one of the important water powers of that section of Prince William Sound. It falls directly into salt water through a height of about 200 feet over a nearly vertical rock bluff. (See Pl. XIII.) About 250 feet from the head of the falls the creek leaves a lake or series of lakes estimated to be 2 to 3 miles long and one-fourth to one-half mile wide. No information is available regarding the extent of the drainage basin or the source of the water. As seen from a point a short distance from the falls, the inflow apparently is mainly derived from the slopes of high mountains east of Davis Creek.

Between the outlet of the lake and the head of the falls—a distance of 200 to 300 feet—the creek is confined between steep walls and falls about 10 feet. A dam could there be constructed with a bottom width of about 100 feet, and it would probably be practicable to raise the level of the lake 50 feet or more. A solid rock foundation could probably be obtained with small expense. Water could be cheaply carried to a power house at sea level by a combination tunnel and pressure pipe or pressure pipe alone.

Assuming a storage area of 1 square mile a dam 50 feet high would store sufficient water under head of 200 feet to produce about 700 horsepower for 365 days with an efficiency of 70 per cent at the wheel. That would require a continuous discharge of approximately 44 second-feet. The only data available regarding the discharge of the stream are two miscellaneous measurements listed below. With those measurements and a knowledge of the high rate of run-off that occurs throughout Prince William Sound from May until September it seems reasonable to believe that an average flow of considerably more than 44 second-feet could be expected throughout the year.

There is considerable fair-sized timber along the shores and lower slopes adjoining Eaglek Bay.

Miscellaneous measurements.

Date.	Stream.	Tributary to—	Locality.	Discharge.
				Sec.-ft.
Aug. 9	Unnamed	Eaglek Bay	Above falls	656
Oct. 11	do	do	do	38

PORT WELLS DISTRICT.

GENERAL FEATURES.

Port Wells forms the extreme northwest part of Prince William Sound, of which it is the largest fiord. From the head of its northern arm, College Fiord, to the head of its southern arm, Cochrane Bay, the distance is about 50 miles. Harriman Fiord, Bettles Bay, Pigot Bay, Passage Canal, and Blackstone Bay are western arms. The eastern side has a more regular shore line. It is surrounded by a country of bold relief. Most of the tributary valleys are occupied by glaciers. In the larger ones the ice generally extends down to or near tidewater, thus eliminating all opportunity for water-power development. Most of the small streams come from glaciers located in their headwaters. All have a large run-off in the summer, but in the winter their flow undoubtedly becomes very low and offers but small possibility of power development except where it can be supplemented by storing excess flow during the summer and fall.

Gold-lode prospecting is in progress near Port Wells.[1] On some of the properties considerable development work has been done, and it is reported that several small stamp mills are to be installed. The town of Golden (sometimes called Port Wells), on the east side of the fiord 4 miles north of Esther Passage, is the local supply point for the district. A weekly launch service is maintained between Valdez

[1] See Johnson, B. L., The Port Wells gold district: U. S. Geol. Survey Bull. 592, pp. 195-243, 1914.

and Port Wells and ocean-going vessels occasionally enter the fiord to discharge freight.

The shores are quite generally timbered with spruce up to an elevation of a few hundred feet. Most of it is stunted and scraggy, though there is a limited quantity of good-sized trees that are suitable for saw logs.

This report is based on a hasty reconnaissance of streams entering the central part of the fiord, where prospecting is being carried on most actively.

DAVIS CREEK.

GENERAL FEATURES.

Davis Creek enters Port Wells at the town of Golden. It has its source in a lake at an elevation of about 140 feet above sea level. (See Pl. XIV, *A*, p. 97.) The lake is about half a mile from tidewater and is estimated to be about 2 miles long and one-quarter mile in average width. It is said to be very deep. High mountains rise abruptly from all sides. Many glaciers and large snow banks occupy depressions between the peaks and on the slopes of the mountains. Between the lake and salt water is a broad, open valley, through which the creek flows in a deep box canyon for most of the way. (See Pl. XIV, *B*.) There is an excellent opportunity for the construction of a pipe line to carry water from the lake to a power house on the beach. A dam 25 feet high with a top length of about 150 feet could be constructed near the outlet of the lake. A solid rock foundation could undoubtedly be obtained. A power system could be easily installed on Davis Creek, and for six or seven months each year the flow would probably be ample for a plant of several hundred horsepower, but in the winter the flow probably becomes very small during protracted periods of low temperatures, and at such times would have a capacity of less than one hundred horsepower unless storage was provided.

DAVIS CREEK AT GOLDEN.

A gage was installed on Davis Creek on August 6, 1913, at the foot of the first falls below the lake, at an elevation of about 100 feet above sea level. The channel below the gage is considered permanent. Measurements were made by wading just below the outlet of the lake.

Discharge measurements of Davis Creek at Golden, Alaska, in 1913.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*		*Feet.*	*Sec.-ft.*
Aug. 6	5.60	179	Nov. 20	4.48	21
Oct. 9	4.89	46			

Daily gage height, in feet, and discharge, in second-feet, of Davis Creek at Golden, Alaska, for 1913.

[Alex. Beyer, observer.]

Day.	August.		September.		October.		November.		December.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
1			5.10	77			4.72	32	3.93	11.6
2			5.10	77			4.92	50	3.91	11.3
3			5.02	63			4.72	32	3.91	11.3
4			4.94	52			4.71	32	3.90	11.2
5			4.89	46			4.95	54	3.89	11.1
6			4.86	43			4.91	48	3.88	11.0
7	5.57	172	4.84	42			4.88	45	3.90	11.2
8	5.94	270	4.82	40			4.81	39	3.88	11.0
9	6.49	437	4.82	40	4.89	46	4.79	37	3.86	10.7
10	5.98	281	4.80	38		41	4.77	36	3.85	10.6
11	5.68	200	5.10	77	4.77	36	4.41	19.1	3.84	10.5
12	5.52	160	5.41	135	4.72	32	4.34	17.6	3.83	10.4
13	5.43	140	5.62	184	4.62	26	4.31	17.0	3.98	12.2
14	5.41	135	5.83	239	4.61	26	4.31	17.0	4.16	14.5
15	5.42	137	5.86	248	4.60	25	4.28	16.5	4.33	17.4
16	5.40	133	6.22	352	4.62	26	4.26	16.1	4.45	20
17	5.44	142	6.10	316	4.63	27	4.33	17.4	4.48	21
18	5.41	135	5.40	133	5.16	88	4.46	20	4.50	22
19	5.30	113	5.80	231	6.20	346		20	4.67	29
20	5.32	117	5.62	184	5.68	200	4.48	21	4.71	32
21	5.40	133	5.38	129	5.10	77	4.73	21	4.73	33
22	5.48	151		396	5.78	226	4.66	20	4.71	32
23	5.50	155	7.20	664	5.67	197	4.48	19	4.64	28
24	5.46	146			5.20	95	4.46	18	4.49	21
25	5.62	184			5.04	67	4.45	17	4.48	21
26	5.84	242			4.91	48	4.41	16	4.47	21
27	6.70	504			4.88	45	4.40	15	4.45	20
28	6.43	418			4.86	43	4.39	14	4.43	19.6
29	5.64	189			4.83	41	4.37	13	4.41	19.1
30	5.46	146			4.48	21	4.36	12	4.39	18.6
31	5.30	113			4.33	17.4			4.38	18.4
Mean		198		165		78.1		25.1		17.8
Accuracy		C.		C.		C.		C.		D.

NOTE.—Gage heights affected by ice from Nov. 21 to 30. Discharges for that period interpolated. Rating curve fairly well defined between 20 and 200 second-feet.

AVERY RIVER.

GENERAL FEATURES.

Avery River is a tributary to Port Wells about 2 miles north of the town of Golden. It drains an area of rugged relief similar to though somewhat larger than that of Davis Creek. The main stream forms in a large glacial cirque, from which it emerges at an elevation of about 100 feet above sea level. A small, shallow lake at the base of the cirque covers an area of 5 or 6 acres. The distance from the outlet of the cirque to tidewater is about one-half mile. At its mouth Avery River has a nearly vertical drop of about 60 feet, falling directly into salt water at high tide. (See Pl. XV, *B*.)

Power could be developed on Avery River either by utilizing the entire fall of 100 feet by carrying the water in a pipe from the outlet of the cirque to a power house located at any convenient point on the

A. FALLS ON BENCH CREEK.

B. FALLS ON AVERY RIVER.

beach, or by building a power house at the foot of the falls and leading the water directly from the head of the falls through the turbines. The latter method would be cheaper, because it would not require so long a pipe line as the former. The particular type of plant that would be best suited for the needs would depend on the amount of power required.

Considerably more power could undoubtedly be developed by utilizing the entire head, though the increase in power would not be in direct proportion to the difference in head, since the discharge would be somewhat greater at the lower intake, and the friction head lost in the pipe line would tend to slightly decrease the advantage of the higher head. A dam 30 to 40 feet high could be constructed at the outlet of the cirque, with a top length of about 300 feet. Considerable storage would thereby be obtained. Several feet increase in head could be obtained by constructing a dam across the canyon at the head of the falls. A small sawmill was erected in the summer of 1913 at the foot of the falls, and was operated by an overshot water wheel.

The minimum flow during the period covered by the records below was 44 second-feet on November 26. With an efficiency of 70 per cent at the wheel, that discharge could produce about 350 horsepower, using the entire head of 100 feet, and a little over 200 horsepower at the lower falls under a head of 60 feet. Sufficient storage might be provided to assure that amount of power throughout the winter, but without storage it would probably be less than half that quantity at minimum flow.

AVERY RIVER NEAR GOLDEN.

A gage was installed on Avery River on August 7, 1913, on the right bank of the creek, about 300 feet above the falls. Low-water measurements were made by wading above the falls. At high stages they were made below the falls from a boat when the tide was low and the river had an unobstructed flow.

Discharge measurements of Avery River near Golden, Alaska, in 1913.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*		*Feet.*	*Sec.-ft.*
Aug. 7	4.98	198	Oct. 10	4.27	57

Daily gage height, in feet, and discharge, in second-feet, of Avery River near Golden, Alaska, for 1913.

[John Rueff, observer.]

Day.	August.		September.		October.		November.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
1			4.68	129	5.20	255	5.00	204
2			4.50	93	4.96	194	6.20	a 535
3			4.42	79	4.78	151	4.82	160
4			4.36	70	4.76	146	4.50	93
5			4.30	61	4.74	142	4.44	83
6			4.32	64	4.56	104	4.34	67
7	4.98	199	4.32	64	4.50	93	4.28	58
8	5.78	415	4.30	61	4.38	73	4.26	56
9	5.50	337	4.30	61	4.32	64	4.24	53
10	5.20	255	4.28	58	4.28	58	4.20	48
11	5.10	229	4.26	56	4.26	56	4.22	51
12	4.96	194	4.30	61	4.19	47	4.30	61
13	4.98	199	4.54	101	4.16	44	4.26	56
14	4.98	199	5.00	204	4.16	44	4.24	53
15	4.98	199	5.70	393	4.16	44	4.20	48
16	4.94	189	5.20	255	4.14	42	4.20	48
17	4.98	199	4.88	174	4.10	38	4.19	47
18	4.98	199	4.78	151	4.08	36	4.18	46
19	4.96	194	5.22	260	6.04	a 489	4.18	46
20	4.98	199	4.96	194	4.54	101	4.18	46
21	5.40	309	4.70	133	4.64	120	4.20	48
22	5.20	255	5.42	315	5.26	271	4.18	46
23	5.10	229	a 7.80	a 999	4.60	112	4.18	46
24	5.80	421	7.50	a 912	4.56	104		45
25	5.60	365	6.50	a 622	4.38	73		44
26	5.10	229	5.62	371	4.28	58	4.16	44
27	6.92	a 744	5.10	229	4.26	56	4.18	46
28	5.42	315	5.18	250	4.20	48	4.28	58
29	5.00	204	5.62	371	4.38	73	4.24	53
30	4.90	179	6.60	651	6.04	a 489	4.20	48
31	4.70	133			5.08	224		
Mean		264		248		124		77.9
Accuracy		D.		C.		C.		C.

a Approximate.

NOTE.—Discharge computed from a rating curve that was based on two measurements and is fairly well defined between 50 and 225 second-feet.

HARRISON LAGOON.

Harrison Lagoon is a small westward projection from Port Wells near the southwest corner of Barry Arm. The only tributary stream of consequence is Lagoon Creek, which enters near the northeast corner. It heads in a circular-shaped lake estimated to be about one-quarter mile in diameter. From the lake to sea level the creek falls more than 300 feet in a distance of 1½ to 2 miles. Above the lake the mountains are high and steep. Between the lake and the lagoon is a broad valley through which the stream flows in a succession of falls, rapids, and stretches of moderate grade, keeping close to the foothills on the north. In the last 500 feet of its course the creek falls nearly 100 feet. There is considerable timber on the valley sides, but open, meadow-like expanses cover much of the lower levels.

The level of the lake could be raised about 10 feet by a dam about 50 feet long at the base and 200 feet at the top. The topography affords a fair opportunity for the construction of a pipe line to the lagoon. Sufficient power could probably be developed in the summer to supply any ordinary mining needs that are liable to arise in the immediate vicinity. In the winter the run-off undoubtedly becomes very low and the storage that could be obtained would only be sufficient to equalize the flow over short periods of time. A flow of 9.0 second-feet as measured at the outlet of the lake on November 20 under a head of 300 feet, would develop about 215 horsepower with an efficiency of 70 per cent. The discharge at the mouth of the creek is increased considerably over that at the lake outlet by numerous small channels from the side slopes.

The result of a miscellaneous measurement made on the creek in 1913 is given in the table on page 105.

HOBO BAY AND CREEK.

GENERAL FEATURES.

Hobo Bay is a small indentation from the west side of Port Wells between Harrison Lagoon on the north and Bettles Bay on the south. Hobo Creek rises in the divide east of Harriman Fiord, and flows southeast with a total length of about 2½ miles, entering Hobo Bay at the head. It is reported that its main source of supply is from glaciers and large snow banks near the head and that the stream drops rapidly as it leaves the mountains. Most of its course is through a broad valley with a moderate grade. The lower end of the valley is contracted by a spur from the south, through which the creek has cut a canyon in the rock. A dam could there be constructed with a height of 50 or 60 feet and a small storage would thereby be provided.

The discharge on November 17 was 19.2 second-feet. That discharge, under a head of 50 feet, would produce only about 76 horsepower with an efficiency of 70 per cent. From the above date until the following May the flow would be considerably less for most of the time.

HOBO CREEK NEAR GOLDEN.

This station was established August 8, 1913, on the right bank of the creek just above high-tide level.

Discharge measurements of Hobo Creek near Golden in 1913.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*		*Feet.*	*Sec.-ft.*
Aug. 8	4.51	87	Nov. 19	3.79	19.2
Oct. 10	3.98	24			

Daily gage height, in feet, and discharge, in second-feet, of Hobo Creek near Golden for 1913.

[Cris. Everson, observer.]

Day.	August.		September.		October.		November.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
1			4.17	44				
2								
3								
4								
5								
6								
7								
8	4.51	88						
9	4.65	110						
10	4.55	94			3.98	24		
11	4.41	72						
12	4.40	71						
13	4.35	64						
14	4.33	62						
15	4.28	56						
16	4.30	58						
17	4.28	56						
18	4.22	49						
19	4.20	47					3.79	19.2
20	4.24	51						
21	4.25	52						
22	4.26	54						
23	4.25	52						
24	4.25	52						
25	4.25	52						
26	4.30	58						
27	4.70	119						
28	4.61	104						
29	4.60	102						
30	4.52	89						
31	4.19	46						
Mean		69.1						
Accuracy		C.						

HUMMER BAY.

Hummer Bay is situated about 2 miles south of Bettles Bay. Two fair-sized streams enter the bay at the head. The northern one is called Hummer Creek; the one to the south is unnamed. They were not visited except at the mouth, but prospectors living near stated that there were no natural power sites on either stream. They both flow through a broad silt-floored valley before entering the bay. At the time of the writer's visit, on August 8, 1913, each showed a high run-off, due to heavy rains and rapid melting of snow and glaciers in the headwaters. They are said to get very low in the fall and winter and at times go dry at their mouths, the small flow then passing through the porous sands beneath the stream bed.

MISCELLANEOUS MEASUREMENTS.

The results of miscellaneous discharge measurements made in 1913 on streams tributary to Port Wells are given in the following table:

Miscellaneous measurements near Port Wells in 1913.

Date.	Stream.	Tributary to—	Locality.	Discharge.
				Sec.-ft.
Aug. 8	Lagoon Creek	Harrison Lagoon	Lake outlet elevation, 300 ft.	83
Nov. 20	....do	....do	....do	9.0
Aug. 8	Hummer Creek	Hummer Bay	Mouth	[a] 240
8	Unnamed	....do [b]	....do	[a] 160

[a] High run-off due to heavy rains and rapid melting of snow and glacier ice in headwaters. These streams are said to go dry at their mouths in the winter.
[b] This stream enters Hummer Bay at the head south of Hummer Creek.

DEVELOPED WATER POWER.

GENERAL CONDITIONS.

The water powers of Prince William Sound remain practically undeveloped. Cordova and Valdez are the only settlements of sufficient size to justify the installation of plants for lighting. Mining has not yet reached the stage where a sufficient future is assured to warrant the construction of expensive hydroelectric plants. Several plants have been installed for mining, but they are of small capacity, cheap, and temporary in construction, well suited for the needs of a property during the development stage, or for a small mine where interruption in service is not serious and a small amount of ore is available.

CORDOVA.

Light and power for Cordova are furnished by the Cordova Power Co. The plant, which is on the east shore of Orca Inlet about 5 miles north of Cordova, was built in the winter of 1908–9 and first put in operation the following June, and except for short periods it has been in operation continuously since that date. A steam plant is used as auxiliary when the water supply is insufficient. From about the 1st of May until the 1st of December there is said to be ample water to supply the present demands for energy, but for the remainder of the year the steam plant is likely to be required at any time.

Water is diverted from Humpback Creek by a rock-filled timber-crib dam to a 30-inch continuous wood-stave pipe leading to the power house, a distance of about 1,350 feet, where a maximum gross head of 156 feet is obtained. The dam is 45 feet high, 86 feet long at the bottom, and 111 feet at the crest, and is 79 feet wide at the bottom, tapering to a width of 10 feet at the top. This type of construction was adopted because there was plenty of rock and timber handy to the dam site. The entrance to the pipe line is placed near the base of the dam, and is provided with suitable headgate and tapered connections. Trouble is sometimes caused by sand and gravel being brought down during high water and blocking the inlet screens.

The water wheel is a 43-inch Pelton, designed to develop a maximum of 200 horsepower under an effective head of 148 feet. It is provided with double nozzle. The upper vent is regulated with a hand-operated needle. The lower one has a plain, open-type discharge, and during the winter it will permit the passage of ice particles that might clog a needle nozzle. Directly connected with the wheel is a 125-kilowatt 2,300-volt 3-phase 60-cycle generator. The excitor is a 9-kilowatt 125-volt machine. A Pelton oil-pressure governor in connection with a hood deflector is used to regulate the speed. Current is stepped up to 11,000 volts for transmission to Cordova. The line follows along the steep hillside a few hundred feet above sea level. Snowslides sometimes cause serious damage at certain points along the line, and falling timber is a source of considerable trouble during wind storms. The steam equipment consists of two 150-horsepower boilers and a 250-horsepower compound engine. Crude oil is used for fuel. A 1,600-barrel tank is provided for storage. The steam plant is used during low-water periods while the reservoir is filling. It is seldom operated more than 4 or 5 hours continuously.

Water power is also developed for the operation of a sawmill situated near the ocean dock. Water is collected in a small reservoir created by a timber dam across a small gulch back of the mill. This supply is augmented by a system of contour ditches which collect the water along the hillside and lead it to the reservoir. A head of about 170 feet is obtained at the mill by carrying the water through 1,800 feet of pipe consisting of 450 feet of 14-inch riveted steel, 450 feet of 15-inch riveted steel, and 900 feet of 18-inch continuous wood-stave pipe. The mill is operated by a 48-inch Tutthill wheel and a 48-inch Pelton wheel with rated capacities of 90 and 60 horsepower, respectively, directly connected to the various machines and log hauls. An 18-inch Tutthill wheel is used to drive several small machines and a 5-kilowatt, 125-volt direct current generator, which furnished electricity for lighting.

ORCA.

The Northwestern Fishing Co. has installed one 36-inch and two 16-inch Pelton water wheels at its cannery at Orca. Water is diverted from a small gulch back of the cannery and carried through 700 feet of 8-inch riveted steel pipe to the wheels, where a head of about 240 feet is obtained. The flow of the stream is sufficient for the operation of the wheels only when the run-off is above the average, owing to rains or melting snow. Water power is supplementary to steam power. Large volumes of steam are required in connection with the canning processes. The company has installed two 150-horsepower boilers, also three 15-horsepower upright steam engines, one 15-horsepower gasoline engine, and a 7.5-kilowatt direct-current generator.

LANDLOCKED BAY.

The Chisna Consolidated Mines Co. installed a small plant on the beach at the mouth of its tunnel several years ago. Water is obtained from Chisna Creek under a head of about 50 feet. Two small Pelton wheels were used to operate a small sawmill, dynamo, and hoist. The plant was nearly in ruins in the summer of 1913 and evidently had not been operated for some time.

GALENA BAY.

The plant of the Galena Bay Mining Co. is on Bottle Creek about 1½ miles from the bay. A rock-filled timber-crib dam 25 feet high crosses the creek at the head of a rock gorge. The power house is situated at the base of the dam and contains a 150-horsepower Francis turbine and a 90-kilowatt dynamo. The fall between the the crest of the dam and the base of the draft tubes is about 48 feet. The electricity has been used for lighting and to operate an air compressor at the mine. The plant has not been in operation for several years. It is said that the water supply was inadequate much of the time during the winter months. Measurements of stream flow on Bottle Creek are published on page 84 of this report.

PORT VALDEZ.

SOLOMON GULCH.

Two water-power plants have been installed on Solomon Gulch. The lower plant is on the beach at the mouth of the creek. This plant was constructed about 1904, and until July 1, 1913, was operated under lease. The lease was held by the Alaska Water, Light & Telephone Co. after June, 1907. The essential equipment consisted of a 150-kilowatt generator operated by a Pelton water wheel. Water was diverted from Solomon Gulch about one-half mile from the power house at an elevation of about 400 feet, and carried in a 2 by 3 foot flume for about one-fourth mile to a point on the ridge facing the bay, where it was conducted through a riveted steel pipe to the power house below. The pipe is 18 inches in diameter at the upper end and 12 inches at the power house. About 1,500 feet above the intake, at the head of the rapids, a dam 14 feet high was built to create storage to carry the daily peak load during low-water periods. The energy was transmitted to Valdez for use for lighting and power.

