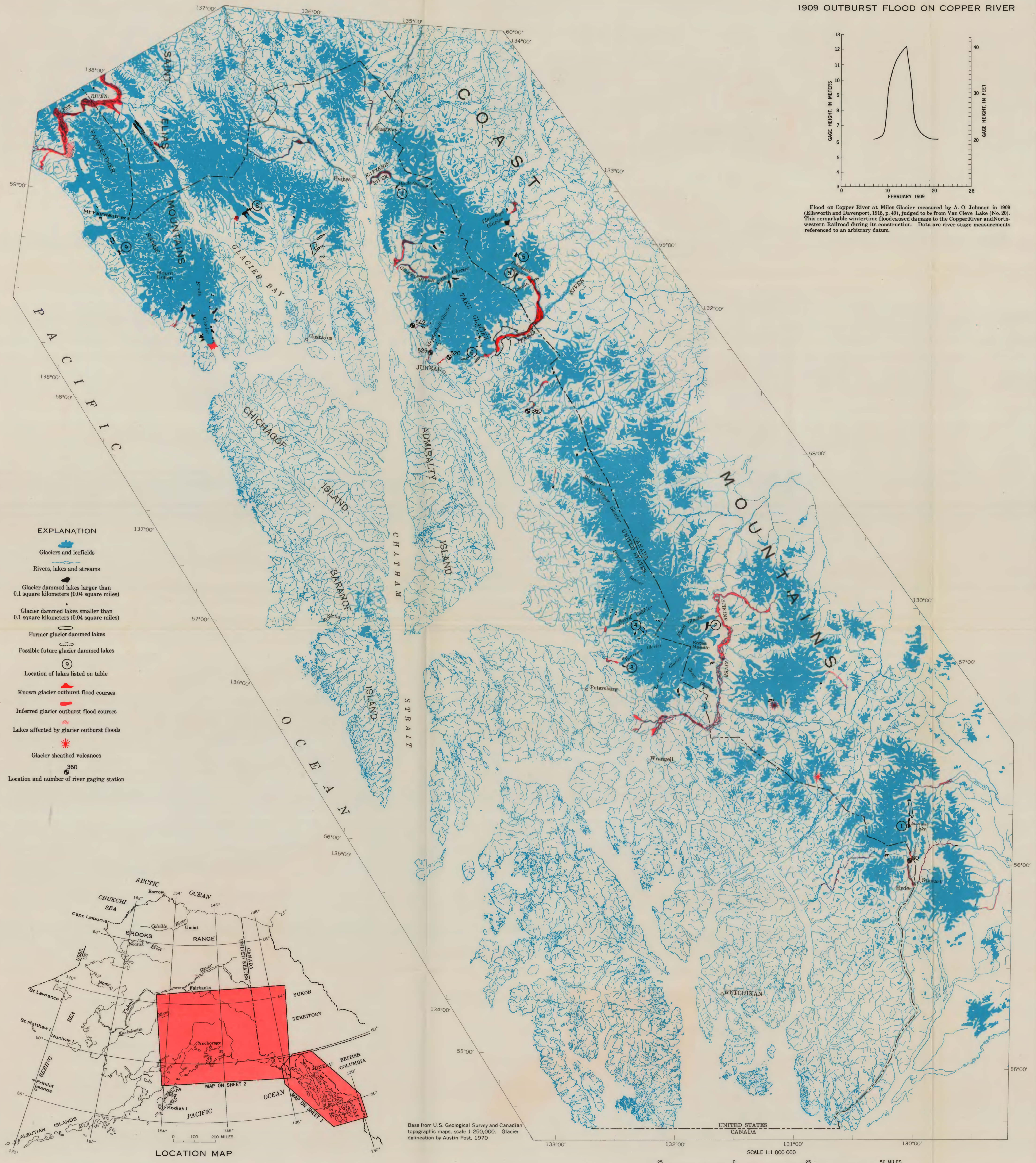
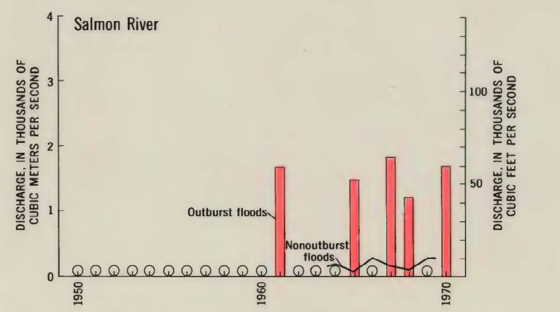


MAP SHOWING LOCATION OF GLACIERS, GLACIER-DAMMED LAKES GLACIER-SHEATHED VOLCANOES AND AREAS SUBJECT TO OUTBURST FLOODING IN SOUTHEASTERN ALASKA

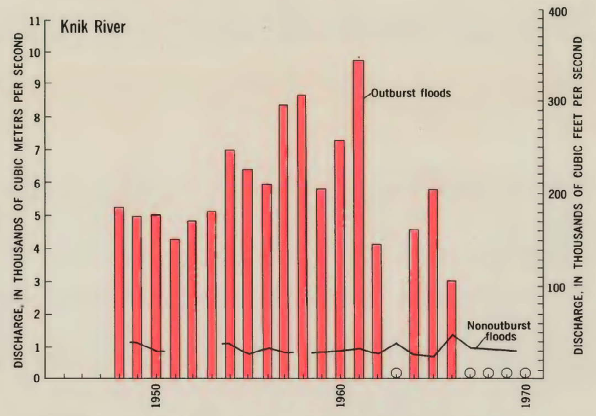
1909 OUTBURST FLOOD ON COPPER RIVER

Flood on Copper River at Miles Glacier measured by A. G. Johnson in 1909 (Ellsworth and Davenport, 1915, p. 49), judged to be from Van Cleve Lake (No. 20). This remarkable wintertime flood caused damage to the Copper River and Northwestern Railroad during its construction. Data are river stage measurements referenced to an arbitrary datum.

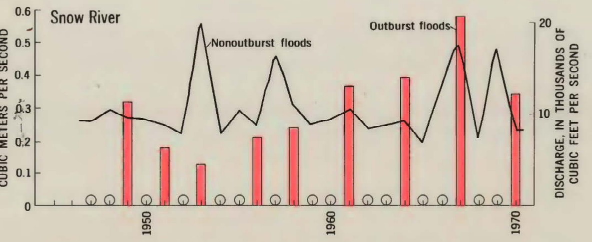
OUTBURST FLOODS AND NON-OUTBURST FLOODS ON FOUR RIVERS



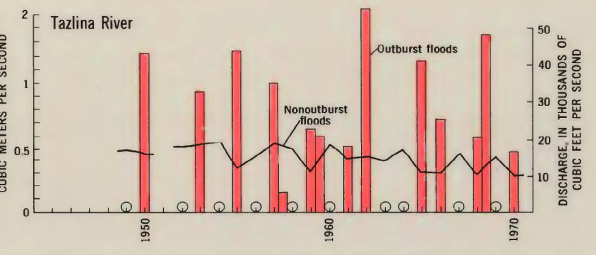
The greatest average daily discharges (red bars) from the release of Summit Lake, British Columbia (No. 1) are many times higher than the greatest average daily discharge each calendar year due to ice melt and rainfall (black line) (gage No. 15-80). Years with no outburst flood are indicated by an open circle. Momentary peak discharges during the day can be 50 percent higher than the daily average discharge at this flashy stream. The 1961 discharge was not measured and is estimated here only to indicate that an outburst did occur (Mathews, 1965, p. 49, and U. S. Geological Survey, 1954-70).



