FLOOD-FREQUENCY ANALYSIS
FOR THE COLVILLE RIVER
NORTH SLOPE, ALASKA

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1.0 INTRODUCTION

The Colville River is located on the north slope of Alaska (Appendix B, Figure 1). Its drainage basin covers an area on the order of 20,670 square miles, making it the largest river on the North Slope. Portions of the drainage basin are contained within three physiographic regions: the Brooks Range, Foothills, and Coastal Plain.

Understanding the flooding regime of the Colville River Delta is critical to the design and placement of potential oil field facilities. Despite the numerous studies conducted on the delta, there is no long-term record of discharge or water surface elevations. This study uses seven years of peak discharge data collected at the head of the delta and data from two nearby rivers (the Kuparuk and Sagavanirktok rivers) to estimate the flood magnitude and frequency of the Colville River. The adopted flood frequency relationship for the Colville River is presented in Table 3 (Appendix A).

2.0 METHODS

Three methods of estimating the flood-frequency relationship on the Colville River were considered. Each method represents a commonly used means of estimating flood frequency relationships within Alaska, and is briefly described below.

2.1 Method A: Single Station Flood Frequency Analysis

Based on observations made at the head of the Colville River Delta, approximately 1 mile downstream from the confluence of the Itkillik River, annual flood peak discharges were estimated for the years 1962, 1977, 1992, 1993, 1994, 1995, and 1996 (ABR, 1996 and Shannon & Wilson, 1996). Using the seven years of flood peak estimates, a single-station flood-frequency analysis was performed. Details of the method, a list of the data used, and the results of the analysis are presented in Appendix C.

2.2 Method B: USGS Regression Equation Estimate

Estimates of flood magnitude and frequency were made using regional regression equations developed by the United States Geological Survey (USGS) (Jones and Fahl, 1994). The equations were adjusted to reflect the annual flood peak experience on the Kuparuk, Sagavanirktok, and Putuligayuk rivers. Details of the method, a list of the data used, and the results are presented in Appendix D.

2.3 Method C: Extrapolation Of Colville River Record Based On Similar Rivers

This method involves extrapolating the flood peak data that have been collected on the Colville River, based on the flood peak data that have been collected on another river with a longer record length. In order for the longer record-length station to be of value, it must be hydrologically similar to the short record-length station (i.e. the Colville River), and there must be annual flood peak data for both stations in at least some of the same years. A relationship is then developed between the flood peak discharge on the short record-length basin and the flood peak discharge on the long record-length basin. Using the relationship, and the data from the long record-length station, flood peaks are estimated for the years in which data are not available for the short record-length station. A single station flood frequency analysis is then conducted based on the extrapolated flood peak record.

The availability of annual peak discharge information on the north slope of Alaska is limited (Appendix A, Table 1). There are only five sites that have drainage basins larger than 1,000 square miles (the Colville River basin is 20,670 square miles in size). In order to extend the flood peak record on the Colville River, it is desirable to use a site in which the flood peak record overlaps the Colville River flood peak record in at least 5 or 6 years. It is also desirable to use a site with a total record length of at least twice the Colville River record.

Only one of the drainage basins larger than 1,000 square miles, the Kuparuk River, has a record length of more than 14 years (Appendix A, Table 1). However, there are two sites on the Sagavanirktok River that have drainage basins in excess of 1,000 square miles and which can be combined to yield a total record length of 23 years: near Pump Station 3 and near Sagwon. Also, data were collected on both the Kuparuk and Sagavanirktok rivers in 6 of the same years it was collected on the Colville River. Thus, the flood peak data collected on the Kuparuk and Sagavanirktok rivers are most likely to provide a meaningful extrapolation of the flood peak record on the Colville River.

Although the Firth River is over 1,000 square miles in size, there are only 12 years of data available on the Firth River. Additionally, only one of those years corresponds to a year in which flood peak data were collected on the Colville River. Therefore, extrapolation of the flood peak record on the Colville River would have to be based on only one year of comparative discharges. For this reason, the Firth River data were not used in this analysis.

In terms of the size of the drainage area, the mean basin elevation, the percent of basin covered with lakes, and the mean annual precipitation, the Kuparuk River basin is somewhat more similar to the Colville River basin than the Sagavanirktok River basin (Appendix B, Figure 2). The Kuparuk River basin may also be more similar to the Colville River basin in terms of the mechanism (i.e. snowmelt, rainfall, or rain on snow) which produces the annual peak discharge.

Based on past experience and the size of the Colville River drainage basin, we expect that the annual peak discharge on the Colville River will normally be a spring breakup event. We believe that the mechanism producing the event is normally snowmelt and, in some years, possibly rain on snow. We believe that this is also true of the Kuparuk River. Of the 26 years of record on the Kuparuk River, the annual peak discharge has occurred prior to June 15 in every year but one. In 1992, the annual peak discharge occurred on August 28 and was clearly the result of rainfall. Of the 23 years of record on the Sagavanirktok River, the annual peak discharge occurred prior to June 15 in only 9 of the years. At least 12 of the annual peak discharges were clearly produced by rainfall. However, the largest peak discharge of record was probably produced by snowmelt at both the Kuparuk River and the Sagavanirktok River stream gaging sites.

Another consideration is the physiographic regions within which the basins are located (Appendix B, Figures 1 and 2). Portions of the Colville River drainage basin are located in each of the three physiographic regions: the Coastal Plain, Foothills, and Brooks Range. Both the Sagavanirktok and the Kuparuk River basins are located in only two of the three physiographic regions, each in a different pair of regions. Thus, both basins are partially similar to the Colville River basin. However, based on physiographic regions, neither basin is clearly more similar to the Colville river than the other basin.

For this reason two separate analyses were conducted. The first analysis involved extending the Colville River peak discharge record based on the peak discharge data collected on the Kuparuk River. A single-station flood-frequency analysis was performed using 7 years of peak-discharge data collected at the head of the Colville River Delta, and 20 years of peak discharge values extrapolated from observations on the Kuparuk River. Details of the method, a list of the data used, and the results are presented in Appendix E.

The second analysis involved extending the Colville River peak discharge record based on the peak discharge data collected on the Sagavanirktok River. A single-station flood-frequency analysis was performed using 7 years of peak-discharge data collected at the head of the Colville

River Delta, and 17 years of peak discharge values extrapolated from observations on the Sagavanirktok River. Details of the method, a list of the data used, and the results are presented in Appendix F.

To develop the final flood-peak-frequency relationship for the Colville River, a weighted average of the two sets of results was used. The weighting factors were based on the percentage of the drainage basin in each of the Brooks Range and Foothills physiographic regions (Appendix B, Figure 3). These two physiographic regions were used to compute the weighting factor because it is felt that the flood peaks on the Colville River are primarily generated as a result of conditions within these two regions. Based on the weighting factors, the weighted flood peak estimates were computed as follows.

$$Q_w = (a)\,(Q_k) + (b)\,(Q_s)$$

Where:

Q_w = weighted Colville River flood peak estimate for the T-year event;

a = the weighting factor for the Colville River flood peak estimate based on the extended data set developed from the Kuparuk River data;

Q_k = Colville River flood peak estimate for the T-year event, based on the extended data set developed from the Kuparuk River data;

b = the weighting factor for the Colville River flood peak estimate based on the extended data set developed from the Sagavanirktok River data; and

Q_s = Colville River flood peak estimate for the T-year event, based on the extended data set developed from the Kuparuk River data.

2.4 Expected Probability

All of the single-station flood-frequency analyses presented in this report make use of the guidelines established by the Interagency Advisory Committee on Water Data (1982) for the preparation of single-station flood-frequency analyses. All of the analyses also make use of the expected probability adjustment. It has been shown by Beard (1974) that the log-Pearson type

III distribution with a weighted skew coefficient underestimates the average exceedance probability associated with a specified flow. It has also been shown that use of the expected probability adjustment, in combination with the log-Pearson type III distribution and a weighted skew coefficient, produces an unbiased estimate of the average exceedance probability associated with a specified flow (Beard, 1974). The need for the expected probability adjustment was recognized by the Interagency Advisory Committee on Water Data (1982) and is discussed in Appendices 11 and 14 of Bulletin 17B. A brief explanation of expected probability is presented in Appendix G.

3.0 RESULTS

Three methods of estimating the flood-frequency relationship on the Colville River were considered. Each method is briefly discussed below. A summary of the computations associated with Methods A and B is presented in Appendices C and D, respectively. A summary of the computations associated with Method C is presented in Appendices E and F. The results from Method C are adopted as the design flood-frequency relationship for the Colville River. A summary of the results from Methods A and C is presented in Table 2 (Appendix A), and the design flood-frequency relationship for the Colville River is presented in Table 3 (Appendix A).

3.1 Method A: Single Station Flood Frequency Analysis

Method A involves the development of a flood-frequency relationship based on the flood peak data that are available for the Colville River at the head of the delta. However, it should be noted that only 7 years of annual flood-peak discharges are available with which to estimate the flood-frequency relationship. Particularly in situations where less than 10 years of data are available, it is often considered prudent to develop the final flood-peak-frequency relationship based on more than one method of estimating the relationship. Often a weighted average of the results from the single-station frequency analysis and another method are used. Another commonly used method is to extend the available data based on a similar nearby stream. Extension of the available data, based on a nearby stream, is the approach referred to as Method C in this report.

The data used and the computations conducted for Method A are presented in Appendix C. A summary of the results is presented in Table 2 (Appendix A). The results of the analysis compare favorably with the other methods for return periods of 50-years or less. For return periods of greater than 50-years the base curve compares favorably with the other estimates, but the expected probability estimate is considerably higher. This is to be expected because of the short record length. As more data become available, the confidence limits on the single station frequency analysis will become closer to the base curve estimate and the expected probability estimate will more closely approach the base curve estimate.

Although the results from Method A generally compare favorably with the results from the other methods, it is felt that Method C produced the most reliable estimate. The Method A results were not weighted with the results from the two data extension analyses used to produce the Method C results, because the data used in Method A were used in the two data extension analyses used to produce the Method C results.

3.2 Method B: USGS Regression Equation Estimate

Method B involves the use of the U.S. Geological Survey (USGS) regional regression equations (Jones and Fahl, 1994) that have been developed for the estimation of flood peak discharge on watersheds for which little or no flood peak data exist. As discussed in Appendix D, the quality of the estimates produced with the USGS equations was checked against the single-station flood-frequency relationships developed for several long-term discharge measurement sites on the North Slope. Based on the single-station flood-frequency relationships for the Kuparuk, Sagavanirktok, and Putuligayuk rivers, the USGS regression equations significantly underestimate the flood peak discharge (Appendix D, Table D-1). Additionally, the magnitude of the adjustment factor that was required to increase the regression equation estimate to a value equal to the single-station expected- probability flood-peak estimate varied considerably from one basin to the next (Appendix D, Table D-1), and had a range of from 1.3 to 5.0.

The peak discharge estimates for the Colville River based on the original regression equations, and the regression equations adjusted with the factors computed from the Kuparuk, Sagavanirktok, and Putuligayuk rivers, are presented in Table D-2 (Appendix D). The peak discharge estimates based on the original regression equations, and the regression equations adjusted based on the Sagavanirktok and Putuligayuk river data, appear to be unrealistically low. For example, based on these methods, the 100-year flood is estimated to be on the order of 151,000 to 248,000 cfs. Of the 7 years of flood-peak data collected on the Colville River, a discharge of 151,000 cfs has been exceeded every year, and a discharge of 248,000 cfs has been exceeded twice (Appendix C, Table C-1). In addition, the antilog of the mean of the logs of the 7 years of Colville River data is approximately 233,000 cfs. Therefore, we might expect the 2-year peak discharge, not the 100-year peak discharge, to be on the order of 200,000 to 250,000 cfs.

The results of the regression equations which were adjusted based on the Kuparuk River data appear to be similar to the results obtained with at least one of the other methods (Appendix A, Table 2). However, because of the large variation in the results obtained using the various adjustment factors and the magnitude of the Kuparuk River adjustment factor, the results of Method C are considered more reliable and will be used to produce the final flood-frequency relationship for the Colville River.

3.3 Method C: Extrapolation Of Colville River Record Based On Similar Rivers

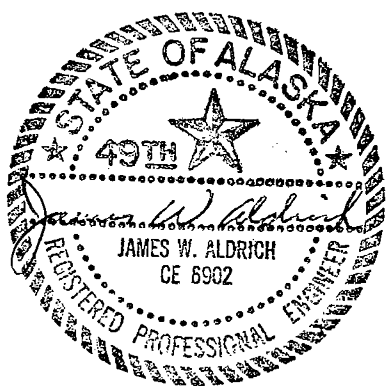
Method C involves extrapolating the flood peak data that have been collected on the Colville River, based on the flood peak data that have been collected at two other rivers with longer record lengths: the Kuparuk River and the Sagavanirktok River. A discussion of the data and the single-station flood-frequency relationship developed from extrapolating the Colville River flood-peak record based on the Kuparuk River flood-peak record is presented in Appendix E. A discussion of the data and the single-station flood-frequency relationship developed from extrapolating the Colville River flood-peak record based on the Sagavanirktok River flood peak record is presented in Appendix F. Because both the Kuparuk and the Sagavanirktok River basins are partially similar to the Colville River basin (see Section 2.3), the adopted flood-peak frequency relationship for the Colville is based on a weighted average of the two analyses. The weighting factors are based on the percentage of the Sagavanirktok and Kuparuk river drainage basins that are contained within the Brooks Range and Foothills physiographic regions. As shown in Figure 3 (Appendix A) the weighting factor associated with the estimate based on an extension of the Kuparuk River data is 0.65. The weighting factor associated with the estimate based on an extension of the Sagavanirktok River data is 0.35. The results of the analyses are summarized in Table 2 (Appendix A), and the adopted flood-peak frequency relationship is summarized in Table 3 (Appendix A). For the adopted flood-peak frequency relationship the discharge estimates were rounded to two significant figures.

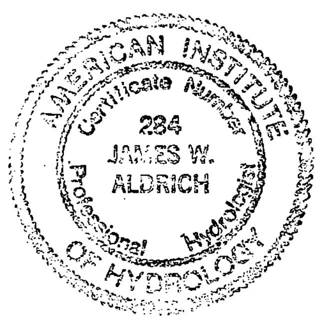
4.0 LIMITATIONS

The analyses, recommendations, and conclusions contained in this report are based on the information and data available, and the state-of-the-practice of hydrology, at the time this report was prepared. If additional information or data become available prior to the start of work on the project, we recommend that this report be reviewed to determine the applicability of the conclusions and recommendations considering the new information and/or data.

SHANNON & WILSON, INC.

Scott R. Ray
Senior Hydrologist





James W. Aldrich, P.E., P.H.
Senior Associate/River Engineer

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APPENDIX A
TABLES

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Table 1: Drainage Basin Characteristics For The Colville River And Other North Slope Rivers

	Drainage Area (sq. miles)	Record Length (years)	Period Of Record	Area Of Brooks Range (%)	Area Of Foothills (%)	Area Of Coastal Plain (%)	Mean Annual Precip-itation (inches)	Area Of Lakes And Ponds (%)	Mean Basin Elevation (feet)	Percentage Of Annual Flood Peaks Caused By Snowmelt
Colville River [1]	20,670	7	[1]	26	64	10	13	3	2,000	100
Kuparuk River [2]	3,130	26	1971-1996	0	39	61	9	2	9,000	96
Sagavanirktok River Near Sagwon [2]	2,208	11 [3]	1969-1979				22	0	3,220	45
Firth River Near Mouth Near Herschel YT [2]	2,200	12	1972-1973, 1975-1984				18	0	2,630	83
Sagavanirktok River Near Pump Station 3 [2]	1,860	14	1983-1996	78	22	0	22	1	3,580	26
Putuligayuk River Near Deadhorse [2]	176	25	1970-1980, 1982-1995							
Kuparuk Trib 1 [3]	92.3	6	1979-1984							
Sakonowyak Creek [3]	49.5	7	1978-1984							
East Creek [3]	43.4	7	1978-1984							
Happy Creek at Happy Valley Camp Near Sagwon [2]	34.5	24	1972-1995							
Atigun River Tributary Near Pump Station 4 [2]	32.6	20	1976-1995							
Sagavanirktok River Tributary Near Pump Station 3 [2]	28.4	17	1979-1995							
Ugnuravik River [3]	26.9	7	1978-1984							
East Kalubik Creek [3]	25.4	4	1981-1984							
Kalubik Creek [3]	17.1	4	1981-1984							
Sagavanirktok River Tributary Near Deadhorse [2]	12	9	1986, 1988-1995							
Nunavak Creek Near Barrow [2]	2.79	24	1972-1995							

Notes:

1. Discharge data have been collected in 1962 by Arnborg et al. (1966), in 1977 by the U.S. Geological Survey, in 1992 by Arctic Hydrologic Consultants (Jorgenson et al. 1993), and in 1993, 1995, and 1996 by Shannon & Wilson, Inc.
2. Discharge data have been collected by the U.S. Geological Survey.
3. Discharge data have been collected by Peratrovich, Nottingham, & Drage, Inc. (1984).
4. There are 11 years of instantaneous peak discharge data, but only 8 years of average daily peak discharge data for the Sagavanirktok River near Sagwon.

Table 2: Summary Of Colville River Flood-Frequency Analyses

	Discharge (cfs)				
	Method A	Method B	Method C		
	Single-Station Frequency Analysis Based On Seven Years Of Colville River Data (Column 1)	USGS Regression Estimate Based On Kuparuk River Adjustment Factor (Column 2)	Single-Station Frequency Analysis Based On Extension Of Colville River Data Using Kuparuk River Data (Column 3)	Single-Station Frequency Analysis Based On Extension Of Colville River Data Using Sagavanirktok River Data (Column 4)	Weighted Average Of Analyses Using Kuparuk And Sagavanirktok River Data (Column 5)[1]
2-Year Base Curve	225,000		256,000	216,000	242,000
2-Year Expected Probability	225,000	247,000	256,000	216,000	242,000
5-Year Base Curve	317,000		403,000	288,000	363,000
5-Year Expected Probability	336,000	339,000	409,000	292,000	368,000
10-Year Base Curve	387,000		510,000	343,000	452,000
10-Year Expected Probability	438,000	402,000	526,000	352,000	465,000
25-Year Base Curve	485,000		656,000	418,000	573,000
25-Year Expected Probability	632,000	494,000	695,000	441,000	606,000
50-Year Base Curve	567,000		773,000	480,000	670,000
50-Year Expected Probability	851,000	566,000	837,000	520,000	726,000
100-Year Base Curve	655,000		896,000	547,000	774,000
100-Year Expected Probability	1,190,000	645,000	997,000	612,000	862,000
200-Year Base Curve	752,000		1,020,000	619,000	880,000
200-Year Expected Probability	1,750,000	732,000	1,180,000	720,000	1,020,000
500-Year Base Curve	893,000		1,210,000	725,000	1,040,000
500-Year Expected Probability	3,030,000	860,000	1,450,000	896,000	1,260,000

Notes:
1. This column is based on the weighted average of the results in columns 3 and 4.