The company has an auxiliary steam plant at Valdez that is used in case of an interruption in the hydroelectric service. It is also available as an auxiliary power at times of low water. It is understood that the water supply even at times of minimum flow in the winter is ordinarily sufficient to furnish all the power that is demanded of the system.

In the spring and summer of 1913 the Alaska Water, Light & Telephone Co. built what is now sometimes known as the "upper plant." The power house, which is situated just above the intake of the lower plant, is a 1½-story wood building, 25 by 45 feet in dimensions. Water is diverted through the base of the storage dam, 1,500 feet above, and carried in a continuous wood-stave pipe made up of 500 feet of 36-inch, 500 feet of 33-inch, and 500 feet of 30-inch, to a 26-inch special Francis turbine rated at a normal capacity of 375 horsepower, with a maximum capacity of 500 horsepower. An effective head of about 140 feet is obtained. The generator is an alterating current, 60-cycle, 2,300-volt machine with a rated capacity of 150 kilowatts. Provisions were made for the installation of a second unit like the above if the demand for power should exceed the initial installation.

The dam was raised to a height of 22 feet to increase the storage for use at times of low run-off in the winter. It is constructed of concrete. Sand and gravel were obtained from the creek bed above the dam site. Suitable switchboards are provided at the power house and a set of transformers raises the current to 6,600 volts for transmission. The line is a two-phase system carried on wooden poles, and extends from the power house to Valdez, a distance of about 4½ miles. Across the tide flats at the head of the bay the poles were driven with a pile driver to a depth of 8 to 10 feet, at high tide. That was done to give them extra security against the action of Lowe River and other glacial streams that are continual sources of trouble.

In the fall of 1913 the Valdez Electric Co. was organized to operate the old plant in competition with the one recently installed. A transmission line was built to Valdez and the old water wheel was replaced by one of more modern type. Exact information is not available concerning the operation of this plant, but it is understood that electricity was first transmitted to Valdez about December 1, 1913.

Measurements of the discharge of Solomon Gulch are listed on page 97.

GLACIER CREEK.

A stamp mill was erected on Mineral Creek near the mouth of Glacier Creek in the summer of 1913. A 36-inch Pelton water wheel was directly connected to the main shaft to furnish power. Water for the operation of the wheel will be obtained from Glacier Creek, at an elevation sufficient to give a head of about 170 feet. The conduit consists of 200 feet of 10-inch by 12½-inch board flume, and 600 feet of steel pipe tapering from a diameter of 10 inches at the pressure box to 3 inches at the power house.

The mill was built by the owners of the Mountain King mine. It has two 1,200-pound stamps. The mine was closed about the time the mill was completed, so that the plant was not put in operation in the fall of 1913. It was planned to commence operation in the spring of 1914.

For stream-flow data, see page 97.

UNO CREEK.

The Sea Coast Mining Co. began the installation of an hydroelectric plant at the mouth of Uno Creek in 1913. A power house of wood construction was built and a right of way was cleared of brush and prepared for laying a riveted steel pipe line. It is proposed to divert the water from Uno Creek by a low, inexpensive dam at an elevation of 321 feet above the wheel shaft. The plans contemplate the installation of a 290-horsepower Francis-Pelton turbine and an alternating current generator of suitable capacity. A part of the energy will be used to operate a small stamp mill that the power company plans to erect. The excess power will be offered for sale to other mines in the vicinity of Shoup Bay that may need power.

Data regarding the flow of Uno Creek are published on pages 95–96 of this report.

WATER-POWER SITES.

The water-power sites of Prince William Sound are as a rule small but widely distributed. The northern part of the sound from Cordova to Port Wells was examined in some detail. In that section there is hardly a bay or inlet but what has one or more tributary streams on which small water powers could be developed for 6 or 8 months during the year. During the months of low-water flow—from January to April—most of the streams reach a very low stage. There are but few streams on which more than two or three hundred horsepower could be developed at minimum flow, and it is doubtful if there is a single stream on which a plant of more than 1,000 horsepower could be operated continuously without storage. There are, however, numerous sites where small to medium-sized reservoirs could be created, and thus many of the streams made to yield at least a small output throughout the year.

One of the most favorable sites for storage is at Silver Lake on Duck River, near Galena Bay. Nearly the entire run-off could probably be controlled by a dam at the outlet, and a uniform output of 4,000 horsepower or more obtained throughout the year. Some other favorable power sites, though affording less storage than Silver Lake, are Power Creek near Cordova, Solomon Gulch near Valdez, an unnamed stream entering Eaglek Bay, and Davis Creek and Avery River tributary to Port Wells. Detail descriptions of the various sites are published on preceding pages.

There is reported to be a power site on Latouche Island. The Beatson Copper Co. has obtained a permit from the Forest Service and is making preliminary investigations. The project involves the diversion of the water of several creeks through pipe lines into a reservoir formed by damming a small lake. From this reservoir the water is to be conducted to the wheels by a pipe line 4,200 feet in length.

In the western part of the sound south of Port Wells there are said to be several good water powers, but no data are available regarding their size or accessibility.

The transmission of electricity is one of the most serious difficulties that will be encountered in utilizing the water powers. Steep rocky mountain slopes, dense growths of bush and trees, heavy snowfall and snowslides, glaciers and broken shore lines are some of the obstacles to be overcome. Unless a market can be created for the power within a short distance of its source it is doubtful if it will ever become of much value. There are, however, good harbor facilities in nearly all parts of the sound, so that ocean-going boats can be anchored within easy transmission distances from the powers. Submarine cable is now being manufactured that will carry electric current up to a pressure of over 20,000 volts. Considerable cable with a capacity of 200 to 300 amperes for 11,000 volts working pressure has been used. Such cable, though expensive, might be practicable for use in crossing narrow bays and inlets where long land lines would be required to carry it around them, or to reach from island to mainland, or from island to island. It might also be of service in crossing glaciers where an overhead line would be very expensive to maintain.

The manufacture of wood pulp should offer a particularly suitable use for the water powers because of the fact that both the timber and the power sites are near tidewater. It is claimed that pulp logs can be towed a distance of 150 to 200 miles at a permissible cost, thus eliminating the necessity of transmitting electricity for long distances to the mills. Any one water power in Prince William Sound would, under such conditions, be within reach of the entire timber supply.

KENAI PENINSULA.

GENERAL FEATURES.

Kenai Peninsula projects from the Alaska mainland in the north-central portion of the Gulf of Alaska. It has an area of approximately 9,000 square miles, most of which lies between meridians 148° and 152° west longitude and parallels 59° and 61° north latitude. The peninsula is bounded by Prince William Sound on the east, the Pacific Ocean on the south, and Cook Inlet on the west. On the north it is joined to the mainland by a strip about 12 miles wide, which separates Portage Bay and Turnagain Arm. These bodies of water are arms of Prince William Sound and Cook Inlet, respectively. Kenai Peninsula has a shore line more than a thousand miles long.

The surface of the peninsula presents two widely differing physiographic features. About three-fourths of its area, lying in the eastern, central, and southern parts, is characterized by high rugged mountains, 5,000 to 7,000 feet in elevation, which are known as the Kenai Mountains, and by valleys deeply cut by the action of the former ice sheet that covered the area, and remnants of which are still found in the higher portions of the peninsula. The remaining fourth consists of a broad lowland, about 25 miles wide, which slopes from an elevation of about 1,800 feet on the south near Kackemak Bay to an elevation of about 50 feet on the north.

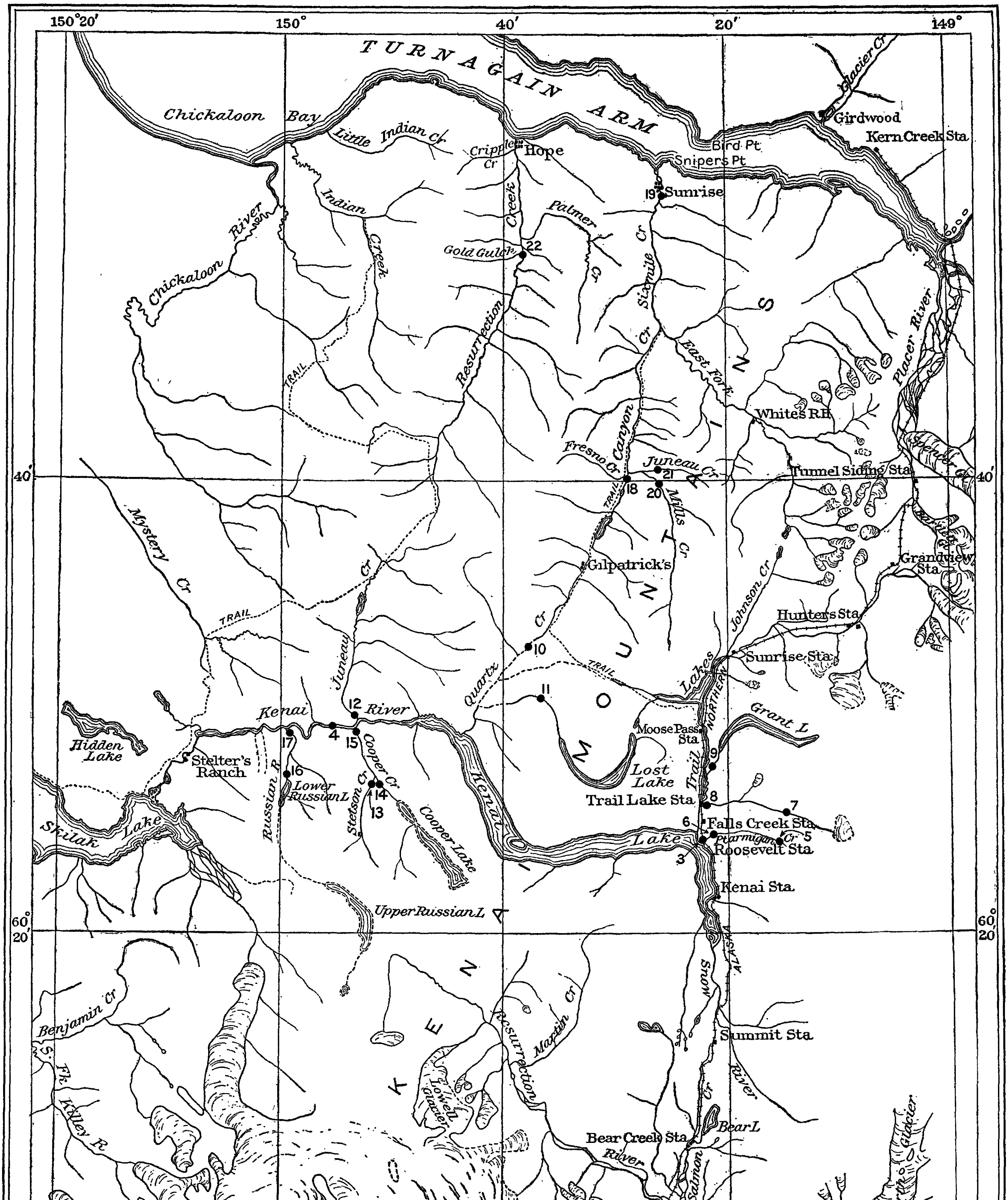
The Kenai Mountains divide lies close to the eastern and southeastern side of the peninsula so that the drainage is principally toward the west and north and the streams flowing into the Pacific and Prince William Sound are short. The largest of the latter is Resurrection River, which is about 25 miles long. It drains an area southwest of Kenai Lake and flows through a wide gravel-floored valley into the head of Resurrection Bay. Kenai River, the largest stream on the peninsula, drains its entire central portion and discharges into Cook Inlet at Kenai. Its drainage area includes two large lakes, Skilak and Kenai, and numerous smaller lakes on its upper tributaries. Kasilof River drains Tustumena Lake and enters Cook Inlet a short distance south of Kenai. Tustumena Lake is about 22 miles long and 6 miles in average width. It is fed by several streams, some of which have their sources in the large glaciers in the Kenai Mountains. Two small streams, Chickaloon and Big Indian rivers, drain a part of the Kenai lowland and discharge into Chickaloon Bay near the west end of Turnagain Arm. The principal streams entering Turnagain Arm from the mountainous area of the peninsula are Resurrection and Sixmile creeks and Placer River.

The fact that steep gradients and waterfalls are identified with streams draining areas of rugged mountainous relief make it obvious that the eastern portion of the peninsula would afford much more favorable opportunities for water-power development than the western portion. Moreover, gold mining, which is the most important industry of the peninsula and which at this time presents the most promising market for water power, is confined to the mountainous area. The investigation of the water supply of the peninsula was carried on only in its eastern portion.

MINERAL RESOURCES.[1]

Gold-bearing lodes have been discovered at many points in the eastern part of Kenai Peninsula, and at the present time form the principal mineral resource of that region. The most important lodes

[1] The mineral resources of Kenai Peninsula are fully treated in Bulletin 587 of the U. S. Geological Survey, Geology and mineral resources of Kenai Peninsula, Alaska, by G. C. Martin, U. S. Grant, and B. L. Johnson, published in 1915.



MAP OF EASTERN PART OF KENAI PENINSULA SHOWING LOCATION OF GAGING STATIONS AND MEASURING POINTS.

are those near Falls Creek, Porcupine Creek, and Moose Pass. Gold quartz veins also occur at several localities between Kenai Lake and Seward. The veins so far discovered are all small. Four or five stamp mills of small capacity have been installed and several similar installations are contemplated. Gold placers have been worked quite extensively on Sixmile River and Resurrection Creek and their tributaries, also on Cooper and Quartz creeks. Most of the richest deposits are now worked out, and the future of placer mining on the peninsula depends almost entirely on whether the low-grade deposits which are practically unexploited can be made to yield a profit.

Considerable bodies of lignitic coal occur in the western part of the peninsula. In any comprehensive study of the power resources of this region those beds would be worthy of consideration.

The Matanuska coal field,[1] containing areas of workable high-grade coal, lies about 65 miles northeast of Turnagain Arm, and the future development of this field is a further factor to be considered in planning extensive hydroelectric installation in Kenai Peninsula.

TIMBER.

Kenai Peninsula is quite heavily timbered in most of its valleys up to elevations of 1,200 to 1,500 feet above sea level. Spruce is the most plentiful variety and the most valuable for commercial uses, but hemlock is found in some localities, and also poplar, birch, cottonwood, willow, and alders. The alders cover the mountain slopes with dense and often almost impenetrable thickets to elevations considerably above the limit of the spruces. A luxuriant growth of wild hay can be found extending well up into the timberless area, but nearer the summits the mountain sides become craggy and rock strewn and support only a limited moss growth.

Except for a strip across the southeastern side, the peninsula lies entirely within the Chugach National Forest. This does not mean that the timber supply is generally distributed over the area because, in fact, the really valuable timber is restricted to a few localities. Immense tracts have been destroyed by the ravages of forest fires, which originated from careless campers or accidental causes. The country is too sparsely populated for dealing with these fires promptly and in an effective way, and once started they can quickly reduce an area covered by timber and moss which it has taken centuries to produce to a waste strewn and tangled with dead and falling trees. The officials of the forest reserve have made energetic efforts to cope with these fires, but too often their handicap is so great as to make their efforts ineffectual. The officials of the Chugach National Forest also have jurisdiction over the development of water power within its boundaries.

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[1] Martin, G. C., and Katz, F. J., Geology and coal fields of the lower Matanuska Valley, Alaska: U. S. Geol. Survey Bull. 500, 1912.

The local spruce lumber was used to some extent in the structures of the Alaska Northern Railway, which has been built across the peninsula, for, although it did not show as great strength as the timber from the States, in many places its use at about $25 per thousand feet was found to be more economical than the latter at $35 to $40 per thousand. Near most of the mining camps there is sufficient timber of a quality satisfactory for mining structures. The quantity of timber which will square greater than 12 inches is very small. All demands for better grades of lumber are supplied from Seattle. The supply of timber suitable for fuel is plentiful, and with labor costing $3 to $4 per day with board cord wood can be procured at quite a reasonable figure.

GAGING STATIONS AND MEASURING POINTS.

The points at which gaging stations were maintained or discharge measurements made on streams in Kenai Peninsula in 1913 are shown by the following list. The numbers correspond to those given on Plate XVI.

1. Lowell Creek above pipe intake.
2. Lowell Creek at mouth.
3. **Kenai Lake at Roosevelt.**
4. **Kenai River at Kenai Dredging Co.'s camp.**
5. Ptarmigan Creek at lake outlet.
6. Ptarmigan Creek at mouth.
7. Falls Creek at intake of Skeen-Lechner ditch.
8. **Falls Creek at railroad crossing.**
9. Grant Creek at mouth.
10. **Quartz Creek at Fairman's Cabin.**
11. Lost Creek 3 miles below lake outlet.
12. Juneau Creek at mouth.
13. Stetson Creek at mouth.
14. Cooper Creek above Stetson Creek.
15. Cooper Creek at mouth.
16. Russian River ¼ mile below lower lake outlet.
17. **Russian River at mouth.**
18. Canyon Creek above Mills Creek.
19. **Sixmile Creek at Sunrise.**
20. **Mills Creek 2 miles above mouth.**
21. Juneau Creek above upper ditch intake.
22. Resurrection Creek above Gold Gulch.

NOTE.—Black-faced type indicates regular gaging stations; light-faced type points of miscellaneous measurements.

LOWELL CREEK.

Lowell Creek is one of the short streams that drain the eastern slope of the Kenai Mountains. It heads in a high glacier west of the town of Seward, and in its course of approximately 5 miles drops with a very steep gradient to its mouth near the head of Resurrection

Bay. (See Pl. XVII, *A*.) It depends for its summer flow principally on the melting of the snow banks and glaciers; in winter its flow is maintained by the occasional thaws and rains. Lowell Creek supplies water for the operation of the hydroelectric plant of the Seward Light & Power Co., which is described on pages 131–133.

Two discharge measurements were made above the pipe intake of this plant and one at the mouth below the return water from the wheel. The last shows a large loss by seepage as the creek passes over the coarse gravel fan which it has deposited as it emerges from its narrow valley.

Discharge measurements of Lowell Creek in 1913.

Date.	Point of measurement.	Discharge.	Date.	Point of measurement.	Discharge.
		Sec.-ft.			*Sec.-ft.*
Aug. 15	Above pipe intake	58	Oct. 28	At mouth	9.3
Oct. 28	do	18.8			

TONSINA CREEK.

Power development has been contemplated on Tonsina Creek, which is the next stream south of Lowell Creek and enters Resurrection Bay about 3 miles south of Seward. The creek is similar in character to Lowell Creek but drains a smaller area. Observation has shown the winter flow to be small and undependable, and the project was consequently abandoned.

RESURRECTION RIVER.

The largest of the streams flowing from the eastern slope of the Kenai Mountains is Resurrection River, whose drainage area lies southwest of Kenai Lake. It is about 25 miles long and its mouth is at the head of Resurrection Bay, about 2 miles from Seward.

Resurrection River is a typical glacial stream, wild and unruly in times of flood, but decreasing to a rivulet in prolonged periods of low temperature. In its lower part it flows through a flat gravel valley, and in many places splits into several channels. (See Pl. XVII, *B*.) The fall in this section is 25 feet to a mile. A scheme to develop power by diverting water in a canal for 3 or 4 miles and utilizing the head thus gained has been abandoned as impracticable.

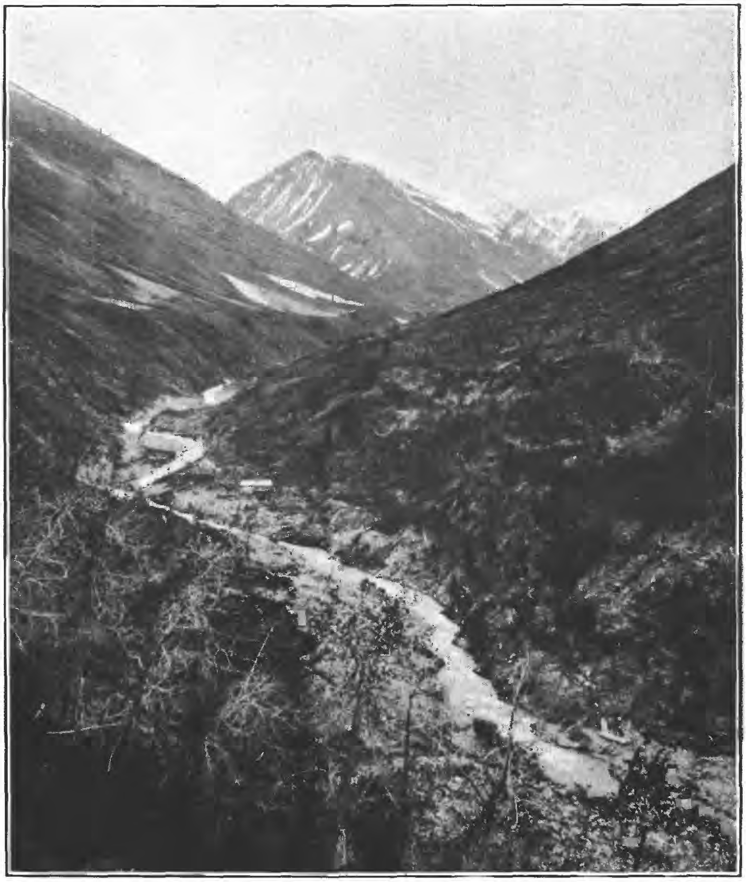
KENAI RIVER DRAINAGE BASIN.

GENERAL FEATURES.

Kenai River drains an area about 90 miles long in an east-west direction and 20 miles in average width. From its mouth on Cook Inlet it stretches nearly across the central part of the peninsula to the head of

A. LOWELL CREEK AT PIPE INTAKE.

B. RESURRECTION RIVER, LOOKING UPSTREAM.



A. UPPER VALLEY OF MILLS CREEK.

B. WEST END OF KENAI LAKE.

Snow River, its most remote tributary. Snow River rises in the glaciers of the mountains bordering the shore of Prince William Sound and discharges into the upper end of Kenai Lake. Kenai Lake is about 22½ miles long and has an area of 22 square miles. (See Pl. XVIII, *B*.) It seems probable that it was formed by the deposition of gravels in the lower part of the valley by the glacier which formerly occupied it, and possibly the lake was scraped out and deepened by the same agency. Streams entering Kenai Lake are Porcupine, Ptarmigan, Trail, and Quartz creeks. Kenai River commences at the outlet of the lake and in the 16 miles to its entrance into Skilak Lake is joined by Juneau and Cooper creeks and Russian River. Skilak Lake is 18 miles long and has an area of 38 square miles. No important drainage comes into it. Below Skilak Lake Kenai River follows a tortuous course of about 50 miles through the flat, plateau-like country to Cook Inlet. Two large tributaries, Killey and Funny rivers, enter from the south in this section.