The draining of Lake George (No. 28) caused flooding far in excess of nonoutburst floods on the Knik River (gage No. 15-2810). The greatest daily average discharges during the breakouts (red bars) are compared with the greatest nonoutburst daily dishcharges (black line) for the same calendar years. The lake failed to refill (open circle) in 1963 and 1967 to the present.

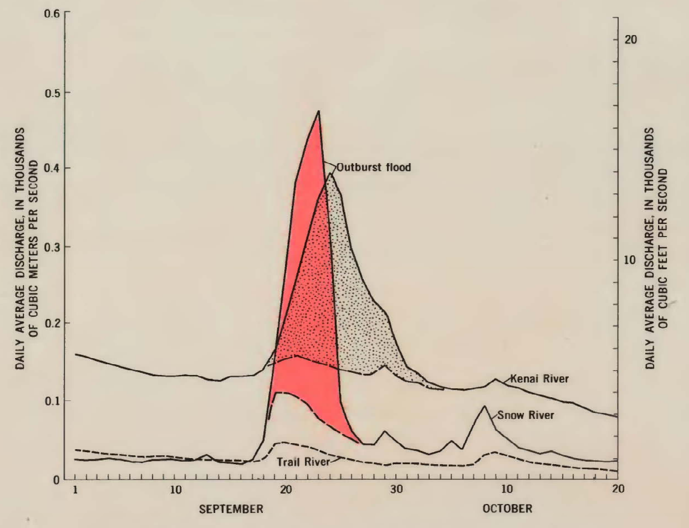


Release of water from an ice dammed lake (No. 26) in the Snow River valley has produced high flows of about the same magnitude as storms, where measured downstream at the outlet of Kenai Lake (gage No. 15-2580). Data are average daily discharge for the highest flow each calendar year. Red bars indicate maximum daily outburst discharge, black line indicates maximum daily discharge from nonoutburst sources. The lake release period was usually 2 years prior to 1958 but since has changed to each 3 years. It may be possible to predict future breakouts of this lake because the lake releases at regular intervals and the peak discharges change systematically. If present trends continue, the next breakout may occur in September 1973 and have a peak daily flow of about 500 cubic meters per second (18,000 cubic feet per second).



Four major glacier dammed lakes release in the Tazlina River basin causing highest average daily discharges (red bars) at gage No. 15-2020 which are often higher but sometimes lower than the nonoutburst highest daily discharges (black line) each calendar year. Some years have no glacier outburst (open circles), while other years have two outbursts. Outbursts were identified by comparing the hydrographs for Klutina and Tonsina Rivers with nearby Tazlina River. Momentary peak discharges are 5 to 10 percent higher than the daily averages shown here. Until the lake dumping sequence in the basin is determined and each lake is monitored, accurate predictions of future breakouts cannot be made for this complex sequence.

1964 OUTBURST FLOOD ON SNOW AND KENAI RIVERS



Glacier outburst flood in September 1964 caused by the dumping of the glacier dammed lake (No. 26) at the head of Snow River. The flood passed the Snow River gage (No. 15-2435) before entering Kenai Lake; the Kenai River gage (No. 15-2580) is located at the outlet of Kenai Lake. The daily average discharge recorded by the two gages shows downstream lowering and attenuating effects of lake and streambank storage on the floodwaters. Momentary peak discharge was 8 percent higher than peak daily flow shown for Snow River. The amount of water due to the lake release (Snow River, in red; Kenai River, dotted) is superimposed on the normal runoff. The discharge of nearby Trail River is shown for comparison. (U. S. Geological Survey, 1965, 1966; Kenai River data, unpublished revisions.)

Table 1.—*Information on selected glacier dammed lakes and the areas flooded by outbursts. (Lake area includes the part of the ice dam which shows crevasse evidence of floating on the lake. The areas flooded may include the entire flood plain of the affected rivers listed. Unless indicated otherwise, the lakes are in Alaska and source maps are those of the U.S. Geological Survey).*

