M'Donald 267

RECONNAISSANCE

Devil Canyon Project - Alaska

Denali Dam Site

INFLOW DESIGN FLOOD STUDY
Reconnaissance

Hydrology Branch
Div. of Project Invest. Denver Apr. 1959

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
COMMISSIONER'S OFFICE
BUILDING 53 DENVER FEDERAL CENTER
DENVER 2, COLORADO

IN REPLY REFER TO [illegible]

Nov 23, [illegible]

To: District Manager, Juneau, Alaska.

From: Chief Development Engineer

Subject: Reconnaissance inflow design flood study--Denali Dam Site--
Devil Canyon Project, Alaska.

In accordance with request as set forth in your letter of October 22, [illegible]8, we have prepared a reconnaissance grade inflow design flood study for Denali Dam site, 3 copies of which are being transmitted to you under separate cover.

The inflow design flood, which is presented graphically on Plate 1 of the study, has a maximum mean daily discharge of 20,000 cfs and a May through September volume of [illegible],728,000 acre-feet.

[illegible] practicable to prepare diversion requirement hydrographs for this study, as only 2 years of recorded flow at the Denali stream gaging station are available. The maximum discharge during this period was 12,700 cfs. with a sustained flow of 8,000 to 10,000 cfs during the months of June through August. This should give the designers some indication of the diversion requirements during construction.

It was recognized that volume is the important item of this study rather than peak, as it was understood that a 200-foot high dam had the capability of storing over [illegible],000 acre-feet. In such a large reservoir area surcharge storage could be utilized in controlling the inflow design flood, making it possible to minimize the spillway capacity. The method used in making this design volume determination is discussed in detail in the study.

To assist in the preparation of an inflow design flood study at some later date, suitable for feasibility estimates at the Denali Dam site, it is highly recommended that at least one recording precipitation station be installed in the vicinity of Denali Dam site in sufficient time to obtain this summer's precipitation. We can furnish you, at no charge other than shipping costs, a recording precipitation gage that will require servicing and changing the chart weekly. You might be able to obtain the services of a resident living near the turnoff from the Denali highway to the Denali Dam site location, to change the charts.

Please inform us immediately regarding your desire on obtaining one or more of these precipitation gages.

Under separate cover (74371)

Denver, Colorado

April 21, 1959

Memorandum

To: Head, Flood Hydrology Section

From: Donald L. Miller

Subject: Inflow design flood study, Denali Dam site--Devil Canyon Project, Alaska

## AUTHORITY

A request that inflow design flood studies for the Devil Canyon Project be prepared in the Denver office was made in the District Manager's letter of October 22, 1958.

## RECOMMENDATIONS

An inflow design flood having a maximum mean daily discharge of 30,000 cfs and a May through September volume of 3,730,000 acre-feet as shown graphically on Plate 1 is recommended for use in preparation of reconnaissance estimates for Denali Dam site.

It is recommended that reconnaissance estimates of diversion requirements during construction be based on the two years of recorded flow at the Denali gage, 1958 and 1957. Maximum discharge was 18,700 cfs, with sustained flow of 8,000 to 10,000 cfs during the months of June, July, and August.

## DESCRIPTION OF STUDY

### Description of Basin

A map of the Susitna River drainage above the stream gaging station at Gold Creek is presented on Plate 2. The drainage area above Denali Dam site, planimetered as 1,280 square miles, is shown. The location of the stream gaging station near Denali, which is upstream from the dam site, is indicated. Attention is called to the glacier areas shown and the braided stream channels indicated. This map was prepared from maps of scale 1/250,000 edited and published by the U. S. Geological Survey.

Engineers H. P. Grout and W. M. Borland of this office made a field inspection trip of the Devil Canyon Project watershed in September 1958. Pertinent excerpts from their travel report dated September 26, 1958, are quoted below:

"Inspection of the Susitna River Basin

"The source of the Susitna River runoff at this time of year appears to be from ground water and some glacial melt. Apparently, during July and August, the principal source is glacier melt. Outside of the mountains, most of the area is very flat, with hundreds of lakes caused by depressions left as the glaciers receded. Cover consists of muskeg (moss and brush plus water), and tundra (moss and brush without much water), some small spruce and hemlock, mostly under 20 feet tall, and small birch trees, also mostly under 20 feet tall. Tundra and muskeg have the capacity to detain rainfall or snowmelt runoff, causing extremely long lag times. On the extremely high elevations, the area is either bare rock, some of which is sound and some in a highly fractured state, or is covered by snow and glaciers. Many of the lakes lack surface outlets, while other lakes have small natural outlets, again pointing to extremely long lag times. Stream gradients for the mountain areas are steep; however, glaciers in this area completely fill the valleys down to the foot of the mountains. Here the stream gradient becomes flat, with a very limited surface contributing area. There has not been time for a streamflow pattern to develop in this area since the recession of the glaciers.

"The reservoir area above Denali Dam is very flat. A 200-foot dam has the capability of storing over 5,000,000 acre-feet. In such a large reservoir area, surcharge storage could be utilized in controlling the inflow design flood, making it possible to utilize a minimum capacity spillway. This means that it will be necessary to derive a maximum probable volume flood extending over the entire spring and summer runoff season. This flood will consist of spring snowmelt plus summer glacial melt. We believe that rain under such conditions would have little effect on the flood volume since glacial melt, snowmelt, and temperature are the all-important factors."

Streamflow records. The following discharge records were available for streams in the Susitna River Basin:

Susitna River at Gold Creek; drainage area 6,160 square miles (approximately); period of record, August 1949 through September 1958.

Susitna River near Denali; drainage area 950 square miles (approximately); period of record, May 1957 through September 1958.

Maclaren River near Paxson; drainage area 280 square miles; period of record, June through September 1958.

Precipitation and temperature records. There are no precipitation or temperature records for stations within the Susitna River Basin above Gold Creek. Locations of such stations near the basin are shown on Plate 2. Records at most of these stations are short--10 to 20 years. The longest record is at Talkeetna, precipitation and temperature records from July 1918 to date.