The eastern part of the basin is characterized by the rugged mountains and glaciated valleys that have already been noted. The former glaciers have also left their mark in the lakes which are found on several of the tributaries. Both of these features are favorable to the development of water power, since heavy falls are usually concentrated near the point where the hanging valley breaks into the main one, and since also the lakes supply possible sites for storage reservoirs. Comparatively heavy grades are found on all the streams, at least over considerable portions of their courses.

KENAI RIVER BETWEEN KENAI AND SKILAK LAKES.

Kenai and Skilak lakes, or Upper and Lower Kenai lakes as they are locally known, lie 460 and 150 feet, respectively, above sea level. Thus, the fall of the river in the 16 miles between the lakes is approximately 310 feet, and, as determined by aneroid, this fall is distributed akout as follows: 60 feet from the Coopers Landing at the outlet of Kenai Lake to the camp of the Kenai Dredging Co., about 3½ miles; 70 feet from this point to the mouth of Russian River, a distance of 3 miles; and about 180 feet in the remaining 9½ miles. There are no falls on Kenai River and rowboats pass down it safely at ordinary stages, but the grade is concentrated in rapid stretches where the current is so swift as to make the hauling of boats up the river very laborious. For 4 or 5 miles below the mouth of Russian River it winds through a flat gravel valley in channels that are constantly shifting and readjusting themselves. Through the remaining section the stream is confined to one permanent channel.

The natural conditions on this stream suggest that the water power available could probably be developed most comprehensively by means of a diversion dam, which would turn the flow of the stream through a canal to some point lower, where a power house could be built and the fall utilized. Although the fall of Kenai River is sufficient to make power development practicable at many points, some of these points are much more favorable than others. Unquestionably power would first be developed in the vicinity of the rapids, which would limit the choice to three sites. There are rapids about one-half mile below Cooper's Landing, which is at the outlet of the lake; a second noticeably heavy grade in the stream is at Schooner Bend, about 5 miles from Coopers Landing, and a third is in the vicinity of the canyon, about 10 or 11 miles below the same point. Below Kenai Lake the river flows for several miles over immense gravel deposits of unknown depth, but at the canyon mentioned above it passes out of this formation and is confined between narrow rock walls for a short distance. A stable dam upon the gravel of the upper valley would undoubtedly require a pile foundation. In the canyon a dam could probably be founded upon bedrock. Timber cribwork filled with rock is thought to be the most economical type of construction for a dam in this locality under present conditions.

The outlet of Kenai Lake is wide and deep and the banks are comparatively low. These conditions do not favor an economical development of storage on the lake. However, these obstacles are not prohibitive to the construction of a dam if the necessary expenditure were warranted.

The minimum discharge of Kenai River from August 18, 1913, to January 31, 1914, is estimated at 504 second-feet; the average flow for the three following months would probably be considerably less. The discharge estimated would develop about 40 horsepower per foot of fall with an efficiency of 70 per cent at the wheel.

KENAI LAKE AT ROOSEVELT.

On August 18, 1913, a gage was installed on Kenai Lake at Roosevelt and was read each day (except three days in October), until November 30. The stage of the lake is reported to have fallen at a uniform rate from this date until December 15, when the final reading was made. The lake froze over on the night of December 15. Kenai Lake is usually frozen over throughout the winter and remains at a very low stage, but occasionally there are exceptions, for in December, 1911, the glacier at the head of Snow River released a tremendous volume of water, which kept the lake at a high stage for a considerable period, and it is reported that during the winter of 1911–12 the lake did not freeze over.

Daily gage height, in feet, of Kenai Lake at Roosevelt, Alaska, for 1913.

[Area 22 square miles. Fred C. Bunce, observer.]

Day.	Aug.	Sept.	Oct.	Nov.	Dec.	Day.	Aug.	Sept.	Oct.	Nov.	Dec.
1		8.67	9.25	7.08		16		6.90	6.98	6.63	
2		8.36	9.06	7.42		17		6.82	6.95	6.60	
3		8.30	8.96	7.38		18	8.89	6.78	6.95	6.53	
4		8.12	8.85	7.33		19	8.81	6.73	6.91	6.48	
5		7.90	8.71	7.35		20	8.82	6.69	6.86	6.41	
6		7.66	8.58	7.32		21	8.88	6.89	6.83	6.40	
7		7.62	8.29	7.26		22	9.02	7.24	6.77	6.32	
8		7.53	8.12	7.16		23	9.08	7.40	6.72	6.26	
9		7.44	7.98	7.01		24	9.14	7.64	6.60	6.09	
10		7.34	7.80	6.82		25	9.14	8.62	6.53	6.00	
11		7.24		6.73		26	9.12	9.34	6.49	5.93	
12		7.19		6.71		27	9.13	9.90	6.41	5.90	
13		7.14		6.68		28	9.15	9.90	6.35	5.79	
14		7.04	7.16	6.66		29	9.09	9.88	6.32	5.72	
15		6.88	7.09	6.65	5.03	30	8.80	9.63	6.52	5.66	
						31	8.72		6.81		

KENAI RIVER AT KENAI DREDGING CO.'S CAMP.

On August 19, 1913, a gage was installed on Kenai River at the camp of the Kenai Dredging Co., 3½ miles below Coopers Landing and about 1½ miles below the mouth of Juneau and Cooper creeks. Two discharge measurements were made at this point from a boat. For a considerable part of September and October it was not possible to obtain readings on this gage, and for these periods the daily discharge has been computed from measurements referred to the gage on Kenai Lake at Roosevelt and readings on that gage.

The Roosevelt gage is about 17 miles from the lake outlet at Coopers Landing and would give a fairly satisfactory indication of the discharge from the lake; but strictly it would not show the discharge at the dredging camp, because Juneau and Cooper creeks enter between the two points. However, it seems that the inaccuracy involved in this assumption can not be great, because there appears to be a fairly well defined relation between the readings of the two gages. For determining the discharges the readings on the Roosevelt gage were taken to the nearest tenth.

The discharge measurements are too few for a very accurate determination of the rating curve, especially at the lower stages, but since the results present the best available information on the flow of an important stream they are here published. The probable error of the monthly means should not exceed 15 per cent.

Kenai River falls very low in the winter, as is shown by the record for January, and it is said that it is often possible to wade across it with ordinary rubber boots. The rapids do not usually freeze entirely over.

Discharge measurements on Kenai River at Kenai Dredging Co.'s camp, 1913.

Date.	Width.	Area of section.	Mean velocity.	Gage height.		Discharge.
				Dredge camp gage.	Roosevelt gage.	
	Feet.	*Sq. feet.*	*Ft. per sec.*	*Feet.*	*Feet.*	*Sec.-ft.*
Aug. 19	202	816	5.53	7.94	8.81	4,510
Oct. 23	189	462	3.85	6.09	6.72	1,780

Daily gage height in feet, and discharge in second-feet, of Kenai River at Kenai Dredging Co.'s camp for 1913–14.

[Chas. G. Hubbard, observer.]

Day.	1913										1914	
	August.		September.		October.		November.		December.		January.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
1	......	......	7.8	4,280	......	5,040	6.2	1,920	5.40	1,070	5.00	740
2	......	......	7.6	3,960	......	4,900	6.4	2,160	5.40	1,070	5.00	740
3	......	......	7.4	3,640	......	4,760	6.5	2,300	5.45	1,120	5.00	740
4	......	......	7.4	3,640	......	4,480	6.5	2,300	5.50	1,160	5.10	820
5	......	......	7.2	3,320	......	4,340	6.6	2,440	5.50	1,160	5.10	820
6	......	......	7.1	3,160	......	4,200	6.6	2,440	5.50	1,160	5.00	740
7	......	......	7.0	3,000	......	3,780	6.6	2,440	5.50	1,160	4.90	660
8	......	......	6.8	2,720	......	3,500	6.4	2,160	5.50	1,160	4.80	580
9	......	......	6.9	2,860	......	3,360	6.4	2,160	5.45	1,120	4.70	504
10	......	......	6.4	2,160	......	3,090	6.3	2,040	5.40	1,070	4.80	580
11	......	......	......	2,320	......	2,800	6.2	1,920	5.40	1,070	4.80	580
12	......	......	......	2,320	......	2,600	6.2	1,920	5.30	980	4.70	504
13	......	......	......	2,200	......	2,400	6.2	1,920	5.30	980	4.70	504
14	......	......	......	2,080	......	2,320	6.1	1,800	5.25	940	4.70	504
15	......	......	......	1,960	......	2,200	6.1	1,800	5.20	900	4.70	504
16	......	......	......	1,960	......	2,080	6.1	1,800	5.20	900	4.75	542
17	......	......	......	1,850	......	2,080	6.0	1,680	5.20	900	4.90	660
18	......	4,620	......	1,850	......	2,080	5.90	1,560	5.20	900	4.80	580
19	8.0	4,620	......	1,740	......	1,960	5.90	1,560	5.25	940	4.75	542
20	8.0	4,620	......	1,740	......	1,960	5.80	1,460	5.35	1,020	4.70	504
21	8.0	4,620	......	1,960	......	1,850	5.80	1,460	5.35	1,020	4.70	504
22	8.0	4,620	......	2,320	......	1,850	5.75	1,410	5.30	980	4.70	504
23	8.2	4,980	......	2,570	......	1,740	5.70	1,360	5.40	1,070	4.70	504
24	8.2	4,980	......	2,830	6.1	1,800	5.70	1,360	5.40	1,070	4.70	504
25	8.2	4,980	......	4,200	5.85	1,510	5.70	1,360	5.30	980	4.70	504
26	8.2	4,980	......	5,180	5.90	1,560	5.60	1,260	5.30	980	4.80	580
27	8.3	5,160	......	6,070	5.90	1,560	5.50	1,160	5.20	900	4.80	580
28	8.3	5,160	......	6,070	5.90	1,560	5.50	1,160	5.20	900	4.70	504
29	8.2	4,980	......	6,070	5.90	1,560	5.50	1,160	5.20	900	4.70	504
30	8.0	4,620	......	5,620	6.2	1,920	5.40	1,070	5.10	820	4.70	504
31	7.9	4,440	......	......	6.2	1,920	......	......	5.10	820	4.70	504
Mean		4,810		3,190		2,670		2,050		1,010		582
Run-off in acre-feet		134,000		190,000		164,000		122,000		62,100		35,800
Maximum		4,440		6,070		5,040		2,440		1,160		820
Minimum		5,160		1,740		1,510		1,070		820		504
Accuracy		B.		B.		B.		B.		C.		C.

PTARMIGAN CREEK.

Ptarmigan Creek drains an area east of Kenai Lake and flows westerly, entering the lake near Roosevelt post office about 5 miles below the head. It is about 4 miles from the mouth of the creek to its outlet from Ptarmigan Lake. Much of the water is derived from the thawing of the snowbanks and glaciers of the high altitudes, the glacial origin being indicated by the milky color of the water, which is characteristic of many glacial streams. Probably much of the suspended matter in the water settles in Ptarmigan Lake.

Ptarmigan Lake lies at an elevation about 300 feet above Kenai Lake and is approximately 3 miles long and one-third mile wide. Its outlet is through a narrow canyon with almost perpendicular rock walls; its banks on both sides are high. The site is very accessible and remarkably well adapted for a storage reservoir. It is estimated that a dam could be built 50 feet high with widths of 40 feet and 100 feet at the bottom and top, respectively. Although the data are too incomplete for making definite deductions regarding the flow, it seems reasonable to suppose that the reservoir formed by such a dam would store the run-off of the creek for the greater part of a year and would supply an admirable means for the control of stream flow. It is roughly estimated from the following measurements and by comparison with other records that at least 1,000 horsepower could be produced at this site throughout the year. A suggested plan of power development is by a ditch leading from the lake down the right side of the valley. Such a ditch, 3 or 4 miles long, and a terminal pipe line of moderate length, could probably be made to utilize the greater part of the fall down to the level of Kenai Lake. In some sections it might be necessary to use a flume and in others it might be advisable to carry the water through tunnels, but the utilization of the creek presents no problems whose solution would be difficult or would involve heavy expense.

The following discharge measurements were made on Ptarmigan Creek:

Discharge measurements of Ptarmigan Creek in 1913.

Date.	Locality.	Discharge.	Date.	Locality.	Discharge.
		Sec.-ft.			*Sec.-ft.*
Aug. 16	500 feet below lake outlet	156	Oct. 11	Mouth	92
Oct. 10	do	95	Oct. 20	do	71

FALLS CREEK.

Falls Creek drains a part of the high, rugged area east of Kenai Lake and north of the Ptarmigan Creek basin. It rises in a high glacier and descends with a steep gradient for about 8 miles to the place where it joins Trail Creek, 1½ miles from its mouth. There are falls about 1 mile from the mouth, where the most favorable conditions for power development on the stream are to be found, but the grade is sufficiently steep over many sections of its course to meet the requirements.

The gold quartz mill of Skeen-Lechner mine is on this creek about 4 miles from its mouth. It is operated by water power in the summer and steam power in the winter, using wood for fuel. A Pelton wheel, 6 feet in diameter, rated at 68 horsepower, is used for running the stamps and an 18-inch wheel for the concentrator and lights. The water is diverted through a ditch 1,000 feet long to the plant, where a head of 112 feet is obtained. The following information regarding the operation of the plant was furnished by P. H. Holdsworth on March 17, 1914.

Steam power was used after November 13, 1913. When cold weather came the creek first froze from the bottom up, but later cut a channel next to the gravel and was estimated to have discharged approximately 180 miner's inches (4.5 second-feet) throughout the winter. At the beginning of cold weather considerable trouble was experienced in passing water through the ditch. It was caused largely by trying to keep the ditch free of ice, but as soon as it became frozen over and covered with snow the bottom and the sides below the ice line were thoroughly thawed. All the water that could be diverted (from 2 to 3 second-feet) at the intake was allowed to pass through the ditch during the winter and no anchor or slush ice was formed. If a bedrock dam had been constructed at the intake, so that all the water could have been diverted, the mill could probably have been operated throughout the winter by water power.

The flow of the creek fluctuates rather widely, as is shown by the accompanying short record. This is due partly to the steep slopes of the drainage basin and the lack of natural storage, in consequence of which the rainfall tends to pass quickly down the stream. The basin possesses no sites favorable for the artificial development of storage. Much of the basin lies in a deep valley and on the northern slope, so that, beginning in October, the sun does not strike these areas for several months and the thawing is very slight. Large quantities of anchor and slush ice flow down the stream during the fall.

A gage was established on Falls Creek on August 23, 1913, about one-fourth mile above its junction with Trail Creek. It was fastened to the right abutment of the Alaska Northern Railway bridge. Gage readings were made until November 7, when the creek was reported as freezing up for the winter.

Discharge measurements of Falls Creek in 1913.

Date.	Locality.	Gage height.	Discharge.	Date.	Locality.	Gage height.	Discharge.
		Feet.	*Sec.-ft.*			*Feet.*	*Sec.-ft.*
Aug. 17	At intake of Skeen-Lechner Ditch.	....	[a] 35	Aug. 23	Alaska Northern Ry. crossing.	3.38	72
Oct. 10	.....do.....	....	[a] 14.3	Oct. 9	.....do.....	2.87	24
Aug. 17	Alaska Northern Ry. crossing.	3.20	51	20	.....do.....	3.45	[b] 15.7

[a] Includes flow of ditch. [b] Ice conditions.

Daily gage height, in feet, and discharge, in second-feet, of Falls Creek at railroad bridge near Roosevelt, Alaska, for 1913.

[Drainage area, 15 square miles. Joe Irvine, observer.]

Day.	August.		September.		October.		November.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
1			3.00	34	3.05	38	2.85	23
2			3.00	34	2.80	20	2.70	15
3			2.95	30	3.00	34	2.65	13
4			2.80	20	3.00	34	2.70	15
5			2.80	20	3.10	42	2.68	14
6			2.80	20	3.00	34	2.65	13
7			2.80	20	2.95	30	2.55	10
8			2.75	18	2.90	26		
9			2.70	15	2.88	25		
10			2.68	14	2.85	23		
11			2.65	13	2.90	26		
12			2.65	13	2.86	24		
13			2.60	11	3.00	22		
14			2.60	11		20		
15			2.60	11		20		
16			2.50	9		18		
17	3.20	52	2.70	15		18		
18		52	2.65	13		16		
19		50	2.68	14		16		
20		50	2.70	15	3.45	16		
21		60	2.70	15	2.75	18		
22		70	2.80	20	2.75	18		
23	3.38	72	3.50	86	2.60	11		
24	3.36	69	4.05	173	2.60	11		
25	3.38	72	4.75	312	2.55	10		
26	3.30	62	3.80	130		10		
27	3.30	62	3.40	74		10		
28	3.20	52	3.25	57		10		
29	3.20	52	3.15	47		20		
30	3.10	42	3.10	42	3.10	42		
31	3.05	38			2.90	26		
Mean discharge		57.0		43.5		22.2		14.7
Second-feet per square mile		3.80		2.90		1.48		.980
Run-off (depth in inches on drainage area)		2.12		3.24		1.71		.26
Maximum		72		312		42		23
Minimum		38		9		10		10
Accuracy		B.		C.		C.		B.

NOTE.—Gage heights affected by ice and discharge estimated Oct. 13-20, 26-29.

GRANT CREEK.

Grant Creek, like Ptarmigan and Falls creeks, has its source in the western slope of the Kenai Mountains, northeast of Kenai Lake, and lies approximately parallel to them on the north of Falls Creek. It drains an area larger than either of these creeks and empties into Trail Creek in the rapid between the Upper and Lower Trail lakes. An important feature of the basin is Grant Lake, whose water surface is about 215 feet above Trail Lake. Its outlet is 1½ miles from the mouth of the creek and it occupies a basin between the steep mountain slopes, approximately 5 miles long and one-half mile wide. Within a short distance from the outlet of the lake the creek descends through a series of rapids and falls into a narrow box canyon, through which it flows the greater part of the way to its junction with Trail Creek.

Its concentrated fall and the availability of the lake as a storage reservoir are factors which make Grant Creek very attractive as a source of water power. It is roughly estimated, from the measurements below and by comparison with records on other streams, that at least 1,500 horsepower could be developed throughout the year at this site by utilizing storage; but without storage the low-water flow might not be sufficient to produce more than three or four hundred horsepower. Of course, on a hasty reconnaissance the feasibility of development can not be definitely determined, but certain schemes of suggested development may be very briefly discussed.

A plant might be built near the outlet of the lake, utilizing only the head furnished by the falls and rapids near this point. The power house would have to be located in a rather inaccessible deep canyon, and this would present some objectionable features.

A conduit diverting from the lake outlet to a point near the mouth of the creek would have to pass for a considerable distance along the almost perpendicular wall of a box canyon.

There are two low passes, one lying on each side of the lake outlet, through which it would be possible to divert water to a power house near the level of Trail Lake. The pass on the right is about 1½ miles above the outlet. At this point it is about 3,500 feet between the lakes, the summit of the dividing ridge being about 40 or 50 feet above Grant Lake and 1,200 feet from it. A swamp 15 feet above the lake extends over half this latter distance. With the water level of the lake raised by a dam, it would be possible, with a combination of ditches, a tunnel, and a pipe line, to conduct the water to a power plant at the edge of Trail Lake at a comparatively low cost. The pass on the left of the outlet was not examined.

At the lake outlet it is estimated that a dam 20 feet high would have a length of 100 feet at the bottom and of 300 feet at the top. A higher dam would require considerable increase in the top length owing to the low slope of the left bank. The foundation would be of rock.

Only two discharge measurements were obtained on Grant Creek, and the results appear below.

Discharge measurements of Grant Creek in 1913.

Date.	Locality.	Discharge.
		Second-feet.
Oct. 9	Mouth	155
Oct. 18	do	84

TRAIL CREEK.

The rapid between Upper and Lower Trail lakes, into which Grant Creek discharges, is about one-fourth mile long and has a fall of 8 or 10 feet. A dam raising the Upper Lake 10 feet could be built on a very favorable site, and its length would not exceed 150 feet. The water could be easily diverted around the rapids in a canal. Such a reservoir would overflow several miles of the track of the Alaska Northern Railway, and so might not prove feasible.

QUARTZ CREEK.

Quartz Creek drains a compact area of 104 square miles lying north of Kenai Lake. Its main valley extends from the mouth of the creek, which is 4 miles from the outlet of Kenai Lake, in a northeasterly direction to the point at which it merges with that of Canyon Creek, the two valleys constituting a low pass from Kenai Lake to Turnagain Arm. Near this pass Quartz Creek valley makes a sharp turn up into the mountain on the southeast. Although the creek has much grade in this upper portion, the tributary drainage is too small to meet a demand for large power. From the pass to Devil Creek, a distance of 4 miles, the creek falls 500 feet, and from that point to the mouth, a distance of 6 miles, the fall is about 300 feet. In this lower portion the creek meanders through a wide flat valley for much of the way, and power development would be impracticable, but in the upper part the valley is narrow and the stream is confined to one channel. Here the conditions are more favorable. This section of the creek has the disadvantage of having no means of increasing the storage upon it.

The principal tributaries of Quartz Creek are Devil and Lost creeks. The former comes in from the northwest; its grade is steep, but its drainage area is too small to make it a very dependable source of water supply. Lost Creek rises in Lost Lake, which lies north of Kenai Lake and at an elevation about 800 feet above it. From the lake outlet it flows northwest and then swings around to the southwest, to its junction with Quartz Creek, about 2 miles from Kenai Lake. Lost Creek has a heavy grade over nearly its whole length, which is about 6 miles, and 1½ miles from its mouth there are falls. Lost Lake is 7 miles long and one-half mile wide and bends almost into a semicircle, with the convex side to the south. The outlet is wide and the banks are low. On the south it is about 2 miles through a low pass from Lost Lake to Kenai Lake. At its upper end there is a low pass to the head of Carter Creek, a short tributary of Upper Trail Lake from the south. If power development were contemplated from the water of Lost Lake, these passes are worthy of investigation as points of diversion. Short tunnels through the dividing ridges would probably be necessary for such a project. One discharge measurement was made on Lost Creek. The result appears in the list of miscellaneous discharge measurements on page 128.

A gage was installed on Quartz Creek on August 24, 1913, at the bridge just above Fairman's cabin, about 7 miles from the mouth and 1 mile above Devils Creek. The gage-height record was kept until November 7, when the creek was reported as freezing up. The results are given below.

Discharge measurements of Quartz Creek at Fairman's cabin in 1913.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*		*Feet.*	*Sec.-ft.*
Aug. 24	3.43	83.6	Oct. 18	3.09	46.2
Sept. 4	3.19	58.1			

Daily gage height, in feet, and discharge, in second-feet, of Quartz Creek at Fairman's cabin near Roosevelt, Alaska, for 1913.

