SUSITNA HYDROELECTRIC PROJECT

REGIONAL FLOOD STUDIES

DECEMBER 1981

Prepared by:
R&M CONSULTANTS, INC.

Prepared for:
ACRES

ALASKA POWER AUTHORITY

ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT

TASK 3 - HYDROLOGY

REGIONAL FLOOD STUDIES

DECEMBER 1981

Prepared for:

ACRES AMERICAN INCORPORATED
1000 Liberty Bank Building
Main at Court
Buffalo, New York 14202
Telephone (716) 853-7525

Prepared by:

R&M CONSULTANTS, INC.
P.O. Box 6087
5024 Cordova
Anchorage, Alaska 99503
Telephone: (907) 279-0483

ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT

TASK 3 - HYDROLOGY

REGIONAL FLOOD STUDIES

TABLE OF CONTENTS

TABLE OF CONTENTS (Cont'd)

LIST OF TABLES

LIST OF FIGURES

susi6/j5

1 - INTRODUCTION

On January 1, 1980, Acres American, Inc., received notice to proceed with the feasibility analysis of the Susitna Hydroelectric Project. The analysis will consider the feasibility of constructing one or possibly two dams along the upper Susitna River. The two primary sites being considered are the Watana and the Devil Canyon sites.

The objective of this study is to provide design flood peak information for the design of the project and for assessing pre-project flood conditions in the Susitna River reaches located downstream and upstream from the proposed Watana and Devil Canyon dam sites. Within this context, two types of floods were studied: the largest annual floods and the largest annual floods during ice conditions (October-May). Procedures were developed to estimate the annual instantaneous peak and the October-May instantaneous peak for selected frequencies of occurrence on ungaged rivers within the upper Susitna River basin. Procedures were also developed to estimate the error associated with estimates made by the above mentioned procedures. Typical hydrographs were developed indicating flood shape, peak, and volume for selected frequencies of occurrence. Flow volume-duration frequency curves were also developed for the May-July and August-October periods on the Susitna River at Gold Creek.

2 - SUMMARY

This report describes the Susitna Regional Flood Peak Frequency Analysis conducted by R&M Consultants, Inc., for Acres American, Inc. Acres American, under contract with the State of Alaska, is conducting a study concerning the feasibility of developing a hydroelectric complex on the upper Susitna River.

The results of single station flood frequency analyses are presented for 12 stations having annual instantaneous flood peak data, and for 11 stations having maximum October-May mean daily flow data. Four frequency distributions were analyzed, from which the Three Parameter Log Normal Distribution was selected. Subsequently, the October-May maximum mean daily flows for selected frequencies of occurrence were converted to instantaneous peaks.

By using the index method of regionalizing the data, procedures were developed to estimate the annual instantaneous peak and the October-May instantaneous peak for selected frequencies of occurrence on ungaged rivers within the upper Susitna River basin. Procedures were also developed to estimate the error associated with estimates made by the above mentioned procedures. The results of this analysis are then compared to those of previous regional analyses.

Typical hydrographs for different frequency floods were developed for the Susitna River at Gold Creek. A flood volume-duration analysis was also conducted for May-July flows recorded at Susitna River at Gold Creek.

3 - FLOOD FREQUENCY ANALYSIS

The Susitna Regional Flood Frequency Analysis was conducted in the following four steps;

a. Single station flood frequency analyses were conducted at stations thought to be hydrologically similar to the upper Susitna River basin.

b. The single station flood frequency analyses were regionalized.

c. An error analysis was conducted in order to estimate the amount of error associated with flood peak estimates in ungaged areas.

d. The results of this analysis were compared with 2 regional analyses which have been conducted by the U.S. Geological Survey.

Each of these steps is explained fully in the report that follows:

3.1 - Single Station Frequency Analysis

In order to select stream gaging stations that are hydrologically similar to the upper Susitna River basin, factors such as mean annual runoff volume, climate, and geology were examined for rivers with USGS stream gaging stations in southcentral Alaska. Of those stations identified, only those with 10 or more years of record and greater than 150 square miles in size were utilized. The basins finally selected were as follows:

Susitna River at Gold Creek
Susitna River near Denali
Maclaren River near Paxson
Susitna River near Cantwell
Chulitna River near Talkeetna
Talkeetna River near Talkeetna
Montana Creek near Montana
Skwentna River near Skwentna
Caribou Creek near Sutton
Matanuska River at Palmer
Tonsina River at Tonsina
Copper River near Chitina

The last four stations are not as good as the first eight, due to their distance from the Susitna basin and their exposure to a maritime climate. However, these differences were not sufficient to warrant exclusion from the analysis.

Three types of floods were abstracted from the records: annual instantaneous peak discharge, annual maximum mean daily discharges, and annual maximum October-May mean daily discharges. Both the annual instantaneous peak discharge and the mean daily discharge data are available for each of the stations selected, with the exception of Montana Creek. Montana Creek is a crest gage station with only annual instantaneous peak discharge data available.

For each station with mean daily discharge data, a ratio was developed between the annual instantaneous peak discharge and the annual maximum mean daily discharge (Table 3.1). Where an occasional annual instantaneous peak discharge value was missing from the station record, the ratio was used to predict the annual instantaneous peak value.