Procedure development. Hydrothermograms for May through September 1958 were computed using mean daily temperatures at Talkeetna minus a base temperature of 40 and 45 and a recession constant of 0.75 estimated from recession portions of the Denali hydrographs. Temperatures at Talkeetna were used because the longer record at this station would provide better data for selecting a design temperature sequence if the hydrothermogram procedure proved successful. Preliminary comparisons of the hydrothermograms with the runoff hydrographs of the Susitna River near Denali and the Maclaren River near Paxson showed good agreement. A base flow was estimated for the Denali hydrograph (see Plate 3) and the net hydrograph computed. The net hydrograph was compared with the hydrothermograms and the following criteria estimated for use for computing a reproduction of the 1958 runoff recorded at the Denali gage:

? Talkutna

1. Use recession constant of 0.75 and Talkeetna mean daily temperatures

2. Use a constant conversion factor of 106 (hydrothermogram value x 106 = mean daily discharge, cfs)

3. For May, use mean temperature minus 45°

4. On June 1, make transition of temperature base and introduce a 2-day lag between temperature and runoff by repeating the May 31st temperature twice, first minus 43° and then minus 41°.

5. For balance of June and for July, use mean temperature minus base of 40°

6. On August 1, introduce transition of temperature base as follows:

   a. August 1-4 Subtract 41°
   b. August 5-8 Subtract 42°
   c. August 9-11 Subtract 43°
   d. August 12-14 Subtract 44°
   e. August 15-September 30 Subtract 45°

7. Compute base flow assuming start at 300 cfs on May 1, rise exponentially at 1.022 until July 15, then recede exponentially at K = .9934

The hydrograph computed by the above criteria is shown on Plate 3 along with the recorded hydrograph. A reasonably good reproduction was obtained. The two periods of wide divergence, June 11-23 and July 26-August 3, are believed due to runoff from rain, as they coincide with periods of precipitation recorded at Talkeetna and other stations. The hydrograph of the Susitna River at Gold Creek is also shown on Plate 3.

The 1957 record at Denali is plotted on Plate 4. Most of the record is estimated with the exception of a few days at the beginning of June, a few daily values during July, and the continuous daily record beginning August 27. The hydrograph of the Susitna River at Gold Creek is also shown on Plate 4.

The 1957 record provides the only means of testing the hydrograph computational criteria outlined above. In that criteria a constant conversion factor of 106 was used to compute discharge values from temperature data. Generally, a conversion factor curve indicating varying rates during the melting season is constructed from analyses of several years of record and an enveloping curve used for design computations. Lack of records precludes this procedure in this instance. To utilize the Susitna River data that are available, an approach incorporating to a limited extent the data from the record at Gold Creek was tried. The conversion factor was assumed to vary directly as the seasonal volumes and the yearly seasonal volumes at Denali were assumed to have the same ratio to each other as do those at Gold Creek. The ratio of the 1957 May-September volume at Gold Creek, 6,515,000 acre-feet, to the 1958 volume, 5,564,000 acre-feet, was 1.17. The 1958 conversion factor of 106 was multiplied by 1.17 to give 124 as a conversion factor for the 1957 seasonal runoff.

A synthetic hydrograph of discharge at Denali was computed using the criteria given previously with the exception that temperatures for 1957 and a constant conversion factor of 124 were used. The computed hydrograph is shown on Plate 4. There is a large discrepancy for the first 15 days of June, but the balance of the computed hydrograph fits the recorded data quite well. Although the record at Denali is incomplete during the first part of June, a peak discharge value of 18,700 cfs on June 7 is published, and it can be seen from the plotting of the hydrograph at Gold Creek that there was considerable snowmelt runoff during the last of May and early June. Climatological data show little precipitation at nearby stations during this period. Referring to the 1958 runoff at Denali as shown by the hydrograph on Plate 3, the initial rise did not reach a discharge as great as that reached later in the season in July. It is believed that the difference in the June portions of the hydrographs for the years 1958 and 1957 indicate that in 1957 there was more snow accumulation in the lower elevations than in 1958. A varying conversion factor with high values coincident with early June would have to be used to more accurately compute a reproduction of the 1957 hydrograph at Denali. A varying rate would conform with usual studies of this type; however, the good agreement of the computed hydrograph with the observed hydrograph data from June 15 through September by the use of a constant conversion factor is believed sufficient justification for adoption of a constant rate approach for this reconnaissance study. It is also believed the reproductions achieved for the 1958 and 1957 hydrographs at Denali are good enough to use the computational procedure or portions thereof for reconnaissance purposes.

Inflow design flood. Seasonal volume is the primary consideration for the inflow design flood for Denali Dam. Results of the analyses discussed can be used as one approach for estimating a design volume assuming that the water content of a design snow cover and the existing glaciers exceed that amount which can be melted by an unusually warm (design) season. The mean monthly temperature records at Talkeetna were examined and the following maximum months of record listed:

| | | |
|---|---|---|
| May | 1942 | August 1923 |
| June | 1935 | September 1929 |
| July | 1918 | |

The mean daily temperatures for these months were tabulated and "excess" or effective melting temperatures, computed using the criteria developed from analyses of the 1958 and 1957 hydrographs. This excess totaled 2,326 degrees compared with excesses of 1,925 and 1,500 degrees for 1957 and 1958, respectively. A design conversion factor was computed using the Gold Creek record and an adjustment for area. The maximum volume for the 9 years of record at Gold Creek was 7,531,000 acre-feet in 1956. This was 1.36 times the Gold Creek volume of 5,524,000 acre-feet in 1958. Multiplying the conversion factor of 106 determined for 1958 for Denali by 1.36 gave 144. The drainage area above the Denali Dam site will be 1,280 square miles compared with 950 square miles above the Denali gage. An adjustment for this increase in area was made using the ratio of the square roots of the respective drainage areas, 1.16, which, multiplied by 144 gave a conversion factor of 167. The total volume of runoff associated with a conversion factor of 167 and a recession constant of 0.75 was 665 cfs days, which multiplied by the temperature excess of 2,326 degrees gave an estimated direct melt-runoff volume of 1,547,000 cfs days, or 3,068,000 acre-feet.