[Drainage area, 30 square miles. Emmet W. Shields, observer.]

Day.	August.		September.		October.		November.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
1			3.30	66	3.35	72	3.30	66
2			3.27	63	3.30	66	3.25	61
3			3.25	61	3.30	66	3.20	56
4			3.20	56	3.40	78	3.20	56
5			3.18	54	3.40	78	3.19	55
6			3.19	55	3.35	72	3.15	52
7			3.18	54	3.30	66	3.15	52
8			3.12	50	3.30	66		
9			3.12	50	3.28	64		
10			3.10	48	3.25	61		
11			3.10	48	3.20	56		
12			3.10	48	3.28	52		
13			3.10	48	3.32	52		
14			3.10	48	3.40	52		
15			3.10	48		52		
16			3.08	46	3.15	52		
17			3.08	46	3.18	54		
18			3.05	44	3.10	48		
19			3.05	44	3.20	56		
20			3.05	44	3.18	54		
21			3.05	44	3.12	50		
22			3.05	44	3.10	48		
23			3.40	78	3.10	48		
24	3.43	82	3.75	135	3.10	48		
25	3.43	82	3.75	135	3.08	46		
26	3.40	78	3.65	117	3.08	46		
27	3.45	85	3.60	108		48		
28	3.50	92	3.50	92	3.10	48		
29	3.45	85	3.45	85	3.05	44		
30	3.43	82	3.40	78	3.30	66		
31	3.30	66			3.35	72		
Mean discharge		81.5		64.6		57.5		56.9
Second-feet per square mile		2.72		2.15		1.92		1.90
Run-off (depth in inches on drainage area)		.81		2.40		2.21		.49
Maximum		92		135		78		66
Minimum		66		44		44		52
Accuracy		B.		B.		B.		B.

NOTE.—Gage heights affected by ice and discharges estimated Oct. 12-15 and 27.

JUNEAU CREEK.

Juneau Creek flows almost due south from its source to its junction with Kenai River, 2 miles below Coopers Landing. Its basin presents an example of the typical hanging valley of this section. The upper part of its basin is comparatively broad and flat and it is locally called Juneau Flat, but about 2 miles from its mouth the stream plunges in a series of cataracts into a deep canyon, and when it emerges continues with an increased grade to its mouth. In the vicinity of the canyon the stream drops about 175 feet within one-fourth mile.

Juneau Lake is about 5 miles from the mouth. It is a small body of water and offers little opportunity for storage. The right side of the outlet rises abruptly but on the left the bank has a long gradual slope.

From 500 to 1,000 horsepower could probably be developed at the canyon from about the first of May until the last part of October, but the minimum flow in the winter might not be sufficient to produce more than one or two hundred horsepower. A record of two measurements made on Juneau Creek is given in the list of miscellaneous discharge measurements (p. 128).

COOPER CREEK.

Cooper Creek heads against Resurrection River and flows generally in a northwesterly direction to Kenai River, which it joins 2 miles below Coopers Landing. It rises in Cooper Lake about 5 miles from its mouth, and through most of its course it occupies a deep rock canyon cut in a broad glacial valley.

Cooper Lake is 6 miles long and about one-half mile in average width. It lies just over a high ridge from the lower end of Kenai Lake and its elevation is about 650 feet higher. Near the outlet the creek has a series of falls, and it is estimated that in a distance of 2 miles it drops 500 feet. That amount of fall would be sufficient to develop about 40 horsepower per second-foot of discharge, with an efficiency of 70 per cent at the wheel. Discharge measurements of Cooper Creek are shown on page 128. They are insufficient to make an estimate of the power capacity of the stream, but they indicate that probably at least 1,000 horsepower could be developed for 5 or 6 months of the year. In the winter the minimum flow might not be sufficient to produce more than 200 to 300 horsepower unless storage could be obtained. At the outlet of the lake the banks are low, so that a long dam would have to be built in order to raise the level of the lake.

Stetson Creek, the principal tributary, enters Cooper Creek about 3 miles from its mouth. Hydraulic mining was formerly carried on extensively in the stream flat near the mouth of Cooper Creek. The water was supplied from Stetson, Wildhorse, and Kickinghorse creeks. A high-line ditch diverts from Stetson Creek and carries along the mountain slope for 4 miles, then dropping to a lower ditch, through which the water flows for 1¾ miles and finally it passes through about 1,300 feet of flume.

RUSSIAN RIVER.

Russian River drains a long, flat glacial valley which, at its head, meets that of the main valley of Resurrection River and forms a low pass between the two drainage basins. Russian River is tributary to Kenai River about 6½ miles below Coopers Landing. There are two lakes in its basin, called, respectively, the Upper and Lower Russian lakes. The Upper Lake is 5 miles long and one-third of a mile wide, and is approximately 600 feet above sea level. Its outlet is said to afford a good site for a storage dam. From the Upper Lake Russian River flows first northwestward and then bends gradually to the north to its entrance into the Lower Lake, a distance of 6 miles. In the upper part of this stretch the stream meanders through low, buttelike hills which occupy the valley bottom, but in the low part the valley is simply a wide, swampy tundra flat. There is but little fall between the lakes.

The Lower Lake is the smaller of the two, being but 2 miles long and little more than one-fourth of a mile wide. Its elevation is estimated at 500 feet above sea-level. The outlet is wide and the banks are comparatively low. From the outlet of this lake the river flows 2 miles to its mouth and drops 170 feet. A large part of this fall is concentrated near the lake outlet.

Power development between the lakes is impracticable, but on the lower river a large part of the fall could undoubtedly be utilized.

Russian River drains an area sufficiently large to yield a very dependable water supply throughout the summer, and if further storage could be developed on the lakes the river would afford an excellent opportunity for power development. The minimum flow during the period covered by the records below was 57 second-feet. Under a head of 170 feet that flow would develop 769 horsepower, with an efficiency of 70 per cent at the wheel. Without storage the winter flow might not be sufficient to produce more than 25 per cent as much.

A gage was installed on Russian River on August 20, 1913, at a point about one-eighth mile above the mouth. The gage readings are somewhat broken. The final reading was made October 31. The discharge at the mouth does not differ very much from that at the outlet of the Lower Lake, for the tributary drainage between the two points is small. One discharge measurement was made of Russian River at the Lower Lake outlet and the result appears on page 128.

Discharge measurements of Russian River at the mouth in 1913.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*		*Feet.*	*Sec.-ft.*
Aug. 20	3.60	123	Oct. 6	3.92	259
Oct. 3	3.84	231	22	3.52	95.7

Daily gage height, in feet, and discharge, in second-feet, of Russian River at mouth, for 1913.

[Drainage area, 60 square miles. C. I. Olsen, observer.]

Day.	August.		September.		October.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
1				115	3.91	260
2				110	3.86	235
3			3.55	105	3.84	225
4				95		250
5			3.48	85	3.96	288
6			3.45	78	3.92	266
7			3.45	78	3.87	240
8			3.45	78	3.84	225
9				75		225
10				70		225
11			3.40	65		200
12				62		200
13				60		175
14			3.36	57		175
15			3.36	57		150
16			3.36	57		150
17			3.36	57		125
18			3.36	57		125
19			3.36	57		125
20	3.60	120		57		100
21	3.61	124	3.36	57		100
22	3.64	136	3.36	57	3.52	96
23	3.68	152	3.44	75		94
24	3.66	144	3.68	152		94
25	3.63	132	4.12	384		90
26	3.63	132	4.30	510		90
27	3.63	132	4.27	489		90
28	3.62	128	4.16	412		88
29		124	4.05	340	3.49	88
30	3.60	120	3.95	282	3.75	182
31		115				180
Mean discharge		130		141		166
Second-feet per square mile		2.17		2.35		2.77
Run-off (depth in inches on drainage area)		.97		2.62		3.19
Run-off in acre-feet		3,090		8,390		10,200
Maximum		152		510		288
Minimnm		115		57		88
Accuracy		B.		B.		C.

NOTE.—Discharge interpolated for days on which gage heights are missing.

MISCELLANEOUS MEASUREMENTS.

The results of miscellaneous discharge measurements made in the basin of Kenai River in 1913 are shown in the table following.

Miscellaneous discharge measurements in Kenai River drainage basin in 1913.

Date.	Stream and locality.	Discharge.	Drainage area.	Discharge per square mile.
		Sec.-ft.	*Sq. miles.*	*Sec.-ft.*
Oct. 17	Lost Creek 3 miles below lake outlet	61	22	2.79
6	Juneau Creek at mouth	103	63	1.63
24	....do	58	63	.92
Aug. 21	Stetson Creek at mouth	35	8	4.39
21	Cooper Creek above Stetson Creek	137	35	3.91
Oct. 6	Cooper Creek at mouth	210	47	4.47
24	....do	104	47	2.21
Aug. 20	Russian River ¼ mile below Lower Lake outlet	132	55	2.40

SIXMILE CREEK DRAINAGE BASIN.

GENERAL FEATURES.

Sixmile Creek drains an area of 258 square miles and enters Turnagain Arm about 16 miles from its head, at Sunrise. It is formed by the union of two large branches, East Fork and Canyon, about 9 miles from Sunrise. The basin is characterized by rugged mountains, many of which are between 4,000 and 5,000 feet in elevation. Most of the streams flow in narrow, steep valleys. A few small glaciers are found at the higher elevations.

From "the forks" to Sunrise, Sixmile Creek has a fall of about 325 feet. There are several rapids, and good dam sites exist at several places. The East Fork and its tributaries are admirably adapted topographically for power development. They have an abundance of rapids, falls, and dam sites. (See Pl. XV, *A*, p. 100.) The objection to it is the fact that its winter flow would be very small and there are no available reservoir sites of an ample size for increasing it. There is a small lake at the head of Bench Creek in Johnson Pass, but it would require a long dam to increase its storage, and the effect it could have upon the control of the stream would be slight.

Canyon Creek has a drainage area of 100 square miles at its mouth, in contrast to the East Fork, which has 117 square miles. Canyon Creek and its tributaries closely resemble the East Fork in character. About 8 miles from "the forks" Mills Creek, which has been an important placer mining stream in the past, branches off to the east. It has a very steep grade, but there are no storage sites on it. (See Pl. XVIII, *A*, p. 115.) Its summer flow is large, but in the fall the decreasing temperature reduces it to a mere rivulet. Juneau Creek is a tributary of Mills Creek, from which water has been obtained for hydraulic mining. Canyon Creek heads in two small lakes, called Upper and Lower Summit lakes, respectively, the former being the larger. No great storage could be obtained from either of these lakes.

SIXMILE CREEK AT SUNRISE.

A gage was installed on Sixmile Creek on August 27, 1913, on the left bank about one-half mile above the mouth, and was read twice each day until November 30. On December 2 the stream was reported as having frozen over except in the rapids.

The discharge measurements were made at a section of the stream opposite the Sunrise post office, about three-eighths of a mile below the gage. Very little drainage comes in between the two points.

Discharge measurements on Sixmile Creek at Sunrise in 1913.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*		*Feet.*	*Sec.-ft.*
Aug. 27	5.75	[a] 1,600	Sept. 25	6.95	[b] 6,150
Sept. 6	4.86	597	Oct. 15	4.64	503

[a] Boat measurement. [b] Float measurement.

Daily gage height, in feet, and discharge, in second-feet, of Sixmile Creek at Sunrise for 1913.

[Drainage area, 258 square miles. Adolph Lawson, observer.]

Day.	August.		September.		October.		November.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
1			5.10	780	5.30	970	5.25	1,020
2			5.00	700	5.30	970	5.10	780
3			4.95	665	5.15	825	5.00	700
4			4.90	630	5.30	970	4.95	665
5			4.85	600	5.25	920	4.85	600
6			4.85	600	5.15	825	4.80	570
7			4.80	570	5.10	780	4.75	545
8			4.80	570	5.05	740	4.65	495
9			4.75	545	4.95	665	4.75	545
10			4.75	545	4.90	630	4.85	600
11			4.70	520	4.80	570	4.80	570
12			4.70	520	4.80	570	4.65	495
13			4.70	520	4.70	520	4.60	470
14			4.70	520	4.65	495	4.60	470
15			4.75	545	4.70	520	4.55	450
16			4.75	545	4.70	520	4.50	430
17			4.75	545	4.70	520	4.70	450
18			4.75	545	4.65	495	4.80	450
19			4.85	600	4.80	570	4.95	450
20			4.90	630	4.70	520	5.25	450
21			4.80	570	4.65	495	5.20	450
22			4.90	630	4.65	495	5.35	430
23			5.15	825	4.65	495	5.55	430
24			5.65	1,420	4.60	470	5.85	430
25			6.75	5,000	4.60	470	5.95	430
26			5.95	2,220	4.50	430	6.15	430
27	5.75	1,590	5.65	1,420	4.75	545	6.40	430
28	5.55	1,270	5.45	1,140	4.75	545	6.90	400
29	5.35	1,020	5.30	970	4.60	470	7.30	400
30	5.25	920	5.35	1,020	5.70	1,500	7.50	400
31	5.20	870			5.30	970		
Mean discharge		1,130		897		661		514
Second-feet per square mile		4.38		3.48		2.56		1.99
Run-off, depth in inches		.81		3.88		2.95		2.22
Maximum		1,590		5,000		1,500		1,020
Minimum		870		520		430		400
Accuracy		A.		A.		A.		A.

NOTE.—Gage heights affected by ice and discharges estimated Nov. 17-30.

MILLS CREEK 2 MILES ABOVE MOUTH.

On August 25, 1913, a gage was installed on Mills Creek, about 2 miles above the mouth, just below the footbridge near Schmesar's cabin. Gage readings were made until November 2, when the creek froze up. Only two discharge measurements were obtained. The error of the mean monthly discharges is probably within 15 per cent.

Discharge measurements on Mills Creek 2 miles above mouth in 1913.

Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*
Aug. 25	3.48	140
Sept. 5	3.02	76.7

Daily gage height, in feet, and discharge, in second-feet, of Mills Creek 2 miles above mouth for 1913.

[Drainage area, 25 square miles. Herman Schmesar, observer.]

Day.	August.		September.		October.		November.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
1			3.15	94	3.10	87	2.78	51
2			3.10	87	3.10	87	2.70	43
3			3.05	81	3.00	75		
4			3.00	75	3.10	87		
5			3.00	75	3.10	87		
6			2.95	69	3.20	101		
7			2.95	69	2.98	73		
8			2.90	63	2.93	67		
9			2.88	61	2.90	63		
10			2.88	61	2.82	55		
11			2.85	58	2.82	55		
12			2.82	55		55		
13			2.85	58		55		
14			2.80	53		50		
15			2.80	53		50		
16			2.80	53		45		
17			2.80	53		45		
18			2.80	53		45		
19			2.83	56		45		
20			2.80	53		50		
21			2.80	53	2.89	62		
22			2.83	56	2.80	53		
23			3.25	108	2.78	51		
24			3.50	143	2.75	48		
25	3.50	143	3.90	203	2.73	46		
26	3.45	136	3.80	187		45		
27	3.60	157	3.40	129		45		
28	3.45	136	3.20	101		45		
29	3.30	115	3.20	101	2.72	45		
30	3.25	108	3.20	101	3.10	87		
31	3.20	101			2.85	58		
Mean discharge		128		82.1		60.1		
Second-feet per square mile		5.12		3.28		2.40		
Run-off (depth in inches on drainage area)		1.33		3.66		2.77		
Maximum		143		203		101		
Minimum		101		53		45		
Accuracy		C.		C.		C.		

NOTE.—Gage heights and discharges (estimated) affected by ice Oct. 12–20 and 26–28.

MISCELLANEOUS MEASUREMENTS.

A gage was installed on Canyon Creek just above the mouth of Mills Creek, but efforts to secure readings were not successful. The discharge measurements made at this point appear in the following list.

One measurement was made of Juneau Creek above all ditch diversions.

Miscellaneous discharge measurements in Sixmile Creek valley in 1913.

Date.	Stream and locality.	Discharge.	Drainage area.	Discharge per square mile.
		Sec.-ft.	*Sq. miles.*	*Sec.-ft.*
Aug. 25	Canyon Creek above Mills Creek	[a] 90	28	3.21
Sept. 4	....do	[a] 60	28	2.13
Oct. 14	....do	44	28	1.56
Aug. 25	Juneau Creek, 500 feet above upper ditch intake	23	4.4	5.23

[a] Includes flow of ditch diverting from Fresno Creek.

RESURRECTION CREEK DRAINAGE BASIN.

The Resurrection Creek drainage basin lies generally parallel to that of Sixmile Creek, and the principal difference in the topography of the two is that the mountains of the former are more smoothly rounded than those of the latter. The area of the drainage basin is 157 square miles.

Resurrection Creek flows northward and empties into Turnagain Arm at Hope, about 8 miles west of Sunrise. About 1 mile from its mouth the creek emerges from its narrow valley into a wide, gravel-floored flat. The valley bottom ascends gradually up to an elevation of 1,600 feet at a point 16 miles from the mouth of the creek. There is a good opportunity for developing power on the stream in the summer. There are no storage reservoir sites or lakes in the basin. Hydraulic mining has been carried on quite extensively on the stream.

The following discharge measurement was made on the stream above Gold Gulch on August 8, 1913: Discharge, 120 second-feet; drainage area, 105 square miles; discharge per square mile, 1.14 second-feet.

POWER PLANT OF THE SEWARD LIGHT & POWER CO.

The Seward Light & Power Co. operates a hydroelectric plant on Lowell Creek and supplies the city of Seward with light and power. The United States Geological Survey is indebted to Mr. S. M. Graff, the president and manager of the company, for the following information concerning this plant and its operation.

The Seward Light & Power Co. was incorporated in November, 1905, and was first operated December 1, 1905. Except for a stop of four days in December, 1910, caused by frazil, and occasional stops on Sunday afternoons for washing the plant and cleaning machinery, the operation has been practically continuous since the date of starting. Commencing with the short days in the late fall, it has been the policy of the management to run without making any stops. The longest period of incessant operation of the plant is 98 days, a very creditable record.

The equipment consists of an Allis-Chalmers (Bullock) alternating-current generator, of 225-kilowatt capacity, operated by a Pelton wheel under a head of 360 feet. The water is supplied from Lowell Creek by a line of 12-inch pipe 9,000 feet in length.

It was Mr. Graff's opinion that Lowell Creek will supply the needs of a city considerably larger than Seward is at present. When the demand exceeds the possible output of the present plant the head can be increased by moving the intake farther up the creek. At times a dam built impervious down to the bedrock would be of value in increasing the available water supply.

Two serious problems identified with winter operation of water-power plants on the southwestern Alaska coast are introduced by snowslides and frazil. In the coastal regions the heavy snowfall accumulates on the precipitous mountain slopes in such masses that it finally becomes unstable and starts to slide; in sliding the mass gathers up acres more of snow on the mountainside, and when it reaches the bottom of the narrow valley it often fills it scores of feet in depth. Such slides occur several times during a winter on Lowell Creek. At one time in the early history of the plant a slide came down upon a former site of the intake house, destroying it and killing an employee who happened to be there at the time. The intake was then removed to a point where the topography was such as to guard against the recurrence of such a catastrophe.

On a stream like Lowell Creek the effect of a snowslide is to dam up the creek and cut down the water, and when all the available water is required by the plant the result is a more or less serious reduction of the voltage. Experience has shown that this usually lasts from 10 to 45 minutes. A factor which determines to a large extent the seriousness of the effect is the proximity of the slide to the pipe intake, for obviously a temporary damming of the stream near the intake will reduce the flow more than if it is at a distance.

Mr. Graff has had considerable experience with frazil and an account of it will be of interest. The most serious trouble from frazil occurred December 8–17, 1910. The weather was favorable for its formation, and the creek was not frozen over. When the ice began to form, the screen at the intake was removed, for otherwise the ice froze to it and shut off the flow. The ice needles which permeated the water entered the pipe and gradually froze in a coat on the interior surface. As this coat became thicker it reduced the cross-section through which water could flow up to the point when the pressure available at the plant was insufficient for running the wheel. The plant was shut down and the water was drained out of the pipe. Finally, when the creek water became warmer, it was admitted again and gradually cut out the ice. The ice was hard and flinty and broke off in pieces too large for passage through the 3-inch nozzle, so that was removed. The ice then came through in large chunks and the shock on the pipe and wheel was tremendous.

To prevent such occurrences the following procedure has been adopted: Temperatures of the water are taken at the plant twice each day—at noon and at midnight. When the temperature is found to be approaching dangerously near 32° F., the intake screen is removed and the frazil is allowed unobstructed admission to the pipe. Usually the formation of the frazil lasts but a short time and the ice does not freeze on the inside of the pipe to a dangerous thickness before the water becomes warmer and thaws it away. However, if conditions do not change and the ice continues to accumulate inside the pipe, when it has reached a thickness estimated at about 2 or 3 inches—since a thickness greater than this would make chunks of ice too large to pass through the nozzle—the water is shut off. It is not permitted to enter again until it becomes warm enough to cut out the ice. Experience has shown that frazil very infrequently forms for more than a few hours, and by taking these precautions shutdowns of the plant because of it are of very short duration and occur much more infrequently.

Water temperatures have been taken at this plant for a number of years, and since such data are scarce, and also because they are of peculiar interest in illustrating one of the problems of Alaskan water-power development, they are here published.

Water temperatures, in degrees Fahrenheit, at power plant of Seward Light & Power Co., 1908–1913.

Day.	October.		November.		December.	
	Noon.	Mid-night.	Noon.	Mid-night.	Noon.	Mid-night.
1908.						
1	....	....	35	34	36	36
2	....	....	34	33	36	36
3	....	....	34	34	36	36
4	....	....	34	34	....	36
5	....	....	34	34	36	36
6	....	....	34	34	....	36
7	....	....	35	35	35	35
8	....	....	35	35	....	35
9	....	....	34	36	36	36
10	....	....	36	36	36	36
11	....	....	36	36	35	35
12	....	....	36	36	35	35
13	....	....	36	36	34½	35
14	....	....	36	36	34	34½
15	....	....	36	38	34	34
16	....	....	36	37	34	35
17	....	....	37	36	36	36
18	....	....	35	36	36	36
19	....	....	36	36	36	36
20	....	....	....	36	36	35
21	....	....	36	36	....	35
22	....	....	....	36	36	36
23	....	....	35	36	....	36
24	35	36	36	36	....	34
25	34	34	36	36	....	36
26	34	35	36	36	36	35
27	35	35	36	36	33	33
28	35	35	36	36	34	34
29	....	34	36	36	34	35
30	34	35	37	36	36	36
31	34	35	....	....	36	36

Water temperatures, in degrees Fahrenheit, at power plant of Seward Light & Power Co., 1908–1913—Continued.