Basin	Lake No. on map	Name of lake or depression	Maximum area (km²)	Maximum area (mi²)	Damming glacier	Area flooded	Comments, hazards, and recommendations	Topographic maps and data sources in addition to aerial photographs
Salmon River	1	Summit Lake (British Columbia)	4.2	1.6	Salmon	Salmon River	Outburst floods began abruptly in 1961. Future outburst floods may occur at 1- to 2-year intervals. Flood damage from this lake was reported by Alaska Department of Highways (1970): "***The drainage of the lake this year caused extensive damage to the Hyder road from mile 6 to 9 with various minor roadway washouts from 3 to 6 mile. ***Due to the magnitude of the flood and extensive damage caused by the flooding, Governor Miller declared Hyder a disaster area." Extreme flood hazards in Salmon River valley. Monitored by Canada.	Map, Iskut River 104B, Canada Map, Salmon Glacier, British Columbia, Special Map by Canadian Army Survey Establishment, 1959 Alaska Department of Highways (1970, p.10), Doell (1963, p. 435), Field (1958a, p. 2a.1.17), Fisher (1969), Gilbert (1969), Mathews 1965, p. 46, and 1971) U.S. Geological Survey gaging station 15–80
Stikine River	2	Flood Lake (British Columbia)	2.9	1.1	Flood	Flood River, Stikine River	Little data on flood history. Lake drains under Flood Glacier, probably annually. Lake is shown much smaller on 1909 map. Extreme flood hazards exist in Flood River and moderate flood hazards in Stikine River lowlands. Collecting data on future floods is recommended.	Map, Telegraph Creek 104G, Canada Map, International Boundary Commission, Sheet 5, 1909 Dawson (1889, p. 53B), Field (1958a, p. 2a.1.45), Kerr (1928, p. 16A), Muir (1915, p. 101), Russell (1898, p. 558) Scidmore (1899, p. 9), Stone (1963a)
Thomas Bay	3	Unnamed	.8	.3	Patterson	Patterson River	Little data on flood history. Drains annually most years during spring or summer. Extreme flood hazard in Patterson River lowlands. Collecting data on future floods is recommended.	Map, Petersburg (D-2), Alaska Stone (1963a)
	4	Witches Cauldron	2.0	.8	Baird	Baird Glacier outwash plain	The Witches Cauldron depression contains several lakes on the surface of the glacier which drain subglacially. A large lake could form in this enclosed basin in the future. In such situations large lakes generally form subglacially; there is little evidence of a subglacial lake at present. Extreme flood hazard on Baird Glacier flood plain due to many dumping lakes in basin.	Map, Sumdum (A-2), Alaska Field (1958a, p. 2a.1.50)
Taku Inlet	5	Tulsequah Lake (British Columbia) Unnamed (British Columbia)	4.0 1.0	1.5 .4	Tulsequah do	Tulsequah River, Taku River do	This lake and a smaller lake up glacier dump most years. In 1920, Tulsequah Lake covered 6 square kilometers (2.3 square miles). A midwinter outburst occurred in January 1926. Extreme flood hazard in Tulsequah River and moderate flood hazard in Taku River lowlands. Monitoring is recommended.	Map, Tulsequah 104K, Canada International Boundary Commission (1952, p. 98–99) Field (1958a, p. 2a.1.70), Kerr (1934, 1936), Mandy (1936, p. B20), Marcus (1960), Miller (1952, p. 74–80: 1963, p. 116, 200; 1970, p. 20); Stone (1955, 1963a)
	6	Dead Branch	3.4	1.3	Norris	Grizzly Bar	Central crevassing indicates the presence of a subglacial lake which occasionally causes the ice to float. Continued recession could form a large lake here. Glory Lake, near terminus of Norris Glacier, dumped vigorously until melting of the ice dam around 1930. These floods prevented the growth of vegetation on Grizzly Bar. Vegetation now becoming established indicates that the Dead Branch subglacial lake has not yet caused major outburst flooding. Moderate flood hazard on Grizzly Bar.	Map, Juneau (B-1), Alaska
Katzehin River	7	Unnamed	1.0	.4	Meade	Katzehin River	May dump annually; generally drained in late August. Collecting data on future floods is recommended.	Map, Skagway (A-1), Alaska
Glacier Bay	8	Unnamed	5.2	2.0	Carroll	Carroll Glacier outwash plain	In 1968 and in 1969 a large lake was formed between Carroll and Plateau Glaciers by the Carroll Glacier surge of 1968. The lake drained under the Carroll Glacier in September each year. In the near future this lake will probably shift to dumping under Plateau Glacier due to the latter's retreat; virtual disappearance of Plateau Glacier's ice dam by about 1990 will drain the lake basin. Extreme flood hazard on Carroll Glacier outwash plain. Monitoring as long as a large lake forms is recommended.	Map, Mt. Fairweather (D-2), Alaska Map, Skagway (A-5), Alaska
Lituya Bay	9	Desolation Valley	4.1	1.6	Lituya	Lituya Glacier outwash plain	Former subglacial lake recently exposed by glacier's recession: Extreme flood hazard on outwash plain at terminus of Lituya Glacier.	Map, Mt. Fairweather (C-5), Alaska
Alsek River	10	Recent Lake Alsek (Yukon Territory)	30 ?	12 ?	Lowell	Alsek River	Extremely hazardous Recent Lake Alsek will reform only if glacier surges recur. Monitoring glacier surges is recommended.	Map, Dezadeash 115A, Canada Kindle (1953, p. 21–22, map 1019A), McConnell (1904, p. 3A–6A), Tarr and Martin (1914, p. 194)
	11	Unnamed (British Columbia)	16 ?	6 ?	Tweedsmuir	Alsek River	Hazardous lake may form if glacier surges moderately. A lake was apparently formed by a surge which occurred around 1945. Monitoring glacier surges is recommended.	Map, Tatshenshini River 114P, Canada Map, Mt. St. Elias, 1:250,000, Alaska
	12	Unnamed (British Columbia)	6.2	2.4	Konamoxt	Melt Creek, Alsek River	Large lake now forming by retreat of Melbern Glacier. As lake increases in size major floods may result. Moderate flood hazard on Melt Creek and Alsek River flood plains.	Map, Tatshenshini River 114P, Canada
Yakutat Bay	13	Russell Fiord at present time	260	100	Hubbard	Would drain directly to Disenchantment Bay under or along margin of glacier	Hubbard Glacier has advanced intermittently since mapped in 1895. The glacier will close off the entrance to Russell Fiord in about 20 years if the present average rate of advance continues. No present flood hazard but extreme danger to boats near glacier margin and in tidal currents at mouth of fiord.	Map, Mt. St. Elias, 1:250,000, Alaska Map, International Boundary Commission, Sheet 13, 1895 Tarr and Martin (1914, p. 108–109, pl. 36, map 3)
Bering River	14	Berg Lake	28	11	Bering	Bering River, Bering Lake	The lake is presently spilling over a bedrock saddle. Retreat of Bering Glacier has greatly increased the size of this lake and recently created an extreme flood hazard on Bering River lowlands. Monitoring is recommended.	Map, Bering Glacier, 1:250,000, Alaska Ellsworth and Davenport (1915, p. 36, pl. 2), Field (1958b, p. 2a.3.4–8), Martin (1905, p. 17; 1908, p. 46–48, pl. 2), Post (1967, table 5), Stone (1963a)
Copper River	15	Iceberg Lake	1.8	.7	Tazlina	Tazlina Glacier outwash plain, Tazlina Lake, Tazlina River, Copper River	Two lakes drain subglacially. In 1962 these lakes dumped at the same time resulting in the highest measured flood on the Tazlina River. Strandlines above Iceberg Lake indicate that the lake has been about 100 meters (300 feet) higher in recent decades. Extreme flood hazard on Tazlina lowlands, moderate flood hazard in Copper River valley. Monitoring is recommended. (See lake No. 16).	Map, Valdez (C-7 and C-8), Alaska Bolton (1963), Post (1967, table 5), Ragle, Sater and Field (1965a, p. 18–19, 28–30, Stone (1963a) U.S. Geological Survey gaging stations 15-2020 and 2120.
		Unnamed on west side of glacier	5.7	2.2				
	16	Unnamed, south Unnamed, north	2.6 .3	1.0 .1	Nelchina	Nelchina River, Tazlina Lake, Tazlina River, Copper River	Two lakes drain subglacially, probably at 2- to 4-year intervals. Extreme flood hazard in Nelchina River and moderate flood hazard in Tazlina River lowlands. If combined with simultaneous floods from lakes No. 15 extremely hazardous flooding could occur on the Tazlina and Copper River lowlands. Monitoring is recommended.	Map, Valdez (C-8), Alaska Post (1967, table 5), Ragle, Sater and Field (1965a, p. 18–19, 26–27, 30), Stone (1963a) U.S. Geological Survey gaging stations 15-2020 and 2120
	17	Lower Skolai Lake	1.0	.4	Nizina	Nizina River, Chitina River, Copper River	A lake 1 kilometer (0.6 mile) long, which drains along glacier margin, has formed infrequently in recent years. Capps (1916) reported "The glacier closes the subglacial outlet of this lake, which then rises rapidly until the hydraulic pressure is sufficient to reopen a channel beneath the ice. Once opened, the lake waters pour out with a rush, flooding Nizina Valley below and leaving icebergs stranded high on the sides of the deserted lake basin." Moffit (1938) stated "At times much timber is destroyed by the cutting away of wooded gravel benches. The bars of the upper Nizina River were piled up with tangled masses of trees brought down by the flood of 1927." Outburst in June 1934 demolished a bridge across the Nizina River. Moderate flood hazard in Nizina River lowlands. Monitoring is recommended.	Map, McCarthy (C-4), Alaska Alaska Department of Highways (1970, p. 9), Capps (1916, p. 15, pl. 4), Hayes (1892, p. 135, 154), Moffitt (1938, p. 14)