Table 3: Design Flood-Frequency Relationship

Return Period	Design Flood Peak Discharge (cfs)
2-Year	240,000
5-Year	370,000
10-Year	470,000
25-Year	610,000
50-Year	730,000
100-Year	860,000
200-Year	1,000,000
500-Year	1,300,000

APPENDIX B
FIGURES

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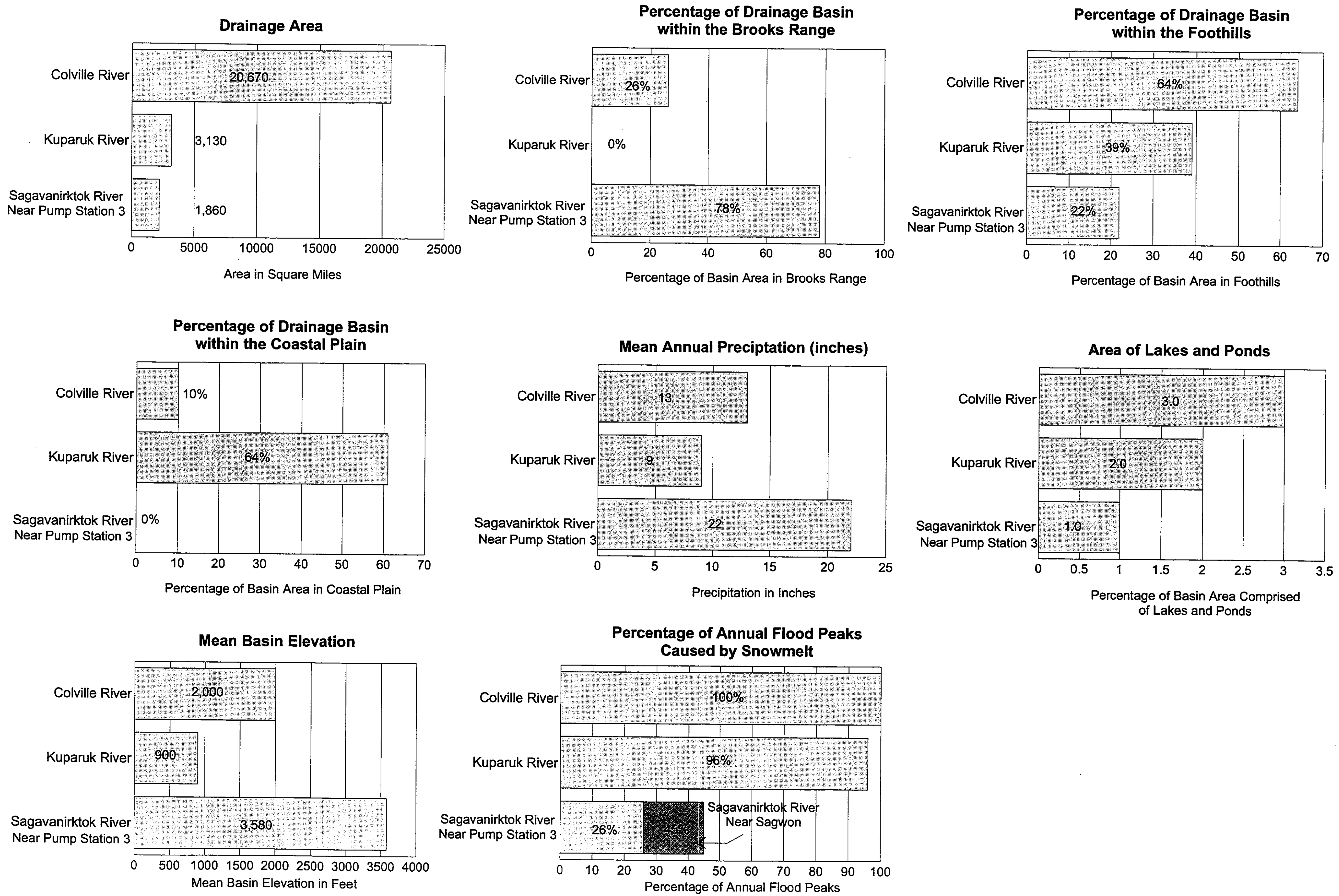

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PROJECT: FLOOD FREQUENCY ANALYSIS FOR THE COLVILLE RIVER, NORTH SLOPE, ALASKA

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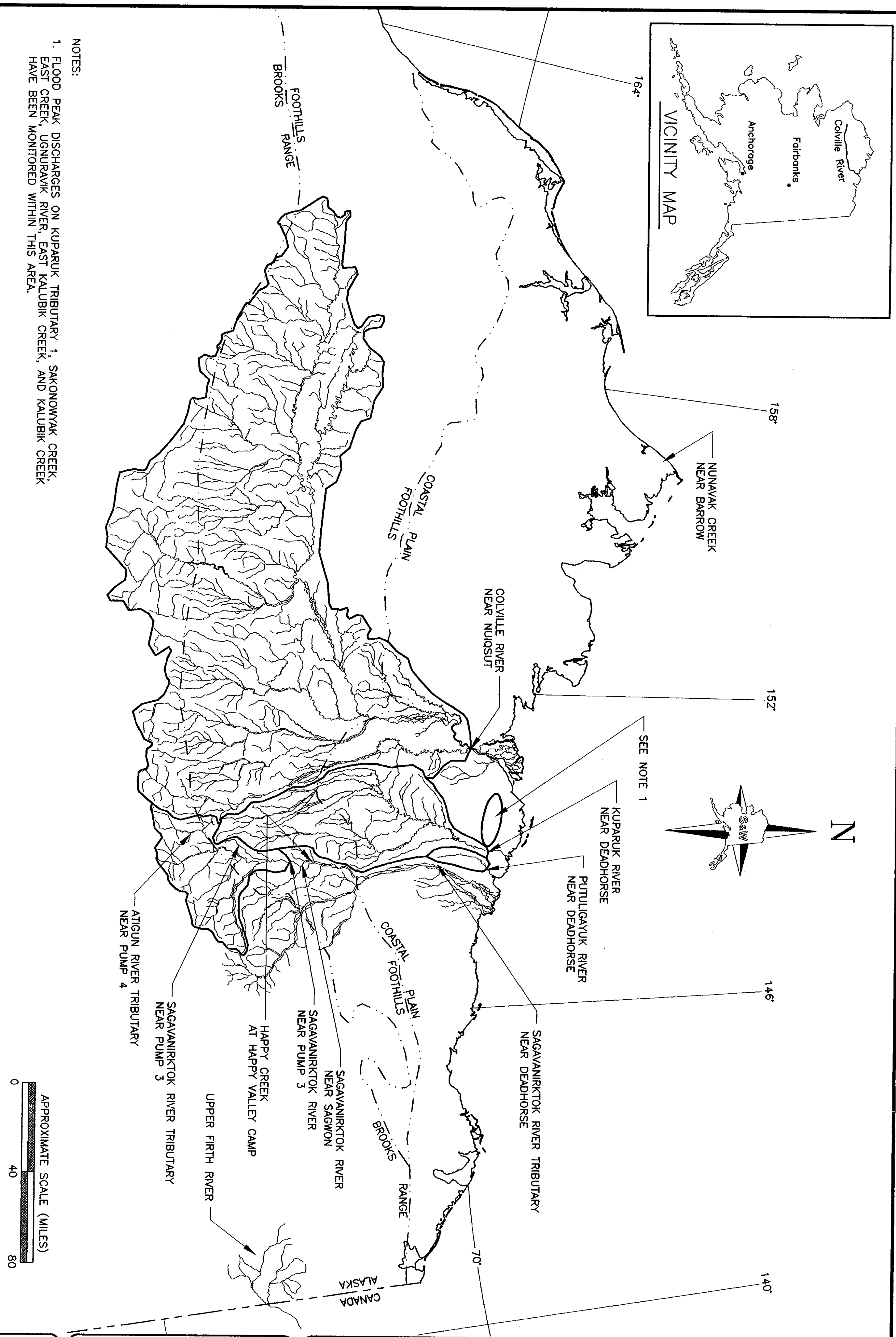

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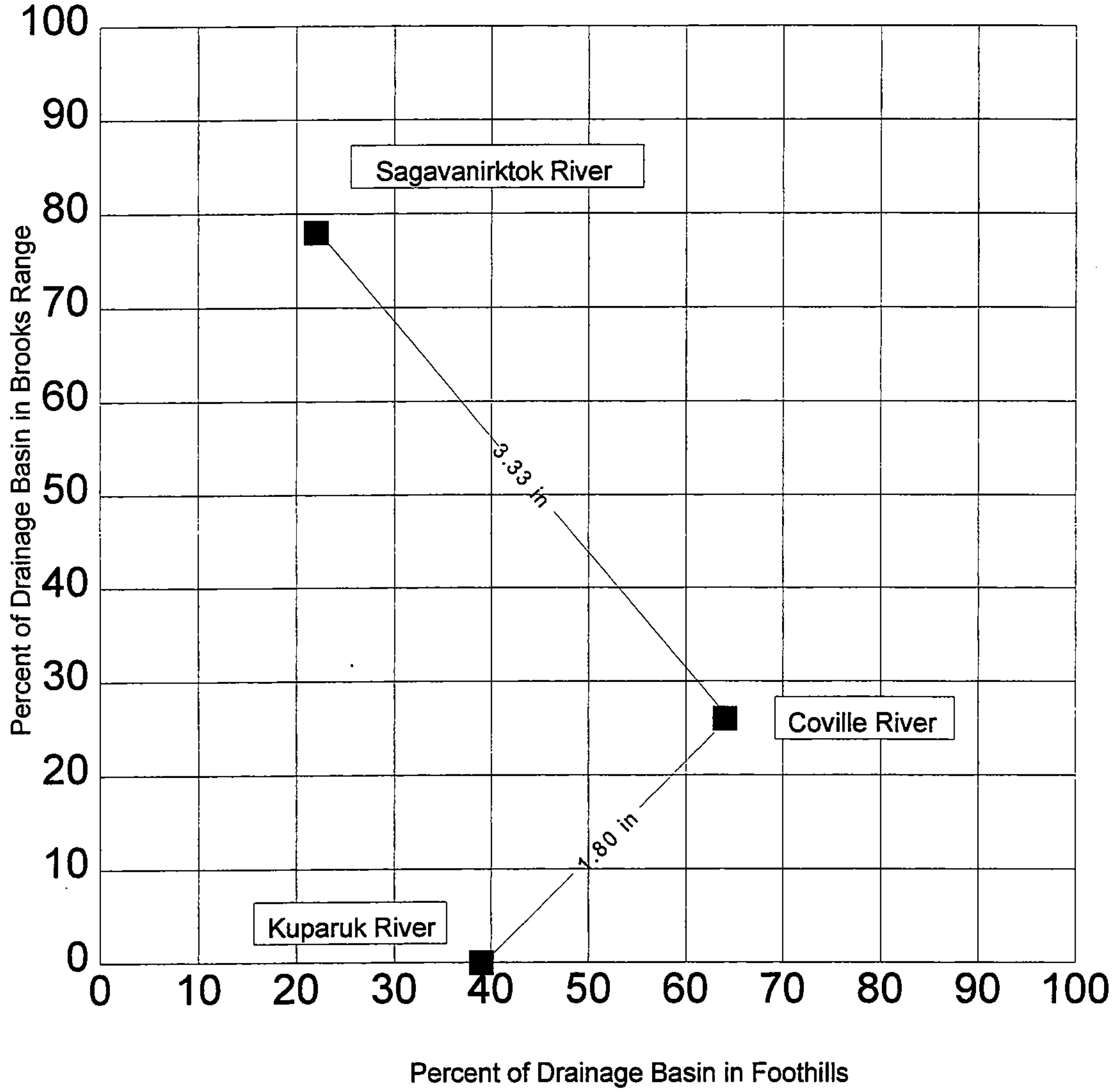

Weight factors are based on the percent area by physiographic region:

Sagavanirktok River = (1-3.33/(3.33+1.80) = 35%

Kuparuk River = (1-1.80/(3.33+1.80)) = 65%

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DRAINAGE BASIN WEIGHTING FACTOR

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Sheet Number: 3

APPENDIX C
SINGLE-STATION FLOOD-FREQUENCY RELATIONSHIP FOR THE COLVILLE RIVER AT THE HEAD OF THE DELTA

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APPENDIX C
SINGLE-STATION FLOOD-FREQUENCY RELATIONSHIP FOR THE COLVILLE RIVER AT THE HEAD OF THE DELTA

Methods And Results

A single-station flood-frequency analysis was performed using the 7 years of peak-discharge data collected at the head of the delta on the Colville River, approximately 1 mile downstream from the confluence of the Itkillik River (Table C-1). The analysis was based on the methods developed by the Interagency Advisory Committee On Water Data (1982). Both the generalized skew (0.13) and the standard error of the generalized skew (1.15), used to produce a weighted skew for the flood-frequency analysis, were taken from the data presented for Region 3 by Jones and Fahl (1994). The U.S. Army Corps of Engineer's Flood Frequency Program HEC-FFA (USACE, 1992) was used to perform the computations. The results of the analysis are presented in Table C-2, and are discussed in Section 3.1.

Table C-1: Summary Of Annual Peak Discharge Data For The Colville River At The Head Of The Delta

Year	Annual Peak Discharge (cfs)	Source of Data
1996	160,000	1
1995	233,000	2
1994	159,000	2
1993	379,000	2
1992	188,000	2
1977	407,000	2
1962	215,000	2

Source of Data:

1. Shannon & Wilson, Inc. 1996. *1996 Colville River Delta Spring Breakup and Hydrologic Assessment, Colville River Delta, North Slope, Alaska.* Prepared for: Michael Baker Engineering, Anchorage, Alaska.
2. ABR, Inc. and Shannon & Wilson Inc. 1996. *Geomorphology and Hydrology of the Colville River Delta, Alaska, 1995.* Prepared For: ARCO Alaska Inc. Anchorage, Alaska.

Table C-2: Colville River Flood-Frequency Analysis Based On Seven Years Of Data

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***********************************        ************************************
*             FFA                 *        *                                  *
*    FLOOD FREQUENCY ANALYSIS     *        *   U.S. ARMY CORPS OF ENGINEERS   *
*    PROGRAM DATE:  FEB 1995      *        * THE HYDROLOGIC ENGINEERING CENTER *
*         VERSION:  3.1           *        *         609 SECOND STREET        *
*    RUN  DATE   AND   TIME:      *        *      DAVIS, CALIFORNIA 95616     *
*       10 SEP 96     11:00:50    *        *          (916) 756-1104          *
*                                 *        *                                  *
***********************************        ************************************



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OUTPUT FILE NAME: COLVILLE.OUT
   DSS FILE NAME: COLVILLE.DSS


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TT   COLVILLE RIVER AT HEAD OF DELTA

**JOB RECORD(S)**
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       A       B  CLIMIT  NDSSCV    IEXT
J2   .00     .00     .00       0       1

**GENERALIZED SKEW**
     ISTN   GGMSE    SKEW
GS          1.322     .13

**HP PLOT **
     HP PLOT FILE                IHPCV  KLIMIT    IPER    BAREA
HP COLVILLE.PCL                      3       0       0 20,670 SQ MI

     SELECTED CURVES ON HPPLOT
          EXPECTED PROBABILITY CURVE
          COMPUTED PROBABILITY CURVE
          CONFIDENCE LIMITS

HP Colville River
HP At Head Of Delta

**SYSTEMATIC EVENTS**
      7 EVENTS TO BE ANALYZED

**END OF INPUT DATA**

ED ++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
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* * * * WARNING - LESS THAN TEN EVENTS FOR ANALYSIS
            BULLETIN 17-B PROCEDURES NOT APPLICABLE.
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Table C-2: Colville River Flood-Frequency Analysis Based On Seven Years Of Data (Continued)

```
* * * * * * * * * * *    FLOOD PEAK DATA    * * * * * * * * * * *

-PLOTTING POSITIONS-
****************************************************************
*......EVENTS ANALYZED.....*...........ORDERED EVENTS..........*
*                  FLOW    *        WATER       FLOW   WEIBULL  *
* MON DAY  YEAR     CFS    *  RANK  YEAR        CFS    PLOT POS *
*--------------------------*-----------------------------------*
*   0   0  1962  215000.   *    1   1977     407000.     12.50  *
*   0   0  1977  407000.   *    2   1993     379000.     25.00  *
*   0   0  1992  188000.   *    3   1995     233000.     37.50  *
*   0   0  1993  379000.   *    4   1962     215000.     50.00  *
*   0   0  1994  159000.   *    5   1992     188000.     62.50  *
*   0   0  1995  233000.   *    6   1996     160000.     75.00  *
*   0   0  1996  160000.   *    7   1994     159000.     87.50  *
****************************************************************


-OUTLIER TESTS  -
----------------------------------------------------------------
HIGH OUTLIER TEST
-----------------


BASED ON   7 EVENTS, 10 PERCENT OUTLIER TEST VALUE K(N) = 1.828

      0 HIGH OUTLIER(S) IDENTIFIED ABOVE TEST VALUE OF  470068.


-----------------
LOW OUTLIER TEST
-----------------


BASED ON   7 EVENTS, 10 PERCENT OUTLIER TEST VALUE K(N) = 1.828

       0 LOW OUTLIER(S) IDENTIFIED BELOW TEST VALUE OF 115204.1
----------------------------------------------------------------

-SKEW WEIGHTING -
----------------------------------------------------------------
BASED ON   7 EVENTS, MEAN-SQUARE ERROR OF STATION SKEW =   .698
DEFAULT OR INPUT MEAN-SQUARE ERROR OF GENERALIZED SKEW =  1.322
----------------------------------------------------------------
```

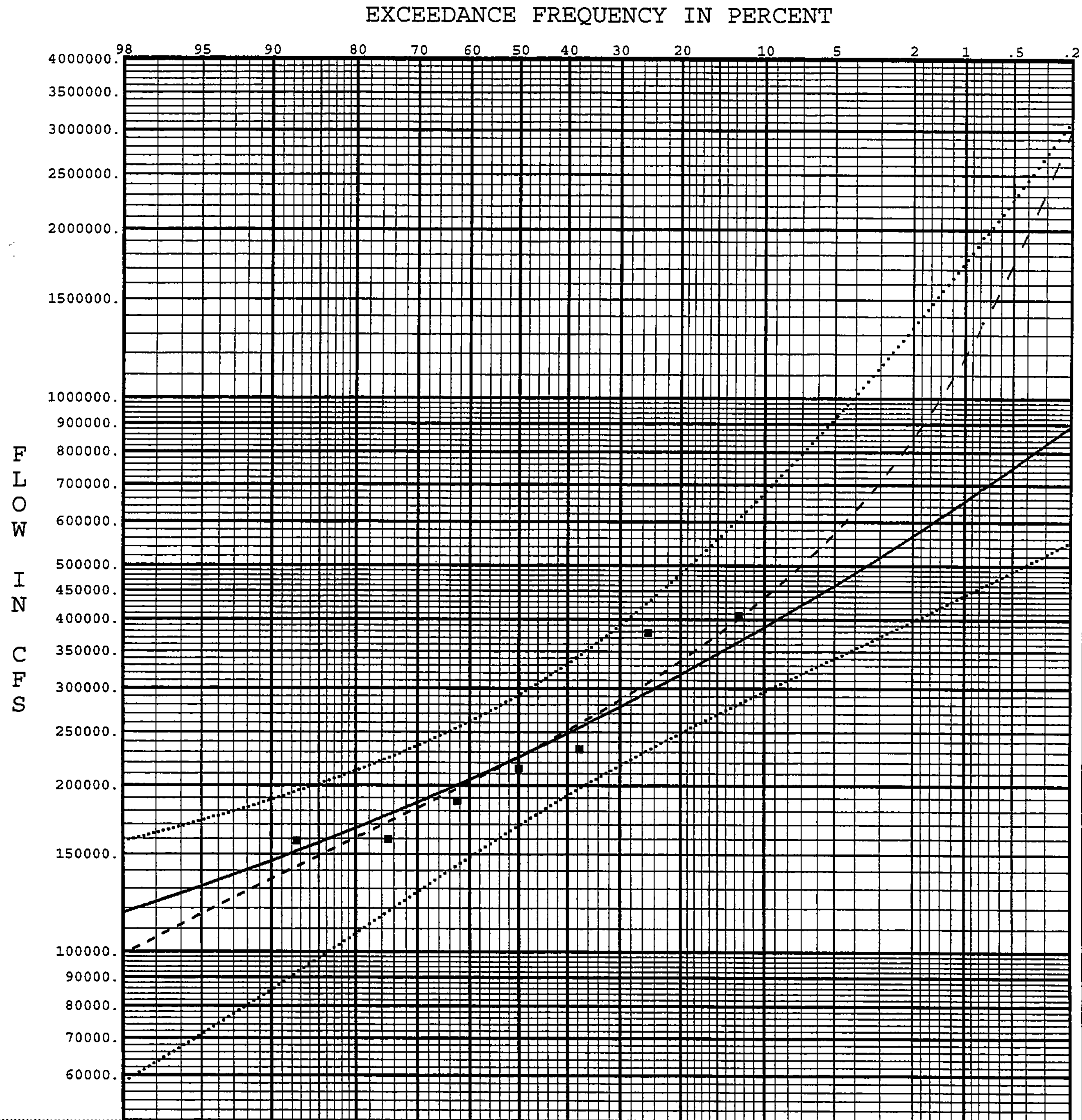
Table C-2: Colville River Flood-Frequency Analysis Based On Seven Years Of Data (Continued)

```
FINAL RESULTS

-FREQUENCY CURVE-
*****************************************************************
*......FLOW IN CFS.......*  PERCENT   *...CONFIDENCE LIMITS...*
*   BASE      EXPECTED   *   CHANCE   *                       *
*   CURVE    PROBABILITY * EXCEEDANCE *  .05 LIMIT   .95 LIMIT *
*------------------------*------------*-----------------------*
*   893000.    3030000.  *       .2   *   3150000.    555000. *
*   752000.    1750000.  *       .5   *   2280000.    490000. *
*   655000.    1190000.  *      1.0   *   1770000.    444000. *
*   567000.     851000.  *      2.0   *   1350000.    399000. *
*   461000.     574000.  *      5.0   *    926000.    341000. *
*   387000.     438000.  *     10.0   *    679000.    297000. *
*   317000.     336000.  *     20.0   *    484000.    249000. *
*   225000.     225000.  *     50.0   *    293000.    170000. *
*   167000.     161000.  *     80.0   *    213000.    108000. *
*   146000.     135000.  *     90.0   *    189000.     85800. *
*   131000.     117000.  *     95.0   *    173000.     71300. *
*   110000.      88200.  *     99.0   *    151000.     51900. *
*****************************************************************
*                       SYSTEMATIC STATISTICS                   *
* LOG TRANSFORM: FLOW, CFS        *      NUMBER OF EVENTS       *
*---------------------------------*-----------------------------*
*  MEAN                    5.3668 * HISTORIC EVENTS          0  *
*  STANDARD DEV             .1670 * HIGH OUTLIERS       0       *
*  COMPUTED SKEW            .7082 * LOW OUTLIERS        0       *
*  REGIONAL SKEW            .1300 * ZERO OR MISSING     0       *
*  ADOPTED SKEW             .5085 * SYSTEMATIC EVENTS        7  *
*****************************************************************


HP PLOT WRITTEN TO THE FILE:   COLVILLE.PCL


+++++++++++++++++++++++++
+ END OF RUN            +
+ NORMAL STOP IN FFA    +
+++++++++++++++++++++++++
```



—— FLOW Frequency (without Exp. Prob.)
- - - FLOW Frequency (with Exp. Prob.)
■ Weibull Plotting Positions
.... 5% and 95% Confidence Limits

FREQUENCY STATISTICS
LOG TRANSFORM OF FLOW, CFS

		NUMBER OF EVENTS	
MEAN	5.3668	HISTORIC EVENTS	0
STANDARD DEV	.1670	HIGH OUTLIERS	0
SKEW	.7082	LOW OUTLIERS	0
REGIONAL SKEW	.1300	ZERO OR MISSING	0
ADOPTED SKEW	.5085	SYSTEMATIC EVENTS	7

Colville River
At Head Of Delta
BASIN AREA = 20,670 SQ MI
WATER YEARS IN RECORD
1962,1977,1992-1996

Figure C-1

APPENDIX D
FLOOD-FREQUENCY ANALYSIS BASED ON THE USGS REGRESSION EQUATIONS WITH ADJUSTMENT FACTORS FROM THE KUPARUK, SAGAVANIRKTOK, AND PUTULIGAYUK RIVERS

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APPENDIX D
FLOOD-FREQUENCY ANALYSIS BASED ON THE USGS REGRESSION EQUATIONS WITH ADJUSTMENT FACTORS FROM THE KUPARUK, SAGAVANIRKTOK, AND PUTULIGAYUK RIVERS

Method

Flood peak estimates for the Colville River at the head of the delta were made using regional regression equations developed by Jones and Fahl (1994) for Area 3. Area 3 includes portions of South-central, Interior, and Northwest regions of Alaska, as well as the North Slope. The regression equations were modified to reflect the annual flood peaks experienced on the Kuparuk, Sagavanirktok, and Putuligayuk rivers. The modification was in the form of adjustment factors, which were applied to the original regression equations. A different adjustment factor was developed for each equation. Thus, the flood peak estimates are the result of the product of the adjustment factors and the original regression equations.