A Fortran IV computer program (Condie et. al., 1977) was used to fit the Gumbel I, Log Normal, Three Parameter Log Normal and Log Pearson Type III distributions to both the annual instantaneous flood peaks and the annual maximum October-May mean daily discharges. The program ranks the annual flood peaks and fits the frequency curves by the method of maximum likelihood. When the maximum likelihood methods have no true solution, a moments fit is used. For the Log Pearson Type III distribution, both the maximum likelihood and the moment fits are calculated in the program. The ranked discharges are assigned plotting positions by the Weibull formula:

$$T = (N + 1) / M \qquad (3.1)$$

Where:

T = return period in years

N = record length in years

M = the rank

Tables 3.2 and 3.3 illustrate the degree of fit achieved by fitting each of the distributions to both the annual instantaneous flood peak series and the annual maximum October-May mean daily discharge series. From the results shown in Table 3.3, the Three Parameter Log Normal Distribution provides the best fit of the data, although the Log Normal Distribution is also acceptable. The Three Parameter Log Normal Distribution is adopted almost exclusively throughout this study. At two stations in the annual maximum October-May mean daily discharge series it was not possible to fit the Three Parameter Log Normal Distribution to the data. At these two stations, Susitna River at Cantwell and Skwentna River near Skwentna, the Log Normal Distribution was used. Plots of the flood frequency curves for each of the stations and flood series are exhibited in Attachments A and B.

Since the computer program only considers recurrence intervals of 1.005, 1.05, 1.25, 2, 5, 10, 20, 50, 100, 200 and 500 years, the graphs of the annual instantaneous flood peak frequency curves were extrapolated to the 10,000-year recurrence interval.

The annual maximum October-May mean daily discharge frequency curves were converted to October-May instantaneous peak discharge frequency curves using the ratios discussed earlier. Thus, the remainder of this study only considers the annual instantaneous flood peak frequencies and the October-May instantaneous flood peak frequencies.

3.2 - Regionalization of Frequency Analyses

Regionalization of the single-station frequency curves involves developing regional relationships which can be used to calculate design flood peaks within a "homogeneous flood region". Theoretically, the flood response of all catchments within a homogeneous flood region is the same. In practice, however, the term "homogeneous" implies that the response characteristics of the individual basins are not significantly different and that these differences, coupled with sampling errors associated with the discharge measurement, yield errors in the regional relationships which are within acceptable limits. The purpose of developing the regional relationships is to apply them to ungaged drainage basins as well as to gaged drainage basins for which discharge records are too short to yield accurate results.

To determine if the stations selected were homogeneous with regard to runoff, a standard Student's "t" test of homogeneity of the $Q_{20}/Q_2 = Y_{20}$ variables was used. For each flood series within the region being analyzed, individual station Y_{20} values were computed (Tables 3.4 and 3.5) and were used to calculate the allowable range in Y_{20} by applying the following equation:

$$\bar{Y}_{20} - (t_{m-1}) \left[S_{20}^2 \left(1 + \frac{1}{(m-1)}\right) \right]^{\frac{1}{2}} < Y_{20} < \bar{Y}_{20} + (t_{m-1}) \left[S_{20}^2 \left(1 + \frac{1}{(m-1)}\right) \right]^{\frac{1}{2}} \quad (3.2)$$

Where:

Y_{20}	=	ratio of 20-year return flood to the mean annual flood for a single station
$\bar{Y}_{20}$	=	an average of the single station Y_{20} values for a particular flood series
t_{m-1}	=	"t" statistic for m-1 degrees of freedom at the 95 percent confidence level
S_{20}	=	standard deviation of the individual stations at the 20-year return period
m	=	number of stations in the region

As can be seen from Tables 3.4 and 3.5, all individual Y_{20} value are within the limits of the 95% confidence level. Therefore, all of the stations selected for use in the Susitna Regional Flood Frequency Analysis are homogeneous with respect to both annual instantaneous peak discharges and October-May instantaneous peak discharges.

Once it was determined that all of the stations selected for use in the analysis were homogeneous with respect to discharge, the index method was used to regionalize the single-station data. The index method consists of two parts (Dalrymple, 1960). The first involves the development of a regional dimensionless frequency curve representing the ratio of the flood of any given frequency to the mean annual flood. The second part requires the development of regression equations for relating the mean annual flood to the physiographic and climatic characteristics of the drainage basins. By combining the mean annual flood with the regional dimensionless frequency curve, a frequency curve for any ungaged location within the region can be developed.

This method assumes that throughout large regions that are considered to be homogeneous with respect to flood producing characteristics, individual basins with widely varying drainage areas will have frequency curves of equal shape and slope. Any differences in the shape and slopes of the individual curves are attributed to sampling error.

To produce a regional curve from single station curves, Dalrymple (1960) recommends that the dimensionless frequency curves for a homogeneous region be evaluated as the median of the individual frequency curves within the region. Since the weighted median has also been found to be useful in this type of analysis (Acres American, 1977), the dimensionless discharges at the 1.005, 1.05, 1.25, 2, 5, 10, 20, 50, 100, 200 and 500-year recurrence intervals were analyzed with regards to the mean, median and weighted median at each recurrence interval (Tables 3.6 and 3.7). The weighted median was determined by using the number of years of record at a station as the weight for that station. The dimensionless frequency curve was estimated from the median of the 12 stations used in the analysis. The median value had a better general fit than either the mean or the weighted median values. The mean value at the 10,000-year return period was abnormally high, while the weighted median values started decreasing after the 100-year return period.