	18	Hidden Creek Lake	2.0	.8	Kennicott	Kennicott River, Chitina River, Copper River	Lake drains subglacially. Water from this lake has been observed to emerge from the "pothole" at the lower end of Kennicott Glacier since early 1900. "In winter * * * a torrent of water rushes down the Kennicott and Nizina Rivers, sometimes flooding the ice all the way to the Copper River" (Moffitt and Capps, 1911). A surge of water over the ice on the Chitina River in March 1968 (J. McKechnie, oral commun., 1970) may have been due to a release of this lake. Moderate to extreme flood hazard on Kennicott River and moderate flood hazard on Chitina River flood plains.	Map, McCarthy (C-6), Alaska Bateman (1922, p. 536), Moffitt (1938, p. 13, pl. 5A), Moffitt and Capps (1911), Stone (1963a) U.S. Geological Survey gaging station 15-2120
	19	Trap Lake	1.0	.4	Tsina	Tsina River, Copper River	Lake drains subglacially and has been recently observed (D. Kennedy, oral commun., 1970) to release to Tsina River at irregular intervals. Hoffman (1970, p.36) reported a flood as follows: "In late summer of 1915, a glacier reservoir on the headwaters of Tsina River caused a flood of unprecedented magnitude that carried away a bridge over the Tsina River. It also flooded the roadhouse and telegraph station at Beaver Dam, Mile 42." Hoffman also reported flooding of the roadhouse and telegraph station in 1919. Moderate to extreme flood hazard on Tsina River flood plain. Monitoring is recommended.	Map, Valdez (A-6), Alaska Hoffman (1970, p. 36), Kuentzel (1970, p. 5), Post (1967, table 5)
	20	Van Cleve Lake	17	6.5	Miles	Miles Lake, Copper River	Lake drains subglacially; no recent data available on flood history; probably drains every 1 to 3 years. Drained catastrophically in 1909. Tarr and Martin (1914) reported "A similar flood on August 16, 1912, perhaps from the draining of a marginal lake, swept down the Copper River from Miles Glacier. It raised the water level 12 feet [3.6 meters] at the railway bridge east of Childs Glacier and, 20 miles [32 kilometers] further south, swept away 1600 feet [688 meters] of railway trestle east of Flag Point, drowning a repair crew foreman." With construction of the Copper River Highway now in progress, future floods will present very serious hazards. Monitoring is recommended.	Maps, Cordova (C-1 and C-2), Alaska Ellsworth and Davenport (1915, p. 49), O'Neel and Hawkins (1910, p. 1), Post (1967, table 5), Stone (1963a), Tarr and Martin (1914, p. 431–432) U.S. Geological Survey gaging station 15-2140
	21	Unnamed	2.0	.8	McPherson	Sheep Creek, Copper River	Lake drains subglacially. R. Kennedy (oral commun., 1970) has reported that in the summer of 1962 or 1963 frightened bears, moose, rabbits, and squirrels were seen running along the roadway without regard to traffic near Mile 39 of the Copper River Highway. Road maintenance personnel witnessed a great flood in progress on Sheep Creek, which they had observed to be tranquil only hours before. The sounds of crashing trees and grinding ice in the darkness led the crew to evacuate the area. By morning, a mile of roadway had been washed out and the streamflow had returned to normal. Another flood from this lake again washed out a part of the highway in 1965. Extreme flood hazard on the Sheep Creek outwash plain. Monitoring is recommended.	Map, Cordova (C-2), Alaska Post (1967, table 5)
Orca Inlet	22	Rude Lake	1.3	.5	Cordova	Rude River	Lake drains subglacially; no data available on outbursts; probably drains annually. Moderate to extreme danger on Rude River flood plain. Collecting data on future floods is recommended.	Map, Cordova (D-5), Alaska Stone (1963a)
Port Valdez	23	Unnamed	1.6	.6	Unnamed	Sheep Creek, Lowe River	Five lakes and depressions are formed by two glaciers in the Sheep Creek basin. Trap Lake (No. 19) generally drains into the Tsina River, but it may be possible for the lake to drain to Sheep Creek. Another lake drains over a bedrock ridge into the Valdez Glacier basin. Two smaller lakes appear to be stable and one prominent depression shows no recent evidence of filling with water. Hoffman (1970, p. 36) reported: "The section of the Valdez-Fairbanks Trail through Keystone Canyon * * * was * * * one of the most expensive stretches to maintain in Alaska. High water, often caused by bursting of glacier reservoirs, annually required expensive maintenance in Keystone Canyon. During the summer of 1913, the bridge on Sheep Creek was carried away by a flood caused by the bursting of a glacier reservoir at the head of the creek. * * * In 1916, a glacier reservoir that burst at the source of a small stream at the head of Keystone Canyon required the reconstruction of that section of the road. In 1919, Bear Creek at Mile 18 filled its channel with 20 feet of boulder, gravel and debris, destroying the bridge." A steel highway bridge across Sheep Creek was destroyed in 1945. Between 5 a.m. and 7:30 a.m. on June 17, 1959 (Bolton, 1959) a relatively new concrete bridge was destroyed at the same stream crossing. Extreme hazard along Sheep Creek, moderate to extreme danger on Lowe River flood plain and in Keystone Canyon. Monitoring is recommended.	Map, Valdez (A-6), Alaska Bolton (1959), Hoffman (1970, p. 7, 36)
	24	Unnamed	2.0	.8	Valdez	Valdez Glacier outwash plain	Three glacier dammed lakes drain subglacially; dumping history is not known. Moderate hazard on Valdez River flood plain. Monitoring is recommended.	Map, Valdez (A-6), Alaska Post (1967, table 5)
Tustumena River	25	Unnamed	1.6	.6	Tustumena	Glacier Creek, Tustumena Lake, Kasilof River	Lake presently drains over a bedrock saddle. No known floods from this source. Potential hazard on Glacier Creek lowlands.	Map, Kenai (A-2), Alaska Post (1967, table 5) U.S. Geological Survey gaging station 15-2420
Kenai River	26	Unnamed	3.4	1.3	Unnamed	Snow River, Kenai Lake, Kenai River, Skilak Lake, Kenai River	Lake drains subglacially; located at unusually high altitude relative to the glacier firn line. Floods in the Snow River valley occurred every 2 to 3 years during November, December, and January from at least 1911 to 1953. Since then floods have been in September and October. Extreme flood hazard on Snow River lowlands; moderate flood hazard on Kenai River. Monitoring is recommended.	Map, Seward (B-6), Alaska Ellsworth and Davenport (1915, p. 114), Indermuhle (1961, p. 28–29) U.S. Geological Survey gaging stations 15-2435, 2580, 2620, 2663 Unpublished observations by U.S. Geological Survey, U.S. Army Corps of Engineers, U.S. Weather Bureau
	27	Unnamed	4.0	1.5	Skilak	Skilak River, Skilak Lake, Kenai River	Lake drains subglacially and created a flood which caused severe damage at Soldotna on January 19, 1969. Area includes estimated limits of a large subglacial lake. Moderate flood hazard on Skilak River and Kenai River lowlands. Monitoring is recommended.	Map, Seward (A-8), Alaska Post (1967, table 5) U.S. Geological Survey gaging station 15-2663
Knik River	28	Lake George	73	28	Knik	Knik River	Lake George, which drains through an ice gorge along the margin of Knik Glacier, has not refilled since 1966. A series of positive ice balances such as that of 1970 may stimulate Knik Glacier to advance and dam the lake again. Extreme flood hazard along Knik River flood plain. Annual monitoring of Lake George should continue.	Maps, Anchorage (A-5, B-4, and B-5), Alaska Field (1958b, 2a.3.29, 40–41), Knudsen (1951), Post (1967, table 5), Stone (1955, 1963a and 1963b) U.S. Geological Survey gaging station 15-2810
Beluga River	29	Strandline Lake	8.8	3.4	Triumvirate	Triumvirate Glacier outwash plain, Beluga Lake, Beluga River	Water cuts an ice gorge along margin of glacier during breakouts. Apparently lake does not drain annually. In August 1970 lake level was very close to overflowing glacier. Extreme flood hazard on Triumvirate Glacier outwash plain and Beluga River lowlands. Collecting data on future floods is recommended.	Maps, Tyonek (B-6 and C-6), Alaska
McArthur River	30	Chakachamna Lake	72	28	Barrier	Chakachatna River	Lake outlet is located along margin of the nearly stagnant terminus of Barrier Glacier. Small movements in this ice have caused rises in the lake level (Gordon Giles, written commun., 1967) and has resulted in changing stage/discharge relationships at the river gage located at Barrier Glacier. These changes have been relatively slow and no outburst floods are expected unless the glacier advances strongly. Very low flood hazard from lake. Floods resulting from glacier melt from volcanic eruptions of Mount Spurr may present serious hazards on Chakachatna River.	Maps, Tyonek (A-7 and A-8), Alaska Jackson (1961, p. 5) U.S. Geological Survey gaging station 15-2945
	31	Blockade Lake	19	7.4	Blockade	McArthur River	Lake drains subglacially every few years. Outburst history is unrecorded. Extreme flood hazard along McArthur River lowlands. Collecting data on future floods is recommended.	Map, Kenai (D-7), Alaska
Big River	32	Summit Lake	4.7	1.8	Unnamed	North Fork Big River, Big River	Lake drains subglacially. Basin has increased considerably in size from 1954 to 1970 as a result of recession of the glacier. Moderate or extreme flood hazard on Big River lowlands. Collecting data on future floods is recommended.	Map, Kenai (D-8), Alaska