The regression equations used to estimate possible flood-frequency-discharge relationships for the Colville River are as follows.

$$Q_2 = AF_2\,[16.2\,A^{0.894}\,P^{0.949}\,(ST+1)^{-0.209}\,E^{-0.345}]$$
$$Q_5 = AF_5\,[43.9\,A^{0.843}\,P^{0.753}\,(ST+1)^{-0.206}\,E^{-0.305}]$$
$$Q_{10} = AF_{10}\,[70.3\,A^{0.818}\,P^{0.667}\,(ST+1)^{-0.202}\,E^{-0.288}]$$
$$Q_{25} = AF_{25}\,[112\,A^{0.793}\,P^{0.588}\,(ST+1)^{-0.194}\,E^{-0.272}]$$
$$Q_{50} = AF_{50}\,[147\,A^{0.778}\,P^{0.544}\,(ST+1)^{-0.187}\,E^{-0.264}]$$
$$Q_{100} = AF_{100}\,[185\,A^{0.765}\,P^{0.509}\,(ST+1)^{-0.179}\,E^{-0.257}]$$
$$Q_{200} = AF_{200}\,[224\,A^{0.754}\,P^{0.480}\,(ST+1)^{-0.171}\,E^{-0.252}]$$
$$Q_{500} = AF_{500}\,[275\,A^{0.742}\,P^{0.451}\,(ST+1)^{-0.160}\,E^{-0.245}]$$

Where:

Q_T = design discharge for the T-year event,

AF_T = adjustment factor for the T-year event,

A = drainage area in square miles,

P = mean annual precipitation in inches,

ST = area of lakes and ponds as a percent of the total drainage basin area, and

E = mean basin elevation in feet.

Note that the bracketed portion of the above equations represents the original Area 3 regional regression equation developed by Jones and Fahl (1994).

Three sets of adjustment factors were developed based on flood-peak data from each of three Arctic rivers: the Kuparuk (USGS Station 15896000), Sagavanirktok (USGS Stations 15910000 and 15910800), and Putuligayuk (USGS Station 15896700) rivers. The adjustment factors (AF_T) were computed using the following equation.

$$AF_T = Q_{ST}/Q_{RT}$$

Where:

Q_{ST} = the expected probability discharge estimate for the T-year event, based on a single-station flood-frequency analysis using available annual flood peak data, and

Q_{RT} = the discharge estimate for the T-year event estimated using the regional regression equations developed by Jones and Fahl.

The single-station flood-frequency analyses for each of the three rivers were conducted using methods developed by the Interagency Advisory Committee On Water Data (1982), and are presented in Tables D-4, D-6, and D-8. All discharges used in the analyses were annual instantaneous peak discharges. Because structures will ultimately be constructed based on the discharge estimates, the flood-frequency relationships used to develop the adjustment factors were based on the expected probability associated with an event of a given magnitude, rather than the computed probability associated with an event of an average magnitude.

Peak discharge data for the Sagavanirktok River have been collected, by the USGS, at two locations. Between 1969 and 1979 data were collected near Sagwon (basin area = 2208 mi^2).

Between 1983 and 1996 data were collected near Pump Station 3 (basin area = 1860 mi²). To provide as much data as possible for use in the single-station frequency analysis, the data from the Sagwon site were extrapolated to the Pump Station 3 site, using the following equation.

$$Q_{PS3} = Q_S * (Area_{PS3} / Area_S)^{0.833}$$

Where:

Q_{PS3} = the discharge for the Sagavanirktok River near Pump Station 3,

Q_s = the discharge for the Sagavanirktok River near Sagwon,

$Area_{PS3}$ = the drainage area for the Sagavanirktok River near Pump Station 3 (1860 mi^2), and

$Area_S$ = the drainage area for the Sagavanirktok River near Sagwon (2208 mi^2).

The basis for this relationship is discussed in Appendix F. The data collected at both the Sagwon and Pump Station 3 sites, and the data used in the single-station frequency analysis for the Sagavanirktok River near Pump Station 3 are presented in Table D-3.

The USGS regional regression equation computations for each of the three rivers, used in developing the adjustment factors, are presented in Tables D-5, D-7, and D-9. The drainage basin characteristics for the three rivers are summarized in Table 1 (Appendix A).

To estimate the flood-frequency-discharge relationship for the Colville River at the head of the delta, the regional regression equations were then applied to the Colville River using each set of adjustment factors. These analyses are presented in Tables C-10 through C-13. The Colville River drainage basin area (20,670 sq mi), the mean basin elevation (2,000 ft), and the percent of the Colville River drainage basin covered by lakes and ponds (3 percent) were estimated based on USGS topographic maps. Plate 2 contained within the report prepared by Jones and Fahl (1994), and titled *A Map Showing Mean Annual Precipitation Contours*, was used to estimate the mean annual precipitation for the basin (13 inches).

Results

A summary of the flood-frequency relationships for the three rivers, estimated using both the single-station frequency analysis and the regional regression equations, is presented in Table D-1. The adjustment factors computed using the Sagavanirktok and the Putuligayuk river data are similar in magnitude, ranging from 1.3 to 1.9 based on the Sagavanirktok River and from 1.5 to 2.3 based on the Putuligayuk River. However, the adjustment factors computed using the Kuparuk River data are considerably larger, ranging from 3.4 to 5.0.

The peak discharge estimates for the Colville River based on the original regression equations, and the regression equations adjusted with the factors computed from the Kuparuk, Sagavanirktok, and Putuligayuk rivers, are presented in Table D-2. The peak discharge estimates based on the original regression equations, and the regression equations adjusted with the factors calculated from the Sagavanirktok and Putuligayuk rivers, appear to be unrealistically low when compared to the available data. The results of the regression equations which were adjusted based on the Kuparuk River data appear to be similar to the results obtained with at least one of the other methods (Appendix A, Table 1). However, because of the large variation in the results obtained using the various adjustment factors, and the magnitude of the Kuparuk River adjustment factor, the USGS regional regression equations were not used to estimate the final flood-frequency-discharge relationship for the Colville River.

Table D-1: Comparison Of Flood-Peak-Discharge Estimates Based On USGS Regression Equations And Single-Station Frequency Analyses For The Kuparuk, Sagavanirktok, And Putuligayuk Rivers

Return Period (years)	Kuparuk River			Sagavanirktok River			Putuligayuk River		
	Peak Discharge (cfs)			Peak Discharge (cfs)			Peak Discharge (cfs)		
	Based On Single-Station Frequency Analysis	Based On USGS Regression Equations	Adjustment Factor	Based On Single-Station Frequency Analysis	Based On USGS Regression Equations	Adjustment Factor	Based On Single-Station Frequency Analysis	Based On USGS Regression Equations	Adjustment Factor
2	45000	13200	3.409	16400	13100	1.252	3130	1380	2.268
5	70700	20300	3.483	23800	18300	1.301	4570	2340	1.953
10	89800	24900	3.606	29200	21500	1.358	5510	3020	1.825
25	117000	30600	3.824	36800	25500	1.443	6680	3950	1.691
50	139000	34400	4.041	43100	28000	1.539	7540	4620	1.632
100	163000	38200	4.267	50100	30500	1.643	8410	5330	1.578
200	190000	41500	4.578	57700	32600	1.770	9270	5980	1.550
500	229000	46100	4.967	69300	35600	1.947	10400	6890	1.509

Notes:

1. Peak discharges based on the single-station frequency analyses are expected probability discharges.
2. The Adjustment Factor for the Sagavanirktok River is based on data collected near Sagwon and near Pump Station 3.
   The Sagwon station data were extrapolated to the station near Pump Station 3 based on the function:
   Q near Pump Station 3 = Q near Sagwon * (1860/2208)^0.883.

Table D-2 : Summary Of Flood-Peak-Discharge Estimates For The Colville River Based On The USGS Regression Equations With Adjustment Factors From The Kuparuk, Sagavanirktok, And Putuligayuk Rivers

Return Period (years)	Adjustment Factors			Colville River Peak Discharge (cfs) Based on the USGS Regression Equations			
	Kuparuk River	Sagavanirktok River	Putuligayuk River	Without Adjustment Factors	With Adjustment Factors Based On Kuparuk River	With Adjustment Factors Based On Sagavanirktok River	With Adjustment Factors Based On Putuligayuk River
2	3.409	1.252	2.268	72,500	247,000	90,700	164,000
5	3.483	1.301	1.953	97,400	339,000	127,000	190,000
10	3.606	1.358	1.825	112,000	402,000	152,000	204,000
25	3.824	1.443	1.691	129,000	494,000	187,000	219,000
50	4.041	1.539	1.632	140,000	566,000	216,000	229,000
100	4.267	1.643	1.578	151,000	645,000	248,000	238,000
200	4.578	1.770	1.550	160,000	732,000	283,000	248,000
500	4.967	1.947	1.509	173,000	860,000	337,000	261,000

Note:

1. The Adjustment Factor for the Sagavanirktok River is based on data collected near Sagwon and near Pump Station 3. The Sagwon station data were extrapolated to the station near Pump Station 3 based on the function:

   Q nr Pump Station 3 = Q nr Sagwon * (1860/2208)^0.883.

Table D-3: Flood Peak Data Collected At The Sagavanirktok River Near Pump Station 3 And The Sagavanirktok River Near Sagwon

Year	Annual Peak Discharge (cfs) [1]			
	Measured Sagavanirktok River Near Sagwon (cfs)	Measured Sagavanirktok River Near Pump Station 3 (cfs)	Extrapolated Sagavanirktok River Near Pump Station 3 [2] (cfs)	Data Used Sagavanirktok River Near Pump Station 3 [2] (cfs)
1969	34900		30000	30000
1970	15200		13100	13100
1971	19300		16600	16600
1972	22200		19100	19100
1973	24700		21200	21200
1974	28900		24900	24900
1975	8340		7170	7170
1976	18700		16100	16100
1977	29600		25500	25500
1978	19800		17000	17000
1979	10800		9290	9290
1980				
1981				
1982				
1983		23000		23000
1984		13100		13100
1985		15300		15300
1986		11600		11600
1987		13300		13300
1988		8940		8940
1989		11500		11500
1990		9440		9440
1991		16400		16400
1992		42900		42900
1993		26300		26300
1994		18000		18000
1995		23100		23100
1996		16400		16400

Notes:
1. The annual peak discharges are instantaneous peak discharges.
2. Peak discharge data between 1969 and 1979 for the Sagavanirktok River near Pump Station 3 were extrapolated from the Sagwon station based on the function:
   Q nr Pump Station 3 = Q nr Sagwon * (1860/2208)^0.883.

Table D-4: Single-Station Flood-Frequency Analysis For The Kuparuk River

```
************************************      *************************************
*              FFA                 *      *                                   *
*     FLOOD FREQUENCY ANALYSIS     *      *   U.S. ARMY CORPS OF ENGINEERS    *
*     PROGRAM DATE:  FEB 1995      *      * THE HYDROLOGIC ENGINEERING CENTER *
*          VERSION:  3.1           *      *        609 SECOND STREET          *
*     RUN  DATE   AND   TIME:      *      *      DAVIS, CALIFORNIA 95616      *
*        23 OCT 96    12:18:54     *      *          (916) 756-1104           *
*                                  *      *                                   *
************************************      *************************************



 INPUT FILE NAME: KUPARUK.DAT
OUTPUT FILE NAME: KUPARUK.OUT
   DSS FILE NAME: KUPARUK.DSS


   -----DSS---ZOPEN:  Existing File Opened,  File: KUPARUK.DSS
                      Unit:  71;  DSS Version: 6-JB

**TITLE RECORD(S)**
TT   KUPARUK RIVER
TT   Generalized skew and standard error of generalized skew obtained from
TT   Jones and Fahl (1994)
TT   All data are annual instantaneous flood peaks

**STATION IDENTIFICATION**
ID   Kuparuk River  Drainage Area = 3130 sq mi

**JOB RECORD(S)**
     IPPC   ISKFX  IPROUT    IFMT     IWYR   IUNIT    ISMRY    IPNCH     IREG
J1      0       2      52       0        0       1        0        0        0

        A       B  CLIMIT  NDSSCV     IEXT
J2    .00     .00     .05       0        0

**FREQUENCY ARRAY**
FR     13    .200    .500   1.000   2.000   4.000   5.000  10.000  20.000  50.000
FR80.000  90.000  95.000  99.000

**GENERALIZED SKEW**
     ISTN   GGMSE    SKEW
GS          1.323     .13

**HP PLOT **
     HP PLOT FILE                  IHPCV  KLIMIT    IPER    BAREA
HP KUPARUK.PCL                         3       0       03130 Sq Mi

     SELECTED CURVES ON HPPLOT
          EXPECTED PROBABILITY CURVE
          COMPUTED PROBABILITY CURVE
          CONFIDENCE LIMITS

HP Kuparuk River

**SYSTEMATIC EVENTS**
     26 EVENTS TO BE ANALYZED

**END OF INPUT DATA**
ED +++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
```

Table D-4: Single-Station Flood-Frequency Analysis For The Kuparuk River Table (continued)

FLOOD PEAK DATA

-PLOTTING POSITIONS- Kuparuk River Drainage Area = 3130 sq mi

EVENTS ANALYZED				ORDERED EVENTS			
MON	DAY	YEAR	FLOW CFS	RANK	WATER YEAR	FLOW CFS	WEIBULL PLOT POS
0	0	1971	77000.	1	1978	118000.	3.70
0	0	1972	45800.	2	1982	104000.	7.41
0	0	1973	82000.	3	1973	82000.	11.11
0	0	1974	24000.	4	1971	77000.	14.81
0	0	1975	22600.	5	1989	75400.	18.52
0	0	1976	55000.	6	1990	70000.	22.22
0	0	1977	66800.	7	1983	68400.	25.93
0	0	1978	118000.	8	1977	66800.	29.63
0	0	1979	24300.	9	1996	58100.	33.33
0	0	1980	40500.	10	1984	56800.	37.04
0	0	1981	27500.	11	1976	55000.	40.74
0	0	1982	104000.	12	1993	52300.	44.44
0	0	1983	68400.	13	1972	45800.	48.15
0	0	1984	56800.	14	1980	40500.	51.85
0	0	1985	34500.	15	1988	38700.	55.56
0	0	1986	38000.	16	1986	38000.	59.26
0	0	1987	15500.	17	1991	37100.	62.96
0	0	1988	38700.	18	1994	36500.	66.67
0	0	1989	75400.	19	1985	34500.	70.37
0	0	1990	70000.	20	1992	30800.	74.07
0	0	1991	37100.	21	1981	27500.	77.78
0	0	1992	30800.	22	1979	24300.	81.48
0	0	1993	52300.	23	1974	24000.	85.19
0	0	1994	36500.	24	1975	22600.	88.89
0	0	1995	20600.	25	1995	20600.	92.59
0	0	1996	58100.	26	1987	15500.	96.30

-OUTLIER TESTS -

LOW OUTLIER TEST

BASED ON 26 EVENTS, 10 PERCENT OUTLIER TEST VALUE K(N) = 2.502

0 LOW OUTLIER(S) IDENTIFIED BELOW TEST VALUE OF 12062.7

HIGH OUTLIER TEST

BASED ON 26 EVENTS, 10 PERCENT OUTLIER TEST VALUE K(N) = 2.502

0 HIGH OUTLIER(S) IDENTIFIED ABOVE TEST VALUE OF 165590.

-SKEW WEIGHTING -

BASED ON 26 EVENTS, MEAN-SQUARE ERROR OF STATION SKEW = .199
DEFAULT OR INPUT MEAN-SQUARE ERROR OF GENERALIZED SKEW = 1.323

Table D-4: Single-Station Flood-Frequency Analysis For The Kuparuk River Table (continued)

FINAL RESULTS

-FREQUENCY CURVE- Kuparuk River Drainage Area = 3130 sq mi

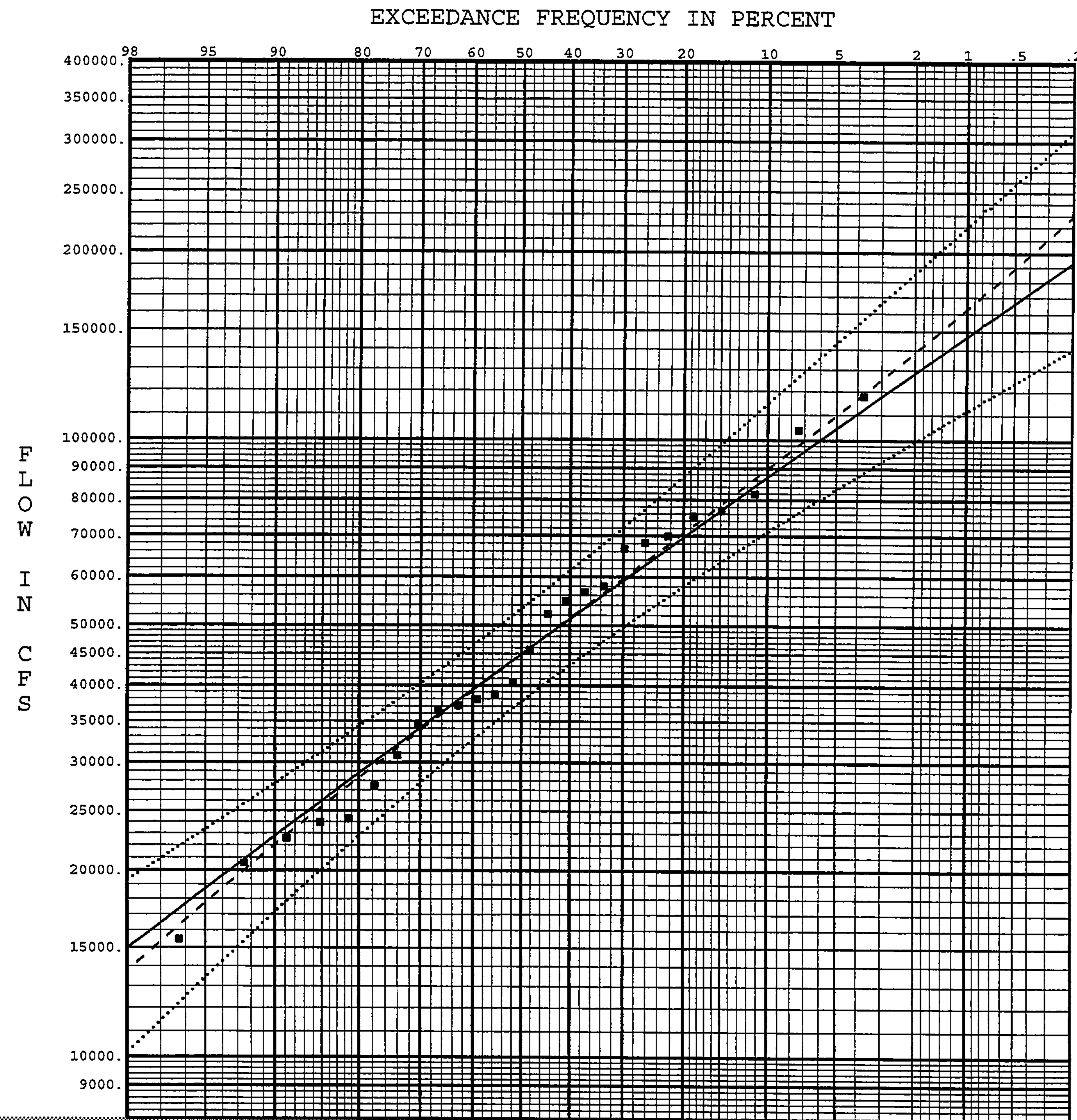
BASE CURVE FLOW IN CFS	EXPECTED PROBABILITY FLOW IN CFS	PERCENT CHANCE EXCEEDANCE	CONFIDENCE LIMITS .05 FLOW IN CFS	CONFIDENCE LIMITS .95 FLOW IN CFS
193000.	229000.	.20	313000.	141000.
167000.	190000.	.50	259000.	124000.
147000.	163000.	1.00	222000.	112000.
128000.	139000.	2.00	187000.	99900.
110000.	117000.	4.00	154000.	87700.
105000.	110000.	5.00	144000.	83700.
87100.	89800.	10.00	115000.	71200.
69500.	70700.	20.00	87500.	58100.
45000.	45000.	50.00	53500.	37800.
28800.	28300.	80.00	34500.	22900.
22800.	22000.	90.00	27900.	17200.
18700.	17800.	95.00	23400.	13500.
12900.	11500.	99.00	17100.	8440.