In addition to the direct melt-runoff volume, base flow and some rain runoff must be added. The base flow volume used in the 1958 and 1957 hydrograph analyses was increased by a direct ratio of the drainage areas (1260/950) and gave an estimated base flow volume of 400,000 acre-feet. The 1958 analyses indicated about 2.0 inches of rain runoff in addition to melt-runoff. Some rain occurred at Talkeetna during the months used for selecting the design temperatures. During September 1929, 8.37 inches was recorded at Talkeetna. Other years of record indicate that warm temperatures during August and particularly during September are accompanied by heavy precipitation. In view of these data, rain runoff volume equivalent to 3.0 inches, 205,000 acre-feet, was added to the design flood volume estimate. The total volume estimate thus becomes 3,673,000 acre-feet.

In lieu of a detailed computation of the inflow design flood by computing the hydrothermogram of the design temperatures, it was decided to adopt a "short-cut" by augmenting the 1957 hydrograph data to design proportions. As shown on Plate 4, a transition was sketched from the computed hydrograph to observed data from May 28 to June 13. Also, observed values for August 27, 28, 29, and 30 were used in place of computed values. The volume of this composite hydrograph,(computed graph May 1 through May 27, sketched graph including observed values May 28 through June 12, computed graph balance of season with exception of August 27, 28, 29, and 30) was 2,330,000 acre-feet. The design volume estimated above was 1.58 times the composite 1957 volume. Rounding this ratio to 1.6, the daily discharge values for the 1957 event as reconstructed were multiplied by 1.6 and the result presented on Plate 1 recommended for use as the reconnaissance inflow design flood for Denali Dam site.

Envelope curves. An envelope curve of May through September volumes for streams considered reasonably comparable to the Susitna River drainage is presented on Plate 5. As drawn, the enveloping curve is controlled by the Susitna River at Gold Creek, 1956, and Susitna River near Denali, 1957. The area versus runoff relationship within the Susitna River Basin as indicated by the 1958 records is also shown on Plate 5. Two points shown on Plate 5 were not enveloped. These are, Copper River near Chitina and Chulitna River near Talkeetna. It is believed these areas are not comparable to the Susitna River Basin. However, it will be noted that the design volume plots above a curve that could be drawn through these points. The curve as drawn indicates a volume of 2,700,000 acre-feet. The design volume of 3,728,000 acre-feet is 1.4 times this envelope curve value.

An envelope curve of peak discharges for Interior Alaska Streams prepared for the Caribou Project is presented as Plate 6. This curve indicates a peak discharge of 25,000 cfs for 1,260 square miles. The maximum daily discharge of the inflow design flood, 30,000 cfs, is 1.2 times this value. No attempt was made to establish a momentary peak discharge for the inflow design flood.

Diversion during construction. There are insufficient records at the Denali gage to attempt a frequency analysis and it is not believed warranted at this time to develop a synthetic study because of the general lack of records. It is believed the two years of record that are available at Denali can be used for reconnaissance estimates of diversion requirements. The maximum discharge known was 13,700 cfs June 7, 1957. Each year there was a sustained flow between 8,000 and 10,000 cfs during June, July and part of August.

Donald L. Miller

I concur:

H. P. Grout

Head, Flood Hydrology Section

Approved:

H. S. RIESBOL

Chief, Hydrology Branch

7-1261

UNITED STATES DEPARTMENT OF THE INTERIOR BUREAU OF RECLAMATION HYDROGRAPH FOR........ File No. Washington....... Field.......