Day.	January.		February.		March.		April.		May.		June.		July.		August.		September.		October.		November.		December.	
	Noon.	Mid-night.	Noon.	Mid-night.	Noon.	Mid-night.	Noon.	Mid-night.	Noon.	Mid-night.	Noon.	Mid-night.	Noon.	Mid-night.	Noon.	Mid-night.	Noon.	Mid-night.	Noon.	Mid-night.	Noon.	Mid-night.	Noon.	Mid-night.
1909.																								
1	36	35	34	34	34	34	36	35	37	36	38	36	38	37	40	38	39	38	37	35	36	35	32½	33
2	34	35	35	35	34	34	35	35	36	36	38	36	40	37	41	38	39	38	38	36	34	34	33	33½
3	35	35	36	35	34	......	35	35	37	36	38	36	40	38	40	38	39	38	36	35	34	34	34	34
4	36	35	35	35	34	34	35	35	38	36	38	36	39	37	......	38	......	38	37	36	34	35	34	34
5	35	35	34	34	35	35	36	35	37	36	37	37	39	38	39	38	......	38	......	35	35	34	33½	33
6	34	35	34	33	36	35	36	35	37	36	37	36	38	38	39	38	39	38	35	34	34	33	33	33
7	35	35	35	35	36	34	36	35	38	37	38	38	38	38	......	38	......	38	36	34	33	33	33	33
8	35	35	33	35	35	35	36	35	37	36	37	36	40	38	......	38	......	39	35	34	35	36	32½	33
9	34	34	34	34	36	35	36	36	36	36	37	36	40	38	40	38	......	38	......	35	35	34	32	32
10	35	34	35	35	35	34	36	36	37	36	38	37	38	38	39	37	39	38	36	36	34	34	33	32½
11	35	35	35	35	35	35	36	36	37	36	38	36	39	38	......	38	39	38	35	37	36	36	32½	32½
12	35	35	34	35	36	35	36	36	38	36	40	37	39	38	41	38	......	38	39	36	36	36	34	34
13	34	34	35	35	36	35	36	35	38	36	38	37	39	38	40	38	41	38	41	37	36	36	......	34
14	34	34	34	35	34	35	36	35	38	36	38	37	40	38	39	38	40	38	38	36	35	34	33	33½
15	33	34	34	35	36	35	36	35	36	37	38	37	41	38	......	38	40	38	37	36	34	34	34	34
16	34	34	35	35	36	35	36	36	37	36	38	37	42	38	......	38	......	37	37	35	34	33	33	33
17	33	34	36	36	36	36	36	36	38	36	38	37	42	38	40	38	......	38	......	35	34	34	34	34
18	34	34	36	36	36½	34	36	36	39	36	38	37	38	38	......	38	40	38	36	35	34	34	34	33
19	34	34	33	33	35	34	36	36	38	36	38	37	41	38	......	38	40	38	35	35	34	34	34	34
20	34	34	34	34	34	35	36	36	37	36	38	36	41	38	......	38	40	36	35	35	34	34	34	34
21	34	34	34	34	36	35	36	36	36	36	40	37	40	38	40	38	37	36	35	34	33	33	34	34
22	34	34	34	34	35	35	37	35	37	36	38	37	41	38	......	38	......	37	36	36	32	......	34	36
23	34	34	35	35	34	34	37	35	......	36	40	37	39	39	40	38	......	37	37	36	......	......	35	36
24	34	35	35	35	35	36	37	35	38	36	38	37	39	38	......	38	38	37	......	35	......	......	34	34
25	34	34	35	35	36	35	38	36	38	36	40	37	39	39	......	38	42	36	37	36	......	......	34	34
26	34	34	36	35	34	33	37	35	39	37	39	38	39	38	......	38	36	34	37	35	......	......	34	34
27	34	34	35	35	34	35	37	36	39	37	......	37	42	38	40	38	37	34	36	36	......	......	33	34
28	34	34	35	34	......	36	36	36	......	37	40	38	40	38	39	38	......	35	36	35	......	......	34	34
29	34	35	......	......	36	35	38	36	38	37	39	37	39	38	......	38	40	36	37	36	......	32½	34	33
30	34	34	......	......	36	35	37	34	......	36	40	37	40	38	39	38	36	36	37	36	33½	32½	34	33½
31	34	34	......	......	36	35	......	......	38	36	......	......	42	38	39	38	......	......	37	36	......	......	34	34

Water temperatures, in degrees Fahrenheit, at power plant of Seward Light & Power Co., 1908–1913—Continued.

Day.	January.		February.		March.		April.		May.		June.		July.		August.		September.		October.		November.		December.	
	Noon.	Mid-night.	Noon.	Mid-night.	Noon.	Mid-night.	Noon.	Mid-night.	Noon.	Mid-night.	Noon.	Mid-night.	Noon.	Mid-night.	Noon.	Mid-night.	Noon.	Mid-night.	Noon.	Mid-night.	Noon.	Mid-night.	Noon.	Mid-night.
1910.																								
1	33	34	34	34	35½	34½	36	37	......	36	36½	36	38	37	39	38	40	38	39	38	37	36	34.	33
2	34	35	34	35	35½	34½	36	36	36	36	36	36	38	37	38	38	40	38	......	37	38	37	32½	32
3	34½	34	......	35	35	34	......	36	36	36	36	36	......	38	39	38	40	38	38	37	38	35	33	33
4	35	36	34	34	35	34½	36	36	36	36	38	36	38	38	38	38	......	38	38	37	36	35	34	32
5	36	35	35	35	35	34	37	35½	......	36	......	36	38	37	38	38	40	38	37	37	36	36	32½	32
6	36	35	35	35	35	34½	36	36	36	35	37	36	38	37	40	39	40	38	38	37	......	34	34	33
7	33½	34	35	35	35	35	36	36	37	35½	37	36	39	38	......	38	40	38	38	37	33	32	33	32
8	33½	33	35	35	35	......	35	35	......	36	38	37	38	37	40	38	40	38	37	36	33	33	33	32
9	34	34	35	35	36	35	35	35	36	35½	......	36	38	37	39	......	41	39	......	......	33	32	32½	32½
10	34	33	35	35	36	35½	......	35½	37	36	38	37	38	37	41	38	41	39	......	......	33	33	32½	......
11	33	34	35	35	36	36	36	35½	......	36	38	36	38	37	41	38	......	39	......	38	33	33	......	......
12	34	34	35	34½	36	35½	36	35	......	36	......	38	40	38	41	39	40	39	38	38	34	34	......	......
13	34	34	35	34½	36	36	36	35½	37	36	38	37	39	38	42	39	39	39	38	37	......	34	......	......
14	34	35	35	34½	36	36	36	36	36	36	38	37	39	38	......	39	39	38	38	36	34	34	33	33
15	34	34	35	35	36	36	36	36	36	36	37	36	38	38	41	39	39	39	38	38	35	35	34	33
16	34	34	36	35½	36	36	36	36	37	36	38	36	39	38	39	39	39	38	38	38	36	35	33½	32½
17	34	34	36	35	36	36	36	36	36	36	37	36	......	38	39	38	39	38	38	38	35	35	33	33
18	34	34	36	35½	36	36	36	36	36	36	38	36	38	37	40	39	39	38	38	38	36	35	34	33
19	33½	34	36	35½	36	36	36	36	36	36	37	36	38	37	41	39	39	38	38	38	36	36	34	33½
20	34	34	36	35½	36	36	36	36	37	36	37	36	38	38	41	39	38	38	38	38	36	36	34	33½
21	34½	35	35	35	36	35½	36	36	36	36	37	36	38	38	41	38	39	38	38	38	37	35	34	34
22	34	34	35½	35	36	35	37	36	36	36	38	36	40	38	40	39	39	38	......	37	36	34	35	34
23	34	34	35	34½	36	35½	37	36	37	36	38	36	40	38	40	39	39	38	38	36	35	34	34	34
24	34	34	35½	34½	36	36	......	36	37	36	38	36	......	38	40	39	40	38	37	35	35	35	35	34
25	35	35	35	35	36	36	36	36	38	36	37	37	40	38	40	39	39	38	35	35	36	34	34	34
26	34	35	35½	35	36	36	37	36	......	36	......	36	41	39	42	39	38	38	34	34	34	33	34	33
27	34	35	35	34	36	36	37	36	37	36	38	36	40	38	......	39	......	38	35	34	......	33	33	33
28	34	35	35½	35½	36	36	38	35½	38	36½	38	36	40	38	40	38	39	38	35	35	33	32	34	34
29	35	34	......	......	36	36	37	36	38	36	38	37	41	38	40	38	......	38	36	36	33	32	34	34
30	34	34	......	......	36	36	37	36	37½	36	38	37	40	38	......	39	39	38	......	37	33	33	34	33
31	34	34	......	......	36	36½	......	......	37	36	......	......	......	38	40	39	......	......	38	37	......	......	34	34
1911.																								
1	35	34	34	34	36	35	36	35	36	35	37	35	38	37	40	38	40	38	39	37	39	38	34	34
2	35	35	34	34	35	34	36	36	36	35	37	35	......	37	41	38	41	38	38	37	38	38	34	35

3	36	35	34	34	35	34	36	36	36	35	37	35	38	37	41	38	......	38	38	38	......	37	34½	34
4	35	35	34	34	35	34	36	36	......	35	......	35	38	36	41	38	40	39	39	37	36	35	34½	35
5	35	35	34	34	35	34	35	36	36	35	37	36	38	36	41	38	40	39	37	37	36	35	35	35
6	35	35	34	34	35	34	35	36	36	35	37	36	40	37	41	38	40	38	38	37	35	34	36	35
7	34	34	34	34	35	34	35	34	......	35	36	36	39	37	42	38	40	38	37	36	34	33	36	35
8	33	34	34	34	35	34	35	34	36	35	36	36	38	37	41	38	39	38	38	37	34	33	36	34
9	34	34	34	35	34	34	34	34	36	35	37	36	......	36	40	38	39	38	39	38	34	34	35	34
10	34	34	35	35	34	34	35	35	36	35	37	36	38	37	41	38	40	38	40	38	35	35	......	34
11	34	34	35	34	33	33	36	35	36	35	36	35	37	37	41	38	40	38	38	38	36	35	34	33½
12	33	34	34	34	33	33	36	35	36	35	37	36	39	37	42	38	39	38	39	38	34	34	34	33
13	34	34	34	34	33	34	35	35	36	35	36	36	40	37	42	40	40	38	41	38	36	35	34	34
14	34	33	35	35	34	34	35	34	......	35	......	36	37	37	42	39	40	38	39	38	36	35	33½	34
15	34	34	34	34	34	34	35	35	37	35	37	36	39	37	42	38	40	37	......	38	36	36	34	33½
16	34	34	35	34	35	34	35	35	37	35	38	36	40	37	41	38	39	37	38	37	36	35	33½	33½
17	34	34	35	34	35	35	35	35	36	35	37	35	40	38	41	38	40	38	38	37	36	34	34	33
18	35	34	35	33	35	35	35	35	36	35	......	35	40	38	41	38	40	38	38	38	38	33	33	33
19	35	34	34	34	34	34	35	35	36	35	37	36	40	38	41	38	40	38	40	39	......	33	34	35
20	34	34	35	34	35	34	36	36	36	35	37	36	40	38	41	38	39	38	39	38	33	32½	35	35
21	35	34	35	35	35	34	36	35	36	35	37	36	40	38	41	38	38	38	39	37	33	34	34	33
22	34	34	35	34	35	34	36	35	36	35	38	36	40	38	42	38	39	38	......	37	34	35	34	33
23	34	33	35	34	36	35	36	36	36	35	38	36	......	38	40	38	40	38	38	37	35	34	33	34
24	33	33	35	34	35	36	36	35	36	35	36	36	39	38	40	40	......	38	38	37	36	34	33	34
25	34	34	35	34	36	35	36	35	36	35	......	36	38	37	39	38	39	38	39	38	35	33	34	34
26	34	34	35	34	35	34	36	35	36	35	38	36	39	38	39	38	39	38	39	38	36	35	34	34
27	34	34	35	34	35	35	35	35	36	35	38	36	39	38	41	38	39	37	39	37	34	35	34	35
28	35	34	36	35	36	36	36	35	......	35	38	36	39	37	41	38	38	37	38	37	36	35	35	35
29	33	35	......	......	36	35	35	35	36	35	38	37	38	37	42	38	38	38	37	37	......	34	35	35½
30	34	34	......	......	35	34	35	35	37	35	37	37	38	37	......	38	38	37	38	38	35	34	35	35
31	34	34	......	......	36	34	......	......	36	35	......	......	39	38	40	38	......	......	38	38	......	......	36	35
1912.																								
1	34	35	36	35	35	34	38	35	38	36	40	36	38	37	40	38	......	38	40	38	39	38	36	36
2	35	35	35	36	35	34	37	35	37	36	......	37	38	37	40	38	......	38	40	38	39	37	36	35
3	35	34½	35	35	35	34	36	35	38	36	40	37	38	39	39	39	40	38	40	38	38	37	34	34
4	34	34	36	36	34	34	36	35	38	36	38	36	38	38	......	38	42	39	39	38	38	37	34	34
5	34	34	36	35	35	35	37	35	39	36	40	37	38	37	39	39	......	38	39	38	38	36	34	35
6	34	34	37	36	34	34	37	35	38	36	39	36	......	......	39	38	39	38	39	37	36	36	34	34
7	......	34	37	36	34	33	36	36	39	36	39	36	38	36	39	38	40	38	39	38	35	35	34	34
8	34	34	37	36	35	34	37	36	38	36	38	36	39	38	......	......	......	38	38	38	36	35	34	34
9	34	34½	36	35	35	35	37	35	37	36	38	37	39	38	......	......	40	38	40	38	36	36	35	35
10	35	34	36	36	......	35	37	35	36	35	38	37	39	37	......	......	39	38	38	38	37	35	36	36
11	35	34	37	36	35	34	37	35	36	35	38	37	39	37	......	38	40	38	39	38	36	36	36	36
12	34	34	37	35	35	34	37	35	36	35	39	36	38	37	40	38	39	41	39	38	36	35	36	36
13	34	35	36	35	35	34	37	36	38	36	38	37	38	37	41	38	......	......	39	38	......	34	36	36
14	35	34	36	35	34	34	36	36	39	36	......	36	38	38	40	39	......	......	39	38	35	35	36	35
15	35	35	35	35	35	34	36	36	40	36	......	36	38	38	41	39	......	......	38	38	36	35	34	36

Water temperatures, in degrees Fahrenheit, at power plant of Seward Light & Power Co., 1908–1913—Continued.

Day.	January.		February.		March.		April.		May.		June.		July.		August.		September.		October.		November.		December.	
	Noon.	Midnight.	Noon.	Midnight.	Noon.	Midnight.	Noon.	Midnight.	Noon.	Midnight.	Noon.	Midnight.	Noon.	Midnight.	Noon.	Midnight.	Noon.	Midnight.	Noon.	Midnight.	Noon.	Midnight.	Noon.	Midnight.
1912—Contd.																								
16	34	35	36	35	36	34	37	36	39	36	......	37	38	37	40	39	......	......	39	37	35	34	......	35
17	36	35	36	36	......	33	38	36	38	36	38	36	39	38	......	38	......	......	......	36	36	36	35	34
18	36	35	36	35	35	35	38	36	40	37	40	37	39	38	......	39	......	......	......	37	34	35	34	35
19	36	35	36	34	36	35	37	36	......	37	40	37	40	38	......	38	......	......	38	36	......	35	36	35
20	35	35½	35	34	36	35	38	35	......	36	40	37	42	38	......	38	......	......	36	36	36	36	35	35
21	36	36	35	33	37	35	39	36	......	37	38	37	42	38	......	38	......	39	37	35	35	35	36	35
22	36	35	33	33	36	36	40	36	39	37	38	37	42	38	......	38	......	38	34	33	36	35	35	33
23	35	35	......	35	36	36	40	36	37	36	38	37	42	38	......	38	......	38	33	33	34	35	32	33
24	36	36	34	34	37	35	40	36	37	36	38	37	......	38	......	38	40	38	34	33	35	35	33	33
25	36	36	35	35	37	35	38	36	37	36	40	37	39	38	......	38	40	......	34	33	......	34	34	34
26	36	36	36	35	37	35	38	36	38	36	40	37	......	38	......	38	......	......	34	35	36	35	34	35
27	36	36	36	34	37	35	38	36	38	36	40	37	......	38	......	38	......	......	......	36	35	34	35	34
28	36	35	36	35	38	35	......	36	38	36	39	37	......	38	......	38	......	......	37	37	34	33	35	34
29	36	35	36	35	35	35	38	36	38	37	......	37	......	38	......	39	......	38	38	37	......	35	34	33
30	36	35	......	......	36	35	40	36	......	36	......	37	40	38	......	39	......	38	38	37	36	35	33	33
31	36	36	......	......	36	35	......	......	39	36	......	......	42	38	40	38	......	......	37	38	......	......	34	33
1913.																								
1	34	33	36	34	35	34	36	35	38	35	38	36	40	37	41	38	40	38	40	38	......	......	......	......
2	34	34	36	34	35	33	36	34	38	35	39	36	41	38	42	38	40	37	38	38	......	......	......	......
3	35	35	36	34	35	35	35	33	38	36	40	36	40	38	41	38	40	37	39	38	......	......	......	......
4	35	35	35	33	36	34	34	33	38	36	39	36	40	38	40	39	40	38	39	38	......	......	......	......
5	35	35	34	33	35	34	35	34	38	36	39	36	41	38	40	38	40	38	39	37	......	......	......	......
6	33	34	35	33	35	34	36	35	38	36	39	37	40	38	......	39	40	38	40	38	......	......	......	......
7	33	34	35	33	36	35	36	35	38	36	40	37	......	38	41	39	40	38	38	37	......	......	......	......
8	34	35	35	34	35	35	36	35	39	36	......	37	40	38	40	38	41	38	38	36	......	......	......	......
9	34	35	36	34	36	35	37	34	38	36	......	37	......	38	42	38	40	38	38	36	......	......	......	......
10	34	35	36	35	36	34	37	34	39	36	39	37	42	38	42	38	......	38	36	35	......	......	......	......
11	35	35	36	34	35	34	37	35	......	36	39	37	......	38	42	38	41	38	36	35	......	......	......	......
12	35	34	36	35	34	34	34	34	39	36	40	37	41	38	40	38	41	38	36	34	......	......	......	......
13	34	34	36	35	34	35	36	34	38	36	40	37	42	38	......	38	41	38	36	35	......	......	......	......
14	34	34	36	35	36	33	36	33	38	36	39	37	41	39	40	38	41	38	35	34	......	......	......	......
15	34	34	36	35	34	34	36	34	39	36	40	37	41	38	42	38	41	38	35	35	......	......	......	......
16	34	34	36	34	34	34	36	35	38	36	38	37	40	38	40	39	41	38	36	34	......	......	......	......
17	34	34	35	35	34	35	37	35	37	36	38	37	40	38	42	39	41	38	......	35	......	......	......	......

18	34	34	35	35	35	34	37	34	......	36	38	37	40	38	41	39	40	39	......	37	......	......	......	......
19	35	34	35	35	36	34	34	33	38	36	40	38	39	38	40	39	40	38	38	37	......	......	......	......
20	34	34	35	35	35	34	36	35	38	36	38	37	......	38	40	39	40	38	37	37	......	......	......	......
21	34	35	35	34	35	34	36	35	......	37	40	37	......	38	40	38	40	38	38	38	......	......	......	......
22	34	34	35	34	34	33	37	35	38	36	......	......	39	38	40	38	......	41	38	37	......	......	......	......
23	35	35	36	35	35	35	37	35	38	36	38	38	41	38	41	38	40	38	38	36	......	......	......	......
24	36	35	36	35	36	34	37	35	38	36	39	38	40	38	41	38	41	39	......	36	......	......	......	......
25	35	35	35	35	36	35	38	35	......	36	38	38	39	37	41	39	40	39	36	34	......	......	......	......
26	36	35	35	35	36	35	38	35	39	36	40	38	40	37	40	39	40	38	35	34	......	......	......	......
27	36	35	35	35	36	35	......	35	38	36	39	38	40	39	40	37	40	38	36	36	......	......	......	......
28	36	35	36	35	36	35	36	35	38	36	38	38	38	38	40	37	40	38	37	37	......	......	......	......
29	36	36	......	......	35	34	36	35	......	36	......	38	38	37	41	37	40	39	39	38	......	......	......	......
30	36	34	......	......	35	34	38	35	38	37	40	38	38	38	41	38	40	38	39	37	......	......	......	......
31	36	......	......	......	36	34	......	35	39	36	......	......	41	38	42	38	......	......	......	......	......	......	......	......

WATER-POWER SITES.

The topography of the mountainous area of Kenai Peninsula, in common with that of most of the Alaskan coast, is favorable for water-power development. The water supply, as determined principally by the climate and the character and distribution of precipitation, is large in summer and fluctuates widely but is much less in winter. Usually the minimum flow of a stream determines the magnitude of the development which should be made upon it, and therefore a stream that has natural storage sites or that affords sites for artificial storage presents advantages not possessed by other streams, for its minimum flow and the possible capacity of the plant can thus be increased. There are many streams whose minimum flow would suffice for plants of 1,000 to 2,000 horsepower for the six-months' period from May 1 to October 31, but there are few if any streams whose flow would be adequate for the development of more than a few hundred horsepower in the other six months without storage. Such data as are available regarding these sites are included in the description of the basins in which they occur. Except in the Kenai Valley the streams of the peninsula afford few artificial storage sites. If winter power were demanded in excess of that which could be obtained from the natural flow of the stream, it would have to be supplied from some other source.

The several lakes of the Kenai Valley have some tendency to regulate the flow of the streams rising in them and furthermore the possibility of developing more storage upon them furnishes a means for increasing this regulatory effect. Dams could be constructed at any of the lake outlets, and at some of them the sites are exceptionally favorable. On Ptarmigan and Grant lakes dams which would hold in a reservoir nearly the entire annual run-off from their tributary drainage areas could probably be constructed at a reasonable expense. Thus the available power of the stream could be used at nearly a constant rate throughout the year, or it could be drawn upon as desired. (See pp. 114–128.) If winter power is desirable and the necessary expense is justified, the advantage of such a water supply over one obtained from the natural flow of a stream is obvious.

The feasibility of connecting the water powers of this valley into a single hydroelectric system could be determined only by extensive surveys and studies of the water supply; the available data are far too inadequate to warrant conclusions. The most important power sites in this valley lie within a radius of 15 miles. If storage was fully developed and power plants installed where practicable, their interconnection by electric transmission lines would furnish means for obtaining the maximum output of power from the available water supply and its most uniform distribution through the year. It seems most probable that any market for power which is likely to materialize in this region would demand continuous power. The primary purpose of the reservoirs in this basin would be to replenish the flow and augment the power output from November 1 to April 30. Any excess of water could be utilized to increase the uniformity of the flow, if that were desired. The run-off available at the various plants, the amount of storage, and the potential value of the water stored in the different reservoirs as measured by the head through which it would act, would be the principal factors in determining the method of manipulating the plants or the release of water from the reservoirs. Even with storage reservoirs developed to their utmost capacity it seems probable that the output of power in summer could considerably exceed that of the winter.