SYSTEMATIC STATISTICS

LOG TRANSFORM: FLOW, CFS		NUMBER OF EVENTS	
MEAN	4.6502	HISTORIC EVENTS	0
STANDARD DEV	.2273	HIGH OUTLIERS	0
COMPUTED SKEW	-.0967	LOW OUTLIERS	0
REGIONAL SKEW	.1300	ZERO OR MISSING	0
ADOPTED SKEW	-.0671	SYSTEMATIC EVENTS	26

HP PLOT WRITTEN TO THE FILE: KUPARUK.PCL

```
++++++++++++++++++++++++
+ END OF RUN           +
+ NORMAL STOP IN FFA   +
++++++++++++++++++++++++
```



—— FLOW Frequency (without Exp. Prob.)

- - - FLOW Frequency (with Exp. Prob.)

■ Weibull Plotting Positions

.... 5% and 95% Confidence Limits

FREQUENCY STATISTICS

LOG TRANSFORM OF FLOW, CFS		NUMBER OF EVENTS	
MEAN	4.6502	HISTORIC EVENTS	0
STANDARD DEV	.2273	HIGH OUTLIERS	0
SKEW	-.0967	LOW OUTLIERS	0
REGIONAL SKEW	.1300	ZERO OR MISSING	0
ADOPTED SKEW	-.0671	SYSTEMATIC EVENTS	26

Kuparuk River
BASIN AREA = 3130 Sq Mi
WATER YEARS IN RECORD
1971-1996

Figure D-1

Table D-5: Flood-Frequency-Discharge Relationship For The Kuparuk River Based On USGS Regression Equations

FLOOD PEAK DISCHARGE - JONES METHOD (Area 3)

This program computes the flood peak discharge on ungaged drainage basins using the regional relationships developed for AREA 3 by Stanley H. Jones and Charles B. Fahl.

REF: Jones, Stanley H. and Charles B. Fahl. 1994. Magnitude and Frequency of Floods in Alaska and Conterminous Basins of Canada. U.S. Geological Survey, Anchorage, AK. Water-Resources Investigations Report 93-4179.

PROJECT: L-1262-13

DRAINAGE BASIN: Kuparuk River

TITLE: Peak Discharge Estimates Without Adjustment Factors

INITIALS: SRR

DATE: 12 Sep 1996

FILE NAME: KUPARUK.MCD

Parameters:

Drainage Area in square miles,	$A := 3130$
Mean basin elevation in feet,	$E := 900$
Percent of drainage area covered by Lakes,(%)	$L := 2.0$
Mean Annual Precipitation in inches,	$P := 9$

Correction Factors:

$C_2 := 1.0$	$C_{50} := 1.0$
$C_5 := 1.0$	$C_{100} := 1.0$
$C_{10} := 1.0$	$C_{200} := 1.0$
$C_{25} := 1.0$	$C_{500} := 1.0$

Table D-5: Flood-Frequency-Discharge Relationship For The Kuparuk River Based On USGS Regression Equations (Continued)

Equations:

$$Q_2 := C_2 \cdot 16.2 \cdot A^{0.894} \cdot P^{0.949} \cdot (L+1)^{-0.209} \cdot E^{-0.345}$$

$$Q_2 = 13218.306$$

$$Q_5 := C_5 \cdot 43.9 \cdot A^{0.843} \cdot P^{0.753} \cdot (L+1)^{-0.206} \cdot E^{-0.305}$$

$$Q_5 = 20343.331$$

$$Q_{10} := C_{10} \cdot 70.3 \cdot A^{0.818} \cdot P^{0.667} \cdot (L+1)^{-0.202} \cdot E^{-0.288}$$

$$Q_{10} = 24865.089$$

$$Q_{25} := C_{25} \cdot 112 \cdot A^{0.793} \cdot P^{0.588} \cdot (L+1)^{-0.194} \cdot E^{-0.272}$$

$$Q_{25} = 30631.185$$

$$Q_{50} := C_{50} \cdot 147 \cdot A^{0.778} \cdot P^{0.544} \cdot (L+1)^{-0.187} \cdot E^{-0.264}$$

$$Q_{50} = 34420.491$$

Table D-5: Flood-Frequency-Discharge Relationship For The Kuparuk River Based On USGS Regression Equations (Continued)

$$Q_{100} := C_{100} \cdot 185 \cdot A^{0.765} \cdot P^{0.509} \cdot (L + 1)^{-0.179} \cdot E^{-0.257}$$

$$Q_{100} = 38223.245$$

$$Q_{200} := C_{200} \cdot 224 \cdot A^{0.754} \cdot P^{0.480} \cdot (L + 1)^{-0.171} \cdot E^{-0.252}$$

$$Q_{200} = 41482.795$$

$$Q_{500} := C_{500} \cdot 275 \cdot A^{0.742} \cdot P^{0.451} \cdot (L + 1)^{-0.160} \cdot E^{-0.245}$$

$$Q_{500} = 46053.342$$

Table D-6: Single-Station Flood-Frequency Analysis For The Sagavanirktok River

```
*************************************        ************************************
*             FFA                   *        *                                  *
*    FLOOD FREQUENCY ANALYSIS       *        *   U.S. ARMY CORPS OF ENGINEERS   *
*    PROGRAM DATE:  FEB 1995        *        * THE HYDROLOGIC ENGINEERING CENTER *
*        VERSION:  3.1              *        *         609 SECOND STREET        *
*    RUN  DATE    AND    TIME:      *        *       DAVIS, CALIFORNIA 95616    *
*       24 OCT 96     12:01:52      *        *          (916) 756-1104          *
*                                   *        *                                  *
*************************************        ************************************



 INPUT FILE NAME: SAGP3BOT.DAT
OUTPUT FILE NAME: SAGP3BOT.OUT
   DSS FILE NAME: SAGP3BOT.DSS


   -----DSS---ZOPEN:  Existing File Opened,  File: SAGP3BOT.DSS
                      Unit:  71;  DSS Version: 6-JB

**TITLE RECORD(S)**
TT   SAGAVANIRKTOK RIVER near Pump Station 3
TT   Generalized skew and standard error of generalized skew obtained from
TT   Jones and Fahl (1994)
TT   NOTE: 1969 - 1979 data extrapolated from SAG River near Sagwon.

**STATION IDENTIFICATION**
ID   Sagavanirktok River, Drainage area = 1860 sq mi

**JOB RECORD(S)**
     IPPC   ISKFX  IPROUT    IFMT    IWYR   IUNIT   ISMRY   IPNCH    IREG
J1     0      2      52       0       0       0       1       1       0

**FREQUENCY ARRAY**
FR    13    .200    .500   1.000   2.000   4.000   5.000  10.000  20.000  50.000
FR80.000  90.000  95.000  99.000

**GENERALIZED SKEW**
     ISTN   GGMSE    SKEW
GS          1.322     .13

**HP PLOT **
     HP PLOT FILE                IHPCV  KLIMIT    IPER    BAREA
HP SAGP3BOT.PCL                    3       0        0 1860 SQ MI

     SELECTED CURVES ON HPPLOT
          EXPECTED PROBABILITY CURVE
          COMPUTED PROBABILITY CURVE
          CONFIDENCE LIMITS

HP Sagavanirktok River
HP near Pump Station 3
HP using data from Sag nr Sagwon

**SYSTEMATIC EVENTS**
     25 EVENTS TO BE ANALYZED

**END OF INPUT DATA**
ED ++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
```

Table D-6: Single-Station Flood-Frequency Analysis For The Sagavanirktok River (continued)

FLOOD PEAK DATA

-PLOTTING POSITIONS- Sagavanirktok River, Drainage area = 1860 sq

EVENTS ANALYZED				ORDERED EVENTS			
MON	DAY	YEAR	FLOW CFS	RANK	WATER YEAR	FLOW CFS	WEIBULL PLOT POS
0	0	1969	30000.	1	1992	42900.	3.85
0	0	1970	13100.	2	1969	30000.	7.69
0	0	1971	16600.	3	1993	26300.	11.54
0	0	1972	19100.	4	1977	25500.	15.38
0	0	1973	21200.	5	1974	24900.	19.23
0	0	1974	24900.	6	1995	23100.	23.08
0	0	1975	7170.	7	1983	23000.	26.92
0	0	1976	16100.	8	1973	21200.	30.77
0	0	1977	25500.	9	1972	19100.	34.62
0	0	1978	17000.	10	1994	18000.	38.46
0	0	1979	9290.	11	1978	17000.	42.31
0	0	1983	23000.	12	1971	16600.	46.15
0	0	1984	13100.	13	1991	16400.	50.00
0	0	1985	15300.	14	1996	16400.	53.85
0	0	1986	11600.	15	1976	16100.	57.69
0	0	1987	13300.	16	1985	15300.	61.54
0	0	1988	8940.	17	1987	13300.	65.38
0	0	1989	11500.	18	1984	13100.	69.23
0	0	1990	9440.	19	1970	13100.	73.08
0	0	1991	16400.	20	1986	11600.	76.92
0	0	1992	42900.	21	1989	11500.	80.77
0	0	1993	26300.	22	1990	9440.	84.62
0	0	1994	18000.	23	1979	9290.	88.46
0	0	1995	23100.	24	1988	8940.	92.31
0	0	1996	16400.	25	1975	7170.	96.15

-OUTLIER TESTS -

LOW OUTLIER TEST

BASED ON 25 EVENTS, 10 PERCENT OUTLIER TEST VALUE K(N) = 2.486

0 LOW OUTLIER(S) IDENTIFIED BELOW TEST VALUE OF 5762.7

HIGH OUTLIER TEST

BASED ON 25 EVENTS, 10 PERCENT OUTLIER TEST VALUE K(N) = 2.486

0 HIGH OUTLIER(S) IDENTIFIED ABOVE TEST VALUE OF 47142.

-SKEW WEIGHTING -

BASED ON 25 EVENTS, MEAN-SQUARE ERROR OF STATION SKEW = .205
DEFAULT OR INPUT MEAN-SQUARE ERROR OF GENERALIZED SKEW = 1.322

Table D-6: Single-Station Flood-Frequency Analysis For The Sagavanirktok River (continued)

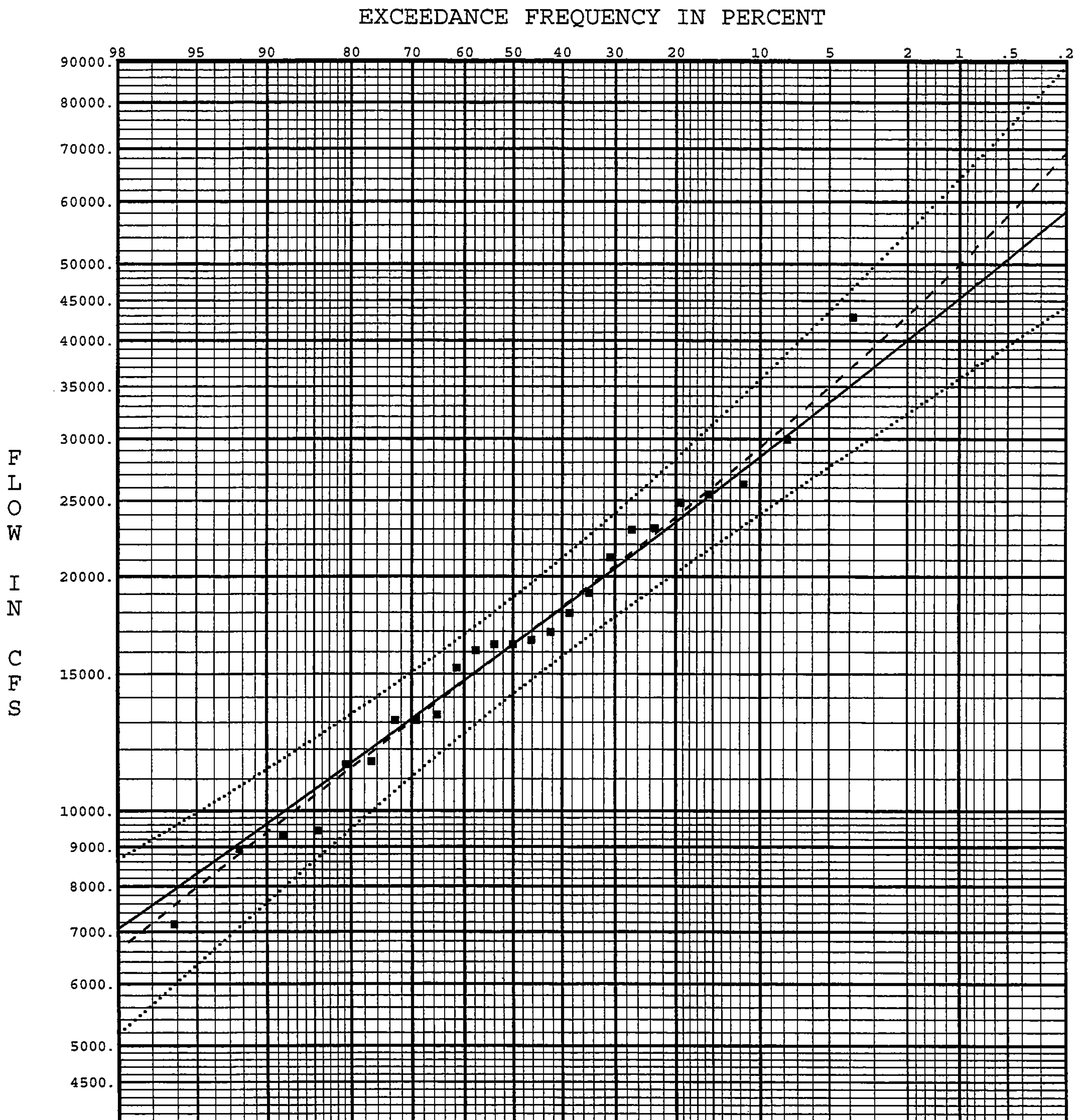
FINAL RESULTS

-FREQUENCY CURVE- Sagavanirktok River. Drainage area = 1860 sq

BASE CURVE FLOW IN CFS	EXPECTED PROBABILITY FLOW IN CFS	PERCENT CHANCE EXCEEDANCE	CONFIDENCE LIMITS .05 FLOW IN CFS	CONFIDENCE LIMITS .95 FLOW IN CFS
58400.	69300.	.20	89300.	44400.
50800.	57700.	.50	74700.	39600.
45400.	50100.	1.00	64600.	36000.
40100.	43100.	2.00	55200.	32400.
35000.	36800.	4.00	46500.	28900.
33400.	34900.	5.00	43800.	27700.
28400.	29200.	10.00	35800.	24100.
23500.	23800.	20.00	28400.	20300.
16400.	16400.	50.00	18900.	14200.
11500.	11400.	80.00	13400.	9530.
9630.	9390.	90.00	11400.	7660.
8320.	7990.	95.00	9990.	6380.
6350.	5840.	99.00	7930.	4540.

SYSTEMATIC STATISTICS

LOG TRANSFORM: FLOW, CFS		NUMBER OF EVENTS	
MEAN	4.2170	HISTORIC EVENTS	0
STANDARD DEV	.1836	HIGH OUTLIERS	0
COMPUTED SKEW	.0894	LOW OUTLIERS	0
REGIONAL SKEW	.1300	ZERO OR MISSING	0
ADOPTED SKEW	.0948	SYSTEMATIC EVENTS	25



—— FLOW Frequency (without Exp. Prob.)
- - - FLOW Frequency (with Exp. Prob.)
■ Weibull Plotting Positions
······· 5% and 95% Confidence Limits

FREQUENCY STATISTICS

LOG TRANSFORM OF FLOW, CFS		NUMBER OF EVENTS	
MEAN	4.2170	HISTORIC EVENTS	0
STANDARD DEV	.1836	HIGH OUTLIERS	0
SKEW	.0894	LOW OUTLIERS	0
REGIONAL SKEW	.1300	ZERO OR MISSING	0
ADOPTED SKEW	.0948	SYSTEMATIC EVENTS	25

Sagavanirktok River
near Pump Station 3
using data from Sag nr Sagwon
BASIN AREA = 1860 SQ MI
WATER YEARS IN RECORD
1969-1979,1983-1996

Figure D-2

Table D-7: Flood-Frequency-Discharge Relationship For The Sagavanirktok River Based On USGS Regression Equations

FLOOD PEAK DISCHARGE - JONES METHOD (Area 3)

This program computes the flood peak discharge on ungaged drainage basins using the regional relationships developed for AREA 3 by Stanley H. Jones and Charles B. Fahl.

REF: Jones, Stanley H. and Charles B. Fahl. 1994. Magnitude and Frequency of Floods in Alaska and Conterminous Basins of Canada. U.S. Geological Survey, Anchorage, AK. Water-Resources Investigations Report 93-4179.