The confidence limits for each of the regional curves are based on values computed at the 1.005, 1.05, 1.25, 2, 5, 10, 20, 50, 100, 200 and 500-year recurrence intervals from the standard deviation of the single station curves about the regional curves, using the following equations.

The standard deviation of single station curve values about the regional curve is given by

$$ST = \left[\frac{\sum_{1}^{m} [(Y_T - \bar{Y}_T)]^2}{(m-1)} \right]^{1/2} \qquad (3.3)$$

Where:

ST = standard deviation at T-year return period

$\bar{Y}_T$ = value of median dimensionless regional curve at T-year return period

Y_T = value of dimensionless single station curve at T-year return period

m = number of single station curves

The standard error of the median (or regional curve in this case) as a proportion of the median is given by

$$SEM_T = \frac{ST}{\bar{Y}_T \ (m)^{\frac{1}{2}}} \qquad (3.4)$$

Where:

SEM_T = relative standard error : median, i.e. regional curve at T-yeaı ›eriod.

The associated 95 percent confidence limits for he regional curve are derived from the standard error and the corresponding "t" statistic coefficients.

A stepwise multiple linear regression computer ·ogram (Dixon et. al., 1977) was used to relate the mean annual ıstantaneous peak flow and the mean October-May instantaneous peak flow to the physiographic and climatic characteristics of tl drainage basins. The program performs a forward steppir multiple linear regression analysis and tests the "significance" ›f variables, both those used in the equation and those remaini: to be used, by their "F" ratio at each step of the analysis. ıe standard error of the estimate and the coefficient of determinǝ on are determined for each step. The physiographic and climat parameters used and their values for each of the stations are presented in Table 3.8.

In order to test the effect of a log-transform oı the flow data, the HEC Multiple Linear Regression computer p gram was used. Non-transform and log-transform regressic analyses were conducted on the mean annual instantaneous eak flow and the mean October-May instantaneous peak flow. T ꞓ non-transformed results obtained by HEC's stepwise backward rogram duplicated results obtained in the initial analysis. The f lowing information indicates that the log-transform analysis di‹ not improve the statistics. Consequently, the non-transform r ȷression equations were selected.

	R^2	Standard Eı ›r of Estimate (s)		95% Error
Mean Annual Flood				
Non-Transform	0.9994	+1465	-1‹ 5	4%
Log-Transform	0.9930	+2612	-2ⸯ 2	14.5%
Oct-May Mean Flood				
Non-Transform	0.9709	+3081	-3‹ 1	20%
Log-Transform	0.9141	+4425	-2‹ 9	50%

The equations that were finally selected, including the coefficient of determination and the standard error of the estimate, are as follows:

Mean Annual Instantaneous Flood Peak

$$Q_A = 7.06(D.A) + 46.36(L) + 697.14(G) + 200.15(MAP) - 49.55(MAS) - 2594 \quad (3.5)$$

$$R^2 = 0.9994$$

$$S.E.E. = 1465$$

Mean October-May Instantaneous Flood Peak

$$Q_{o-m} = 1.56(D.A.) + 143.35(L) - 2894 \quad (3.6)$$

$$R^2 = 0.9853$$

$$S.E.E. = 3081$$

Where:

Q_A	=	Mean Annual Instantaneous Flood Peak, cfs.
Q_{o-m}	=	Mean October-May Instantaneous Flood Peak, cfs.
D.A.	=	Drainage Area, sq. mi.
L	=	Stream Length, mi.
G	=	Percent of Drainage Area Covered by Glaciers, %
MAP	=	Mean Annual Precipitation, in.
MAS	=	Mean Annual Snowfall, in.

Of the five parameters selected for computing the mean annual instantaneous flood peaks, drainage area explains over 98 percent of the variation between the regional mean annual flood and those of the individual stations. However, inclusion of the other four basin and climatic parameters (main channel length, percent of glacial area, mean annual precipitation, and mean annual snowfall) significantly reduced the standard error of estimate for the mean annual flood peak. Since the regional mean annual flood is the basis from which all other recurrence intervals are estimated, the four other parameters were included.

Similar logic applies to the selection of parameters for the mean October-May instantaneous flood peak. Drainage area and main channel length explain over 97 percent of the variation. However, inclusion of additional parameters did not significantly decrease the standard error of estimate in this case, so only the above two parameters were used.

3.3 - Relative Standard Error of the Estimate for the Index Method

Equation (3.3) gives the standard deviation, S_T, of the dimensionless frequency curves about the regional curve. Equation (3.7) is then used to calculate the associated relative standard error of estimate, SE_T.

$$SE_T = \frac{S_T}{\bar{Y}_T} \qquad (3.7)$$

Where:

$\bar{Y}_T$ = value of median dimensionless regional curve for the T-year return period

SEM_T in Equation (3.4) represents the standard error of estimate of the median or regional curve. SE_T in Equation (3.7) represents the standard error of the individual station curves about the regional curve. Note that $SEM_T = SE_T \; / \; (m)^{\frac{1}{2}}$.

In order to combine the errors SE_T associated with the application of the index curve with the errors in the calculation of the mean annual flood, Equation (3.8) is applied. An outline of the derivation of this equation is presented in the report entitled "Regional Flood Frequency Analysis" (Acres American, 1977).

$$SEC_T = (SE_T^2 + SE_2^2)^{\frac{1}{2}} \qquad (3.8)$$

Where:

SEC_T = composite relative standard error of estimate of T-year event

SE_2 = relative standard error of estimate associated with the evaluation of the mean annual flood

Figures 3.1 and 3.2 present dimensionless flood frequency curves which can be used in conjunction with Equations (3.5) and (3.6) to predict the annual instantaneous and October-May instantaneous flood peaks at specific recurrence intervals. The figures also present curves for computing the associated composite 95 percent confidence limits for the estimate.