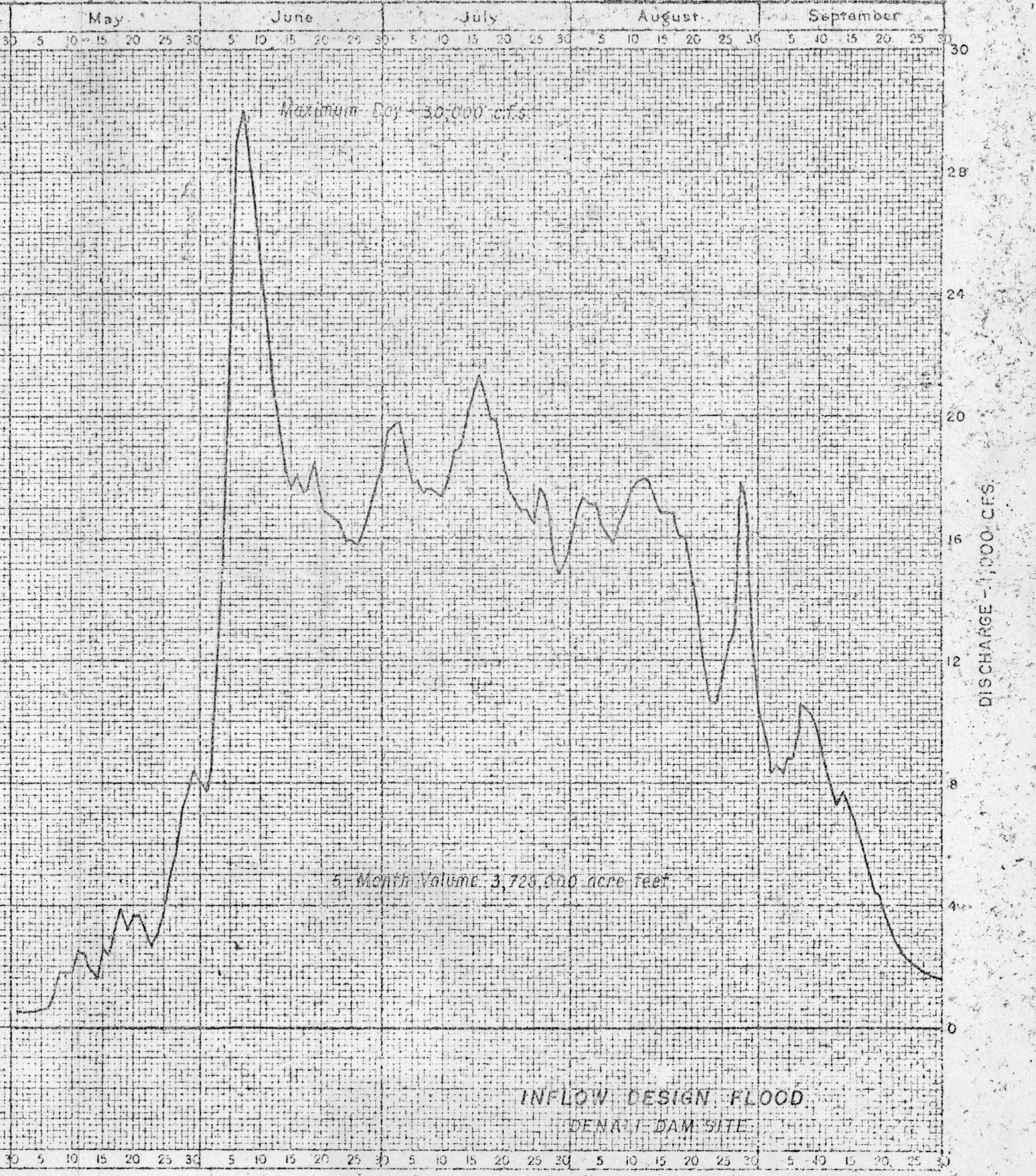
INFLOW DESIGN FLOOD

| Day of Month | May | June | July | August | September |
|---|---|---|---|---|---|
| | Daily Discharge, 1,000 cfs | | | | |
| 1 | 0.5 | 7.7 | 19.5 | 16.8 | 9.6 |
| 2 | 0.5 | 8.8 | 19.7 | 17.3 | 8.3 |
| 3 | 0.5 | 12.6 | 19.8 | 17.1 | 8.6 |
| 4 | 0.5 | 17.6 | (18.7) | 17.1 | 8.3 |
| 5 | 0.6 | 24.0 | 17.8 | 16.4 | 8.8 |
| 6 | 0.6 | 28.8 | 17.9 | 16.2 | 8.9 |
| 7 | 1.0 | (30.0*) | 17.5 | 15.8 | 10.6 |
| 8 | 1.8 | 28.8 | 17.6 | 16.6 | 10.4 |
| 9 | 1.8 | 27.2 | 17.5 | 16.9 | 10.2 |
| 10 | 1.8 | 24.8 | 17.4 | 17.6 | 9.3 |
| 11 | 2.5 | 23.2 | 18.0 | 17.8 | 8.6 |
| 12 | 2.4 | 21.1 | 18.9 | 17.9 | 7.9 |
| 13 | 1.9 | 19.4 | 19.0 | 17.8 | 7.3 |
| 14 | 1.6 | 18.3 | 19.7 | 17.2 | 7.7 |
| 15 | 2.6 | 17.7 | 20.5 | 16.8 | 7.2 |
| 16 | 2.4 | 18.1 | 21.3 | 16.8 | 6.7 |
| 17 | 3.0 | 17.5 | 20.6 | 16.8 | 5.9 |
| 18 | 3.9 | 17.6 | 19.9 | 16.1 | 5.2 |
| 19 | 3.2 | 16.5 | 19.9 | 16.0 | 4.4 |
| 20 | 3.7 | 17.0 | 18.5 | 14.8 | 4.3 |
| 21 | 3.7 | 16.8 | 17.6 | 13.8 | 3.6 |
| 22 | 3.1 | 16.7 | 17.2 | 11.9 | 3.1 |
| 23 | 2.7 | 16.6 | 16.9 | 10.6 | 2.7 |
| 24 | 3.1 | 15.9 | 16.9 | 10.6 | 2.4 |
| 25 | 3.7 | 15.9 | 16.5 | 11.7 | 2.2 |
| 26 | 4.9 | 15.8 | 17.6 | 12.5 | 2.0 |
| 27 | 5.6 | 16.1 | 17.0 | 12.8 | 1.9 |
| 28 | 7.0 | 16.8 | 15.4 | 17.8 | 1.8 |
| 29 | 7.7 | 17.6 | 14.8 | 17.1 | 1.7 |
| 30 | 8.4 | 18.3 | 15.1 | 13.0 | 1.6 |
| 31 | 8.0 | | 15.9 | 10.4 | |
| Totals | 94.7 | 565.2 | 560.6 | 478.0 | 131.2 |