PROJECT: L-1262-13

DRAINAGE BASIN: Sagavanirktok River near Pump Station 3

TITLE: Peak Discharge Estimates Without Adjustment Factors

INITIALS: CJH

DATE: 21 Oct 1996

FILE NAME: SAGP3.MCD

Parameters:

Drainage Area in square miles,	$A := 1860$
Mean basin elevation in feet,	$E := 3580$
Percent of drainage area covered by Lakes,(%)	$L := 1.0$
Mean Annual Precipitation in inches,	$P := 22$

Correction Factors:

$C_2 := 1.0$	$C_{50} := 1.0$
$C_5 := 1.0$	$C_{100} := 1.0$
$C_{10} := 1.0$	$C_{200} := 1.0$
$C_{25} := 1.0$	$C_{500} := 1.0$

Table D-7: Flood-Frequency-Discharge Relationship For The Sagavanirktok River Based On USGS Regression Equations (Continued)

Equations:

$$Q_2 := C_2 \cdot 16.2 \cdot A^{0.894} \cdot P^{0.949} \cdot (L+1)^{-0.209} \cdot E^{-0.345}$$

$$Q_2 = 13104.299$$

$$Q_5 := C_5 \cdot 43.9 \cdot A^{0.843} \cdot P^{0.753} \cdot (L+1)^{-0.206} \cdot E^{-0.305}$$

$$Q_5 = 18346.858$$

$$Q_{10} := C_{10} \cdot 70.3 \cdot A^{0.818} \cdot P^{0.667} \cdot (L+1)^{-0.202} \cdot E^{-0.288}$$

$$Q_{10} = 21502.377$$

$$Q_{25} := C_{25} \cdot 112 \cdot A^{0.793} \cdot P^{0.588} \cdot (L+1)^{-0.194} \cdot E^{-0.272}$$

$$Q_{25} = 25481.813$$

$$Q_{50} := C_{50} \cdot 147 \cdot A^{0.778} \cdot P^{0.544} \cdot (L+1)^{-0.187} \cdot E^{-0.264}$$

$$Q_{50} = 27974.261$$

Table D-7: Flood-Frequency-Discharge Relationship For The Sagavanirktok River Based On USGS Regression Equations (Continued)

$$Q_{100} := C_{100} \cdot 185 \cdot A^{0.765} \cdot P^{0.509} \cdot (L + 1)^{-0.179} \cdot E^{-0.257}$$

$$Q_{100} = 30507.735$$

$$Q_{200} := C_{200} \cdot 224 \cdot A^{0.754} \cdot P^{0.480} \cdot (L + 1)^{-0.171} \cdot E^{-0.252}$$

$$Q_{200} = 32566.345$$

$$Q_{500} := C_{500} \cdot 275 \cdot A^{0.742} \cdot P^{0.451} \cdot (L + 1)^{-0.160} \cdot E^{-0.245}$$

$$Q_{500} = 35635.084$$

Table D-8: Single-Station Flood-Frequency Analysis For The Putuligayuk River

```
************************************        **************************************
*               FFA                *        *                                    *
*     FLOOD FREQUENCY ANALYSIS     *        *   U.S. ARMY CORPS OF ENGINEERS     *
*     PROGRAM DATE:  FEB 1995      *        * THE HYDROLOGIC ENGINEERING CENTER *
*          VERSION:  3.1           *        *         609 SECOND STREET          *
*     RUN  DATE   AND   TIME:      *        *      DAVIS, CALIFORNIA 95616       *
*        26 OCT 96     11:48:13    *        *           (916) 756-1104           *
*                                  *        *                                    *
************************************        **************************************


 INPUT FILE NAME: PUT.DAT
OUTPUT FILE NAME: PUT.OUT
   DSS FILE NAME: PUT.DSS


   -----DSS---ZOPEN:  Existing File Opened,  File: PUT.DSS
                      Unit:  71;  DSS Version: 6-JB

**TITLE RECORD(S)**
TT   PUTULIGAYUK RIVER

**JOB RECORD(S)**
     IPPC   ISKFX  IPROUT    IFMT    IWYR   IUNIT   ISMRY   IPNCH    IREG
J1     0       2      52       0       0       1       1       0       0

        A       B  CLIMIT  NDSSCV    IEXT
J2    .00     .00     .00       0       0

**FREQUENCY ARRAY**
FR    13    .200    .500   1.000   2.000   4.000   5.000  10.000  20.000  50.000
FR80.000  90.000  95.000  99.000

**GENERALIZED SKEW**
     ISTN   GGMSE    SKEW
GS          1.323     .13

**HP PLOT **
     HP PLOT FILE                   IHPCV  KLIMIT    IPER    BAREA
HP   PUT.PCL                            3       0       0 176 Sq Mi

     SELECTED CURVES ON HPPLOT
          EXPECTED PROBABILITY CURVE
          COMPUTED PROBABILITY CURVE
          CONFIDENCE LIMITS

HP Putuligayuk River

**SYSTEMATIC EVENTS**
     25 EVENTS TO BE ANALYZED

**END OF INPUT DATA**
ED ++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
```

Table D-8: Single-Station Flood-Frequency Analysis For The Putuligayuk River (continued)

FLOOD PEAK DATA

-PLOTTING POSITIONS-

EVENTS ANALYZED				ORDERED EVENTS			
MON	DAY	YEAR	FLOW CFS	RANK	WATER YEAR	FLOW CFS	WEIBULL PLOT POS
0	0	1970	1900.	1	1980	5800.	3.85
0	0	1971	4980.	2	1995	5700.	7.69
0	0	1972	4500.	3	1986	5440.	11.54
0	0	1973	4000.	4	1971	4980.	15.38
0	0	1974	2000.	5	1989	4950.	19.23
0	0	1975	2000.	6	1991	4640.	23.08
0	0	1976	3130.	7	1978	4630.	26.92
0	0	1977	1800.	8	1972	4500.	30.77
0	0	1978	4630.	9	1973	4000.	34.62
0	0	1979	1100.	10	1988	3990.	38.46
0	0	1980	5800.	11	1983	3130.	42.31
0	0	1982	2290.	12	1976	3130.	46.15
0	0	1983	3130.	13	1987	3120.	50.00
0	0	1984	1640.	14	1993	2990.	53.85
0	0	1985	2880.	15	1994	2900.	57.69
0	0	1986	5440.	16	1985	2880.	61.54
0	0	1987	3120.	17	1992	2500.	65.38
0	0	1988	3990.	18	1982	2290.	69.23
0	0	1989	4950.	19	1974	2000.	73.08
0	0	1990	769.	20	1975	2000.	76.92
0	0	1991	4640.	21	1970	1900.	80.77
0	0	1992	2500.	22	1977	1800.	84.62
0	0	1993	2990.	23	1984	1640.	88.46
0	0	1994	2900.	24	1979	1100.	92.31
0	0	1995	5700.	25	1990	769.	96.15

-OUTLIER TESTS -

LOW OUTLIER TEST

BASED ON 25 EVENTS, 10 PERCENT OUTLIER TEST VALUE K(N) = 2.486

1 LOW OUTLIER(S) IDENTIFIED BELOW TEST VALUE OF 805.9

STATISTICS AND FREQUENCY CURVE ADJUSTED FOR 1 LOW OUTLIER(S)

HIGH OUTLIER TEST

BASED ON 24 EVENTS, 10 PERCENT OUTLIER TEST VALUE K(N) = 2.467

0 HIGH OUTLIER(S) IDENTIFIED ABOVE TEST VALUE OF 9480.

-SKEW WEIGHTING -

BASED ON 25 EVENTS, MEAN-SQUARE ERROR OF STATION SKEW = .240
DEFAULT OR INPUT MEAN-SQUARE ERROR OF GENERALIZED SKEW = 1.323

Table D-8: Single-Station Flood-Frequency Analysis For The Putuligayuk River (continued)

FINAL RESULTS

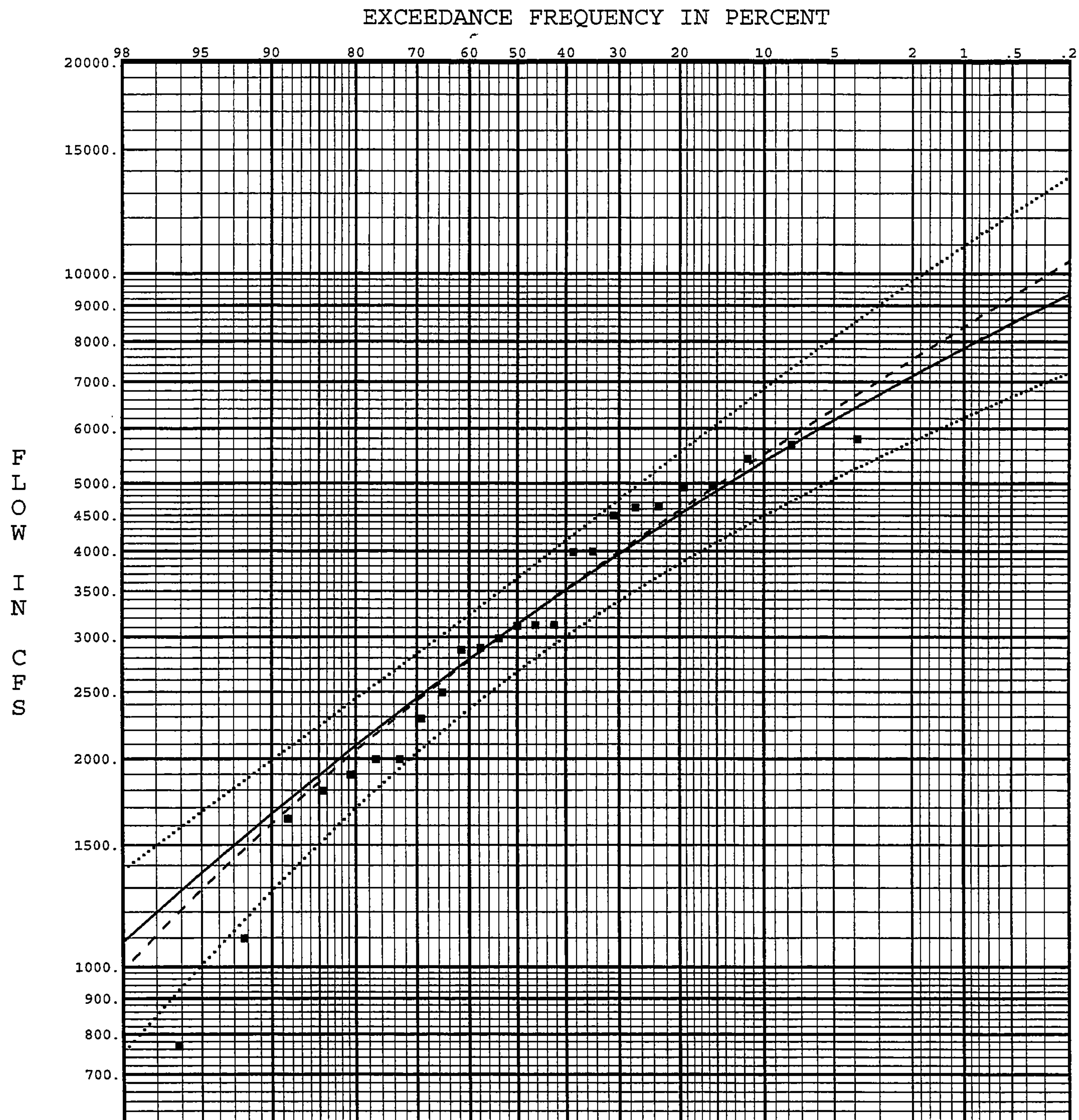
-FREQUENCY CURVE-

BASE CURVE FLOW IN CFS	EXPECTED PROBABILITY FLOW IN CFS	PERCENT CHANCE EXCEEDANCE	CONFIDENCE LIMITS .05 FLOW IN CFS	CONFIDENCE LIMITS .95 FLOW IN CFS
9350.	10400.	.20	13800.	7240.
8500.	9270.	.50	12200.	6690.
7830.	8410.	1.00	11000.	6240.
7140.	7540.	2.00	9790.	5770.
6410.	6680.	4.00	8550.	5260.
6170.	6400.	5.00	8150.	5080.
5380.	5510.	10.00	6870.	4500.
4510.	4570.	20.00	5560.	3840.
3130.	3130.	50.00	3670.	2690.
2090.	2060.	80.00	2450.	1700.
1670.	1610.	90.00	2000.	1290.
1370.	1290.	95.00	1680.	1010.
926.	814.	99.00	1210.	615.

SYNTHETIC STATISTICS

LOG TRANSFORM: FLOW, CFS		NUMBER OF EVENTS	
MEAN	3.4840	HISTORIC EVENTS	0
STANDARD DEV	.1996	HIGH OUTLIERS	0
COMPUTED SKEW	-.4569	LOW OUTLIERS	1
REGIONAL SKEW	.1300	ZERO OR MISSING	0
ADOPTED SKEW	-.3669	SYSTEMATIC EVENTS	25

HP PLOT WRITTEN TO THE FILE: PUT.PCL



—— FLOW Frequency (without Exp. Prob.)
- - - FLOW Frequency (with Exp. Prob.)
■ Weibull Plotting Positions
······· 5% and 95% Confidence Limits

FREQUENCY STATISTICS

LOG TRANSFORM OF FLOW, CFS		NUMBER OF EVENTS	
MEAN	3.4840	HISTORIC EVENTS	0
STANDARD DEV	.1996	HIGH OUTLIERS	0
SKEW	-.4569	LOW OUTLIERS	1
REGIONAL SKEW	.1300	ZERO OR MISSING	0
ADOPTED SKEW	-.3669	SYSTEMATIC EVENTS	25

Putuligayuk River
BASIN AREA = 176 Sq Mi
WATER YEARS IN RECORD
1970-1980,1982-1995

Figure D-3

Table D-9: Flood-Frequency-Discharge Relationship For The Putuligayuk River Based On USGS Regression Equations

FLOOD PEAK DISCHARGE - JONES METHOD (Area 3)

This program computes the flood peak discharge on ungaged drainage basins using the regional relationships developed for AREA 3 by Stanley H. Jones and Charles B. Fahl.

REF: Jones, Stanley H. and Charles B. Fahl. 1994. Magnitude and Frequency of Floods in Alaska and Conterminous Basins of Canada. U.S. Geological Survey, Anchorage, AK. Water-Resources Investigations Report 93-4179.

PROJECT: L-1262-13

DRAINAGE BASIN: Putuligayuk River near Deadhorse AK

TITLE: Peak Discharge Estimates Without Adjustment Factors

INITIALS: SRR

DATE: 12 Sep 1996

FILE NAME: PUT.MCD

Parameters:

Drainage Area in square miles,	$A := 176$
Mean basin elevation in feet,	$E := 135$
Percent of drainage area covered by Lakes,(%)	$L := 8.0$
Mean Annual Precipitation in inches,	$P := 8$

Correction Factors:

$C_{2} := 1.0$	$C_{50} := 1.0$
$C_{5} := 1.0$	$C_{100} := 1.0$
$C_{10} := 1.0$	$C_{200} := 1.0$
$C_{25} := 1.0$	$C_{500} := 1.0$

Table D-9: Flood-Frequency-Discharge Relationship For The Putuligayuk River Based On USGS Regression Equations (Continued)

Equations:

$$Q_2 := C_2 \cdot 16.2 \cdot A^{0.894} \cdot P^{0.949} \cdot (L+1)^{-0.209} \cdot E^{-0.345}$$

$$Q_2 = 1379.221$$

$$Q_5 := C_5 \cdot 43.9 \cdot A^{0.843} \cdot P^{0.753} \cdot (L+1)^{-0.206} \cdot E^{-0.305}$$

$$Q_5 = 2339.552$$

$$Q_{10} := C_{10} \cdot 70.3 \cdot A^{0.818} \cdot P^{0.667} \cdot (L+1)^{-0.202} \cdot E^{-0.288}$$

$$Q_{10} = 3018.927$$

$$Q_{25} := C_{25} \cdot 112 \cdot A^{0.793} \cdot P^{0.588} \cdot (L+1)^{-0.194} \cdot E^{-0.272}$$

$$Q_{25} = 3947.777$$

$$Q_{50} := C_{50} \cdot 147 \cdot A^{0.778} \cdot P^{0.544} \cdot (L+1)^{-0.187} \cdot E^{-0.264}$$

$$Q_{50} = 4621.21$$

Table D-9: Flood-Frequency-Discharge Relationship For The Putuligayuk River Based On USGS Regression Equations (Continued)

$$Q_{100} := C_{100} \cdot 185 \cdot A^{0.765} \cdot P^{0.509} \cdot (L+1)^{-0.179} \cdot E^{-0.257}$$

$$Q_{100} = 5325.453$$

$$Q_{200} := C_{200} \cdot 224 \cdot A^{0.754} \cdot P^{0.480} \cdot (L+1)^{-0.171} \cdot E^{-0.252}$$

$$Q_{200} = 5981.749$$

$$Q_{500} := C_{500} \cdot 275 \cdot A^{0.742} \cdot P^{0.451} \cdot (L+1)^{-0.160} \cdot E^{-0.245}$$

$$Q_{500} = 6889.475$$

Table D-10: Flood-Frequency-Discharge Relationship For The Colville River Based On The USGS Regression Equations Without Adjustment Factors

FLOOD PEAK DISCHARGE - JONES METHOD (Area 3)

This program computes the flood peak discharge on ungaged drainage basins using the regional relationships developed for AREA 3 by Stanley H. Jones and Charles B. Fahl.

REF: Jones, Stanley H. and Charles B. Fahl. 1994. Magnitude and Frequency of Floods in Alaska and Conterminous Basins of Canada. U.S. Geological Survey, Anchorage, AK. Water-Resources Investigations Report 93-4179.

PROJECT: L-1262-13

DRAINAGE BASIN: Colville River

TITLE: Peak Discharge Estimates Without Adjustment Factors

INITIALS: SRR

DATE: 12 Sep 1996

FILE NAME: COLVILL1.MCD

Parameters:

Drainage Area in square miles,	$A := 20670.0$
Mean basin elevation in feet,	$E := 2000.0$
Percent of drainage area covered by Lakes,(%)	$L := 3.0$
Mean Annual Precipitation in inches,	$P := 13$

Correction Factors:

$C_2 := 1.0$ $C_{50} := 1.0$

$C_5 := 1.0$ $C_{100} := 1.0$

$C_{10} := 1.0$ $C_{200} := 1.0$

$C_{25} := 1.0$ $C_{500} := 1.0$

Table D-10: Flood-Frequency-Discharge Relationship For The Colville River Based On The USGS Regression Equations Without Adjustment Factors (Continued)

Equations:

$$Q_2 := C_2 \cdot 16.2 \cdot A^{0.894} \cdot P^{0.949} \cdot (L+1)^{-0.209} \cdot E^{-0.345}$$

$$Q_2 = 72422.874$$

$$Q_5 := C_5 \cdot 43.9 \cdot A^{0.843} \cdot P^{0.753} \cdot (L+1)^{-0.206} \cdot E^{-0.305}$$

$$Q_5 = 97332.388$$

$$Q_{10} := C_{10} \cdot 70.3 \cdot A^{0.818} \cdot P^{0.667} \cdot (L+1)^{-0.202} \cdot E^{-0.288}$$

$$Q_{10} = 111581.268$$

$$Q_{25} := C_{25} \cdot 112 \cdot A^{0.793} \cdot P^{0.588} \cdot (L+1)^{-0.194} \cdot E^{-0.272}$$

$$Q_{25} = 129301.009$$

$$Q_{50} := C_{50} \cdot 147 \cdot A^{0.778} \cdot P^{0.544} \cdot (L+1)^{-0.187} \cdot E^{-0.264}$$

$$Q_{50} = 140145.86$$

Table D-10: Flood-Frequency-Discharge Relationship For The Colville River Based On The USGS Regression Equations Without Adjustment Factors (Continued)

$$Q_{100} := C_{100} \cdot 185 \cdot A^{0.765} \cdot P^{0.509} \cdot (L + 1)^{-0.179} \cdot E^{-0.257}$$

$$Q_{100} = 151102.243$$

$$Q_{200} := C_{200} \cdot 224 \cdot A^{0.754} \cdot P^{0.480} \cdot (L + 1)^{-0.171} \cdot E^{-0.252}$$

$$Q_{200} = 159917.403$$

$$Q_{500} := C_{500} \cdot 275 \cdot A^{0.742} \cdot P^{0.451} \cdot (L + 1)^{-0.160} \cdot E^{-0.245}$$

$$Q_{500} = 173229.492$$

Table D-11: Flood-Frequency-Discharge Relationship For The Colville River Based On The USGS Regression Equations With Adjustment Factors From The Kuparuk River

FLOOD PEAK DISCHARGE - JONES METHOD (Area 3)

This program computes the flood peak discharge on ungaged drainage basins using the regional relationships developed for AREA 3 by Stanley H. Jones and Charles B. Fahl.

REF: Jones, Stanley H. and Charles B. Fahl. 1994. Magnitude and Frequency of Floods in Alaska and Conterminous Basins of Canada. U.S. Geological Survey, Anchorage, AK. Water-Resources Investigations Report 93-4179.

PROJECT: L-1262-13

DRAINAGE BASIN: Colville River

TITLE: Peak Discharge Estimates Using Adjustment Factors Based On Kuparuk River Data

INITIALS: CJH

DATE: 23 Oct 1996

FILE NAME: COLVILL2.MCD

Parameters:

Drainage Area in square miles,	$A := 20670.0$
Mean basin elevation in feet,	$E := 2000.0$
Percent of drainage area covered by Lakes,(%)	$L := 3.0$
Mean Annual Precipitation in inches,	$P := 13$

Correction Factors:

$C_{2} := 3.409$	$C_{50} := 4.041$
$C_{5} := 3.483$	$C_{100} := 4.267$
$C_{10} := 3.606$	$C_{200} := 4.578$
$C_{25} := 3.824$	$C_{500} := 4.967$

Table D-11: Flood-Frequency-Discharge Relationship For The Colville River Based On The USGS Regression Equations With Adjustment Factors From The Kuparuk River (Continued)

Equations:

$$Q_2 := C_2 \cdot 16.2 \cdot A^{0.894} \cdot P^{0.949} \cdot (L+1)^{-0.209} \cdot E^{-0.345}$$

$$Q_2 = 246889.578$$

$$Q_5 := C_5 \cdot 43.9 \cdot A^{0.843} \cdot P^{0.753} \cdot (L+1)^{-0.206} \cdot E^{-0.305}$$

$$Q_5 = 339008.708$$

$$Q_{10} := C_{10} \cdot 70.3 \cdot A^{0.818} \cdot P^{0.667} \cdot (L+1)^{-0.202} \cdot E^{-0.288}$$

$$Q_{10} = 402362.054$$

$$Q_{25} := C_{25} \cdot 112 \cdot A^{0.793} \cdot P^{0.588} \cdot (L+1)^{-0.194} \cdot E^{-0.272}$$

$$Q_{25} = 494447.059$$

$$Q_{50} := C_{50} \cdot 147 \cdot A^{0.778} \cdot P^{0.544} \cdot (L+1)^{-0.187} \cdot E^{-0.264}$$

$$Q_{50} = 566329.419$$

Table D-11: Flood-Frequency-Discharge Relationship For The Colville River Based On The USGS Regression Equations With Adjustment Factors From The Kuparuk River (Continued)

$$Q_{100} := C_{100} \cdot 185 \cdot A^{0.765} \cdot P^{0.509} \cdot (L + 1)^{-0.179} \cdot E^{-0.257}$$

$$Q_{100} = 644753.272$$

$$Q_{200} := C_{200} \cdot 224 \cdot A^{0.754} \cdot P^{0.480} \cdot (L + 1)^{-0.171} \cdot E^{-0.252}$$

$$Q_{200} = 732101.873$$

$$Q_{500} := C_{500} \cdot 275 \cdot A^{0.742} \cdot P^{0.451} \cdot (L + 1)^{-0.160} \cdot E^{-0.245}$$

$$Q_{500} = 860430.887$$

Table D-12: Flood-Frequency-Discharge Relationship For The Colville River Based On The USGS Regression Equations With Adjustment Factors From the Sagavanirktok River

FLOOD PEAK DISCHARGE - JONES METHOD (Area 3)

This program computes the flood peak discharge on ungaged drainage basins using the regional relationships developed for AREA 3 by Stanley H. Jones and Charles B. Fahl.