3.4 - Comparison with Results of Previous Studies

Previous regional flood studies carried out in the Susitna River basin and surrounding basins include:

(a) Lamke, R.D. (1979)

Multiple regression equations for different recurrence intervals were developed for two regions of the state. Area I consists of most areas of Alaska with a maritime climate, excluding the Aleutian Islands and the Pacific Ocean side of the Alaska Peninsula. Area II consists of those parts of Alaska with transitional, continental, and arctic climates, together with the Aleutian Islands and the Pacific Ocean side of the Alaskan Peninsula which have maritime climate. The Susitna River basin is included in Area II.

(b) Freethey, G.W. and D.R. Scully (1980)

Multiple regression equations for different recurrence intervals were developed using peak discharges from 50 Cook Inlet gaging stations with 10 years or more of data.

No regional flood studies in the area have used the index method.

Table 3.9 lists the parameters used in the regression analyses and compares the standard errors of estimate for the 2-, 5-, 10-, 50- and 100-year flood peaks. Values for the 100-year flood peaks were not derived by either of the USGS studies. It is evident from this table that the standard errors achieved in this study are lower than those in the other studies. Fewer stations were used in this study, but the stations were either within the transitional climate region or were on its borders. The USGS studies used gaging stations over much larger areas, with consequently larger differences in climate. Attachment C presents a comparison between the Susitna Regional Flood Peak estimates and estimates using the two USGS methods.

TABLE 3.1

RATIO OF INSTANTANEOUS FLOOD PEAKS TO MAXIMUM MEAN DAILY FLOW FOR SPECIFIC STATIONS

Station Name	Location	QP/QD[1]	Standard Deviation	Number in Sample
Susitna River	at Gold Creek	1.060	0.036	31
Caribou Creek	near Sutton	1.617	0.365	22
Matanuska River	at Palmer	1.221	0.168	24
Susitna River	near Denali	1.104	0.049	19
Maclaren River	near Paxson	1.091	0.077	19
Susitna River	near Cantwell	1.082	0.059	6
Chulitna River	near Talkeetna	1.044	0.032	13
Talkeetna River	near Talkeetna	1.219	0.102	16
Skwentna River	near Skwentna	1.067	0.044	18
Tonsina River	at Tonsina	1.031	0.036	28
Copper River	near Chitina	1.043	0.061	23