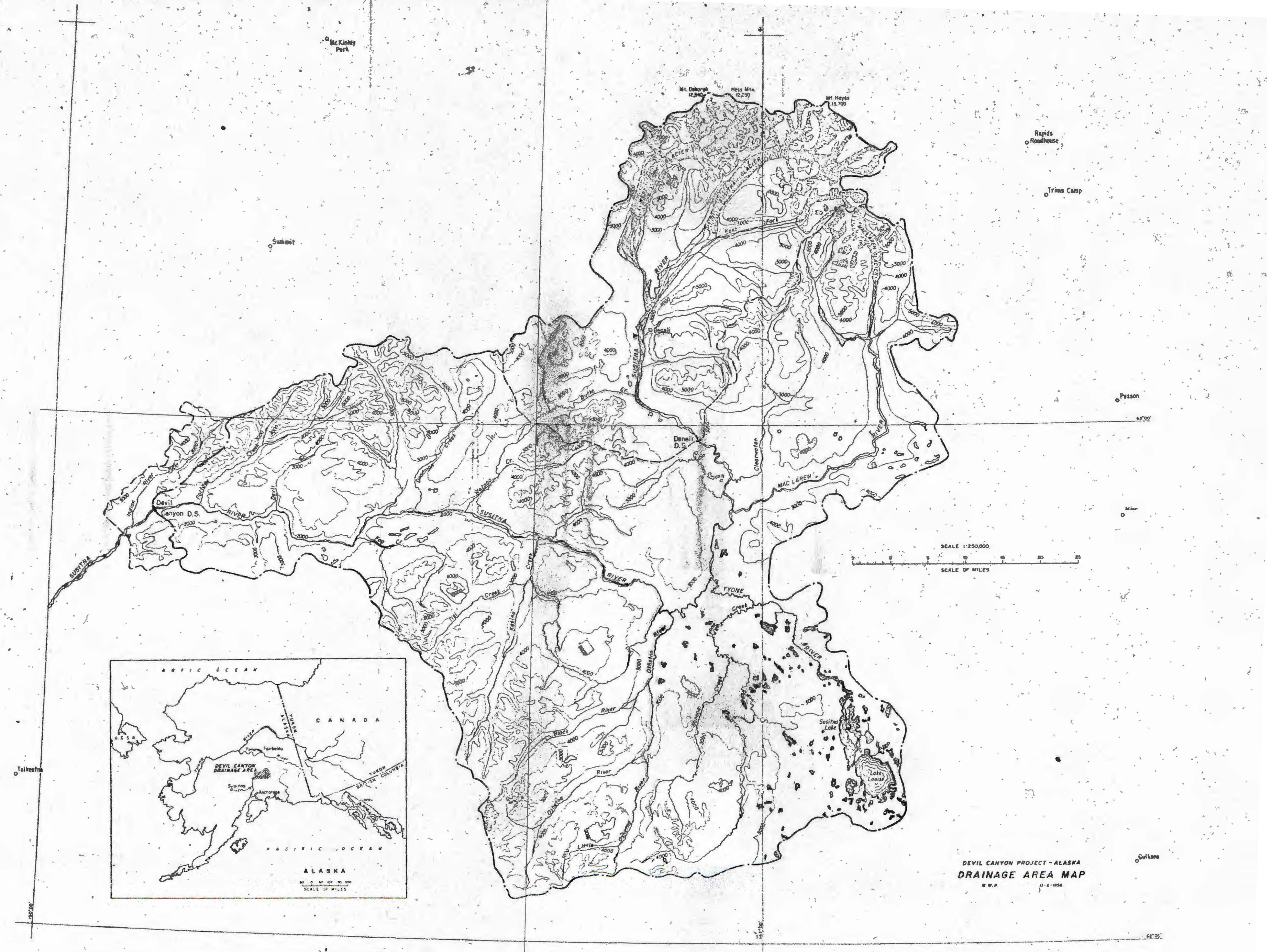
*Use 30,000 as peak

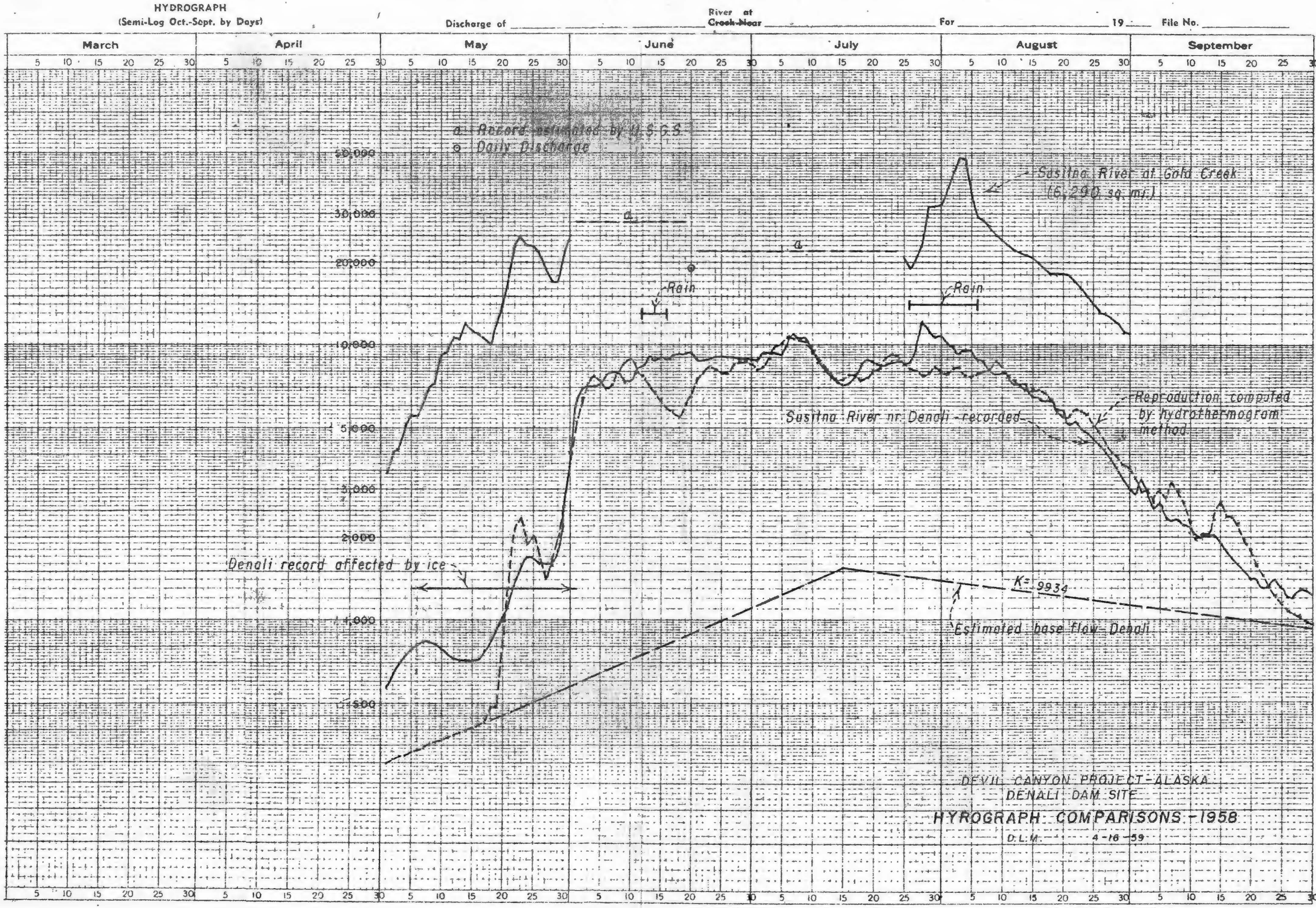
Devil Canyon Project--Alaska
DENALI DAM SITE
INFLOW DESIGN FLOOD
Reconnaissance