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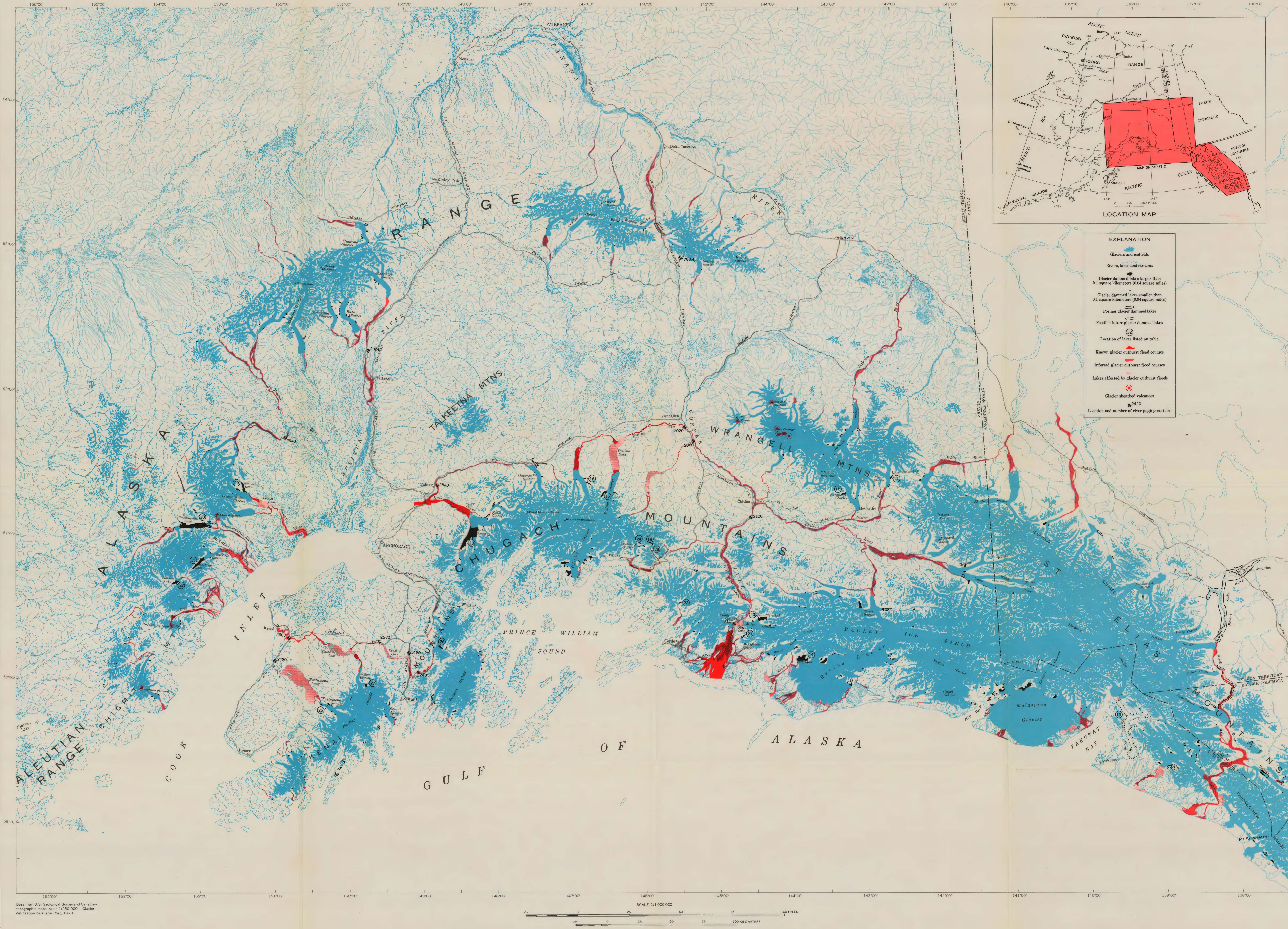
GLACIER DAMMED LAKES AND OUTBURST FLOODS IN ALASKA