REF: Jones, Stanley H. and Charles B. Fahl. 1994. Magnitude and Frequency of Floods in Alaska and Conterminous Basins of Canada. U.S. Geological Survey, Anchorage, AK. Water-Resources Investigations Report 93-4179.

PROJECT: L-1262-13

DRAINAGE BASIN: Colville River

TITLE: Peak Discharge Estimates Using Adjustment Factors Based On Sagavanirktok River Data

INITIALS: CJH

DATE: 21 Oct 1996

FILE NAME: COLVILL3.MCD

Parameters:

Drainage Area in square miles,	$A := 20670.0$
Mean basin elevation in feet,	$E := 2000.0$
Percent of drainage area covered by Lakes,(%)	$L := 3.0$
Mean Annual Precipitation in inches,	$P := 13$

Correction Factors:

$C_{2} := 1.252$	$C_{50} := 1.539$
$C_{5} := 1.301$	$C_{100} := 1.643$
$C_{10} := 1.358$	$C_{200} := 1.770$
$C_{25} := 1.443$	$C_{500} := 1.947$

Table D-12: Flood-Frequency-Discharge Relationship For The Colville River Based On The USGS Regression Equations With Adjustment Factors From the Sagavanirktok River (Continued)

Equations:

$$Q_2 := C_2 \cdot 16.2 \cdot A^{0.894} \cdot P^{0.949} \cdot (L+1)^{-0.209} \cdot E^{-0.345}$$

$$Q_2 = 90673.438$$

$$Q_5 := C_5 \cdot 43.9 \cdot A^{0.843} \cdot P^{0.753} \cdot (L+1)^{-0.206} \cdot E^{-0.305}$$

$$Q_5 = 126629.437$$

$$Q_{10} := C_{10} \cdot 70.3 \cdot A^{0.818} \cdot P^{0.667} \cdot (L+1)^{-0.202} \cdot E^{-0.288}$$

$$Q_{10} = 151527.362$$

$$Q_{25} := C_{25} \cdot 112 \cdot A^{0.793} \cdot P^{0.588} \cdot (L+1)^{-0.194} \cdot E^{-0.272}$$

$$Q_{25} = 186581.356$$

$$Q_{50} := C_{50} \cdot 147 \cdot A^{0.778} \cdot P^{0.544} \cdot (L+1)^{-0.187} \cdot E^{-0.264}$$

$$Q_{50} = 215684.478$$

Table D-12: Flood-Frequency-Discharge Relationship For The Colville River Based On The USGS Regression Equations With Adjustment Factors From the Sagavanirktok River (Continued)

$$Q_{100} := C_{100} \cdot 185 \cdot A^{0.765} \cdot P^{0.509} \cdot (L+1)^{-0.179} \cdot E^{-0.257}$$

$$Q_{100} = 248260.986$$

$$Q_{200} := C_{200} \cdot 224 \cdot A^{0.754} \cdot P^{0.480} \cdot (L+1)^{-0.171} \cdot E^{-0.252}$$

$$Q_{200} = 283053.804$$

$$Q_{500} := C_{500} \cdot 275 \cdot A^{0.742} \cdot P^{0.451} \cdot (L+1)^{-0.160} \cdot E^{-0.245}$$

$$Q_{500} = 337277.821$$

Table D-13: Flood-Frequency-Discharge Relationships For The Colville River Based On The USGS Regression Equations With Adjustment Factors From The Putuligayuk River

FLOOD PEAK DISCHARGE - JONES METHOD (Area 3)

This program computes the flood peak discharge on ungaged drainage basins using the regional relationships developed for AREA 3 by Stanley H. Jones and Charles B. Fahl.

REF: Jones, Stanley H. and Charles B. Fahl. 1994. Magnitude and Frequency of Floods in Alaska and Conterminous Basins of Canada. U.S. Geological Survey, Anchorage, AK. Water-Resources Investigations Report 93-4179.

PROJECT: L-1262-13

DRAINAGE BASIN: Colville River

TITLE: Peak Discharge Estimates Using Adjustment Factors Based On Putuligayuk River Data

INITIALS: SRR

DATE: 25 Oct 1996

FILE NAME: COLVILL4.MCD

Parameters:

Drainage Area in square miles,	$A := 20670.0$
Mean basin elevation in feet,	$E := 2000.0$
Percent of drainage area covered by Lakes,(%)	$L := 3.0$
Mean Annual Precipitation in inches,	$P := 13$

Correction Factors:

$C_2 := 2.268$	$C_{50} := 1.632$
$C_5 := 1.953$	$C_{100} := 1.578$
$C_{10} := 1.825$	$C_{200} := 1.550$
$C_{25} := 1.691$	$C_{500} := 1.509$

Table D-13: Flood-Frequency-Discharge Relationships For The Colville River Based On The USGS Regression Equations With Adjustment Factors From The Putuligayuk River (Continued)

Equations:

$$Q_2 := C_2 \cdot 16.2 \cdot A^{0.894} \cdot P^{0.949} \cdot (L+1)^{-0.209} \cdot E^{-0.345}$$

$$Q_2 = 164255.078$$

$$Q_5 := C_5 \cdot 43.9 \cdot A^{0.843} \cdot P^{0.753} \cdot (L+1)^{-0.206} \cdot E^{-0.305}$$

$$Q_5 = 190090.154$$

$$Q_{10} := C_{10} \cdot 70.3 \cdot A^{0.818} \cdot P^{0.667} \cdot (L+1)^{-0.202} \cdot E^{-0.288}$$

$$Q_{10} = 203635.815$$

$$Q_{25} := C_{25} \cdot 112 \cdot A^{0.793} \cdot P^{0.588} \cdot (L+1)^{-0.194} \cdot E^{-0.272}$$

$$Q_{25} = 218648.007$$

$$Q_{50} := C_{50} \cdot 147 \cdot A^{0.778} \cdot P^{0.544} \cdot (L \div 1)^{-0.187} \cdot E^{-0.264}$$

$$Q_{50} = 228718.043$$

Table D-13: Flood-Frequency-Discharge Relationships For The Colville River Based On The USGS Regression Equations With Adjustment Factors From The Putuligayuk River (Continued)

$$Q_{100} := C_{100} \cdot 185 \cdot A^{0.765} \cdot P^{0.509} \cdot (L+1)^{-0.179} \cdot E^{-0.257}$$

$$Q_{100} = 238439.34$$

$$Q_{200} := C_{200} \cdot 224 \cdot A^{0.754} \cdot P^{0.480} \cdot (L+1)^{-0.171} \cdot E^{-0.252}$$

$$Q_{200} = 247871.975$$

$$Q_{500} := C_{500} \cdot 275 \cdot A^{0.742} \cdot P^{0.451} \cdot (L+1)^{-0.160} \cdot E^{-0.245}$$

$$Q_{500} = 261403.303$$

APPENDIX E
SINGLE-STATION FLOOD-FREQUENCY RELATIONSHIP FOR THE COLVILLE RIVER AT THE HEAD OF THE DELTA USING AN EXTENDED DATA SET BASED ON THE KUPARUK RIVER

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SINGLE-STATION FLOOD-FREQUENCY RELATIONSHIP FOR THE COLVILLE RIVER AT THE HEAD OF THE DELTA USING AN EXTENDED DATA SET BASED ON THE KUPARUK RIVER

Methods

Although 7 years of peak-discharge data are available for the Colville River, the length of record is considered marginal for a single-station flood-frequency analysis. Consequently, peak discharge data from the Kuparuk River were used to extend the Colville River peak discharge record. A flood-frequency relationship was then developed from the extended flood-peak-discharge record.

Of the North Slope rivers with a significant peak-discharge record, the Kuparuk River, with 26 years of records, is closest to the Colville River in drainage basin size and proximity. Additionally, as we suspect is the case with the Colville River, the annual flood peak discharge is nearly always the result of snowmelt.

To increase the number of annual Colville River flood peaks for use in estimating a flood frequency relationship on the Colville River, a Line of Organic Correlation (Hirsch, 1982) was developed between the magnitude of the Colville River flood peaks and the magnitude of the Kuparuk River flood peaks. Years in which data are available for both rivers included: 1977, 1992, 1993, 1994, 1995, and 1996. The annual instantaneous flood peaks on both the Colville and the Kuparuk rivers were the result of snowmelt runoff in 1977, 1993, 1994, 1995, and 1996.

However, in 1992 the instantaneous annual flood peak on the Kuparuk River was the result of rainfall, while it is thought that the instantaneous annual flood peak on the Colville was the result of snowmelt. To estimate the peak snowmelt discharge on the Kuparuk River in 1992, the average ratio between the instantaneous peak snowmelt discharge and the average daily discharge occurring on the same day as the instantaneous peak was calculated from the Kuparuk River data. The instantaneous peak snowmelt discharge for the Kuparuk River in 1992 was then estimated using the average ratio (approximately 1.08), and the highest average daily discharge that occurred during the spring of 1992.

Although the 1996 annual flood peak was the result of snowmelt, an instantaneous peak discharge estimate is not available for the 1996 spring peak discharge on the Kuparuk River (USGS, personal communication). Therefore the instantaneous spring peak discharge on the Kuparuk River was estimated as described above, based on a USGS estimate of the average daily discharge on the day of the instantaneous peak (USGS, personal communication).

A Line of Organic Correlation was developed to predict the instantaneous peak discharge on the Colville River based on the instantaneous peak discharge on the Kuparuk River, using the data common to both rivers (1977, 1992, 1993, 1994, 1995, and 1996). Because error is associated with both data sets, the use of ordinary least squares (OLS) regression is not appropriate. A better solution is to fit a line that minimizes the deviations of the observations about the line in both the X and Y directions. This method of estimating a "best fit" line is called the Line of Organic Correlation (LOC) or Maintenance of Variance Extension (MOVE.1; Hirsch, 1982). The methods discussed in Hirsch (1982) were used to perform the LOC analysis. The results of the LOC analysis are presented in Table E-1.

It should be noted that there is one datum point in the data set which appears to be an outlier. This point represents the 1996 spring breakup. We believe that it plots as it does because of the sequence of thawing and freezing which occurred this spring. The Colville River experienced two spring flood peaks, while the Kuparuk River only experienced one spring flood peak. An early flood peak on the Colville River depleted much of the snowpack within the Colville River basin before the Kuparuk River started to flow. The second peak on the Colville River was the larger of the two, but was still smaller than the 2-year flood. Flow on the Kuparuk River peaked about the same time as the second peak on the Colville River. Although this doesn't happen every year, we believe that double peaks on the Colville River may not be particularly unusual. Thus, we believe the data point should be retained and it simply shows that there is significant variability within the relationship.

The LOC equation was then used to estimate peak discharges on the Colville River for the entire period during which data had been collected on the Kuparuk River. The results of this analysis are presented in Table E-2.

Based on the flood peak estimates presented in Table E-2, a flood frequency-discharge relationship was developed based on the methods established by the Interagency Advisory Committee on Water Data (1982). Both the generalized skew (0.13) and the standard error of the generalized skew (1.15), used to produce a weighted skew for the flood-frequency analysis, were taken from the data presented for Region 3 by Jones and Fahl (1994). The U.S. Army Corps of Engineer's Flood Frequency Program HEC-FFA (USACE, 1992) was used to perform the computations.

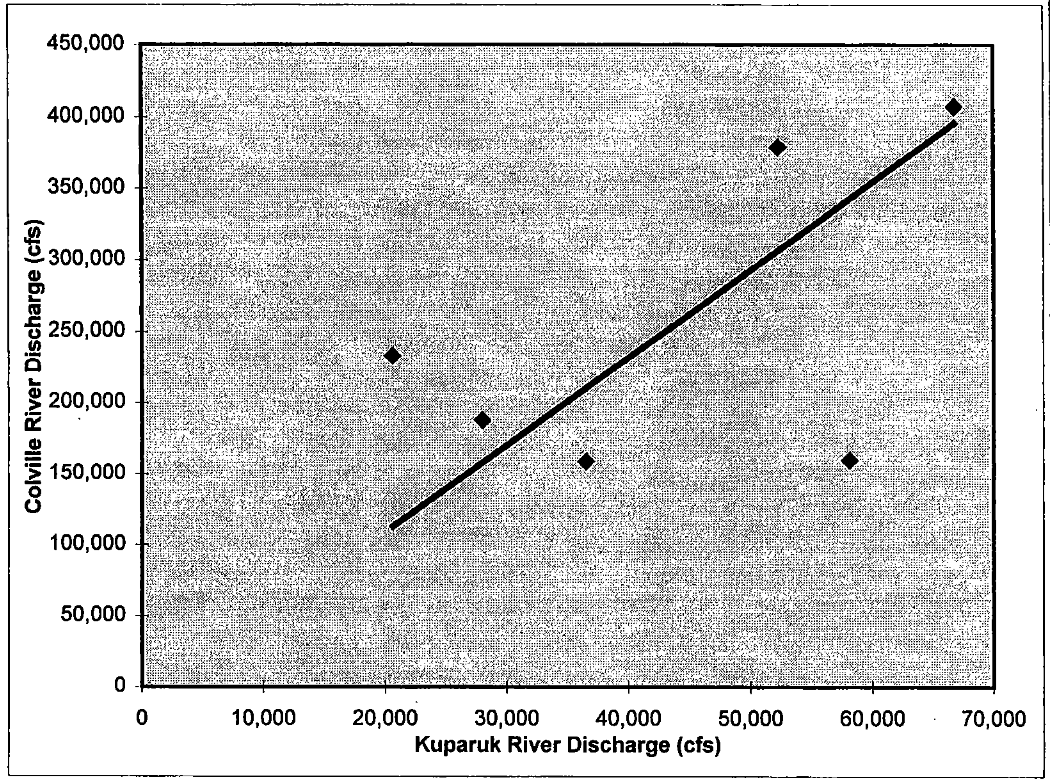
Results

The results of the flood frequency analysis are presented in Table E-3 and summarized in Table 2. The flood frequency curve developed by the analysis is presented in Figure E-1.

Table E-1: Line Of Organic Correlation (LOC) Relating Peak Discharge On The Colville River To The Peak Snowmelt Discharge On The Kuparuk River

Input Data

Year	Kuparuk River Instantaneous Peak Discharge (cfs)	Colville River Instantaneous Peak Discharge (cfs)
1977	66,800	407,000
1992	28,000	188,000
1993	52,300	379,000
1994	36,500	159,000
1995	20,600	233,000
1996	58,100	160,000



Output Data

Kuparuk River

Mean Discharge in cfs ($\bar{x}$) 43,716.67

Standard Deviation in cfs (S_x) 18,148.65

Colville River

Mean Discharge in cfs ($\bar{y}$) 254,333.33

Standard Deviation in cfs (S_y) 111,077.75

Line Of Organic Correlation **(y= a + bx)**

$$b = \frac{S_y}{S_x}$$

b = 6.12044

$$a = \bar{y} - b\,\bar{x}$$

a = -13,231.90

Final Result

Colville River Peak Discharge = -13,231.90 + [6.12044 * Kuparuk River Peak Discharge]

Table E-2: Colville River Flood Peak Estimates Based On Extrapolation From The Kuparuk River Data

Year	Kuparuk River Peak Spring Discharge (cfs)	Estimated Colville River Peak Discharge (cfs)	Measured Colville River Peak Discharge (cfs)	Peak Discharge Used In Flood Frequency Model (cfs)
1962			215,000	215,000
1971	77,000	458,000		458,000
1972	45,800	267,000		267,000
1973	82,000	489,000		489,000
1974	24,000	134,000		134,000
1975	22,600	125,000		125,000
1976	55,000	323,000		323,000
1977	66,800		407,000	407,000
1978	118,000	709,000		709,000
1979	24,300	135,000		135,000
1980	40,500	235,000		235,000
1981	27,500	155,000		155,000
1982	104,000	623,000		623,000
1983	68,400	405,000		405,000
1984	56,800	334,000		334,000
1985	34,500	198,000		198,000
1986	38,000	219,000		219,000
1987	15,500	82,000		82,000
1988	38,700	224,000		224,000
1989	75,400	448,000		448,000
1990	70,000	415,000		415,000
1991	37,100	214,000		214,000
1992	28,000		188,000	188,000
1993	52,300		379,000	379,000
1994	36,500		159,000	159,000
1995	20,600		233,000	233,000
1996	58,100		160,000	160,000

Table E-3: Single-Station Flood-Frequency Analysis For The Colville River Using An Extended Data Set Based On The Kuparuk River

```
************************************     ************************************
*              FFA                 *     *                                  *
*    FLOOD FREQUENCY ANALYSIS      *     *   U.S. ARMY CORPS OF ENGINEERS   *
*    PROGRAM DATE:  FEB 1995       *     * THE HYDROLOGIC ENGINEERING CENTER *
*         VERSION:  3.1            *     *        609 SECOND STREET         *
*    RUN  DATE   AND   TIME:       *     *      DAVIS, CALIFORNIA 95616     *
*       24 OCT 96    18:28:31      *     *         (916) 756-1104           *
*                                  *     *                                  *
************************************     ************************************


 INPUT FILE NAME: COL_KUP.DAT
OUTPUT FILE NAME: COL_KUP.OUT
   DSS FILE NAME: COL_KUP.DSS


   -----DSS---ZOPEN:  Existing File Opened,  File: COL_KUP.DSS
                      Unit:  71;  DSS Version: 6-JB

**TITLE RECORD(S)**
TT   COLVILLE RIVER AT HEAD OF DELTA

**JOB RECORD(S)**
     IPPC   ISKFX  IPROUT    IFMT    IWYR   IUNIT   ISMRY   IPNCH    IREG
J1      0       2      52       0       0       1       1       0       0

        A       B  CLIMIT  NDSSCV    IEXT
J2    .00     .00     .00       0       1

**FREQUENCY ARRAY**
FR     13    .200    .500   1.000   2.000   4.000   5.000  10.000  20.000  50.000
FR80.000  90.000  95.000  99.000

**GENERALIZED SKEW**
     ISTN   GGMSE    SKEW
GS          1.322     .13

**HP PLOT **
     HP PLOT FILE                 IHPCV  KLIMIT    IPER    BAREA
HP COL_KUP.PCL                        3       0       0 20,670 SQ MI

     SELECTED CURVES ON HPPLOT
          EXPECTED PROBABILITY CURVE
          COMPUTED PROBABILITY CURVE
          CONFIDENCE LIMITS

HP Colville River
HP At Head Of Delta
HP RECORD EXTENDED WITH
HP KUPARUK RIVER DATA

**SYSTEMATIC EVENTS**
     27 EVENTS TO BE ANALYZED

**END OF INPUT DATA**
ED +++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
```