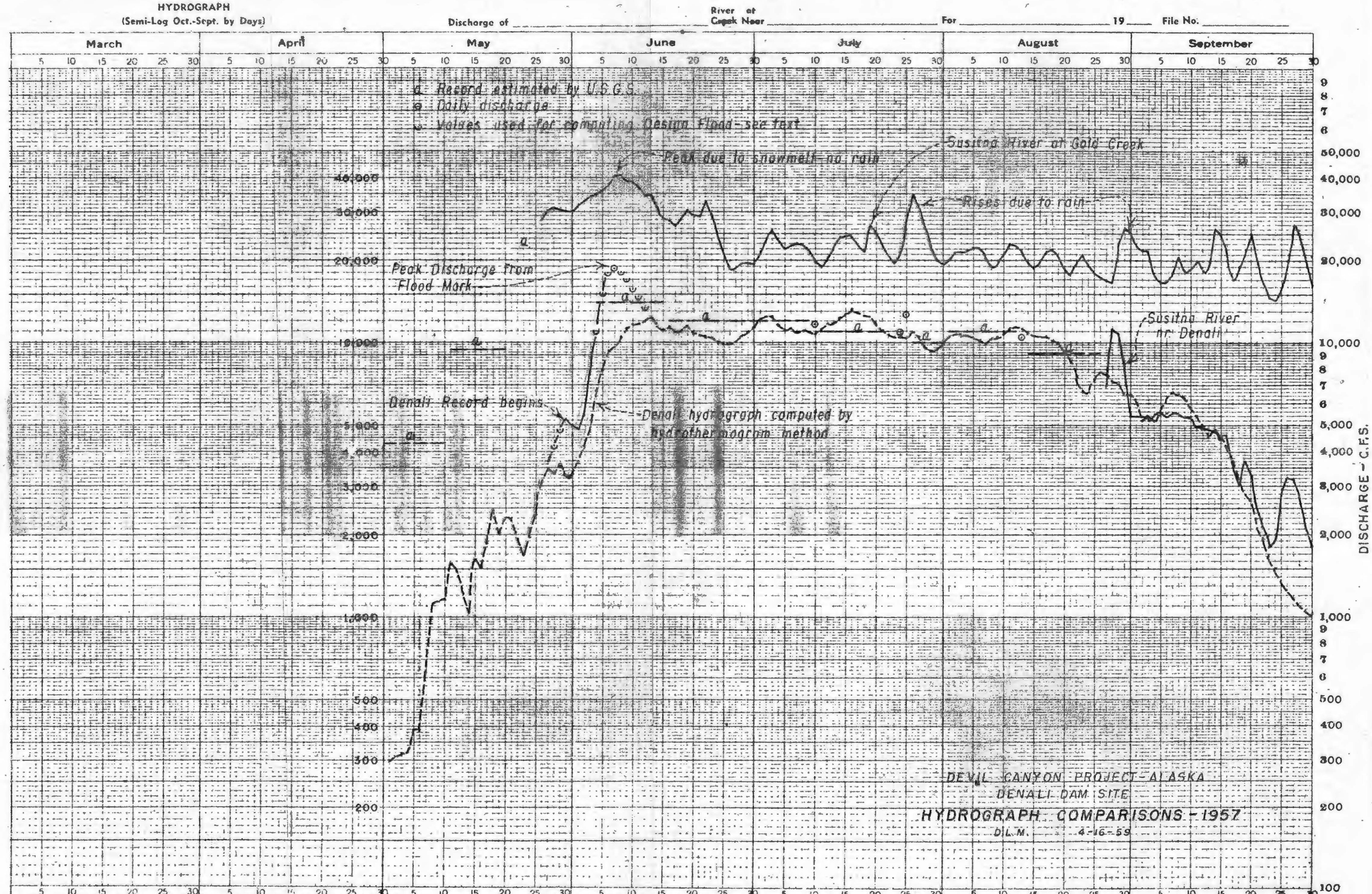
Hydrology Branch, Denver April 16, 1959




Plotted by.......... Checked by.......... Date..........


McKinley Park
Summit
Mt. Deborah 12,540
Hess Mtn. 12,030
Mt. Hayes 13,700
Rapids Roadhouse
Trims Camp
Denali
Denali D.S.
Paxson
Devil Canyon D.S.
SUSITNA
RIVER
MAC LAREN
TYONE
Susitna Lake
Lake Louise
Talkeetna
Gulkana
SCALE 1:250,000
SCALE OF MILES
CANADA
PACIFIC OCEAN
ALASKA
DEVIL CANYON DRAINAGE AREA
DEVIL CANYON PROJECT - ALASKA
DRAINAGE AREA MAP


HYDROGRAPH
(Semi-Log Oct.-Sept. by Days)
Discharge of
River at
For
19
File No.
March
April
May
June
July
August
September
a Record estimated by U.S.G.S.
⊙ Daily Discharge
Susitna River at Gold Creek (6,290 sq. mi.)
Rain
Rain
Reproduction computed by hydrothermogram method
Susitna River nr. Denali - recorded
Denali record affected by ice
K=.9934
Estimated base flow - Denali
DEVIL CANYON PROJECT - ALASKA
DENALI DAM SITE
HYROGRAPH COMPARISONS - 1958
D.L.M. 4-16-59
DISCHARGE CFS