The cost of construction, operation, and maintenance of 8 or 10 power plants, such as this project would involve, would probably exclude it from the class of cheap power, and only great industrial growth in this region would warrant such a development. On the other hand, the construction presents no serious difficulties, and the region is easily accessible, so there is no reason to believe the cost would be prohibitive.

WILLOW CREEK DISTRICT.

GENERAL FEATURES.

Willow Creek district is the common designation of the area that includes the gold fields lying about 20 miles northeast of Knik, a settlement on Knik Arm of Cook Inlet. The district comprises about 90 square miles, and includes the divide between Little Susitna River and the South Fork of Willow Creek, a tributary of Susitna River. This divide is the southwestern extension of the Talkeetna Range, and lies approximately in longitude 149° 20′ west and latitude 61° 40′ north. Willow Creek, augmented by Grubstake Gulch and Wet Gulch from the south, and by a fork from the north formed by Peterson and Purches creeks, flows westerly out of the mountains and into the flat valley of Susitna River, which it joins about 35 miles from the mouth. Willow Creek is about 40 miles long from its mouth to its most remote sources. Grubstake Gulch has been a producer of placer gold in the past, but at present active mining operation in the Willow Creek basin is confined to the quartz claims of the Gold Bullion Mining Co.

The topographic features of the district are varied. The northern part is characterized by steep, craggy mountains; the southern part is occupied by the much less rugged ridge, known as Bald Mountain. Several of the peaks exceed 5,000 feet in elevation. The valleys are U-shaped, glacial troughs ranging in elevation from 1,500 to 3,500 feet. High up in these valleys the slopes are heavily strewn with coarse glacial débris, broken rock, and talus. The large proportion of void spaces in this formation affords an excellent reservoir for the summer water supply. Ice forms in these spaces during the winter, and by gradually thawing away in the summer it is an important factor in the distribution of stream flow at a time when it is of commercial value for the development of water power for the quartz mills. Practically all snow disappears during the summer. Small scattered glaciers lie at the head of Archangel Creek and a larger one at the head of the main branch of Little Susitna River.

A condition of considerable economic significance in the Willow Creek district is the scarcity of timber suitable either for fuel or for building. In the lower parts of the valleys of Willow Creek and Little Susitna River timber is plentiful and good, but on Willow Creek it does not extend above Wet Gulch and on the Little Susitna above a point about 2 miles below the mouth of Fishhook Creek. Alders and willows fringe the mountain sides to a considerably higher elevation, but they disappear some distance below the places at which the quartz mills have been installed. Mining timber and wood for fuel must be hauled 4 to 8 miles and up steep grades, and the cost of this haulage increases the cost of the wood to a degree which almost prohibits its use for fuel.

A hasty reconnaissance of the water supply of the Willow Creek district was made in September, and such data as were collected are here presented.

Four or five small gold lode mines are being worked in this district,[1] and the indications are favorable for further discoveries.

GAGING STATIONS AND MEASURING POINTS.

The points at which gaging stations were maintained or discharge measurements made on streams in the Willow Creek district in 1913 are listed below, with numbers corresponding to those shown on Plate XIX.

1. **Craigie Creek at Gold Bullion mill.**
2. **Little Susitna River at mile 28.**
3. Sidney Creek at lake outlet.
4. **Fishhook Creek at mile 33½.**

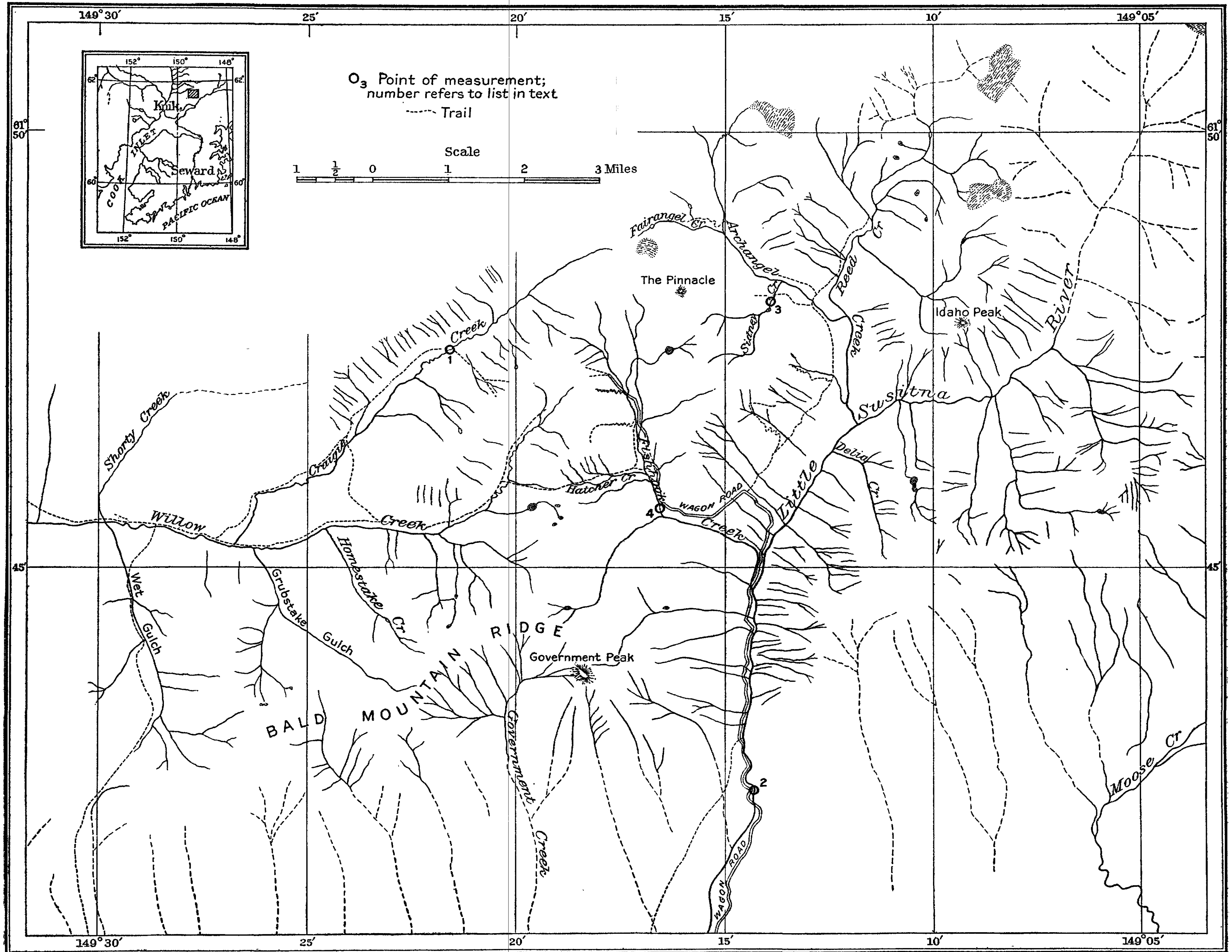
NOTE.—Black-faced type indicates that daily estimates of discharge are available.

CRAIGIE CREEK AT GOLD BULLION MILL.

Craigie Creek rises in the heart of the Willow Creek region and flows southwesterly about 7 miles to join Willow Creek near its head.

The mill of the Gold Bullion Mining Co. is on Craigie Creek about 4 miles from its mouth. Water power is utilized for the operation

[1] See Capps, S. R., The Willow Creek district, Alaska: U. S. Geol. Survey Bull. 592, pp. 245-272, 1914.



MAP OF WILLOW CREEK DISTRICT SHOWING LOCATION OF GAGING STATIONS AND MEASURING POINTS.

of the plant. A ditch about 1,000 feet long diverts from Craigie Creek to the mill, where it passes through a 12-inch turbine water wheel under a head of about 28 feet. The United States Geological Survey is indebted to the management of the company for a carefully kept weir record on the creek throughout the summer of 1913.

The weir was 10 feet long, sharp crested, of the Cippoletti type, and had end contractions. Readings were generally made three times a day at times closely approximating 7 a. m., 12 m., and 5 p. m. The discharges for each of these readings have been computed and appear with the readings below. During the early part of the season a marked daily fluctuation in the flow is shown, owing to the thawing of the snow and ice in the daytime. It is believed that as a general rule the flow increased up to about 6 p. m. and began to decrease about 7 p. m., reaching the daily minimum the next forenoon. The mean daily discharge shown in the following table was computed from the mean of the discharges at 7 a. m. and 5 p. m., but occasionally the discharge at noon was given some weight in the determination.

The water supply decreased to such an extent the last of August and first of September as to seriously handicap the operation of the mill. During this time it was possible to run but two of the seven stamps.

Height on weir, in inches, and discharge, in second-feet, of Craigie Creek at Gold Bullion mill for 1913.

	7 a. m.		12 m.		5 p. m.		Mean discharge.
	Height.	Discharge.	Height.	Discharge.	Height.	Discharge.	
June.							
1	......	......	......	......	......	......	18
2	7	14	7⅞	18	9¼	22	18
3	8⅜	19	8¼	19	11⅝	31	25
4	9¾	24	10	25	13⅝	40	32
5	11¼	30	11¾	32	14¾	44	37
6	11¾	32	12⅜	34	15⅝	48	40
7	12½	35	12½	35	16	50	42
8	12¾	36	16⅛	51	17⅝	58	47
9	14⅛	42	15⅝	48	18¾	64	53
10	15	46	14¾	44	15½	48	47
11	12⅛	33	12¾	36	13¾	40	36
12	11⅜	30	13¼	38	14⅞	45	38
13	12⅞	36	13¾	40	15½	48	42
14	13¾	40	......	......	......	......	45
15	13¼	38	16½	53	19⅞	70	54
16	14¾	44	16¾	54	19¼	66	55
17	14⅛	42	14⅝	44	18¾	64	53
18	13⅞	41	14¼	42	18⅛	61	51
19	14⅝	44	14⅛	42	16¾	54	49
20	12¾	36	12	33	15	46	41
21	11⅜	30	10⅝	27	13⅜	38	34
22	11¾	32	11½	31	15½	48	40
23	11⅞	32	12	33	15¾	49	40
24	11⅝	31	11⅜	30	15¼	47	39
25	11⅜	30	11⅞	32	13½	39	34

Height on weir, in inches, and discharge, in second-feet, of Craigie Creek at Gold Bullion mill for 1913—Continued.

	7 a. m.		12 m.		5 p. m.		Mean discharge.
	Height.	Discharge.	Height.	Discharge.	Height.	Discharge.	
June—Continued.							
26	11⅛	29	11	29	12⅛	33	31
27	11	29	11⅛	29	14⅜	43	36
28	12¼	34	11⅞	32	12⅛	33	34
29	10⅝	27	9⅞	24	9⅜	23	25
30	7¾	17	7¾	17	8⅜	19	18
July.							
1	7⅝	17	7⅜	16	9¾	24	20
2	8¼	19	......	......	11⅜	30	24
3	9⅛	22	10½	27	11⅝	31	26
4	10⅞	28	......	......	12⅛	33	30
5	9¾	24	9⅝	24	12⅛	33	28
6	10¼	26	......	......	10⅛	25	26
7	8⅝	20	......	......	9½	23	22
8	9½	23	......	......	8⅞	21	22
9	7⅝	17	......	......	10⅞	28	22
10	8⅛	18	9⅜	23	11⅜	30	24
11	15	46	......	......	12⅛	33	40
12	9¾	24	9¼	22	9⅜	23	24
13	8¾	21	8¼	19	12⅞	36	28
14	9¼	22	9⅜	23	9½	23	22
15	8½	20	7¼	16	7½	16	18
16	7¾	17	7¼	16	7½	16	16
17	7	15	......	......	7¼	16	16
18	6¾	14	6⅜	13	6⅞	14	14
19	6¼	12	6	12	6⅛	12	12
20	9¼	22	......	......	8¾	21	22
21	6⅞	14	6⅝	14	6⅜	13	14
22	7½	16	7⅜	16	7½	16	16
23	7	15	6¾	14	6⅞	14	14
24	6½	13	6	12	6⅞	14	14
25	7	15	6¾	14	6¾	14	14
26	7⅜	16	8⅝	20	9⅜	23	20
27	8⅜	19	8	18	7¾	17	18
28	7⅛	15	8⅛	18	8⅞	21	18
29	7¼	16	6½	13	6⅝	14	15
30	6⅛	12	6⅛	12	6	12	12
31	5¾	11	6¼	12	6⅞	14	12
August.							
1	5¾	11	5⅞	11	......	......	11
2	5½	10	5⅜	10	5⅜	10	10
3	5⅜	10	5¼	9.6	5⅜	10	10
4	5⅜	10	5⅛	9.2	5⅜	10	10
5	5⅛	9.2	5	8.9	5⅜	10	9.6
6	7	15	6½	13	6¼	12	14
7	6	12	6	12	6	12	12
8	5⅝	11	5⅝	11	6¼	12	12
9	5⅜	10	5⅛	9.2	6	12	11
10	6	12	5⅝	11	5½	10	11
11	5½	10	5¼	9.6	5½	10	10
12	5⅛	9.2	5	8.9	5⅛	9.2	9.2
13	5⅛	9.2	5	8.9	5	8.9	9.0
14	4¾	8.2	4⅝	7.9	4⅝	7.9	8.0
15	4½	7.6	4⅜	7.3	4⅜	7.3	7.4
16	4¼	6.9	4½	7.6	4⅝	7.[illegible]	7.4
17	4⅛	6.6	4	6.3	4⅛	6.6	6.6
18	4½	7.6	4½	7.6	4⅜	7.9	7.8
19	8½	20	13⅞	41	12	33	26
20	10⅞	28	9⅞	24	9⅞	24	26
21	7½	16	7⅛	15	7⅛	15	16
22	6½	13	6¼	12	6¼	12	12
23	5⅞	11	5⅞	11	5⅝	11	11
24	5½	10	5½	10	5¾	11	10
25	5⅝	11	5⅝	11	5¾	11	11

Height on weir, in inches, and discharge, in second-feet, of Craigie Creek at Gold Bullion mill for 1913—Continued.

	7 a. m.		12 m.		5 p. m.		Mean discharge.
	Height.	Discharge.	Height.	Discharge.	Height.	Discharge.	
August—Continued.							
26	7 3/4	17	9 3/8	23	11 1/8	29	23
27	15 7/8	50	16	50	14	41	46
28	10	25	9 5/8	24	9 5/8	24	24
29							18
30			6 1/4	12			12
31	6 7/8	14	7 1/4	16	7 5/8	16	15
September.							
1	6 3/8	13			6 1/4	12	12
2	5 7/8	11	5 3/4	11			11
3	5 1/2	10	5 3/8	10	5 1/4	9.6	9.8
4	5	8.9	4 7/8	8.5	4 3/4	8.2	8.6
5	4 5/8	7.9	4 1/2	7.6	4 1/2	7.6	7.8
6	4 5/16	7.1			4 1/4	6.9	7.0
7	4 1/8	6.6	4	6.3	4	6.3	6.4
8	3 7/8	6.0	3 7/8	6.0	3 13/16	5.9	6.0
9	3 3/4	5.7	3 3/4	5.7	3 5/8	5.5	5.6
10	3 5/8	5.5	3 1/2	5.2			5.3
11	3 7/16	5.1	3 3/8	5.0			5.0
12	3 1/16	4.3	2 15/16	4.1			4.2
13	2 7/8	3.9	2 15/16	4.1	2 15/16	4.1	4.0
14	2 11/16	3.6	3 5/16	4.8	3 1/4	4.7	4.2
15	3 3/16	4.6	3 3/16	4.6	3 3/16	4.6	4.6
16	3 1/8	4.5	3 1/8	4.5	3 1/8	4.5	4.5
17	3 3/8	5.0	3 1/4	4.7	3 3/8	5.0	4.9
18	3 1/4	4.7	3 1/8	4.5	3 1/8	4.5	4.6
19	3	4.2	3	4.2	2 15/16	4.1	4.2
20	2 7/8	3.9					3.9
21	2 7/8	3.9	2 3/4	3.7	2 11/16	3.6	3.8
22	2 3/4	3.7	3 3/4	5.8			10
23	17 3/4	59	13 3/4	40	11	29	44
24	10 3/8	26			10 3/8	26	26
25	8 1/4	19					16
26			4 5/16	7.1	4	6.3	7.1
27	3 1/4	4.7	3	4.2	2 3/4	3.7	4.2
28	2 3/4	3.7					3.7
29							3.7
30	4 1/2	7.6					7.6

Monthly discharge of Craigie Creek at Gold Bullion mill for 1913.

Drainage area 2.8 square miles.

Month.	Discharge in second-feet.			Second-feet per square mile.	Run-off (depth in inches).	Run-off in acre-feet.	Accuracy.
	Maximum.	Minimum.	Mean.				
June	55	18	38.4	13.7	15.29	2,280	B.
July	40	12	20.1	7.18	8.28	1,240	B.
August	46	6.6	13.7	4.89	5.64	842	B.
September	44	3.7	8.32	2.97	3.31	495	B.

LITTLE SUSITNA RIVER.

Little Susitna River rises in a glacier a few miles northeast of the Willow Creek region and flows in a general southwesterly direction to the point at which it is joined by Archangel and Fishhook creeks, which take the drainage opposite the head of Willow Creek and flow generally to the south and east. About 20 miles from its head the Little Susitna emerges from the hills and bends to the west, following the base of Bald Mountain, from which it receives many small streams. It continues on this course about 30 miles until it is well out into the flat, swampy valley of Susitna River, and then turns more to the south and 20 miles beyond enters Cook Inlet.

Two discharge measurements of the Little Susitna were made about 14 miles from its head and 3 miles below the mouth of Fishhook Creek, at a point just above the highway bridge which crosses it about 28 miles from Knik. Gage heights were obtained for a short period, but the measurements are insufficient for estimates of daily discharge.

Discharge measurements of Little Susitna River at mile 28.

Date.	Gage height.	Discharge.	Drainage area.	Discharge per square mile.
	Feet.	*Sec.-feet.*	*Sq. miles.*	*Sec.-feet.*
Sept. 10	3.75	141	61	2.31
Sept. 13	3.70	135	61	2.21

Daily gage height, in feet, of Little Susitna River at mile 28 for 1913.

[Drainage area, 61 square miles. Huie Goodell, observer.]

Day.	Sept.	Oct.	Day.	Sept.	Oct.	Day.	Sept.	Oct.
1			11	3.70		21	3.70	
2		3.80	12	3.70		22		
3			13	3.69		23		
4			14	3.66		24		
5			15	3.65		25		
6			16	3.64		26		
7			17	3.66		27		
8			18	3.64		28		
9			19	3.60		29		
10	3.76		20	3.60		30		
						31		

ARCHANGEL CREEK.

Archangel Creek rises in the rugged mountains of the northern part of the Willow Creek district and flows in general to the south and east. Like all other streams in the vicinity, it has heavy grades and is well adapted for supplying power to run small mills when the water supply is sufficient. The water power is likely to be utilized, as there are a number of quartz prospects on the creek and its branches.

The following discharge measurement was made on Sidney Creek, a branch draining a southern slope of the basin, at the outlet of a small lake, where it is proposed to divert water for running a mill.

September 12, 1913: Gage height, 3.11 feet; discharge, 1.88 second-feet; drainage area, 1.1 square miles; discharge per square mile, 1.71 second-feet.

The discharge probably represents about the minimum for the summer. The lake outlet is at the point where a hanging valley breaks into the main valley, and the creek falls more than 200 feet in one-fourth mile. Without doubt the water supply is sufficient for running a small mill the greater part of the summer.

FISHHOOK CREEK.

Fishhook Creek drains the area south of Archangel Creek. The mills of the Gold Quartz and Free Gold Mining companies are near its head, and both have small hydraulic plants. During the last of the summer they were handicapped by shortage of water. The Free Gold Mining Co. was put to considerable expense in building ditches to gather in all the drainage available, but even this was inadequate during the latter part of the summer and it was necessary to use a gasoline engine for auxiliary power.

A few gage heights were obtained and the following discharge measurement was made on Fishhook Creek at a point 1¾ miles below the site of the mill used by the Free Gold Mining Co. in 1913 and above the mouth of the first large tributary on the right, about 2½ miles from the mouth and about 33½ miles from Knik.

September 12, 1913: Gage height, 3.24 feet; discharge, 12.6 second-feet; drainage area, 4.7 square miles; discharge per square mile, 2.68 second-feet.

Daily gage height, in feet, and discharge, in second-feet, of Fishhook Creek at mile 33½ for 1913.

[Drainage area, 4.7 square miles. H. C. Emery, observer.]

Day.	Sept.	Oct.	Day.	Sept.	Oct.	Day.	Sept.	Oct.
1			11			21	3.30	
2		3.26	12	3.25		22	3.35	
3			13	3.25	3.60	23		
4		3.23	14	3.25	3.60	24	3.40	
5		3.00	15	3.23	3.15	25	3.42	
6		3.00	16	3.25	3.10	26		
7			17	3.23	3.03	27		
8		3.20	18	3.20	3.05	28	3.43	
9			19			29		
10			20			30	3.30	
						31		

NOTE.—Gage heights affected by ice Oct. 5–18.

DEVELOPED WATER POWERS.

Three water-power plants have been installed in the Willow Creek district for the operation of gold quartz mills, as follows: The Alaska Gold Quartz Mining Co. develops 15 to 20 horsepower on Fishhook Creek by Pelton wheel under a head of 120 feet, using the power to operate a 4-stamp mill; the Alaska Free Gold Mining Co. develops about 25 horsepower on Fishhook Creek by a Pelton wheel under a head of 35 feet, using the power to operate a Lane mill; the Gold

Bullion Mining Co. develops about 25 horsepower on Craigie by a turbine wheel under a 28-foot head and uses the power to operate a 7-stamp mill.

The water supply for these plants is sufficient for their operation only about three or four months during the summer.

WATER-POWER SITES.

Up to the present the only water-power developments which have been justified by the ore prospects of the Willow Creek district have been those directly at the mill sites from the water supply available at those points. These mill sites are so far up the stream that the tributary drainage area is too small to furnish the necessary supply in dry seasons for even the present small plants. Consequently, the plants must be partly or wholly shut down at these times or the water power must be supplemented from other sources. The cost of auxiliary power in these inaccessible regions is so great as to be prohibitive unless the ore is very rich. At one of the mills it was stated that cordwood costs $40 per cord, and that gasoline, which was there used, costs 70 cents per gallon at the mill. Water-power development in winter is impossible on these sites.