1 Mean Ratio of Annual Instantaneous Flood Peak to Annual Maximum Mean Daily Flow.

TABLE 3.2

DISTRIBUTION STATISTICS FOR ANNUAL INSTANTANEOUS PEAK AND OCT-MAY MEAN DAILY PEAK FLOWS

				GUMBEL I				LOG NORMAL				3 PARAMETER LOG NORMAL					LOG PEARSON TYPE III (Moments)			LOG PEARSON TYPE III (maximum likelihood)		
STATION NUMBER	RIVER NAME	LOCATION	N	CS	CK	SUM OF DEVIATIONS	MEAN DEVIATION	CSL	CKL	SUM OF DEVIATIONS	MEAN DEVIATION	CSLA	CKLA	AVG.CV.	SUM OF DEVIATIONS	MEAN DEVIATION	AVG.CV.	SUM OF DEVIATIONS	MEAN DEVIATION	AVG.CV.	SUM OF DEVIATIONS	MEAN DEVIATIONS
ANNUAL INSTANTANEOUS PEAKS FLOWS																						
2920	Susitna R.	at Gold Cr.	25	0.6830	2.9269	-22.90	5.16	0.0664*	2.8362	-19.28	4.23	-0.0805	2.9658*	15.01*	-18.09*	4.11*	15.39	-19.01	3.97	15.51	-20.67	4.38
2820	Caribou Cr.	nr. Sutton	21	0.9338	4.2274	-22.03	7.14	-0.0491	3.6494	-19.39*	7.07*	-0.0228*	3.6401*	15.53*	-19.56	7.11	16.49	-19.57	7.15	16.16	-21.98	7.31
2840	Matanuska R.	at Palmer	17	0.2193	3.6631	10.05	4.32	-0.5370	3.9370	5.46	4.17*	-0.0121*	3.5943*	10.59	2.03*	5.53	Upper Boundary Is Too Low			Upper Boundary Is Too Low		
2910	Susitna R.	nr. Denali	20	2 4985	10.3480	-49.50	12.95	1.8453	7.0725	-33.19*	11.21	0.0633*	4.2263*	23.59*	-38.16	8.39*	35.46	-38.81	8.39*	No Solution		
2912	Maclaren R.	nr. Paxson	22	0.9062	3.4430	-15.76	7.16	0.5539	2.6682*	- 8.75	6.14	-0.3915*	2.6565	25.66	8.93	3.99*	15.93*	- 8.13*	4.90	No Solution		
2915	Susitna R.	nr. Cantwell	11	0.3325	3.1946	- 0.90*	6.46	-0.1474	3.2888	1.15	5.85*	-0.1172*	3.2667*	18.79*	1.32	6.01	19.01	1.92	6.21	Upper Boundary Is Too Low		
2924	Chulitna R.	nr. Talkeetna	18	2.9054	13.7449	-33.82	10.15	2.0599	10.0328	-23.88*	10.58	0.3512*	6.8509*	14.05	-27.36	9.21*	Lower Boundary Is Too High			12.89*	-29.93	9.45
2927	Talkeetna R.	nr. Talkeetna	15	1.8140	6.6111	- 1.99	8.16	1.0398	4.7599	5.88	8.80	-0.0921*	4 0752*	30.54*	- 0.74*	5.27	40.08	- 3.38	5.65	32.65	- 5.43	1.92*
2928	Montana Cr.	nr. Montana	10	0.9133	6.6962*	-26.31	9.59*	-1.2149	7.5292	-26.37	11.51	0.0324*	5.9998	22.31	-25.50*	9.65	Upper Boundary Is Too Low			Upper Boundary Is Too Low		
2943	Skwentna R.	nr. Skwentna	20	1.0748	4.6668*	-20.24	5.42	0.4430	4.0757	-19.07	6.23	0.0346*	4.2125	11.90*	-18.27*	5.42	13.81	-18.61	5.20*	12.23	-20.29	5.53
2080	Tonsina R.	at Tonsina	28	0.6969	3.3804	-11.33	3.54	0.0306*	2.8533	- 9.96	3.44	-0.0817	2.8733*	12.73*	- 9.15*	3.09*	12.88	- 9.88	3.38	12.83	-11.34	3.65
2120	Copper R.	nr. Chitina	25	1.6079	7.3832	-16.95	3.39	0.9367	5.5081	-15.77	3.71	0.1061*	4.8017*	8.59	- 15.57*	3.11*	11.98	-15.68	3.14	8.35*	-16.99	3.40
OCT-MAY MEAN DAILY PEAK FLOWS																						
2920	Susitna R.	at Gold Cr.	30	0.2895	3.8267	9.49	6.04	-0.9208	5.1200*	4.47	5.98	0.0009*	3.6135	8.76	- 3.39*	3.82*	Upper Boundary Is Too Low			Upper Boundary Is Too Low		
2820	Caribou Cr.	nr. Sutton	23	1.1847	4.6347	-16.66	12.90	-0.5297	4.3442	-4.40*	2.82*	0.0363*	3.4587*	22.25	- 9.95	7.51	24.25	- 9.34	7.36	20.34*	-12.39	8.25
2840	Matanuska R.	at Palmer	24	1.7691	8.7422	-16.47	6.90	-0.0550	3.6148*	-10.60*	5.97	-0.0449*	3.6202	19.25*	-10.70	6.95	20.73	-10.91	6.94	20.35	-13.76	6.79*
2910	Susitna R.	nr. Denali	16	1.3238	5.3382*	-10.57	9.09	0.1569	3.6858	- 9.12*	7.30	-0.0939*	3.6889	25.84*	-20.81	6.56*	27.98	-10.54	6.76	27.46	-12.55	6.83
2912	Maclaren R.	nr. Paxson	15	2.1811	9.2765	0.90	13.63	0.6728	4.3661	0.51*	10.37	-0.1931*	3.8534*	38.51*	- 6.32	5.31*	47.26	- 7.98	7.13	44.44	-11.66	6.17
2915	Susitna R.	nr. Cantwell	10	-0.0092	3.7052	6.56	5.88*	-0.9043*	4.5940*	5.33*	6.58	NO SOLUTION					29.00	10.07	5.54	No Solution		
2924	Chulitna R.	nr. Talkeetna	11	0.5364	3.9480	-1.16	7.93	-0.1723	3.3067	0.39*	6.28	-0.1638*	3.3051*	24.41	0.45	6.29	24.45	1.52	6.22*	18.11*	2.06	7.66
2927	Talkeetna R.	nr. Talkeetna	15	0.4151	3.1464	0.02*	11.90	-0.2369	2.6070*	0 14	11.01*	-0.1968*	2.6042	22.46*	0.56	11.34	22.83	1.65	11.23	Upper Boundary Is Too Low		
2928	Montana Cr.	nr. Montana	0**																			
2943	Skwentna R.	nr. Skwentna	15	-0.1794*	2.1487	-0.72	9.03	-0.4334	2.3244*	-0.58*	8.86	NO SOLUTION					15.68	1.10	7.98*	No Solution		
2080	Tonsina R.	at Tonsina	26	2.4301	12.2475	-1.32*	10.02	0.2485	3.9367	5.01	9.98	-0.0632*	3.6135*	21.23*	7.76	9.92	24.10	5.92	9.83	23.11	3.26	9.81*
2120	Copper R.	nr. Chitina	21	0.2134	3.0599	-1.53*	3.47	-0.3625	3.0558	-5.10	3.21*	-0.0281*	2.9764*	9.73	-7.64	3.61	12.11	- 6.77	3.20*	7.96*	- 9.00	4.02

N = record length in years
CS = coefficient of skewness of natural data
CK = coefficient of kurtosis of natutal data
CSL = coefficient of skewness of the natural logs of the data
CKL = coefficient of kurtosis of the natural logs of the data
CSLA = coefficient of skewness of the natural logs of the transformed data
CKLS = coefficient of kurtosis of the natural logs of the transformed data

Avg.CV. = average coefficient of variation for all return periods estimated
Sum of Deviations = $\Sigma Q-Q_D/Q_D$ for 1.25, 2, 5, 10 and 20 year return periods
Mean Deviation = $\Sigma|Q-Q_D|/5$ for 1.25, 2, 5, 10 and 20 year return periods
GI = Gumbel I
LN = Log Normal
3PLN = Three Parameter Log Normal
LP-M = Log Pearson Type III (moments)
LP-ML = Log Pearson Type III (maximum likelihood)

* Distribution best fitting a given parameter
** A Crest-Gage sration only
Upper boundary is too low - less than twice the magnitude of the largest flood on record.
Lower boundary is too high - greater than the smallest flood on record.