HYDROGRAPH
(Semi-Log Oct.-Sept. by Days)
Discharge of
River at Creek Near
For
19
File No:
March
April
May
June
July
August
September
a Record estimated by U.S.G.S.
⊙ Daily discharge
Values used for computing Design Flood-see text
Peak due to snowmelt-no rain
Susitna River at Gold Creek
Rises due to rain
Peak Discharge from Flood Mark
Susitna River nr. Denali
Denali Record begins
Denali hydrograph computed by hydrothermogram method
DISCHARGE – C.F.S.
DEVIL CANYON PROJECT-ALASKA
DENALI DAM SITE
HYDROGRAPH COMPARISONS - 1957
D.L.M. 4-16-59


PLATE 4

| No. | Stream and Station | May-Sept. Volume 1,000 a.ft. | Area | Maximum yr. of Record |
|---|---|---|---|---|
| 1 | Chena River at Fairbanks | 1,651.0 | 1,980 | 1948 |
| 3 | Copper River near Chitina | 24,080 | 20,600 | 1958 |
| 4 | Eklutna Creek near Palmer | 286.8 | 119 | 1953 |
| 5 | Gakona River at Gakona | 698.8 | 620 | 1956 |
| 6 | Little Susitna River near Palmer | 208.1 | 61.9 | 1949 |
| 7 | Matanuska River at Palmer | 3,078.5 | 2,070 | 1949 |
| 8 | Nenana River near Windy | 872.3 | 710 | 1956 |
| 9 | Nenana River near Healy | 2,504.0 | 1,910 | 1956 |
| 10 | Salcha River at Salchaket | 1,804.8 | 2,170 | 1949 |
| 11 | Ship Creek near Anchorage | 114.2 | 91.2 | 1949 |
| 12 | Susitna River at Gold Creek | 7,581.0<br>5,564.0 | 6,290 | 1956<br>1958 |
| 13 | Tanana River near Tok Junction | 5,098.2 | 6,800 | 1950 |
| 14 | Tanana River at Big Delta | 9,332.0 | 13,500 | 1949 |
| 15 | Tazlina River near Glennallen | 3,217.6 | 2,670 | 1953 |
| 16 | Klutina River at Copper Center | 1,329.8 | 880 | 1953 |
| 17 | Tonsina River at Tonsina | 732.9 | 420 | 1953 |
| 18 | Tanana River at Northway Junction | 1,455.2 | 3,280 | 1950 |
| 19 | Chulitna River near Talkeetna | 5,312.2 | 2,570 | 1958 (1 yr. record) |
| 20 | Susitna near Denali | 2,252.6<br>1,646 | 950 | 1957<br>1958 |
| 21 | Maclaren River near Paxson | 668.5 | 280 | 1958 (May estimated) |