The first and easiest method of supplying the deficient power is by increasing the effective head at the plant. This can usually be accomplished easily, for the streams have heavy grades and much head can be obtained in comparatively short distances. In such a plant there would usually be a small flow of water acting under a high head. Wheels for such installations as would sometimes be desired in this region are not carried in the regular stock of water-wheel manufacturers, but it is believed that if the conditions under which they were to operate were known, wheels specially designed could be secured which would give good results.

Another method of solving the power problem is to develop electric power on the lower stretches of the streams where the flow is larger and more dependable and transmit it to the property. A scheme for cooperation in the development of hydroelectric power on the Little Susitna River for the common use of the mining companies of the region has already been proposed. In the vicinity of the mouth of Fishhook Creek the Little Susitna has a fall of about 150 feet to the mile. The valley in this section varies from the U-shaped glacial form to a narrow rock canyon, and it is everywhere filled with heavy granite bowlders. Concentrated fall and the topography make some sites more favorable for power development than others. The most suitable type of development is probably a diversion dam, built only high enough to divert the required amount of water, and a combination of canal and pipe line for carrying the water to the wheel.

The flow of the Little Susitna for six or seven months of the year under tho head that it is possible to utilize would probably be ample for any power requirements that are likely to arise in this district. The discharge on September 13 at mile 28 was 135 second-feet, or 2.21 second-feet per square mile. That flow would develop about 11 horsepower per foot of fall, with an efficiency of 70 per cent at the wheel. With a flow of 0.5 second-foot per square mile about 2.4 horsepower could be produced for every foot fall.

Little is known of the winter flow, but judging from the climatic conditions which prevail in this region it must fall to a very low stage. If winter operation was desirable and the stream flow was not found to be sufficient to provide the power, the closeness of the Matanuska coal fields affords a possible solution of the problem. If these coal fields are developed, it should be possible to furnish fuel for an auxiliary steam plant operating in conjunction with the hydroelectric plant at a comparatively low figure.

Except that the plant would be more remote from the coal fields, hydroelectric power could be generated on the lower part of Willow Creek quite as well as on the Little Susitna, if a central power plant in that vicinity should promise to be more convenient. Such a plant as is suggested would involve considerable expense, but unquestionably would have many offsetting advantages. The feasibility of the project depends on the future promise of the mining industry in the region. If the ore deposits are sufficiently large, the outlay would be justified.

COST OF POWER.

Under ordinary conditions water power is cheaper than steam power. There are, however, so many unfavorable conditions that may have to be overcome in the installation and operation of a water-power plant that its cost, compared with other sources of power, should be carefully considered before definitely deciding in its favor.

Ordinarily, the cost per unit of power developed is much less for a large plant than for a small one. At the present time the industries in the area considered in this report do not require power in large quantities. Aside from railway operation, there are no power requirements aggregating 1,000 horsepower within the province of any one water-power site. Energy is needed principally for the operation of small mines and for lighting. With few exceptions a 200-horsepower plant would be ample. Under such conditions a development may be very expensive, whereas if the same power site was developed to its maximum capacity the energy might be sold at a much lower figure if a market could be obtained for the entire output.

In order to obtain continuous water power throughout the year it will be necessary on most of the streams to provide storage to assure a sufficient water supply during the winter. Otherwise an auxiliary source of power, such as a steam or gas engine plant, must be provided. In either case the initial expense would generally be considerably greater than it would be if a steam or gas engine plant alone was installed. Most of the mines are small, with a rather uncertain future, for which reason the operators prefer to keep the first cost of their plants as low as possible, even though they must bear a heavier operating expense. When an ore body is worked out the chances are that the power plant that was used in recovering the ore will become practically valueless. It is therefore evident that for a small ore deposit a high rate of depreciation must be charged against the plant.

The cost of installing and operating a water-power system is affected by such an infinite variety of conditions that each development becomes a problem peculiar to itself, and cost data from other installations are of uncertain value. A factor that should tend to produce low installation costs for power development in southern Alaska is the fact that most of the power sites are near tidewater, thus permitting the equipment to be landed near the site at a minimum of cost. Another item of expense that will not usually enter into the cost of development in Alaska to any great extent is the acquisition of rights of way and flowage rights. The streams are, as a rule, more valuable for water power than for other uses, such as domestic supply, irrigation, or navigation, and therefore a conflict of interests will not arise, as so frequently happens in many localities in the States.

The item of expense that tends to increase the cost of construction work in Alaska as much if not more than any other over similar work in more populous countries is that of wages. Wages are high not only because of the high cost of living but also because of the isolated position of the country with respect to labor markets. An increase in wages is also warranted by the rather unfavorable conditions under which men are frequently required to live.

Several small hydroelectric plants ranging from 100 to 350 horsepower have been installed along the coast between Cordova and Seward, and from indefinite cost data that are available regarding three of them the average cost of installation appears to have been about $150 per horsepower. So far as can be learned the plants were constructed under rather unfavorable conditions (one plant was constructed during the spring when there was from 5 to 15 feet of snow at the site), and undoubtedly represent a somewhat higher initial cost than would ordinarily be necessary. The water supply, however, is not sufficient to develop the rated capacity of the generating equipment during low-water period. Therefore, if dams were constructed that would create adequate reservoir capacity to assure enough water during the winter the cost of the above installations would probably approach $150 per horsepower, even though the plant were installed under the most favorable conditions.

The following description and estimated cost of installation and operation of a hydroelectric plant in southeastern Alaska is taken from Western Engineering, January, 1914. It is reported that the scheme of development described in the article has since been modified.

LONG LAKE POWER DEVELOPMENT.

By E. P. KENNEDY.[1]

Long Lake, which lies about 2 miles from the beach at an elevation of 727 feet, has an area of 3.1 square miles. It is situated near Speel River, between Ketchikan and Skagway, 35 miles southeast of Juneau, Alaska. Water measurements for eight months and an estimate for the remaining four give a yearly run-off of 21,757 million cubic feet, and as the drainage area is taken at 32.4 square miles the above run-off amounts to 24 feet, or an equalized yearly flow of 689 cubic feet per second. The initial plant will use 300 second-feet, which is equivalent to a run-off of 10.4 feet over an area of 32.4 square miles.

The power plant is to be situated near Second Lake, 2,000 feet from and 535 feet below Long Lake and about 1½ miles from the beach. This plant will consist of two units, each 5,000-kilowatt capacity and each to be direct connected to a water turbine utilizing 300 second-feet.

To be assured of a continuous flow of 300 second-feet the lake will be drawn on by tapping with a tunnel or by a siphon to a depth of 12 feet and the two spillways from the lake closed, thus raising the lake level 25 feet, giving an available storage of 37 feet.

The cost of this power installation would be:

Power house with two 5,000-kilowatt units, complete	$250,000
Pipe lines, two 60-inch, with head gates	93,594
Closing spillways from lake	10,000
Tapping lake	5,000
Contingencies and incidentals	3,000
Plant for construction	[2]13,882
Total	375,476

Or a capital cost of $37.54 per kilowatt or $27.95 per horsepower.

The cost of operating the above plant would be per year:

General expenses	$6,000
Operating labor	6,000
Supplies, etc	4,000
Total	16,000
Operating cost per year per kilowatt	1.60
Interest and depreciation, 8 per cent on capital cost	3.00
Cost of kilowatt year	4.60
Cost of horsepower year	3.43

[1] Asst. Supt. Alaska Treadwell Gold Mining Co., Treadwell, Alaska.

[2] Original cost of plant $25,882. Value of plant after construction period estimated $12,000, thus leaving $13,882 to be charged to water power system.

To be assured of a yearly average of 10,000 kilowatts the generators should be run at 25 per cent above normal capacity for 6 months of the year while there is a large excess of water, and thus provide for unforeseen shutdowns.

Surveyed lake area is 3.1 square miles, or 86,423,040 square feet, requiring 20 feet in depth at this area to provide for the required storage.

This storage is obtained by raising the lake level 25 feet and drawing on the lake 12 feet. The increased area obtained by raising the lake will make up for the decreased area by drawing the lake and also provide sufficient storage below the 2 feet of ice.

Power estimate is based on a pipe-line loss of 1 per cent, water-wheel efficiency of 82 per cent, generator efficiency of 93 per cent; total efficiency of 75 per cent from the water. Three hundred second-feet under 542-foot head at 75 per cent will generate 10,320 kilowatts.

From flow measurements the following figures are obtained:

	Measured flow (cubic feet).	Mean discharge in second-feet.[a]	Required flow for 300 second-feet.	From storage (cubic feet).
January	324,187,200	121	803,520,000	479,332,800
February	283,046,400	117	725,760,000	442,713,600
March	374,976,000	140	803,520,000	424,544,000
April	352,512,000	136	777,600,000	425,088,000
May	1,154,390,400	431	803,520,000	....
June	2,947,104,000	1,137	777,600,000	....
July	5,340,729,600	1,994	803,520,000	....
August	4,860,492,480	1,815	803,520,000	....
September	4,473,792,000	1,726	777,600,000	....
October	803,520,000	300	803,520,000	....
November	518,400,000	200	777,600,000	259,200,000
December	324,187,200	121	803,520,000	479,331,800
	21,757,337,280	689	9,460,800,000	2,510,210,200

[a] Inserted by C. E. E.

The foregoing estimates are exceedingly low, and if after construction and operation of the plant they are found to be correct it is believed that the project will be one of the cheapest that has ever been installed.

The cost of $3.43 per horsepower per year, which includes all operating expenses besides interest and depreciation on the capital cost, could be increased several fold and still be much cheaper than steam power with coal selling at cost.

It should be noted that the estimate does not include the construction of a dam, which is often necessary and frequently makes up a large percentage of the total cost.

A point in connection with the above project that is worthy of note—though not pertinent to the cost—is the high rate of run-off on which the capacity of the plant is based. The average yearly flow is estimated to be 689 second-feet or more than 21 second-feet per square mile.

The cost of developing the Silver Lake power site in the Prince William Sound region has been estimated with considerable care by interested parties. Their estimates contemplated a plant of 750 horsepower capacity, a 10-foot dam at the outlet of the lake, and 8 or 10 miles of transmission line at a total cost of about $55,000 or a little over $73 per horsepower. This site could no doubt be developed to a capacity of several thousand horsepower without increasing the cost in anywhere near the same ratio.

Estimated cost of operating a 300-horsepower steam plant per year (365 days, 24 hours per day), assuming capital cost of $100 per horsepower, or total cost of $30,000.

Price of coal per long ton	$9	$6	$4	$3
Interest and depreciation, at 10 per cent	$3,000	$3,000	$3,000	$3,000
4 pounds coal per horsepower-hour	42,228	28,152	18,768	14,076
3 engineers, 8-hour shifts, at $5 per day	5,475	5,475	5,475	5,475
3 firemen, 8-hour shifts, at $4 per day	4,380	4,380	4,380	4,380
Oil, waste, and supplies	1,200	1,200	1,200	1,200
Total for plant	56,283	42,207	32,823	28,131
Total per horsepower per year	187.61	140.69	109.41	93.77

Estimated cost of operating steam plant 6 months.

Price of coal per long ton	$9	$6	$4	$3
Interest and depreciation, at 10 per cent	$3,000	$3,000	$3,000	$3,000
4 pounds coal per horsepower hour	21,114	14,076	9,384	7,038
3 engineers, 8-hour shifts, at $5 per day	2,738	2,738	2,738	2,738
3 firemen, 8-hour shifts, at $4 per day	2,190	2,190	2,190	2,190
Oil, waste, and supplies	600	600	600	600
Total for plant	29,642	22,604	17,912	15,566
Total per horsepower for 6 months	98.81	75.35	59.71	51.89

Estimated cost of operating a 300-horsepower hydroelectric plant per year (365 days, 24 hours per day), assuming capital cost of $150 per horsepower and 5 miles of transmission line at $2,000; total cost of system, $55,000.

Interest and depreciation, at 10 per cent	$5,500
4 operators, at $6 per day—2 shifts, with 1 operator at generating and 1 at distributing end	8,760
1 lineman, at $4 per day	1,460
Oil, waste, and supplies	1,000
Total for plant	16,720
Total per horsepower per year	55.73

Estimated cost of operating hydroelectric plant 6 months.

Interest and depreciation, at 10 per cent	$5,500
4 operators, at $6 per day	4,380
1 lineman, at $4 per day	730
Oil, waste, and supplies	500
Total for plant	11,110
Total per horsepower for 6 months	37.03

The purposes of the above tables is not so much to show the actual cost of producing power as it is to give some idea of comparative cost of steam and water power. Although the above figures may be considerably in error, it is believed the assumptions regarding the steam plant are in its favor as opposed to the hydroelectric system, thus giving added weight to the final conclusion that the water power is much the cheaper. For example, it is arbitrary what interest and depreciation charges should be made, but it is generally conceded that they should be greater for a steam plant than for a hydroelectric plant, though in this estimate the same charge (10 per cent) is assumed.

The consumption of coal per horsepower-hour is known to vary widely among different plants, but for one of 300 horsepower it is seldom less than 4 pounds and more often 50 to 100 per cent greater. The estimated cost of labor may be questioned, but it should be noted that the total is assumed to be slightly greater for the hydroelectric plant than for the steam, which is far from probable.

The capital cost of steam plants varies between wide limits, due to different types used and the variety of conditions under which they are installed. Average costs for different sizes and types of plants have been determined from a large number of installations in the United States and Canada. For plants with simple noncondensing engines with capacities from 10 to 100 horsepower the unit cost of installation has been found to vary from a maximum of $225 to a minimum of about $75. Larger plants of 100 to 2,000 horsepower with compound condensing engines are somewhat cheaper per unit of capacity, the average cost varying from a minimum of about $50 for the largest to a maximum of about $170 for the smallest. The assumed cost of $100 per horsepower for the plant under discussion is believed to be more likely less than greater than what it would actually cost.

In estimating the cost of steam power it is considered that the energy is to be used near the point where it is generated, but if the market is not near tidewater or a line of railroad it would probably be cheaper to install electric generators and transmit the energy by wire than to transport the fuel, in which case the capital cost of the plant would be considerably greater than that assumed.

Comparative cost of different systems, summarized from previous tables.

Price of coal per ton	$9.	$6.	$4.	$3.
Steam alone per horsepower year	$187.61	$140.69	$109.41	$93.77
Steam plant 6 months + hydroelectric plant 6 months, per horsepower year	135.84	112.38	96.74	88.92
Hydroelectric plant alone per horsepower year	55.73			

In the table above are summarized from previous tables the estimated unit costs of one horsepower per year, from a steam plant alone, from a hydroelectric plant alone, and from a plant using steam and hydroelectric power each for six months. The figures show that the cost of water power at $55.73 per horsepower year is only about one-third that for steam with coal at $9 per ton, which is about the minimum price that coal sold for in 1913 at tidewater in south-central Alaska. With coal at $3 per ton, which is probably less than it can be sold for when the Matanuska and Bering River fields are commercially available, the cost of water power is still about 40 per cent less than that for steam. The combined steam and hydroelectric plant is also shown to be more economical than steam alone, even with coal at the minimum figure.

California crude oil is now being used to a considerable extent in place of coal in Alaska, and so long as coal must be shipped from British Columbia or points on the Pacific coast of the United States, the advantage of oil will probably continue, but when local coal becomes available it is doubtful if that condition will persist. Compared with coal, oil weighs about 35 per cent less for equal heat values and occupies about 50 per cent less space. An average ratio in heat values that is frequently used is 3.5 barrels of oil to one ton of coal. The selling price in 1913 at Cordova was $2 per barrel.

Wood is used but little for the development of power. It can not compete with other fuels even under the prevailing high price, except where the timber is locally available and the other fuels must be transported for a considerable distance. About two cords of wood are generally considered the equivalent of one ton of coal.

Gasoline is used to some extent by small power consumers in isolated localities where wood is not available and where lack of transportation facilities demands economy in weight of both equipment and fuel. About one pint of gasoline or denatured alcohol is required per horsepower-hour when the engine is being run under favorable conditions, such as most efficient load, proper compression and time of ignition and most suitable explosive mixture. As ordinarily operated gasoline engines may require several times the above quantity of fuel per unit of power developed. In quantities of 50 to 100 gallons gasoline sold for $0.40 per gallon at points on the coast near Prince William Sound in 1913.

A WATER-POWER RECONNAISSANCE IN SOUTHEASTERN ALASKA.[1]

By John C. Hoyt.

INTRODUCTION.

The territory covered by this report (see fig. 5) includes that portion of southeastern Alaska extending southward from White Pass for a distance of about 350 miles. Detailed investigations of water-power resources were made in three districts of this area—Ketchikan, Juneau, and Skagway. Data were also obtained at Sitka and other points and from conversation with persons familiar with the country.

From Ketchikan the plants of the local power company, the New England Fish Co., and the Metlakatla Fish Co., at Beaver Falls and Sulzer, were visited. The undeveloped possibilities at Hadley, Kasaan Bay, Cholmondley Sound, Georges Arm, Carroll Inlet, Unuk River, and about Sulzer were investigated also.

From Juneau the developments of the Treadwell Co., on Douglas Island, of the Perseverance and other companies, in Silverbow Basin, and of the Amalga Co., at Eagle River, were visited. The conditions in Taku Inlet, including Turner Lake, were investigated and information was obtained in regard to Endicott River and the streams between Juneau and Eagle River.

At Skagway the local power plant and the plant of the Chilkat Fish Co. were visited, and a trip was made over White Pass and another to Haines, from which the Porcupine Creek district was visited.

At Sitka data were obtained in regard to Chichagof Island in Klag Bay.

GENERAL TOPOGRAPHIC FEATURES.

Southeastern Alaska comprises a narrow strip of mainland and a series of islands separated from one another by a network of channels and straits. Both the mainland and the islands are indented with many bays, fiords, and inlets, which, with the other natural conditions, practically cut off all travel except by boat. (See Pl. XX, *A*.)

[1] This report is a reprint with slight changes of article in U. S. Geol. Survey Bull. 442, pp. 147–157, 1909.

With the exception of small areas of flat lands along the larger rivers and at places along the coast, the entire area is mountainous. The mountains rise abruptly from the shore line and reach a maximum elevation varying from 4,000 feet in the southern part of the area to 7,000 feet in the northern part. Owing to this topography,

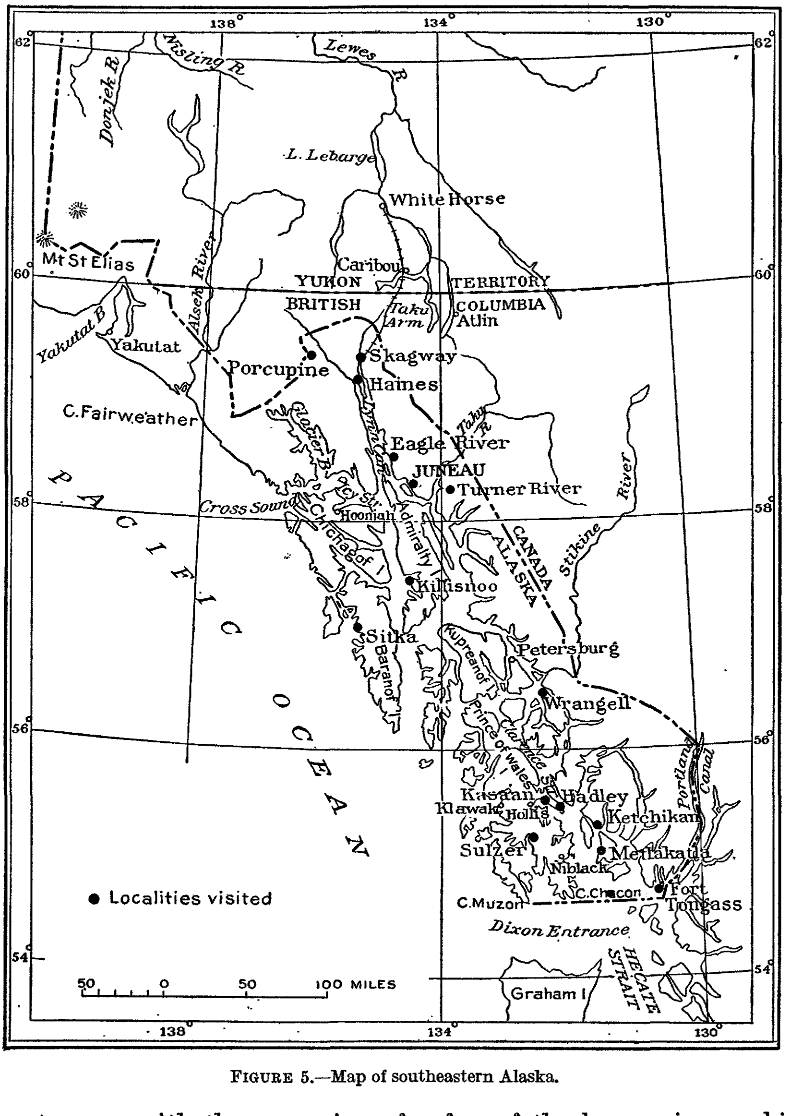


FIGURE 5.—Map of southeastern Alaska.

the streams, with the exception of a few of the larger rivers which come through the mountains from the interior, have small and precipitous drainage areas. Their courses are short and they have a large fall; in fact, many of the streams are made of a series of cataracts. (See Pl. XXI, *A*.)

A. TYPICAL COAST SCENE.

B. TYPICAL FOREST VIEW.

A. TYPICAL DRAINAGE AREA AND STREAM.

B. HANGING BASIN SHOWING OUTLET WITH FALLS AT SHORE LINE.

In the northern part of the area most of the streams head in the glaciers which cover a large portion of the country. In the lower southern part of the area many of the streams head in small lakes which occur a short distance back from the shore line in the hanging valleys that are characteristic of this area. Most of the streams flowing from these lakes are precipitous, and many of them empty into the ocean with a cataract at the shore line. (See Pl. XXI, *B*.) These lakes afford excellent opportunities for storage, as the topography near them is such that a dam can usually be constructed for raising their water level. The most successful powers already developed depend on such storage during a large part of the year, and further development in this region will depend on the availability of such lakes.

GEOLOGY.

In general, there is over the underlying rock of the country but a small depth of soil; hence the facilities for ground-water storage are exceedingly scanty. The underlying rock of the islands and of the mainland up to the foothills is limestone, slate, and schist; in the remainder of the area it is granite.

At the mouths of some of the larger rivers there are alluvial flats and glacial deposits, but the coast is, except in a few places, rocky and steep.

CLIMATE.[1]

As shown in the following tables, the climate is similar to that of the extreme northwestern part of the United States. The last frosts occur not much later than the 1st of May and the first frosts do not come until early in September. The number of growing days, therefore, averages about 180.