By
Austin Post and Lawrence R. Mayo
1971

For sale by the U.S. Geological Survey, price $1.50 per set
Explanatory pamphlet accompanies map



Base from U.S. Geological Survey and Canadian topographic maps, scale 1:250,000. Glacier delineation by Austin Post, 1970

MAP SHOWING LOCATION OF GLACIERS, GLACIER-DAMMED LAKES, GLACIER-SHEATHED VOLCANOES AND AREAS SUBJECT TO OUTBURST FLOODING IN SOUTH CENTRAL ALASKA

GLACIER DAMMED LAKES AND OUTBURST FLOODS IN ALASKA

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1971

PHOTOGRAPHS ILLUSTRATING THE VARIABILITY OF GLACIER DAMMED LAKES

TULSEQUAH LAKE NEARLY DRAINED BY AN OUTBURST FLOOD

TULSEQUAH LAKE (NO. 5), COAST MOUNTAINS. LOCATED JUST EAST OF THE INTERNATIONAL BOUNDARY IN CANADA, THIS LAKE GENERALLY DRAINS CATASTROPHICALLY IN LATE SUMMER. THE RESULTING FLOODS MOVE DOWN THE TAKU RIVER VALLEY WHERE A HIGHWAY CONNECTION TO JUNEAU HAS BEEN PROPROSED.

SUMMIT LAKE FILLED TO NEAR MAXIMUM LEVEL

SUMMIT LAKE (NO. 32) WHICH IS DAMMED BY AN UNNAMED GLACIER IN THE CHIGMIT MOUNTAINS. THIS PHOTOGRAPH, TAKEN IN AUGUST 1963, SHOWS THE LAKE NEAR ITS MAXIMUM LEVEL AND ICEBERGS ARE BEING DISCHARGED FROM THE GLACIER MARGIN.

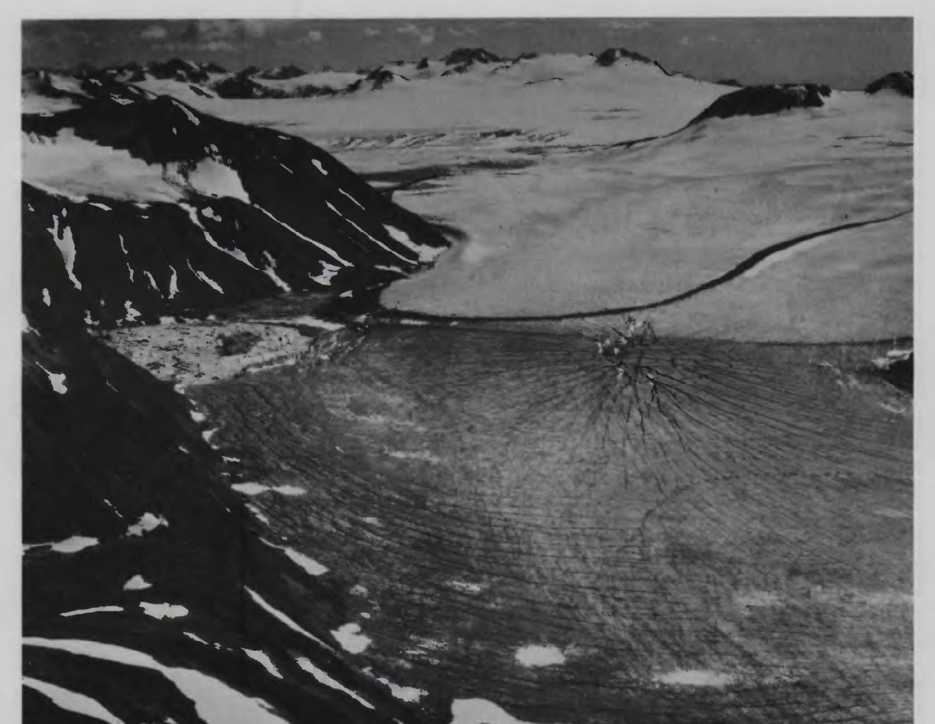
SUMMIT LAKE ALMOST COMPLETELY DRAINED

SUMMIT LAKE (NO. 32) PHOTOGRAPHED IN AUGUST 1970. THE LAKE HAS DRAINED THROUGH A SUBGLACIAL CHANNEL TO NORTH FORK BIG RIVER (RIGHT). THIS GLACIER HAS BEEN RETREATING FOR MANY YEARS; THE PRESENT ICE DAM WILL FAIL COMPLETELY IF RETREAT CONTINUES FOR A FEW MORE DECADES.

BLOCKADE LAKE IN THE PROCESS OF REFILLING

BLOCKADE LAKE (NO. 31), CHIGMIT MOUNTAINS. THIS LAKE IS IMPOUNDED BEHIND A MASSIVE ICE DAM 15.2 KILOMETERS (9.5 MILES) IN LENGTH FORMED WHERE BLOCKADE GLACIER LATERALLY ENTERS A DEEP, NARROW VALLEY AT THE FAR END OF THE LAKE. ALTHOUGH THE MAJOR FLOW OF ICE IS TO THE EASTERN TERMINUS, A PORTION OF THE ICE FLOWS TOWARD THE LAKE TERMINATING IN AN ICE CLIFF FROM WHICH LARGE ICEBERGS ARE DISCHARGED. THIS LAKE DOES NOT DUMP ANNUALLY BUT LARGE CHANGES IN SURFACE LEVEL INDICATE THAT THE ICE DAM FAILS EVERY FEW YEARS CAUSING MAJOR FLOODS ON MC ARTHUR RIVER.

SKILAK GLACIER—SHOWING LATERAL AND SUBGLACIAL LAKES



THIS ICE DAMMED LAKE (NO. 27) IS LOCATED IN AN EMBAYMENT BETWEEN SKILAK GLACIER AND AN UNNAMED GLACIER IN THE KENAI MOUNTAINS. AN EXPOSED LAKE CAN BE SEEN ON THE LEFT; THE RADIAL PATTERN OF CREVASSES IN THE CENTER OF THE GLACIER SUGGESTS THAT THIS ICE IS RAISED AND LOWERED BY ALTERNATE FILLING AND DRAINING OF A SUBGLACIAL LAKE. WATER FROM THIS LAKE CREATED A DEVASTATING FLOOD IN THE KENAI RIVER VALLEY IN JANUARY 1969.