Table E-3: Single-Station Flood-Frequency Analysis For The Colville River Using An Extended Data Set Based On The Kuparuk River (Continued)

```
* * * * * * * * * * *     FLOOD PEAK DATA     * * * * * * * * * * *

-PLOTTING POSITIONS-
******************************************************************
*......EVENTS ANALYZED.....*...........ORDERED EVENTS..........*
*                   FLOW   *        WATER       FLOW   WEIBULL  *
* MON DAY  YEAR      CFS   *   RANK  YEAR        CFS   PLOT POS *
*--------------------------*--------------------------------------*
*   0   0  1962  215000.   *     1   1978    709000.      3.57  *
*   0   0  1971  458000.   *     2   1982    623000.      7.14  *
*   0   0  1972  267000.   *     3   1973    489000.     10.71  *
*   0   0  1973  489000.   *     4   1971    458000.     14.29  *
*   0   0  1974  134000.   *     5   1989    448000.     17.86  *
*   0   0  1975  125000.   *     6   1990    415000.     21.43  *
*   0   0  1976  323000.   *     7   1977    407000.     25.00  *
*   0   0  1977  407000.   *     8   1983    405000.     28.57  *
*   0   0  1978  709000.   *     9   1993    379000.     32.14  *
*   0   0  1979  135000.   *    10   1984    334000.     35.71  *
*   0   0  1980  235000.   *    11   1976    323000.     39.29  *
*   0   0  1981  155000.   *    12   1972    267000.     42.86  *
*   0   0  1982  623000.   *    13   1980    235000.     46.43  *
*   0   0  1983  405000.   *    14   1995    233000.     50.00  *
*   0   0  1984  334000.   *    15   1988    224000.     53.57  *
*   0   0  1985  198000.   *    16   1986    219000.     57.14  *
*   0   0  1986  219000.   *    17   1962    215000.     60.71  *
*   0   0  1987   82000.   *    18   1991    214000.     64.29  *
*   0   0  1988  224000.   *    19   1985    198000.     67.86  *
*   0   0  1989  448000.   *    20   1992    188000.     71.43  *
*   0   0  1990  415000.   *    21   1996    160000.     75.00  *
*   0   0  1991  214000.   *    22   1994    159000.     78.57  *
*   0   0  1992  188000.   *    23   1981    155000.     82.14  *
*   0   0  1993  379000.   *    24   1979    135000.     85.71  *
*   0   0  1994  159000.   *    25   1974    134000.     89.29  *
*   0   0  1995  233000.   *    26   1975    125000.     92.86  *
*   0   0  1996  160000.   *    27   1987     82000.     96.43  *
******************************************************************

-OUTLIER TESTS  -
------------------------------------------------------------------
LOW OUTLIER TEST
-----------------

BASED ON  27 EVENTS, 10 PERCENT OUTLIER TEST VALUE K(N) = 2.519

       0 LOW OUTLIER(S) IDENTIFIED BELOW TEST VALUE OF  66557.3

-----------------
HIGH OUTLIER TEST
-----------------

BASED ON  27 EVENTS, 10 PERCENT OUTLIER TEST VALUE K(N) = 2.519

      0 HIGH OUTLIER(S) IDENTIFIED ABOVE TEST VALUE OF  988714.
------------------------------------------------------------------

-SKEW WEIGHTING -
------------------------------------------------------------------
BASED ON  27 EVENTS, MEAN-SQUARE ERROR OF STATION SKEW =   .184
DEFAULT OR INPUT MEAN-SQUARE ERROR OF GENERALIZED SKEW =  1.322
------------------------------------------------------------------
```

Table E-3: Single-Station Flood-Frequency Analysis For The Colville River Using An Extended Data Set Based On The Kuparuk River (Continued)

FINAL RESULTS

-FREQUENCY CURVE-

FLOW IN CFS: BASE CURVE	FLOW IN CFS: EXPECTED PROBABILITY	PERCENT CHANCE EXCEEDANCE	CONFIDENCE LIMITS: .05 LIMIT	CONFIDENCE LIMITS: .95 LIMIT
1210000.	1450000.	.20	1980000.	871000.
1020000.	1180000.	.50	1610000.	759000.
896000.	997000.	1.00	1360000.	678000.
773000.	837000.	2.00	1130000.	598000.
656000.	695000.	4.00	919000.	520000.
620000.	652000.	5.00	857000.	495000.
510000.	526000.	10.00	673000.	416000.
403000.	409000.	20.00	507000.	336000.
256000.	256000.	50.00	305000.	215000.
163000.	161000.	80.00	196000.	130000.
129000.	125000.	90.00	158000.	97900.
106000.	101000.	95.00	133000.	77100.
74100.	66700.	99.00	97800.	49000.

SYSTEMATIC STATISTICS

LOG TRANSFORM: FLOW, CFS		NUMBER OF EVENTS	
MEAN	5.4091	HISTORIC EVENTS	0
STANDARD DEV	.2326	HIGH OUTLIERS	0
COMPUTED SKEW	-.0060	LOW OUTLIERS	0
REGIONAL SKEW	.1300	ZERO OR MISSING	0
ADOPTED SKEW	.0107	SYSTEMATIC EVENTS	27

HP PLOT WRITTEN TO THE FILE: COL_KUP.PCL

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++++++++++++++++++++++++++
+ END OF RUN             +
+ NORMAL STOP IN FFA     +
++++++++++++++++++++++++++
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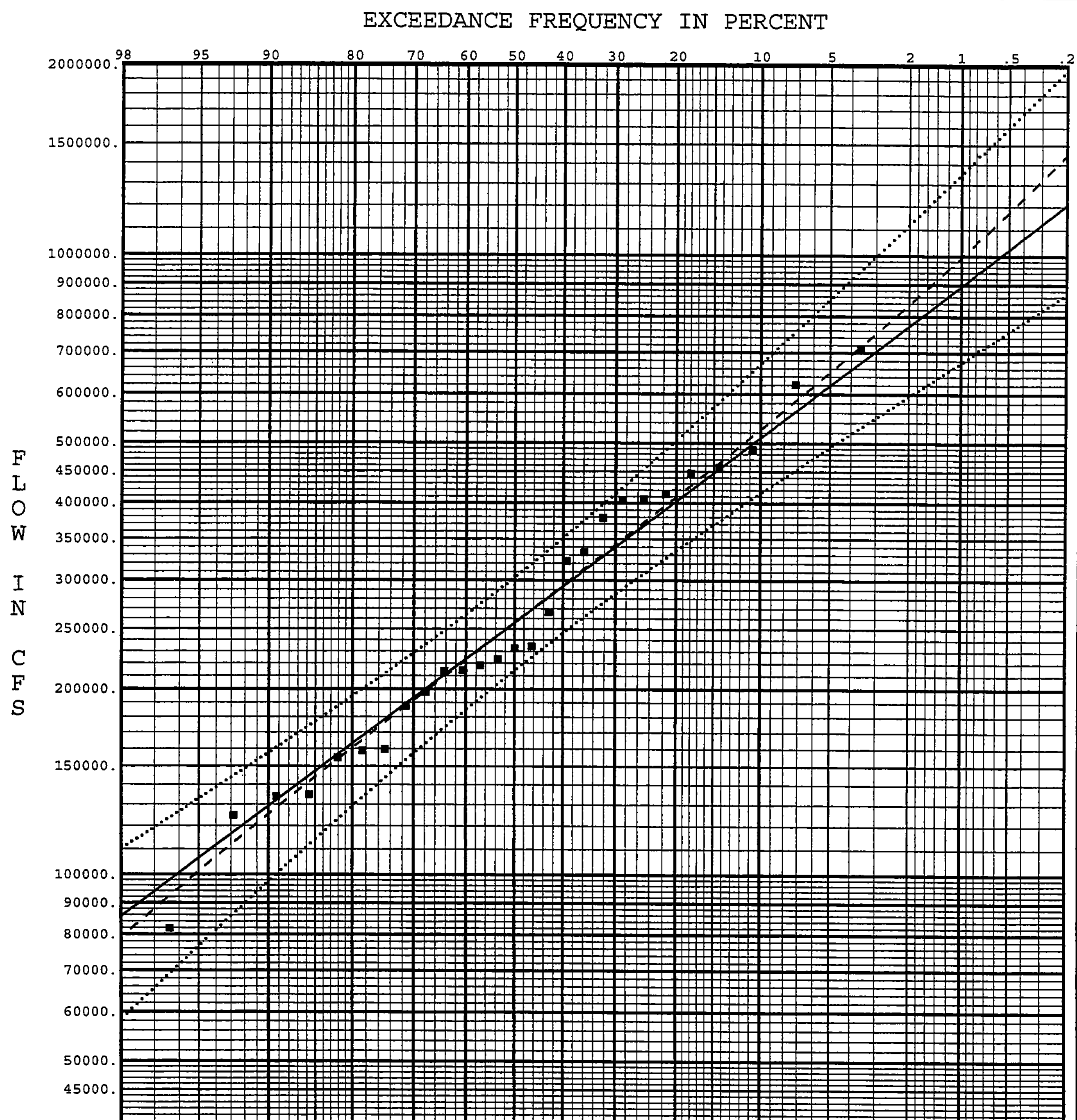

—— FLOW Frequency (without Exp. Prob.)
- - - FLOW Frequency (with Exp. Prob.)
■ Weibull Plotting Positions
······· 5% and 95% Confidence Limits

FREQUENCY STATISTICS

LOG TRANSFORM OF FLOW, CFS		NUMBER OF EVENTS	
MEAN	5.4091	HISTORIC EVENTS	0
STANDARD DEV	.2326	HIGH OUTLIERS	0
SKEW	-.0060	LOW OUTLIERS	0
REGIONAL SKEW	.1300	ZERO OR MISSING	0
ADOPTED SKEW	.0107	SYSTEMATIC EVENTS	27

Colville River
At Head Of Delta
RECORD EXTENDED WITH
KUPARUK RIVER DATA
BASIN AREA = 20,670 SQ MI
WATER YEARS IN RECORD
1962,1971-1996

Figure E-1

APPENDIX F
SINGLE-STATION FLOOD-FREQUENCY RELATIONSHIP FOR THE COLVILLE RIVER AT THE HEAD OF THE DELTA USING AN EXTENDED DATA SET BASED ON THE SAGAVANIRKTOK RIVER

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SINGLE-STATION FLOOD-FREQUENCY RELATIONSHIP FOR THE COLVILLE RIVER AT THE HEAD OF THE DELTA USING AN EXTENDED DATA SET BASED ON THE SAGAVANIRKTOK RIVER

Methods

As discussed in Appendix E, the length of the flood peak discharge record on the Colville River is considered marginal for development of a single-station flood-frequency relationship. As another check on the flood-frequency relationship developed solely with the Colville River data (Appendix C), data from the Sagavanirktok River were used to estimate Colville River flood peak discharges in years when data were collected on the Sagavanirktok River but not on the Colville River. These additional data were used, in combination with the flood peak data collected on the Colville River, to estimate a flood-frequency relationship for the Colville River.

Discharge data have been collected on the Sagavanirktok River, by the USGS, at two locations. Between 1969 and 1979 discharge data were collected near Sagwon (basin area = 2,208 mi^2). Between 1983 and 1996 discharge data were collected near Pump Station 3 (basin area = 1,860 mi^2). To provide as much data as possible for use in extending the Colville River discharge record, a single data set was prepared for the Sagavanirktok River. Since all but one of the Colville River peak discharge measurements were collected during the period when the Sagavanirktok River measurements were being made near Pump Station 3, the measurements made at the Sagwon station were extrapolated to the Pump Station 3 location using the equation:

$$Q_{PS3} = Q_S * (\text{Area}_{PS3} / \text{Area}_S)^{0.833}$$

where

Q_{PS3} = the discharge for the Sagavanirktok River near Pump Station 3;

Q_s = the discharge for the Sagavanirktok River near Sagwon;

Area_{PS3} = the drainage area for the Sagavanirktok River near Pump Station 3 (1,860 mi^2);

Area_S = the drainage area for the Sagavanirktok River near Sagwon (2,208 mi^2).

The exponent used in the relationship was developed based on equations relating discharge to drainage area found in two previous studies (Office of the State Pipeline Coordinator, 1981; Kane and Janowicz, 1989). In both studies, equations for estimating discharge at specific return periods were presented in the form:

$$Q_T = a\text{Area}^b$$

where

Q_T = the peak discharge having a return period of T-years;

a = the regression constant; and

b = the regression coefficient.

The regression coefficients associated with the equations for the 2-, 5-, and 10-year floods, presented in both studies, were averaged to obtain the exponent (0.833) used in the relationship for the Sagavanirktok River. Only the 2-, 5-, and 10-year return periods were used because only one of the measured discharges at each Sagavanirktok River station exceeded the 10-year flood for that station.

Unlike the Colville River, a high percentage of the annual flood-peak discharges on the Sagavanirktok River results from rainfall rather than snowmelt. To make a meaningful correlation to the Colville River, the highest average daily discharge that occurred during each spring on the Sagavanirktok River was used, rather than the instantaneous annual peak discharge. The one exception is the 1979 peak discharge at the Sagwon station. No average daily discharge data were collected that year. However, it is known that the 1979 instantaneous annual peak discharge occurred during the spring snowmelt. Therefore, it was used without adjustment to estimate the average daily peak discharge near Pump Station 3, because the difference between the instantaneous peak discharge and the average daily discharge on the same day is thought to be less than the variability due to extrapolating data from one station to another. No average daily discharge data were collected in 1969 or 1970 as well. However, the instantaneous peak discharges from these years were not used, because it is thought that they probably occurred as a result of rainfall.

The data collected at both the Sagwon and Pump Station 3 stations, and the extrapolated data for the Sagavanirktok River near Pump Station 3, are presented in Table F-1.

A Line Of Organic Correlation (LOC) was developed to predict the instantaneous peak discharge on the Colville River based on the average daily spring peak discharge on the Sagavanirktok River, using the data common to both rivers (1977, 1992, 1993, 1994, 1995, and 1996). Because error is associated with both data sets, the use of ordinary least squares (OLS) regression is not appropriate. A better method is to fit a line that minimizes the deviations of the observations about the line in both the X and Y directions. This method of estimating a "best fit" line is called the Line of Organic Correlation (LOC) or Maintenance of Variance Extension (MOVE.1; Hirsch, 1982). The methods discussed in Hirsch (1982) were used to perform the LOC analysis. The results are presented in Table F-2.

It should be noted that there is one datum point in the regression data set which appears to be an outlier. This point represents the 1996 spring breakup. We believe that it plots as it does because of the sequence of thawing and freezing which occurred this spring. The Colville River experienced two spring flood peaks. An early flood peak on the Colville River depleted much of the snowpack within the Colville River basin. The second peak on the Colville River was the larger of the two, but was still smaller than the 2-year flood. Flow on the Sagavanirktok River peaked a few days after the second peak on the Colville River. Although this doesn't happen every year, we believe that double peaks on the Colville River may not be particularly unusual. Thus, we believe the data point should be retained and it simply shows that there is significant variability within the relationship.

The LOC equation was then used to estimate peak discharges on the Colville River for the entire period during which data had been collected on the Sagavanirktok River. The results of this analysis are presented in Table F-3.

Using the flood peak estimates presented in Table F-3, a flood frequency-discharge relationship was developed based on the methods established by the Interagency Advisory Committee on Water Data (1982). Both the generalized skew (0.13) and the standard error of the generalized skew (1.15), used to produce a weighted skew for the flood-frequency analysis, were taken from the data presented for Area 3 by Jones and Fahl (1994). The U.S. Army Corps of Engineer's Flood Frequency Program HEC-FFA (USACE, 1992) was used to perform the computations.

Results

The results of the flood frequency analysis are presented in Table F-4 and summarized in Table 2. The flood frequency curve developed by the analysis is presented in Figure F-1.

Table F-1: Data For The Sagavanirktok River Near Pump Station 3 And For The Sagavanirktok River Near Sagwon

Year	Spring Peak Discharge (cfs) [1]			
	Measured Sagavanirktok River Near Sagwon (cfs)	Measured Sagavanirktok River Near Pump Station 3 (cfs)	Extrapolated Sagavanirktok River Near Pump Station 3 [2] (cfs)	Data Used Sagavanirktok River Near Pump Station 3 [2] (cfs)
1969				
1970				
1971	15,500		13,300	13,300
1972	20,000		17,200	17,200
1973	9,000		7,740	7,740
1974	10,000		8,600	8,600
1975	7,400		6,360	6,360
1976	11,500		9,890	9,890
1977	22,000		18,900	18,900
1978	18,000		15,500	15,500
1979	10,800 [3]		9,290	9,290
1980				
1981				
1982				
1983		20,000		20,000
1984		7,720		7,720
1985		2,500		2,500
1986		8,400		8,400
1987		6,000		6,000
1988		7,800		7,800
1989		10,000		10,000
1990		8,400		8,400
1991		10,000		10,000
1992		10,000		10,000
1993		14,000		14,000
1994		1,700		1,700
1995		10,100		10,100
1996		13,800		13,800

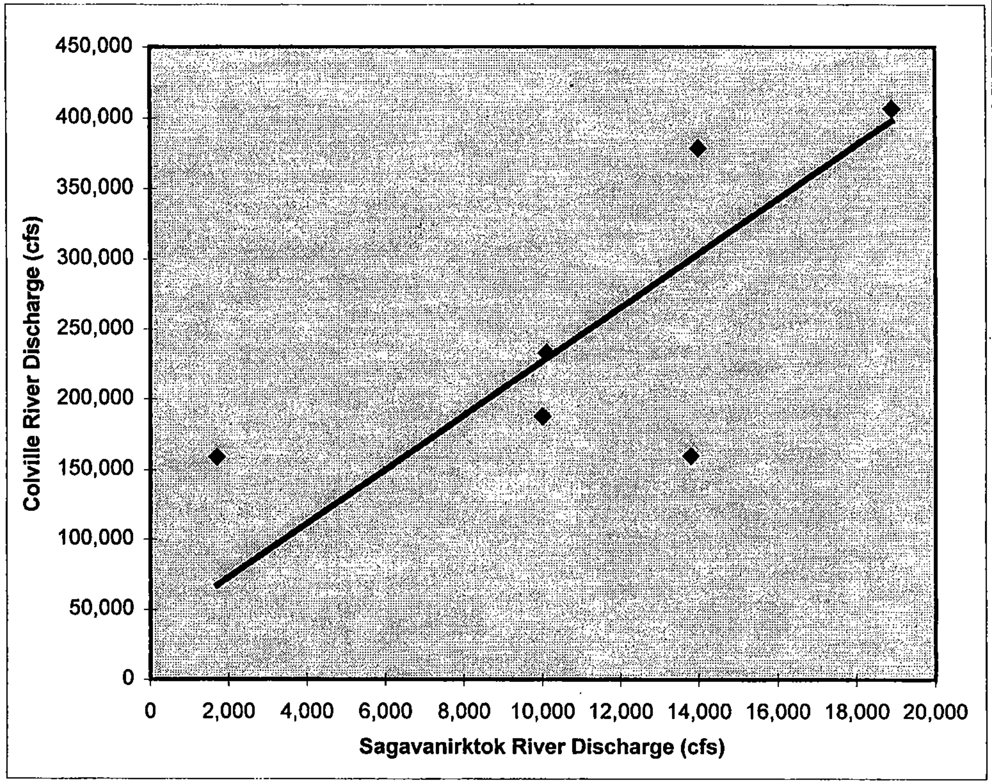
Notes:

1. The spring peak discharges are average daily discharges.
2. Peak discharge data between 1969 and 1979 for the Sagavanirktok River near Pump Station 3 were extrapolated from the Sagwon station based on the function: Q nr Pump Station 3 = Q nr Sagwon * (1860/2208)^0.883.
3. The 1979 discharge at the Sagwon station is an instantaneous peak discharge rather than an average daily discharge. It was used without adjustment to estimate the average daily peak discharge near Pump Station 3 because the difference between the instantaneous peak discharge and the average daily discharge on the same day is thought to be less than the variability due to extrapolating data from one station to another.

Table F-2: Line Of Organic Correlation (LOC) Relating Peak Discharge On The Colville River To The Average Daily Spring Peak Discharge On The Sagavanirktok River

Input Data

Year	Sagavanirktok River Average Daily Peak Discharge (in cfs)	Colville River Instantaneous Peak Discharge (in cfs)
1977	18,900	407,000
1992	10,000	188,000
1993	14,000	379,000
1994	1,700	159,000
1995	10,100	233,000
1996	13,800	160,000



Output Data

Sagavanirktok River

Mean Discharge in cfs ($\bar{x}$) 11,416.67

Standard Deviation in cfs (S_x) 5,770.76

Colville River

Mean Discharge in cfs ($\bar{y}$) 254,333.33

Standard Deviation in cfs (S_y) 111,077.75

Line Of Organic Correlation **(y= a + bx)**

$$b = \frac{S_y}{S_x}$$

b = 19.24838

$$a = \bar{y} - b\bar{x}$$

a = 34,581.04

Final Result

Colville River Peak Discharge = 34,581.04 + [19.24838 * Sagavanirktok River Peak Discharge]

F-6

L-1262-13

Table F-3: Colville River Flood Peak Estimates Based On Extrapolation From The Sagavanirktok River Data

Year	Sagavanirktok River Peak Spring Discharge (cfs)	Estimated Colville River Peak Discharge (cfs)	Measured Colville River Peak Discharge (cfs)	Peak Discharge Used In Flood Frequency Model (cfs)
1962			215,000	215,000
1971	13,300	291,000		291,000
1972	17,200	366,000		366,000
1973	7,740	184,000		184,000
1974	8,600	200,000		200,000
1975	6,360	157,000		157,000
1976	9,890	225,000		225,000
1977	18,900		407,000	407,000
1978	15,500	333,000		333,000
1979	9,290	213,000		213,000
1980				
1981				
1982				
1983	20,000	420,000		420,000
1984	7,720	183,000		183,000
1985	2,500	83,000		83,000
1986	8,400	196,000		196,000
1987	6,000	150,000		150,000
1988	7,800	185,000		185,000
1989	10,000	227,000		227,000
1990	8,400	196,000		196,000
1991	10,000	227,000		227,000
1992	10,000		188,000	188,000
1993	14,000		379,000	379,000
1994	1,700		159,000	159,000
1995	10,100		233,000	233,000
1996	13,800		160,000	160,000

Note:

1. The spring peak discharges for the Sagavanirktok River near Pump Station 3 are average daily discharges.
2. The estimated discharges for the Colville River were based on an "LOC" between spring flood peak discharge data collected on the Sagavanariktok and Colville rivers in 1992, 1993, 1994, 1995, and 1996.
3. The peak discharges for the Colville River are instantaneous peak discharges.