The winter temperature ranges from 10° below to nearly 60° above zero; the summer temperature ranges from 35° to 80°, with occasional extremes between 85° and 90°.

Precipitation varies considerably in different portions of the area. Along the west coast and in the area along Dixon Entrance, which is exposed to the direct winds from the Pacific, it is rather high, ranging from 130 inches a year at Fort Tongass to 88 inches at Juneau. In passing inland it decreases and at Skagway is only 21 inches.

A disagreeable feature of the country is the large number of rainy days, which averages about 200, except in the vicinity of Skagway, where it is less than 100. The rains are usually not heavy. Notwithstanding the great precipitation, it dries off quickly after showers, a fact which indicates that the humidity is low.

[1] For more complete records and discussions of climate see pp. 15-34 of this volume.

Temperature and precipitation in southeastern Alaska.[a]

Month.	Fort Tongass (1 year,[b] 16 months—June, 1868, to September, 1870).				Fort Wrangell (2 years, 40 months—May, 1868, to August, 1882).			
	Temperature (°F.).		Precipitation.		Temperature (°F.).		Precipitation.	
	Maximum.	Minimum.	Inches.	Number of days over 0.01 inch.	Maximum.	Minimum.	Inches.	Number of days over 0.01 inch.
January	47	6	12.92	18.5	47	−4	6.07	17.6
February	45	23	10.79	21.5	58	2	8.11	20.0
March	59	−2	8.21	17.5	54	−10	2.89	12.6
April	60	33	9.57	19.0	64	24	4.11	16.6
May	70	38	7.70	15.5	78	35	3.71	18.6
June	75	43	6.66	10.3	86	38	3.56	13.7
July	91	52	10.58	16.6	82	44	3.69	15.8
August	81	47	6.71	9.6	84	43	3.07	14.3
September	67	38	17.66	19.3	73	38	6.63	17.2
October	58	37	14.11	20.0	67	31	7.36	13.2
November	51	32	15.46	27.0	53	4	11.27	17.8
December	47	24	13.33	19.0	52	−3	10.41	22.5
Year	....	....	133.10	213.8	....	....	70.88	199.9

Month.	Killisnoo (16 years, 43 months—May, 1881, to December, 1902).				Juneau (2 years, 39 months—June, 1881, to February, 1897).			
	Temperature (°F.).		Precipitation.		Temperature (°F.).		Precipitation.	
	Maximum.	Minimum.	Inches.	Number of days over 0.01 inch.	Maximum.	Minimum.	Inches.	Number of days over 0.01 inch.
January	52	−2	5.98	18.0	50	−4	10.61	18.1
February	50	−10	4.96	14.9	50	−4	4.85	11.2
March	52	−2	4.04	15.0	50	10	6.62	18.7
April	63	15	3.50	11.0	63	13	5.25	15.0
May	76	24	3.38	12.3	71	26	7.36	16.7
June	76	33	2.36	9.9	82	38?	4.99	14.6
July	84	38	4.19	11.7	88	38	5.59	15.5
August	81	36	4.90	16.5	82	38	7.53	15.6
September	69	27	7.79	19.3	85	31	12.19	18.4
October	60	25	7.92	22.3	66	20	10.05	19.8
November	53	1	5.16	16.9	60	−1	10.47	18.4
December	54	1	4.81	17.6	45	1	8.16	19.8
Year	....	....	58.97	185.4	....	....	93.06	201.8

[a] Brooks, A. H., Geography and geology of Alaska: U. S. Geol. Survey Prof. Paper 45, pp. 158–170, 1906.
[b] The records were not continuous, and the number of years given indicates simply the number of continuous twelvemonth periods covered.

Temperature and precipitation in southeastern Alaska—Continued.

Month.	Skagway (31 months—November, 1898, to December, 1902).				Sitka (17 years, 44 months—November, 1867, to December, 1902).			
	Temperature (°F.).		Precipitation.		Temperature (°F.).		Precipitation.	
	Maximum.	Minimum.	Inches.	Number of days over 0.01 inch.	Maximum.	Minimum.	Inches.	Number of days over 0.01 inch.
January	42	− 4	0.90	7.5	51	− 2	12.17	16.8
February	44	− 9	.57	2.5	54	− 3	7.47	15.9
March	63	−10	.64	3.0	65	− 1	6.70	18.0
April	61	16	2.39	10.5	70	19	5.61	16.2
May	79	25	.77	4.7	80	28	4.11	16.1
June	90	34	.60	5.0	80	33	3.31	13.6
July	92	39	1.73	5.7	87	35	3.55	14.9
August	80	32	1.51	8.5	82	39	5.84	16.8
September	76	30	3.47	13.5	74	32	9.67	19.5
October	60	16	3.22	12.0	67	25	11.96	21.7
November	51	7	2.17	8.0	59	5	9.80	19.5
December	57	− 4	3.78	11.7	59	7	7.88	18.9
Year			21.75	92.6			88.10	207.9

Dates of freezing in southeastern Alaska.[a]

Station and year.	Last killing frost.	Last frost.	First frost.	First killing frost.	Growing days.
Fort Tongass:					
1868			Nov. 6	Dec. 19	
1869		Mar. 19	Sept. 29	Dec. 17	210
1870		Mar. 14			
Fort Wrangell:					
1869			Sept. 20	Oct. 15	
1875	Mar. 14	Apr. 20	Oct. 5	Oct. 29	229
1876	Apr. 30	June 5	Sept. 14	Oct. 29	182
1882			Oct. 2	Oct. 8	
Juneau:					
1889			Nov. 18		
1890		Mar. 29	Oct. 6		191?
1891		May 2	Sept. 20		141?
1895			Sept. 10	Sept. 19	
1899			Sept. 4		
1900				Sept. 22	
Skagway:					
1899		May 9		Sept. 4	117?
1900	Apr. 9				
1902		July 7	Aug. 27		50?
Killisnoo:					
1884			Sept. 13		
1885			Sept. 28	Oct. 12?	
1888			Oct. 15		
1891		May 6	Sept. 27		143
1892		Mar. 31	Oct. 14		197
1893		May 2	Oct. 18		169
1895			Sept. 3	Sept. 12	
1897			Sept. 27		
Sitka:					
1868		Apr. 21			
1869			Sept. 19		
1870			Oct. 19		
1871				Oct. 31	
1872				Oct. 7	
1873	May 27		Nov. 5		162
1881		May 8			
1900	June 1		Aug. 25	Oct. 1	122
1901				Nov. 1	

[a] Brooks, A. H., Geography and geology of Alaska: U. S. Geol. Survey Prof. Paper 45, pp. 171-172, 1906.

VEGETATION.

Owing to the mild temperature, the long days in summer, and the heavy precipitation, the vegetation in southeastern Alaska is very luxuriant. Except where the soil is too shallow or the slopes too rocky, the whole area is covered with dense forests of spruce, cedar, and hemlock and is in the national forests. (See Pl. XX, *B*, p. 158.) Among this timber there is a heavy undergrowth of devil's-club, berries, and other small plants. In the southern part of the area trees vary in diameter up to 6 feet and grow up the slopes to the mountain tops. Toward the north the size of the trees diminishes, the undergrowth is not so heavy, and the timber does not extend to the top of the mountains, which are either small or glacier covered.

Much of the forest is overmature and defective timber is common, but in coves and gullies for several miles back from the coast there are many fine stands of spruce and cedar which have never been injured by fire or cutting.

The logging practice now in vogue takes only the best spruce trees which can be felled into the water or on slopes where they can be skidded in by hand. Of course it is difficult to log in a mountainous country, but much timber can be logged in southeastern Alaska with no more difficulty than attends many operations in the Pacific Coast States, if modern methods are introduced.

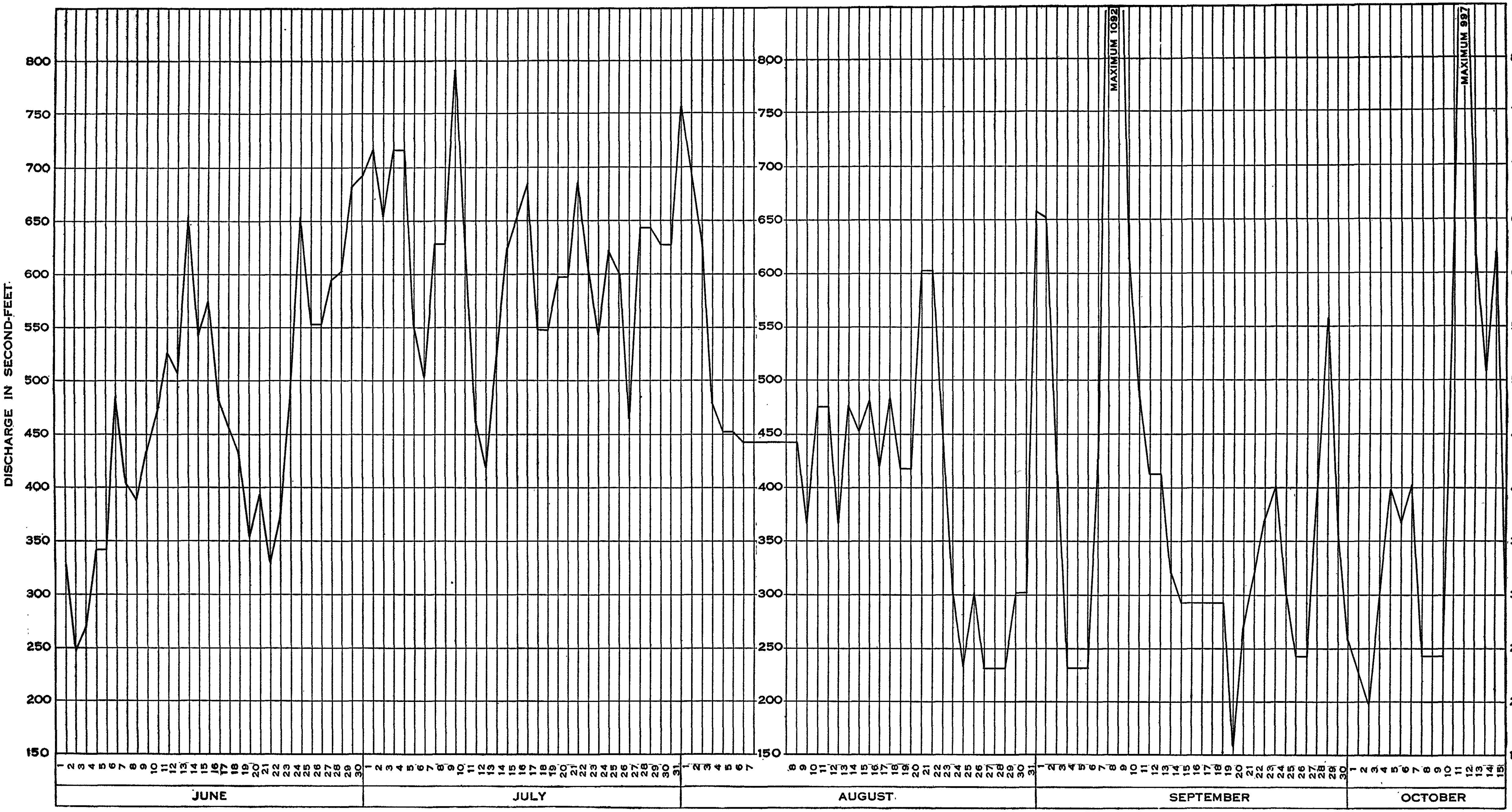
So far only the spruce has been used for saw timber, but both spruce and hemlock are undoubtedly good pulp woods. The few sawmills now operating in southeastern Alaska obtain their timber from the national forests, but the supply of timber is much greater than is required by local needs. The Forest Service is desirous of increasing the timber sales, and the present price of stumpage is low—only $1 a thousand board feet. Full information on this subject can be obtained from the forest supervisor at Ketchikan.

Aside from the native growth, garden truck, berries, and the hardy grains and grasses can be raised in all parts of this area. Strawberries, raspberries, and huckleberries grow both wild and cultivated and are of most excellent quality. Grasses and grains are difficult to harvest and cure owing to the large amount of rain.

The areas suitable for agriculture are small and are expensive to bring under cultivation. Agriculture is carried on with difficulty on account of the swampy condition of the ground, which is hard to work with horses unless well drained.

GENERAL CONDITIONS OF RUN-OFF.

The run-off from the streams in this area results principally from direct rainfall, melting snow, and melting glaciers. In view of the large rainfall, the excellent forest cover, and the glacial areas, the



HYDROGRAPH OF PORCUPINE CREEK.

From records furnished by Porcupine Gold Mining Co.

general deduction would be that this section should have many large streams with an abundant and well-sustained run-off. This, however, is not the case, as the catchment areas are small, and although the total yield per square mile is considerable, the streams are not large and they fluctuate very rapidly.

The forest effects are principally offset by the deep slopes and shallow soil, which afford but little ground storage. The streams respond very quickly to the rainfall and their volume drops with equal quickness as soon as it ceases to rain. Frequently they are reduced from a maximum to a minimum flow within a few days. This is illustrated in the hydrograph of Porcupine Creek near Haines, in the northern part of the area (Pl. XXII). This stream has a drainage basin of 34 square miles and heads in a large glacial area.

In many places, owing to the steep slopes, there are no well-defined streams but instead the water runs down the mountain side in many small channels, some on the surface and others between the soil and the rock. In some of the developments the water is obtained by contour ditches which bring the water together from these streams.

Most of the large glaciers terminate at elevations but little above sea level and are therefore practically of small value as a source of water supply for the development of power. The smaller glaciers are beneficial only during the summer months, as their water is cut off early in the fall by the frosts. It is probable that many of the extreme variations in the glacier-fed streams are due to the making and breaking of ice jams which raise and hold back the water.

The streams which head in lakes have a much better sustained flow and are practically the only ones in the area which are of much value for power, as any large development must depend on storage both for the winter months and during dry parts of the summer.

The principal defect in the water supply, so far as the production of power is concerned, is the extreme low flow during the winter months. On the smaller streams, which have no storage, there is practically no flow in winter, and even on the streams having lake storage the flow is extremely low, as shown in the records for Turner River (fig. 6), which empties into Taku Inlet near Juneau. This stream has a drainage area of 66 square miles and heads in Turner Lake, which offers excellent facilities for storage. A portion of the area is also covered with glaciers. The scantiness of the winter flow is due largely to the meager amount of storage capacity in the ground, which freezes to bedrock, thus holding back the water.

INDUSTRIAL CONDITIONS.

With the exception of a few towns along the shore and scattered mining camps and fisheries, southeastern Alaska is very sparsely settled. The only ready means of transportation is by boat. Aside

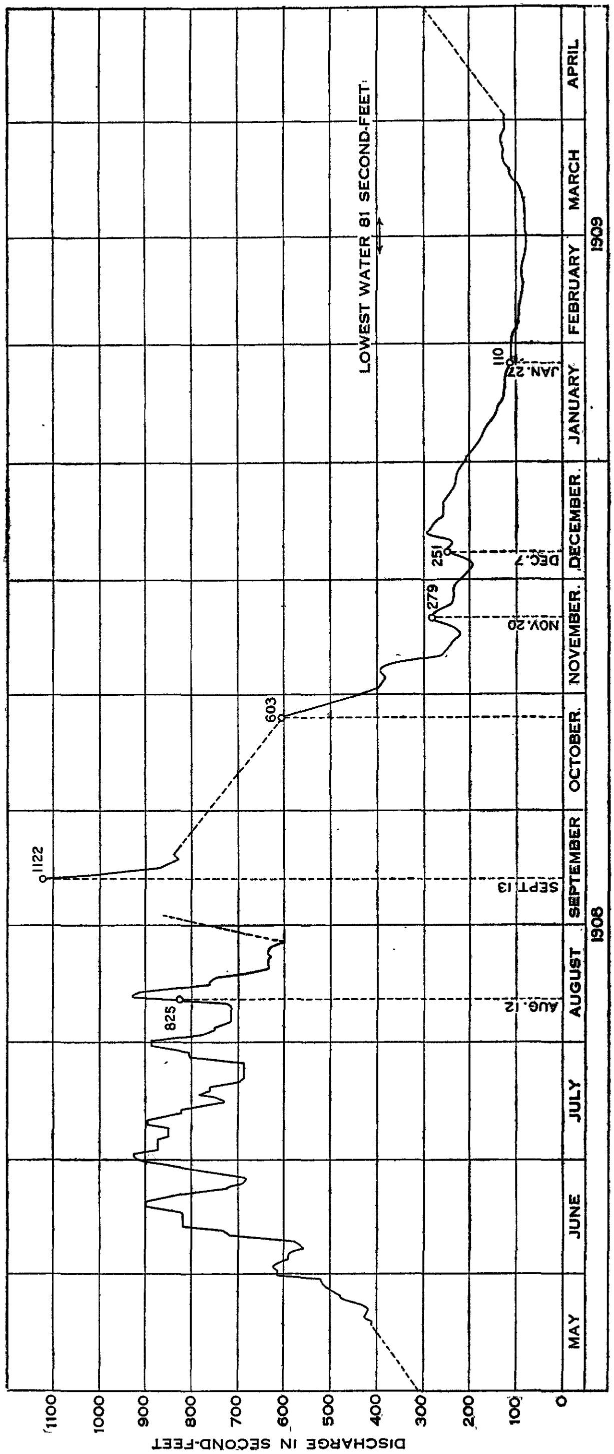


FIGURE 6.—Hydrograph of Turner River. From record furnished by Alaska Treadwell Gold Mining Co.

from the regular steamers which run from Seattle and other ports, each town has a local service connecting it with adjoining towns and camps by gasoline launches.

There are practically no roads and the country back from the shore line is almost inaccessible. The building of Government roads, which is now under way, will be a great help to the development of the country.

The two well-developed industries are fishing and mining. The larger part of the fishing is for the salmon canneries. An icing plant has just been established at Ketchikan. The mines are principally quartz mines, yielding gold and copper.

Next to fishing and mining comes lumbering, which at present is but little developed and is confined to shingle mills and a few small sawmills that meet the local demands. Agriculture, owing to the small amount of suitable land available, will always be of very minor importance.

The success and future development of both the mining and the lumbering interests depend wholly on their ability to get cheap power. Most of the mines so far opened have been in the Juneau belt and are in ore of low grade, large amounts of which must be cheaply handled in order to make them profitable. The best paying mines owe their successful operation to the presence of cheap power in their immediate vicinity, and their future development will depend on the procuring of further cheap power. This is a vital question with the older companies, and they are investigating every possible source of power. The fishing industry demands only a small amount of power during the canning season. This can readily be obtained at small expense in the vicinity of the plants.

In developing the timber resources it will be possible to produce cheap steam power by the use of sawmill waste as fuel. The ultimate development, however, for both lumber and pulp will be through the establishment of mills at accessible power sites.

The future development of electrochemical processes may open a new industry for this region. In its present stage, however, there is no field in Alaska for this industry.

Practically the whole area here considered is included in the Tongass National Forest, and therefore the conditions governing the national forests will, in a large measure, regulate the development of the timber and other resources of this country.

POWER POSSIBILITIES.

As shown in the subjoined table there were 102 water wheels in southeastern Alaska in 1908, developing 15,319 horsepower. This table is based on a special water-power census taken by the United

States Census Bureau, and the amounts are made up from statements received from power owners in the various sections. These figures have not been verified, but it is believed that they are somewhat large, as they probably give the maximum development, and this can be maintained only during a small portion of the year. Most of the plants have but little power during the winter months.

In considering the development of the water powers in southeastern Alaska the possibility of developing power from lignite and coal deposits in that region must be taken into account. When these deposits are opened, fuel will probably be available at a comparatively low cost on account of the ease of water transportation, and steam power may be produced much more cheaply and will be more reliable than the water power.

A great drawback to water-power development in this region is the difficulty of transmission. The country, as already stated, is cut by numerous channels, has a rough topography, and is covered with dense forests. Therefore transmission lines are difficult and expensive to construct, and this practically prohibits development at sites where the power can not be utilized at the point of development. In view of these difficulties, the possibilities at the present time for large power development in southeastern Alaska are not great, and such projects should be closely scrutinized as to their feasibility both from an engineer's standpoint and from that of an investor.

The opening of new mining districts and the development of the timber interests in this region will create a more widely distributed demand for power and enable the utilization of sites which at the present time can not be considered as available. As already stated, the success of any large water-power development, to be run during the entire year, will depend on the possibility of adequate storage. The meager topographic data available indicate that there are probably many lakes throughout the region which will offer excellent storage facilities.

Developed water power in southeastern Alaska, 1908.

Owner.	Location of plant.	Number of wheels.	Horse-power.	Character of industry.
Porcupine Gold Mining Co	Porcupine Creek	2	50	Placer mining.
Columbia Canning Co	Haines	3	70	Cannery.
Nugget Creek Mining Co	do	2	24	Mining.
Columbia Canning Co	Leonard Creek	3	25	Salmon cannery.
Shakan Salmon Co	Shakan Creek	4	150	Do.
Cahoon Creek Placer Co	McKinley Creek	2	100	Placer mining.
Union Iron Works	Gold Creek	1	8	Machine shop.
Hydraulic Pipe and Boiler Works	Juneau	1	8	Pipe and boiler works.
Finn & Young	Shakan	1	25	
William Duncan	Metlakatla	2	53	Sawmill and salmon cannery.
R. G. Ketchum	Kupreanof Island	1	50	Barrel factory.
Alaska Industrial Co	Jumbo Creek	1	150	
Do	Sulzer	1	30	Mining.
American Gold Mining Co	Sheep Creek	3	80	Do.
Yukon Publishing Co	Skagway	1	3	Newspaper.
Home Power Co	Lake Dewey	1	125	Light and power.
New England Fish Co	Lake Whitman and Coal Creek.	2	1,100	Fish freezing and ice making.
J. P. Jorgenson & Co	Juneau	1	25	Lumber.
Ebner Gold Mining Co	Gold Creek	4	4,000	Quartz mining.
Alaska Perseverance Mining Co	Silverbow Basin	8	880	Mining.
Alaska-Juneau Gold Mining Co	do	2	500	Do.
F. H. Partridge	Hoonah	2	15	Sawmill.
Alaska Copper Co	Lake Creek	4	300	Smelter and sawmill.
A. Murray	Douglas	2	5	Wood turning, etc.
Juneau Iron Works	Juneau	1	6	General repairs.
Treadwell group	Douglas Island	37	6,297	Gold mining.
Citizens' Light, Power and Water Co.	Ketchikan Creek	2	240	Do.
Alaska Electric Light and Power Co.	Gold Creek	5	1,000	Do.
Chichagof Gold Mining Co	Clay Bay	1	150	Do.
		99	15,319	

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