Theoretical Values

Gumbel I	Log Normal	3PLND
CS=1.14	CSL=0.0	CSLA=0.0
CK=5.4	CKL=3.0	CKLA=3.0

TABLE 3.3

MEAN DISTRIBUTION STATISTICS FOR ANNUAL INSTANTANEOUS PEAK AND OCT. - MAY MAXIMUM MEAN DAILY FLOWS

	ANNUAL INSTANTANEOUS PEAKS			OCT. - MAY MAXIMUM DAILY FLOWS		
	MEAN	STANDARD DEVIATION	COEFFICIENT OF VARIATION (%)	MEAN	STANDARD DEVIATION	COEFFICIENT (VARIATION (%)
Gumbel I						
Coefficient of Skew	1.22	0.83	68	0.92	0.91	99
Coefficient of Kurtosis	5.86*	3.34	57	5.46*	3.20	59
Sum of Deviations	-17.64	15.79	90	-2.86	8.43	295
Mean Deviation	6.95	2.89	42	8.80	3.17	36
Log Normal						
Coefficient of Skew	0.42	0.92	219	0.23	0.48	209
Coefficient of Kurtosis	4.85	2.29	47	3.73	0.87	23
Sum of Deviations	-13.59	12.61	93	-1.27*	5.45	429
Mean Deviation	6.91	2.95	43	7.21	2.70	37
Three Parameter Log Normal						
Coefficient of Skew	-0.02*	0.17	850	0.09*	0.08	89
Coefficient of Kurtosis	4.10	1.27	31	3.41	0.40	12
Sum of Deviations	-13.34*	14.06	105	-4.45	6.32	142
Mean Deviation	5.91	2.26	38	6.79*	2.52	37
Log Pearson Type III (moments)						
Sum of Deviations	-14.58	11.78	81	-2.53	7.50	296
Mean Deviation	5.33	1.74	33	7.22	2.21	31
Log Pearson Type III (maximum likelihood)						
Sum of Deviations	-18.09	7.89	44	-7.72	7.25	94
Mean Deviation	5.09*	2.57	50	7.08	1.80	25

* Distribution best fitting a given parameter.

TABLE 3.4

HOMOGENEITY TEST
ANNUAL INSTANTANEOUS PEAKS

Station	$Q_{20}/Q_2 = Y_{20}$
Susitna River at Gold Creek	1.83
Caribou Creek near Sutton	1.82
Matanuska River at Palmer	1.49
Susitna River near Denali	1.81
MacLaren River near Paxson	2.02
Susitna River near Cantwell	1.68
Chulitna River near Talkeetna	1.47
Talkeetna River near Talkeetna	2.33
Montana Creek near Montana	1.96
Skwentna River near Skwentna	1.49
Tonsina River at Tonsina	1.72
Copper River near Chitina	1.35

$\bar{Y}_{20} = 1.748$

$S_{20} = 0.2776$

Limits of 95% Confidence Interval

1.11 - 2.39

The stations selected for use in the Susitna Regional Flood Peak Frequency Analysis are homogenous with respect to the annual instantaneous peaks at the 95% confidence level.

TABLE 3.5

HOMOGENEITY TEST
OCTOBER - MAY INSTANTANEOUS PEAKS

Station	$Q_{20}/Q_2 = Y_{20}$
Susitna River at Gold Creek	1.57
Caribou Creek near Sutton	2.63
Matanuska River at Palmer	2.24
Susitna River near Denali	2.35
MacLaren River near Paxson	3.32
Susitna River near Cantwell	2.33
Chulitna River near Talkeetna	1.98
Talkeetna River near Talkeetna	2.12
Skwentna River near Skwentna	1.76
Tonsina River at Tonsins	2.45
Copper River near Chitina	1.50

$\bar{Y}_{20} = 2.205$

$S_{20} = 0.5175$

Limits of 95% Confidence Interval

0.99 - 3.41

The stations selected for use in the Susitna Regional Flood Frequency Analysis are homogenous with respect to the October - May instantaneous peaks at the 95% confidence level.