DESOLATION VALLEY—FORMATION AND EVOLUTION OF TWO LAKES

TWO LARGE ICE DAMMED LAKES ARE IN THE PROCESS OF FORMATION IN DESOLATION VALLEY, FAIRWEATHER RANGE. IN THE FOREGROUND IS DEBRIS COVERED ICE WITH SEVERAL LARGE LONGITUDINAL AND CONCENTRIC CREVASSES WHICH ARE ATTRIBUTED TO RAISING AND LOWERING OF THE ICE DUE TO FLOATING. WATER IS VISIBLE ALONG THE MARGINS AND IN THE LARGER CREVASSES. BETWEEN DESOLATION AND LITUYA GLACIERS (UPPER CENTER) THE ICE HAS RECENTLY BROKEN UP AND A LARGE LAKE (NO. 9) IS NOW CLEARLY VISIBLE. THE LAKE PARTIALLY DRAINS SUBGLACIALLY AT INTERVALS TO LITUYA BAY (MIDDLE DISTANCE). THE RECENT FORMATION OF THESE LAKES IS DUE TO THINNING OF THE GLACIERS OCCUPYING THE VALLEY.

BERG LAKE—A RECENTLY DEVELOPED HAZARDOUS SITUATION

BERG LAKE (NO. 14), NEAR KATALLA. RETREAT OF AN ARM OF BERING GLACIER, WHICH IN 1905 FILLED MOST OF THIS LARGE EMBAYMENT, HAS JOINED FIVE SEPARATE LAKES THAT OCCUPIED INDIVIDUAL BAYS OF THE PRESENT LAKE. LOWERING OF THE ICE DAM IF CONTINUED WILL ALMOST CERTAINLY LEAD TO THE RELEASE OF IMMENSE FLOODS IN THE NEAR FUTURE. THE BERING RIVER FLOOD PLAIN AND AREA SURROUNDING BERING LAKE ARE ENDANGERED BY THIS INCREASINGLY CRITICAL SITUATION.

RUSSELL FIORD—SITE OF A LARGE POTENTIAL LAKE

DISENCHANTMENT BAY AND RUSSELL FIORD (NO. 13), NEAR YAKUTAT. THE MASSIVE HUBBARD GLACIER, DRAINING AN AREA OF APPROXIMATELY 4,000 SQUARE KILOMETERS (1,550 SQUARE MILES) DISCHARGES INNUMERABLE ICEBERGS INTO THE BAY FROM AN ICE CLIFF NEARLY 100 METERS (300 FEET) HIGH AND 10 KILOMETERS (6 MILES) LONG. THE GLACIER HAS BEEN SLOWLY ADVANCING SINCE IT WAS MAPPED IN 1895. IF THE ADVANCE CONTINUES AT THE SAME RATE, IN A FEW DECADES THE GLACIER WILL CLOSE OFF RUSSELL FIORD (FOREGROUND) TURNING THIS ARM OF THE SEA INTO A LAKE 230 SQUARE KILOMETERS (90 SQUARE MILES) IN AREA.

PHOTOGRAPHS ILLUSTRATING HOW TEMPORARY LAKES ARE CAUSED BY PERIODICALLY SURGING GLACIERS

TIKKE GLACIER AT BEGINNING OF SURGE

TIKKE GLACIER, LOCATED IN CANADA NORTH OF GLACIER BAY, IS SUBJECT TO PERIODIC SURGES IN WHICH THE ICE SUDDENLY ADVANCES SEVERAL KILOMETERS AT APPROXIMATELY 20-YEAR INTERVALS. THIS VIEW OF THE GLACIER WAS TAKEN IN AUGUST 1965 WHEN A SURGE WAS MOVING RAPIDLY DOWN THE GLACIER. LATERAL VALLEYS TO THE RIGHT OF THE GLACIER DO NOT CONTAIN LAKES; FARTHER UP GLACIER ON THE LEFT SIDE THE FAST-MOVING ICE RECENTLY HAS DAMMED THE LATERAL STREAMS.

TIKKE GLACIER AFTER SURGE

TIKKE GLACIER IN AUGUST 1966 AFTER THE CULMINATION OF THE SURGE SHOWN IN PROGRESS IN THE VIEW TO THE LEFT. THE ADVANCING ICE HAS NOW FORMED DAMS BLOCKING BOTH SIDE VALLEYS ON THE RIGHT SIDE OF THE GLACIER. SINCE COMPLETING ITS RAPID MOVEMENT, THE GLACIER HAS RELAPSED INTO NEAR STAGNATION. THE GLACIER DAMMED LAKES PROBABLY WILL FILL AND DUMP ANNUALLY UNTIL MELTING REMOVES THE ICE DAMS. TIKKE GLACIER IS ONLY ONE OF NEARLY 200 SURGING GLACIERS IN ALASKA AND ADJACENT CANADA WHICH CAN BE EXPECTED TO FORM HAZARDOUS LAKES PERIODICALLY.

PHOTOGRAPHS ILLUSTRATING THE EFFECTS OF AN OUTBURST FLOOD DUE TO VOLCANIC ACTIVITY

REDOUBT VOLCANO BEFORE 1966 ERUPTION

REDOUBT VOLCANO, CHIGMIT MOUNTAINS. PHOTOGRAPH AUGUST 1963 SHOWING CONDITIONS BEFORE THE ERUPTIONS BEGAN IN JANUARY 1966. THE LARGE, UNNAMED GLACIER SHOWN HERE DESCENDS FROM THE SUMMIT CRATER. ALTHOUGH THE GLACIER IS LITTERED BY MUCH DEBRIS ON ITS LOWER REACHES, THE SPECTACULAR ICE CASCADES ON THE MOUNTAIN SLOPES ARE ALMOST DEBRIS FREE, INDICATING RECENT DECADES OF LITTLE VOLCANIC ACTIVITY.

GLACIER ON REDOUBT VOLCANO AFTER ERUPTION

REDOUBT VOLCANO IN AUGUST 1966 SHOWING CHANGES IN THE GLACIER RESULTING FROM THE ERUPTIONS. STEAM CLOUDS FROM THE ACTIVE CRATER STILL OBSCURED THE SUMMIT OF THE MOUNTAIN. THE ICE CASCADES FLOWING FROM THE SUMMIT CRATER HAVE BEEN COMPLETELY DESTROYED AND A LARGE STREAM OF YELLOWISH, DEBRIS-LADEN WATER WAS RUSHING DOWN THE GORGE IN ITS PLACE. AERIAL OBSERVATIONS IN 1967 INDICATED LOWERING OF THE GLACIER SURFACE LEVEL IN THE CRATER WHICH SUGGESTS THAT ICE MELT DUE TO VOLCANIC HEAT WAS THE PRINCIPAL SOURCE OF THE FLOOD WATER. THE LOWER GLACIER IS ALMOST COMPLETELY BURIED BY DEBRIS DEPOSITED BY THE FLOOD WATERS.