Table F-4: Single-Station Flood-Frequency Analysis For The Colville River Using An Extended Data Set Based On The Sagavanirktok River

```
************************************     ************************************
*             FFA                   *     *                                  *
*    FLOOD FREQUENCY ANALYSIS       *     *   U.S. ARMY CORPS OF ENGINEERS   *
*    PROGRAM DATE:  FEB 1995        *     * THE HYDROLOGIC ENGINEERING CENTER *
*         VERSION:  3.1             *     *       609 SECOND STREET          *
*    RUN  DATE   AND   TIME:        *     *     DAVIS, CALIFORNIA 95616      *
*       24 OCT 96     16:33:59      *     *        (916) 756-1104            *
*                                   *     *                                  *
************************************     ************************************



 INPUT FILE NAME: COL_SAG.DAT
OUTPUT FILE NAME: COL_SAG.OUT
   DSS FILE NAME: COL_SAG.DSS


   -----DSS---ZOPEN:  Existing File Opened,  File: COL_SAG.DSS
                      Unit:  71;  DSS Version: 6-JB

**TITLE RECORD(S)**
TT   COLVILLE RIVER AT HEAD OF DELTA

**JOB RECORD(S)**
     IPPC   ISKFX  IPROUT    IFMT    IWYR   IUNIT   ISMRY   IPNCH    IREG
J1      0       2      52       0       0       1       1       0       0

        A       B  CLIMIT  NDSSCV    IEXT
J2    .00     .00     .00       0       1

**FREQUENCY ARRAY**
FR     13    .200    .500   1.000   2.000   4.000   5.000  10.000  20.000  50.000
FR80.000  90.000  95.000  99.000

**GENERALIZED SKEW**
     ISTN   GGMSE    SKEW
GS          1.322     .13

**HP PLOT **
     HP PLOT FILE                  IHPCV  KLIMIT    IPER    BAREA
HP COL_SAG.PCL                         3       0       0 20,670 SQ MI

     SELECTED CURVES ON HPPLOT
          EXPECTED PROBABILITY CURVE
          COMPUTED PROBABILITY CURVE
          CONFIDENCE LIMITS

HP Colville River
HP At Head Of Delta
HP RECORD EXTENDED WITH
HP SAG RIVER DATA

**SYSTEMATIC EVENTS**
     24 EVENTS TO BE ANALYZED

**END OF INPUT DATA**
ED +++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
```

Table F-4: Single-Station Flood-Frequency Analysis For The Colville River Using An Extended Data Set Based On The Sagavanirktok River (Continued)

```
* * * * * * * * * * *  FLOOD PEAK DATA   * * * * * * * * * * *

-PLOTTING POSITIONS-
****************************************************************
*......EVENTS ANALYZED.....*...........ORDERED EVENTS..........*
*                  FLOW    *          WATER      FLOW   WEIBULL  *
* MON DAY  YEAR    CFS     *   RANK   YEAR       CFS    PLOT POS *
*--------------------------*-----------------------------------*
*   0   0  1962  215000.   *     1    1983     420000.     4.00  *
*   0   0  1971  291000.   *     2    1977     407000.     8.00  *
*   0   0  1972  366000.   *     3    1993     379000.    12.00  *
*   0   0  1973  184000.   *     4    1972     366000.    16.00  *
*   0   0  1974  200000.   *     5    1978     333000.    20.00  *
*   0   0  1975  157000.   *     6    1971     291000.    24.00  *
*   0   0  1976  225000.   *     7    1995     233000.    28.00  *
*   0   0  1977  407000.   *     8    1989     227000.    32.00  *
*   0   0  1978  333000.   *     9    1991     227000.    36.00  *
*   0   0  1979  213000.   *    10    1976     225000.    40.00  *
*   0   0  1983  420000.   *    11    1962     215000.    44.00  *
*   0   0  1984  183000.   *    12    1979     213000.    48.00  *
*   0   0  1985   83000.   *    13    1974     200000.    52.00  *
*   0   0  1986  196000.   *    14    1986     196000.    56.00  *
*   0   0  1987  150000.   *    15    1990     196000.    60.00  *
*   0   0  1988  185000.   *    16    1992     188000.    64.00  *
*   0   0  1989  227000.   *    17    1988     185000.    68.00  *
*   0   0  1990  196000.   *    18    1973     184000.    72.00  *
*   0   0  1991  227000.   *    19    1984     183000.    76.00  *
*   0   0  1992  188000.   *    20    1996     160000.    80.00  *
*   0   0  1993  379000.   *    21    1994     159000.    84.00  *
*   0   0  1994  159000.   *    22    1975     157000.    88.00  *
*   0   0  1995  233000.   *    23    1987     150000.    92.00  *
*   0   0  1996  160000.   *    24    1985      83000.    96.00  *
****************************************************************


-OUTLIER TESTS  -
----------------------------------------------------------------
LOW OUTLIER TEST
-----------------


BASED ON  24 EVENTS, 10 PERCENT OUTLIER TEST VALUE K(N) = 2.467

      1 LOW OUTLIER(S) IDENTIFIED BELOW TEST VALUE OF  86956.7

STATISTICS AND FREQUENCY CURVE ADJUSTED FOR  1 LOW OUTLIER(S)


-----------------
HIGH OUTLIER TEST
-----------------


BASED ON  24 EVENTS, 10 PERCENT OUTLIER TEST VALUE K(N) = 2.467

      0 HIGH OUTLIER(S) IDENTIFIED ABOVE TEST VALUE OF  544587.
----------------------------------------------------------------


-SKEW WEIGHTING -
----------------------------------------------------------------
BASED ON  24 EVENTS, MEAN-SQUARE ERROR OF STATION SKEW =    .279
DEFAULT OR INPUT MEAN-SQUARE ERROR OF GENERALIZED SKEW =  1.322
----------------------------------------------------------------
```

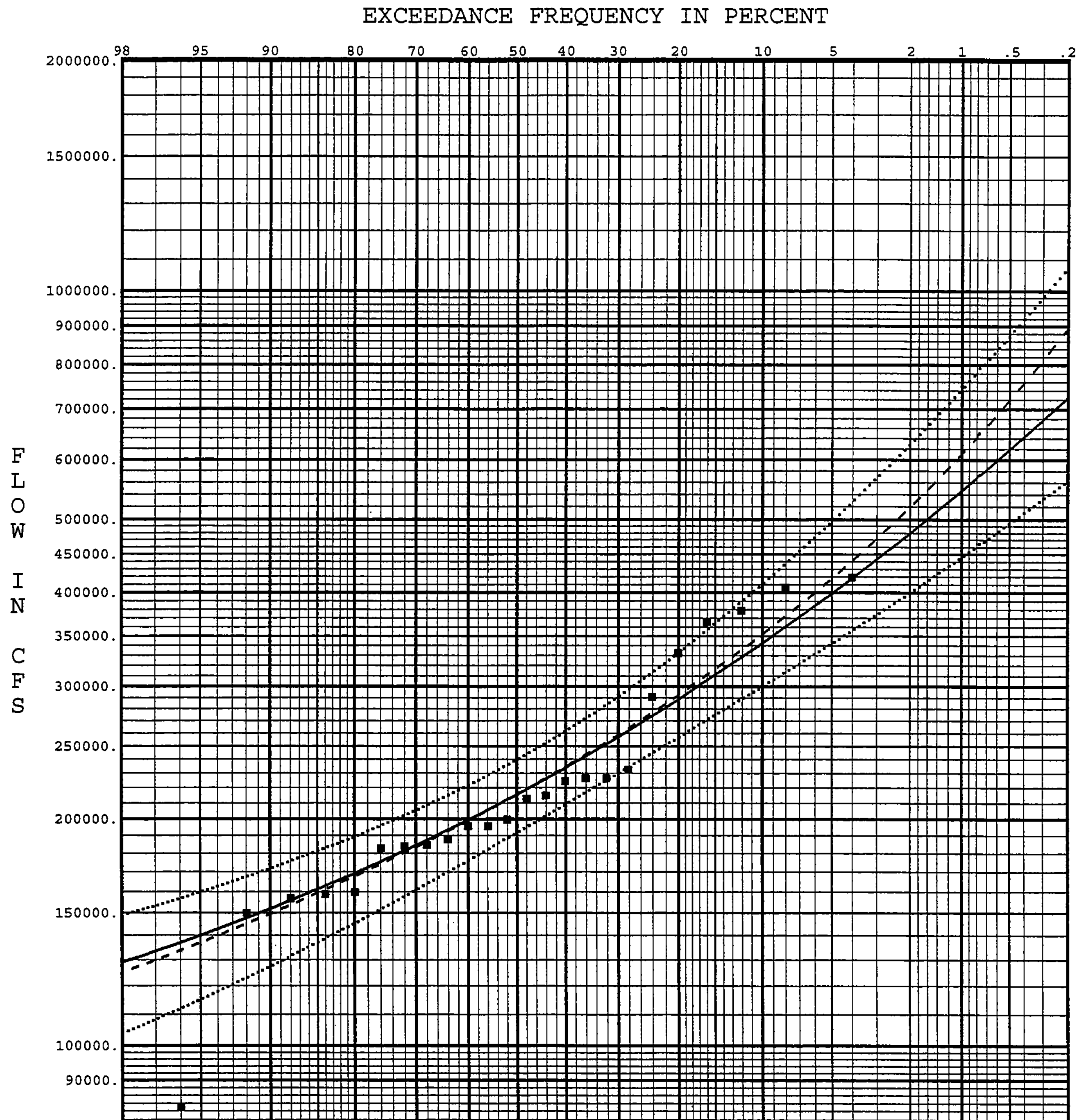
Table F-4: Single-Station Flood-Frequency Analysis For The Colville River Using An Extended Data Set Based On The Sagavanirktok River (Continued)

```
FINAL RESULTS

-FREQUENCY CURVE-
*****************************************************************
*......FLOW IN CFS.......*   PERCENT   *...CONFIDENCE LIMITS...*
*    BASE     EXPECTED   *    CHANCE   *                       *
*   CURVE    PROBABILITY * EXCEEDANCE *  .05 LIMIT   .95 LIMIT *
*------------------------*-------------*-----------------------*
*   725000.    896000.   *       .20   *  1080000.    565000.  *
*   619000.    720000.   *       .50   *   879000.    496000.  *
*   547000.    612000.   *      1.00   *   748000.    448000.  *
*   480000.    520000.   *      2.00   *   632000.    401000.  *
*   418000.    441000.   *      4.00   *   530000.    357000.  *
*   399000.    418000.   *      5.00   *   499000.    343000.  *
*   343000.    352000.   *     10.00   *   412000.    301000.  *
*   288000.    292000.   *     20.00   *   334000.    257000.  *
*   216000.    216000.   *     50.00   *   241000.    192000.  *
*   169000.    168000.   *     80.00   *   190000.    146000.  *
*   152000.    150000.   *     90.00   *   172000.    128000.  *
*   140000.    137000.   *     95.00   *   160000.    115000.  *
*   123000.    118000.   *     99.00   *   143000.     97800.  *
*****************************************************************
*                       SYNTHETIC STATISTICS                    *
* LOG TRANSFORM: FLOW, CFS         *       NUMBER OF EVENTS     *
*----------------------------------*----------------------------*
*  MEAN                     5.3484 *  HISTORIC EVENTS       0   *
*  STANDARD DEV              .1400 *  HIGH OUTLIERS        0     *
*  COMPUTED SKEW             .7465 *  LOW OUTLIERS         1     *
*  REGIONAL SKEW             .1300 *  ZERO OR MISSING      0     *
*  ADOPTED SKEW              .6390 *  SYSTEMATIC EVENTS      24  *
*****************************************************************


HP PLOT WRITTEN TO THE FILE:   COL_SAG.PCL


+++++++++++++++++++++++++
+ END OF RUN            +
+ NORMAL STOP IN FFA    +
+++++++++++++++++++++++++
```



—— FLOW Frequency (without Exp. Prob.)
- - - FLOW Frequency (with Exp. Prob.)
■ Weibull Plotting Positions
········ 5% and 95% Confidence Limits

FREQUENCY STATISTICS
LOG TRANSFORM OF FLOW, CFS

		NUMBER OF EVENTS	
MEAN	5.3484	HISTORIC EVENTS	0
STANDARD DEV	.1400	HIGH OUTLIERS	0
SKEW	.7465	LOW OUTLIERS	1
REGIONAL SKEW	.1300	ZERO OR MISSING	0
ADOPTED SKEW	.6390	SYSTEMATIC EVENTS	24

Colville River
At Head Of Delta
RECORD EXTENDED WITH
SAG RIVER DATA
BASIN AREA = 20,670 SQ MI
WATER YEARS IN RECORD
1962,1971-1979,1983-1996

Figure F-1

APPENDIX G
EXPECTED PROBABILITY

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LIST OF TABLES

LIST OF FIGURES

APPENDIX G
EXPECTED PROBABILITY

Expected Probability - What is it?

The base curve of a flood frequency analysis is the average discharge associated with a given exceedance probability.[1] In other words, the base curve presents the average discharge that will be exceeded X or more times per 100 events. However, once a structure is built the discharge which the structure can safely accommodate is fixed. We are not interested in the average discharge the structure can safely accommodate. Instead, we need to know the average number of times the design discharge will be exceeded per 100 events. Unfortunately, the average number of times the discharge is likely to be exceeded per 100 events is usually not the same as the exceedance probability associated with the base curve. The average exceedance probability is referred to as the expected probability. The following example will help to clarify the difference between the base curve and the expected probability curve, and demonstrate the need to use the expected probability curve in the design of water resources structures.

Based on the base curve (.50 curve) in Figure G-1, a discharge of 1,140 cfs will be exceeded an average of five times per 100 events. If we build a structure based on a design discharge of 1,140 cfs, what is the average number of times the design discharge is likely to be exceeded per 100 events? Your first answer might be that the design event will be exceeded an average of five times per 100 events. But is that correct?

The average number of times the design discharge will be exceeded per 100 events is computed from the confidence limits on the base curve. For example, at a design discharge of 1,140 cfs there is a 5 percent chance that the design discharge will be exceeded 23 or more times per 100 events (Figure G-1); a 10 percent chance that the design discharge will be exceeded 17 or more times per 100 events; and a 25 percent chance that the design discharge will be exceeded 10 or more times per 100 events. Similarly, there is a 50, 75, 90, and 95 percent chance that the design discharge will be exceeded 5, 2.4, 1.0, 0.6 or more times per 100 events, respectively. The average of the number of times the design discharge will be exceeded is the average exceedance probability (or expected probability). As shown in Table G-1, the design discharge will be exceeded an average of 8.4 times per 100 events, not five times per 100 events as one might have expected.

If the acceptable risk for which the structure was designed is five times per 100 events, the structure was underdesigned. In order for the average number of exceedances to be five times

[1]Exceedance Probability is simply the number of times an event will be equaled or exceeded per 100 events.

per 100 events, the design discharge would have to be greater than 1,140 cfs. Use of the mathematically derived expected probability curve will provide an estimate of the discharge for which the average number of exceedances per 100 events is 5. Based on Figure G-1 and the expected probability curve, the discharge with an average number of exceedances of 5 per 100 events is 1,260 cfs. This can be confirmed by following the procedure that is described in the paragraph above, using a discharge of 1,260 cfs. The results of conducting such an analysis are presented in Table G-2. Finally, it should be noted that as the number of years of record increases, the confidence limits on the base curve get tighter and the expected probability curve approaches the base curve.

Table G-1: Exceedance Per 100 Events Based On The Confidence Intervals Shown On Figure G-1. Design Flow Is 1,140 CFS.

Confidence Interval	Exceedance Per 100 Events
.05	23
.10	17
.25	10
.50	5
.75	2.4
.90	1.0
.95	0.6
Average = .50	**Average = 8.4**

Table G-2: Exceedance Per 100 Events Based On The Confidence Intervals Shown On Figure G-1. Design Flow Is 1,260 CFS.

Confidence Interval	Exceedance Per 100 Events
.05	15.9
.10	10.4
.25	5.6
.50	2.3
.75	0.7
.90	0.3
.95	0.1
Average = .50	**Average = 5.0**

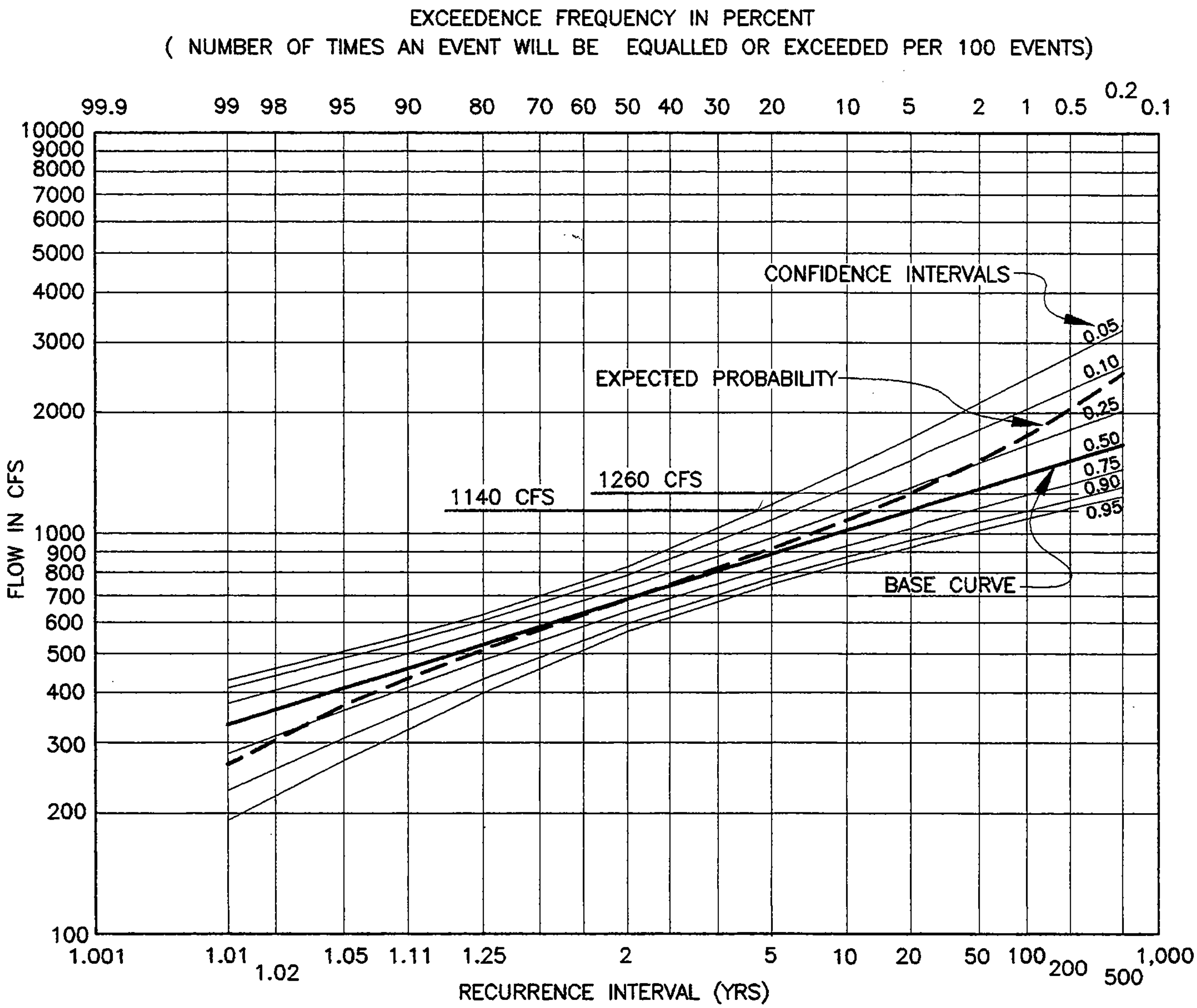

FIGURE:	SHANNON & WILSON, INC. GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS		PROJECT: FLOOD FREQUENCY ANALYSIS
G-1	DATE: 10/24/96	PROJECT:	LOCATION: YATUK CREEK NEAR KLAWOCK, ALASKA
	DRAWN: BC	FILE: FFRQ1262.DWG	
	CHECKED: SR	SCALE: NONE	