misc7/w6

TABLE 3.6

REGIONAL ANNUAL INSTANTANEOUS DIMENSIONLESS FLOOD VALUES

Return Period	Susitna River at Gold Creek	Caribou Creek near Sutton	Matanuska River at Palmer	Susitna River near Denali	MacLaren River near Paxson	Susitna River near Cantwell	Chulitna River near Talkeetna	Talkeetna River near Talkeetna	Skwentna River near Skwentna	Tonsina River at Tonsina	Copper River near Chitina	Montana Creek near Montana	Mean	Median	Weighted Median
1.005	0.50	0.45	0.45	0.81	0.79	0.49	0.76	0.62	0.66	0.53	0.76	0.17	0.58	0.52	0.58
1.050	0.58	0.55	0.57	0.83	0.81	0.59	0.80	0.66	0.72	0.61	0.81	0.34	0.66	0.64	0.76
1.25	0.75	0.73	0.77	0.88	0.86	0.76	0.88	0.77	0.84	0.77	0.89	0.63	0.79	0.77	0.86
2	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
5	1.36	1.36	1.24	1.26	1.32	1.31	1.19	1.46	1.22	1.31	1.15	1.45	1.30	1.31	1.24
10	1.60	1.59	1.38	1.51	1.63	1.50	1.33	1.86	1.36	1.52	1.25	1.72	1.52	1.52	1.69
20	1.83	1.82	1.49	1.81	2.02	1.68	1.47	2.33	1.49	1.72	1.35	1.96	1.75	1.77	1.84
50	2.14	2.10	1.63	2.29	2.67	1.91	1.67	3.04	1.66	1.98	1.47	2.26	2.07	2.04	1.79
100	2.38	2.32	1.72	2.74	3.27	2.08	1.82	3.67	1.79	2.17	1.56	2.47	2.33	2.25	1.94
200	2.63	2.54	1.81	3.26	3.99	2.25	1.98	4.39	1.92	2.37	1.65	2.68	2.62	2.46	2.10
500	2.96	2.83	1.92	4.07	5.15	2.47	2.21	5.48	2.09	2.63	1.78	2.95	3.05	2.73	2.46
10,000	3.84	3.64	1.97	9.97	11.65	3.10	2.99	11.54	2.75	3.39	2.20	3.62	5.06	3.51	3.06

TABLE 3.7

REGIONAL OCTOBER - MAY INSTANTANEOUS DIMENSIONLESS FLOOD VALUES

Return Period	Susitna River at Gold Creek	Caribou Creek near Sutton	Matanuska River at Palmer	Susitna River near Denali	MacLaren River near Paxson	Susitna River near Cantwell	Chulitna River near Talkeetna	Talkeetna River near Talkeetna	Skwentna River near Skwentna	Tonsina River at Tonsina	Copper River near Chitina	Mean	Median	Weighted Median
1.005	0.36	0.18	0.34	0.40	0.45	0.33	0.40	0.35	0.48	0.39	0.48	0.38	0.39	0.45
1.050	0.51	0.30	0.44	0.48	0.50	0.43	0.50	0.45	0.57	0.47	0.59	0.48	0.48	0.48
1.25	0.74	0.57	0.66	0.67	0.65	0.65	0.70	0.67	0.75	0.66	0.78	0.68	0.67	0.75
2	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
5	1.28	1.67	1.51	1.53	1.76	1.54	1.42	1.47	1.34	1.56	1.24	1.48	1.51	1.24
10	1.44	2.15	1.88	1.93	2.47	1.93	1.70	1.80	1.55	2.00	1.38	1.84	1.88	1.93
20	1.57	2.63	2.24	2.35	3.32	2.33	1.98	2.12	1.76	2.45	1.50	2.20	2.24	2.35
50	1.73	3.31	2.74	2.94	4.70	2.88	2.35	2.54	2.02	3.10	1.63	2.72	2.74	2.94
100	1.84	3.84	3.13	3.42	5.96	3.31	2.63	2.87	2.22	3.64	1.73	3.14	3.13	3.42
200	1.94	4.40	3.53	3.93	7.43	3.77	2.91	3.20	2.42	4.22	1.82	3.60	3.53	1.94
500	2.06	5.18	4.10	4.66	9.76	4.40	3.30	3.67	2.69	5.05	1.93	4.25	4.10	2.06

TABLE 3.8

PHYSIOGRAPHIC AND CLIMATIC PARAMETERS[1]