PHOTOGRAPHS ILLUSTRATING DAMAGE CAUSED BY OUTBURST FLOODS

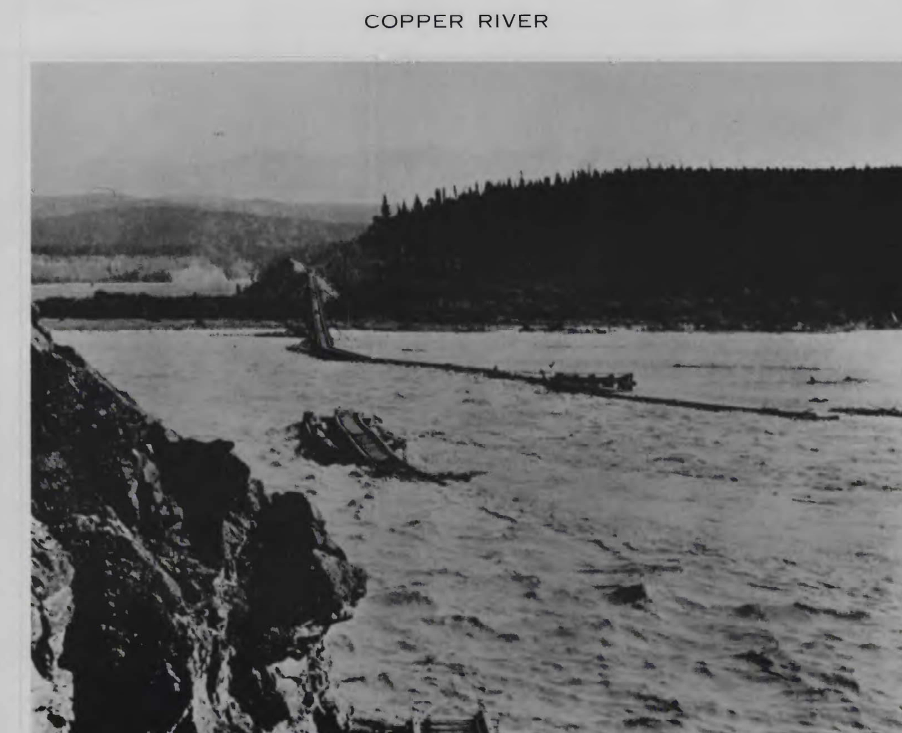
SHEEP CREEK

BRIDGE AT SHEEP CREEK, EAST OF VALDEZ ON THE RICHARDSON HIGHWAY. DENSE LOW WILLOW AND ALDER GROWING ON THE FLOOD PLAIN INDICATE SEVERAL YEARS WITHOUT FLOOD ACTIVITY, BUT ABSENCE OF LARGE TREES SUGGESTS THAT DAMAGING FLOODS HAD OCCURRED EARLIER. BRIDGE FORMS A CONSTRUCTION IN THE FLOOD PLAIN. ALASKA DEPARTMENT OF HIGHWAYS PHOTOGRAPH, DATE UNKNOWN.

SHEEP CREEK

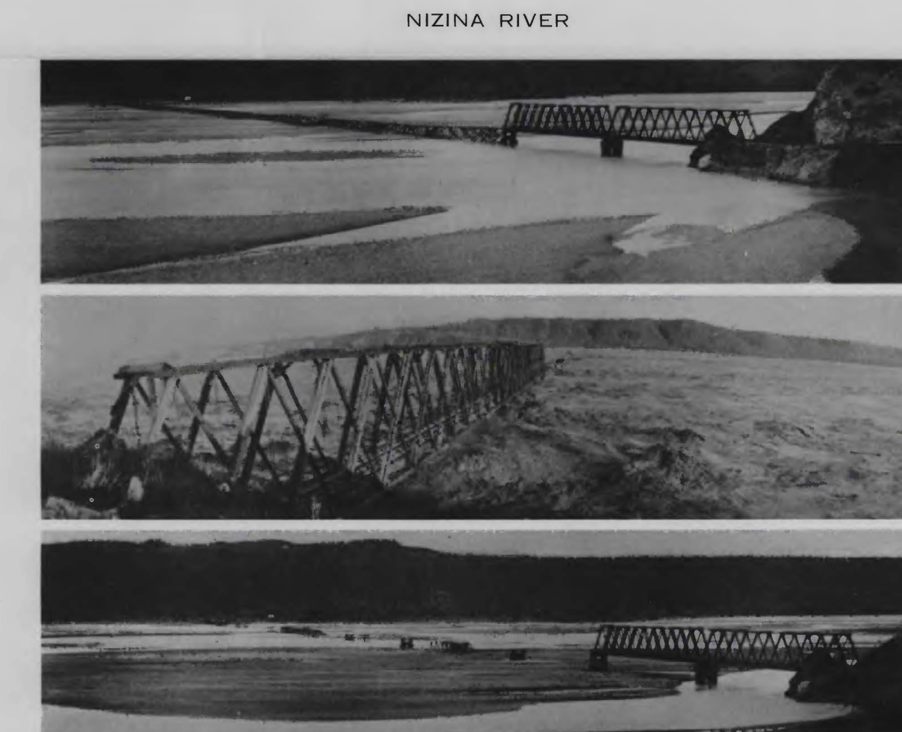
SAME BRIDGE AT SHEEP CREEK PARTIALLY BURIED BY DEBRIS RESULTING FROM A GLACIER OUTBURST FLOOD FROM A TINY GLACIER DAMMED LAKE (NO. 23). SEDIMENT BURIED MUCH OF THE WILLOW AND ALDER BRUSH, BUT AS THE FLOOD DID NOT CARRY AWAY THE COTTONWOOD TREES AT THE EDGE OF THE FLOOD PLAIN THIS FLOOD COULD NOT HAVE BEEN OF MUCH GREATER VOLUME THAN PREVIOUS FLOODS. APPROXIMATELY 7.5 METERS (25 FEET) DEPTH OF DEBRIS WAS DEPOSITED AT THE BRIDGE SITE; LARGE-SCALE EROSION UPSTREAM MUST HAVE TAKEN PLACE TO PROVIDE THE FILL MATERIAL. ALASKA DEPARTMENT OF HIGHWAYS PHOTOGRAPH, SEPTEMBER 1945.

COPPER RIVER



COPPER RIVER AND NORTHWESTERN RAILWAY BRIDGE NEAR CHITINA BEING SWEPT AWAY BY A MAJOR FLOOD WHICH OCCURRED IN AUGUST 1932. GENERALLY CLEAR, BALMY WEATHER PREVAILED AT THE TIME SO THE FLOOD IS JUDGED TO HAVE BEEN DUE TO A GLACIER DAMMED LAKE OUTBURST, PROBABLY ORIGINATING FROM LAKES DAMMED BY TAZLINA GLACIER. ALASKA DEPARTMENT OF HIGHWAYS PHOTOGRAPH, AUGUST 1932.

NIZINA RIVER



PHOTOGRAPHS OF BRIDGE ACROSS NIZINA RIVER NEAR MCCARTHY, ALASKA, SHOWING EFFECTS OF OUTBURST FLOOD OF JUNE 1934 ORIGINATING AT LOWER SKOLAI LAKE (NO. 17) ALASKA DEPARTMENT OF HIGHWAYS PHOTOGRAPHS. *A*, IN 1933 BEFORE FLOOD. *B*, BEING DEMOLISHED BY OUTBURST FLOOD. PHOTOGRAPH BY BEN JACKSON. *C*, IN 1934 AFTER FLOOD

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GLACIER DAMMED LAKES AND OUTBURST FLOODS IN ALASKA

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