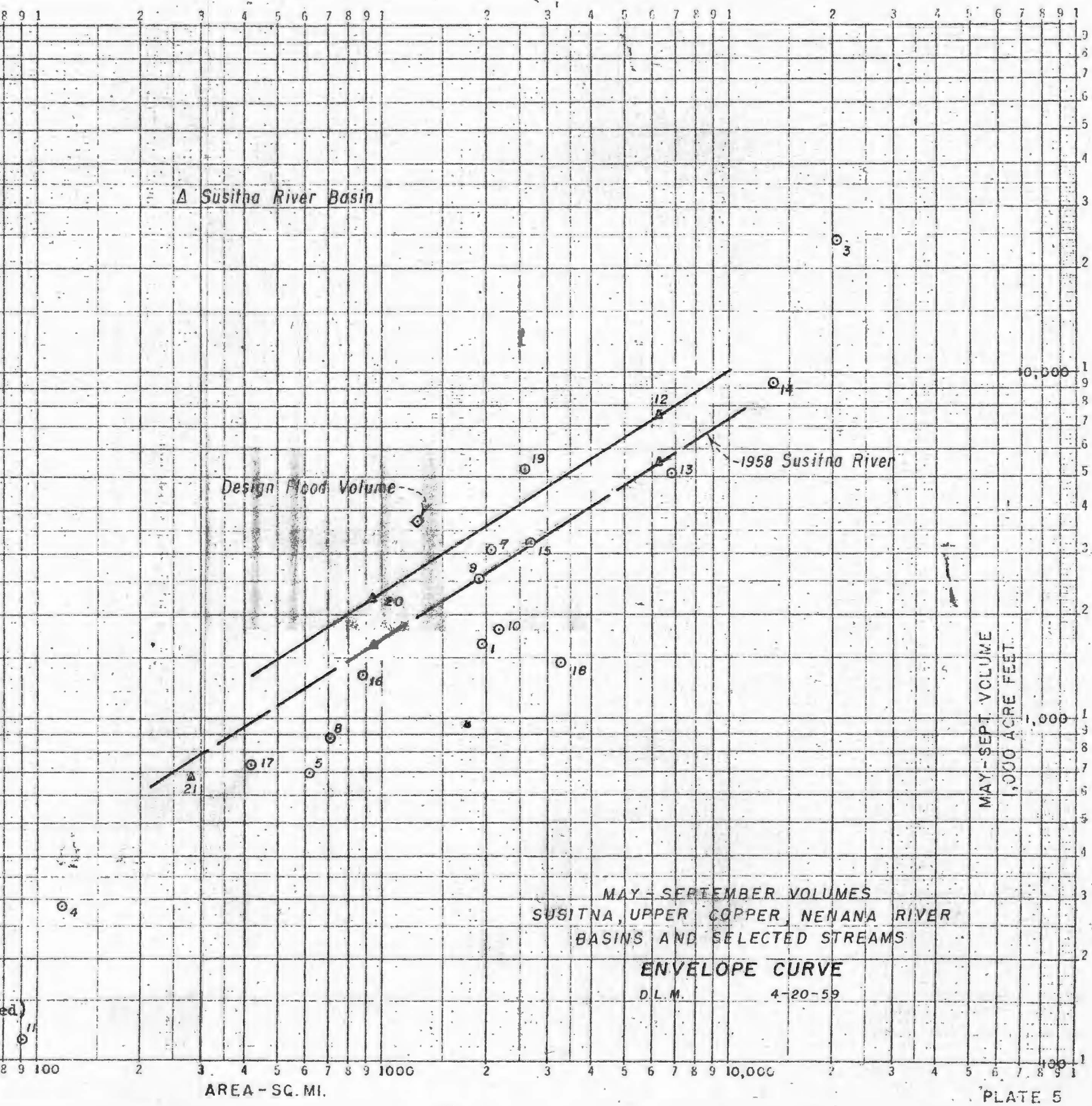
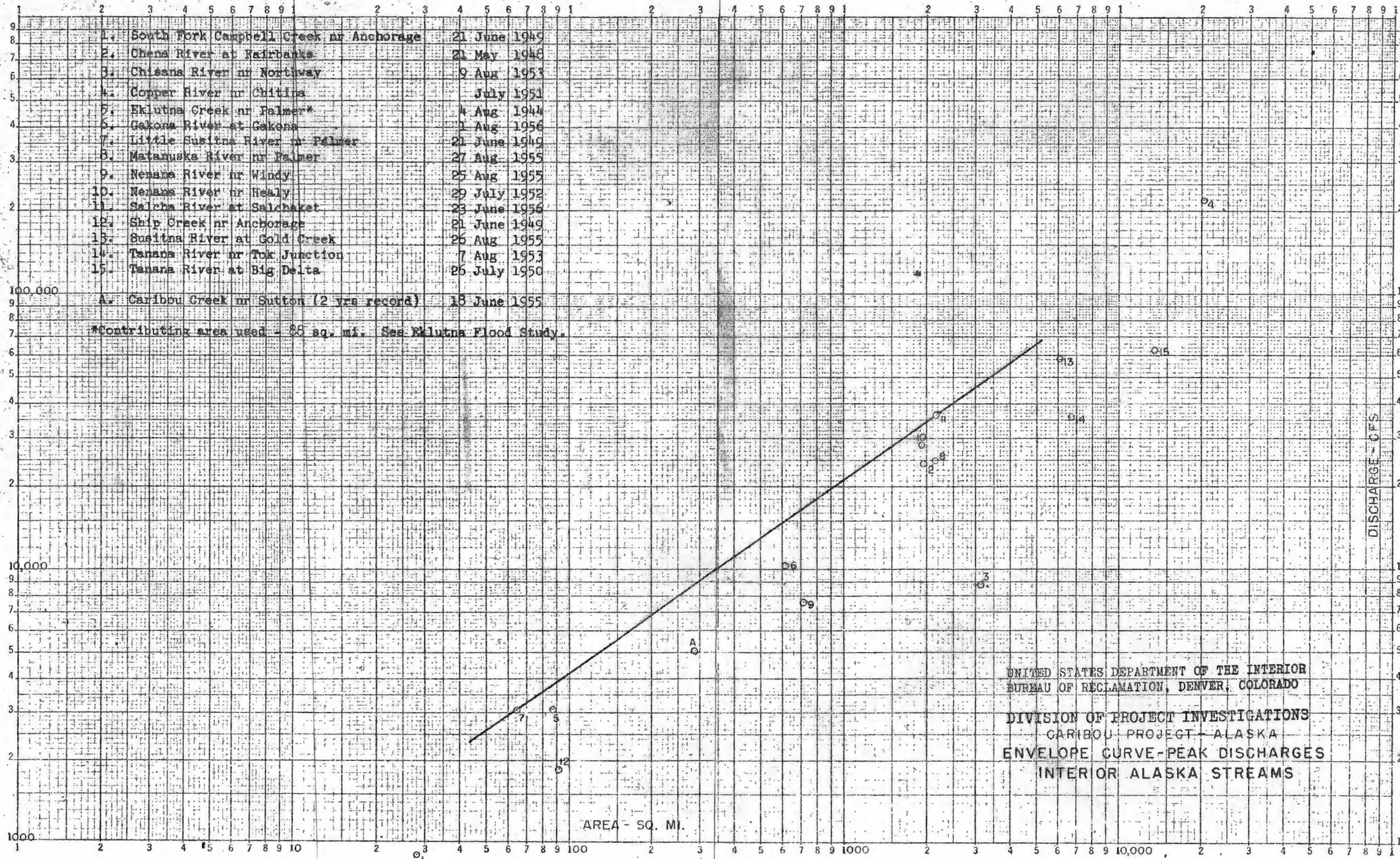



PLATE 5



1. South Fork Campbell Creek nr Anchorage 21 June 1949
2. Chena River at Fairbanks 21 May 1948
3. Chisana River nr Northway 9 Aug 1953
4. Copper River nr Chitina July 1951
5. Eklutna Creek nr Palmer* 4 Aug 1944
6. Gakona River at Gakona 1 Aug 1956
7. Little Susitna River nr Palmer 21 June 1949
8. Matanuska River nr Palmer 27 Aug 1955
9. Nenana River nr Windy 25 Aug 1955
10. Nenana River nr Healy 29 July 1952
11. Salcha River at Salchaket 23 June 1956
12. Ship Creek nr Anchorage 21 June 1949
13. Susitna River at Gold Creek 26 Aug 1955
14. Tanana River nr Tok Junction 7 Aug 1953
15. Tanana River at Big Delta 26 July 1950
A. Caribou Creek nr Sutton (2 yrs record) 18 June 1955
*Contributing area used - 88 sq. mi. See Eklutna Flood Study.
AREA - SQ. MI.
DISCHARGE - CFS
100,000
10,000
1000
10
100
1000
10,000
UNITED STATES DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION, DENVER, COLORADO
DIVISION OF PROJECT INVESTIGATIONS
CARIBOU PROJECT - ALASKA
ENVELOPE CURVE-PEAK DISCHARGES
INTERIOR ALASKA STREAMS