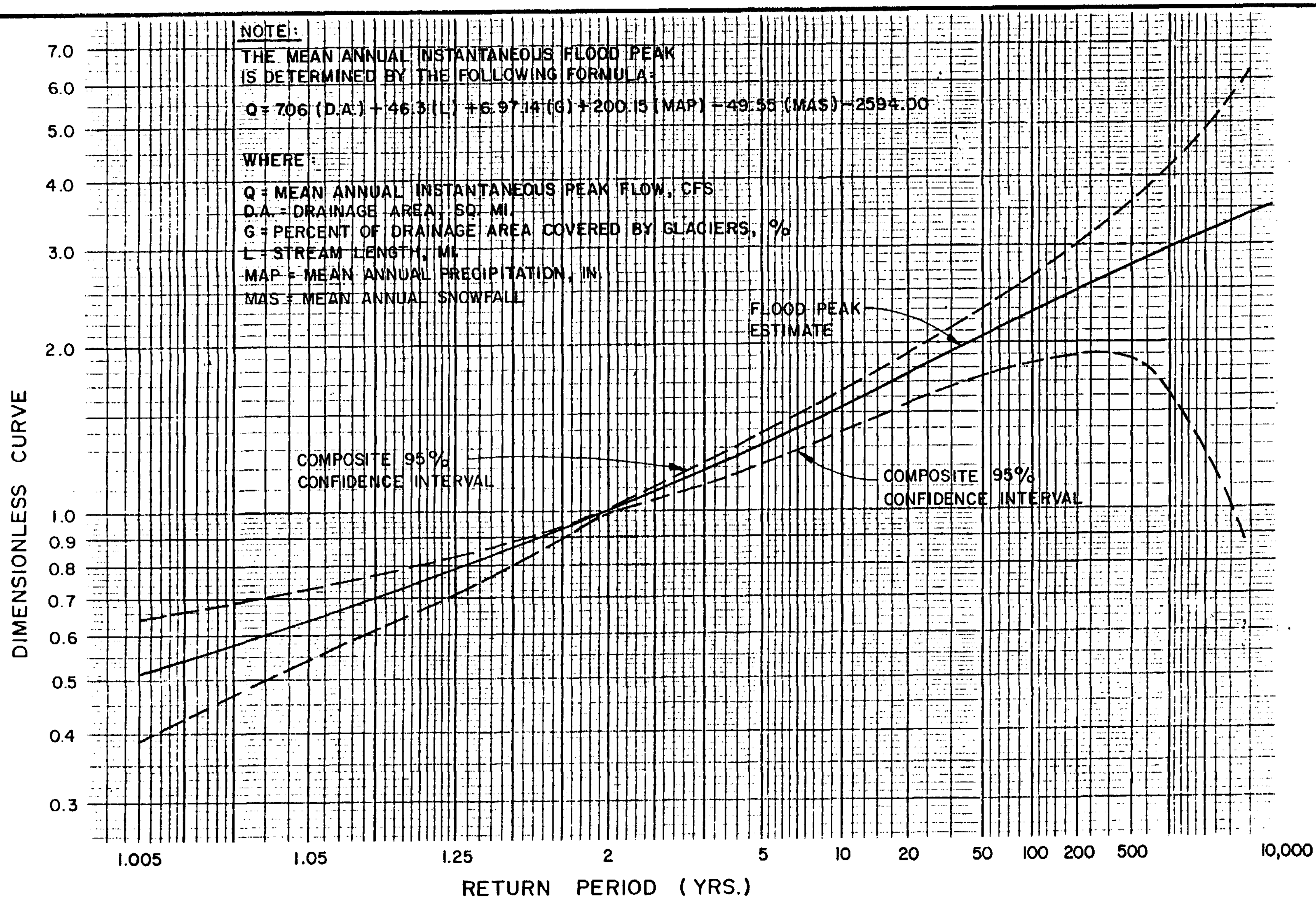
Station Name	Location	Drainage Area (sq. mi.)	Main Channel Slope (ft./mi.)	Stream Length (mi.)	Mean Basin Elevation (ft.)	Area of Lakes & Ponds (%)	Area of Forests (%)	Area of Glaciers (%)	Mean Annual Precipitation (in.)	Precipitation Intensity (in.)	Mean Annual Snowfall (in.)	Mean Minimum January Temperature (°F)
Susitna R.	at Gold Creek	6,160	10.2	189.0	3420.0	1.0	7.0	5.0	29.0	2.0	200.0	-4.0
Caribou Cr.	nr. Sutton	289	13.6	30.0	4190.0	0.0	10.0	0.0	28.0	1.5	80.0	2.0
Matanuska R.	at Palmer	2,070	79.7	77.0	4000.0	0.0	14.0	12.0	35.0	1.5	80.0	4.0
Susitna R.	nr. Denali	950	56.6	51.0	4510.0	1.0	1.0	25.0	60.0	2.0	400.0	-6.0
MacLaren R.	nr. Paxson	280	133.0	23.0	4520.0	1.0	0.0	19.0	55.0	1.5	400.0	-6.0
Susitna R.	nr. Cantwell	4,140	10.0	107.0	3560.0	2.0	5.0	7.0	32.0	1.5	200.0	-4.0
Chulitna R.	nr. Talkeetna	2,570	23.0	87.0	3760.0	1.0	22.0	27.0	55.0	1.6	250.0	-5.0
Talkeetna R.	nr. Talkeetna	2,006	35.0	90.3	3630.0	0.0	25.0	7.0	70.0	2.5	150.0	-2.0
Montana Cr.	nr. Montana	164	114.0	25.0	1930.0	3.0	54.0	0.0	40.0	2.2	90.0	0.0
Skwentna R.	nr. Skwentna	2,250	30.6	98.0	2810.0	5.0	34.0	16.0	43.0	2.0	140.0	-5.0
Tonsina R.	at Tonsina	420	71.0	46.0	3600.0	4.0	27.0	11.0	25.0	2.0	180.0	-2.0
Copper R.	nr. Chitina	20,600	14.4	178.0	3620.0	3.0	22.0	17.0	37.0	2.0	120.0	-4.0

1 Values in this table are from the report entitled "Flood Characteristics of Alaska Streams" by Lanake (1979).

TABLE 3.9
COMPARISON OF REGRESSION EQUATIONS

Study	Homogenous Flood Region	Number of Hydrometric Stations Used	Physiographic Parameters Utilized	Recurrence Interval (Years)	SE of Estimate (Percent)
Present	Susitna & Neighboring Stations	12	D.A., L, G, MAP, MAS	2	±18
				5	±19
				10	±21
				50	±29
				100	±34
(a)	Area II	163	D.A., MAP, LP, F, T	2	±77
		163		5	±78
		132		10	±79
		26		50	±68
(b)	Cook Inlet	50	D.A., LP, MAP	2	+56, -36
				5	+51, -34
				10	+52, -34
				50	+61, -38

D.A. = drainage area, mi^2
L = stream length, miles
G = percent of basin as glaciers
MAP = mean annual precipitation, inches
MAS = mean annual snowfall, inches
LP = percent of area as lakes and ponds
F = percent of area forested
T = mean minimum January temperature, °F



Prepared by:

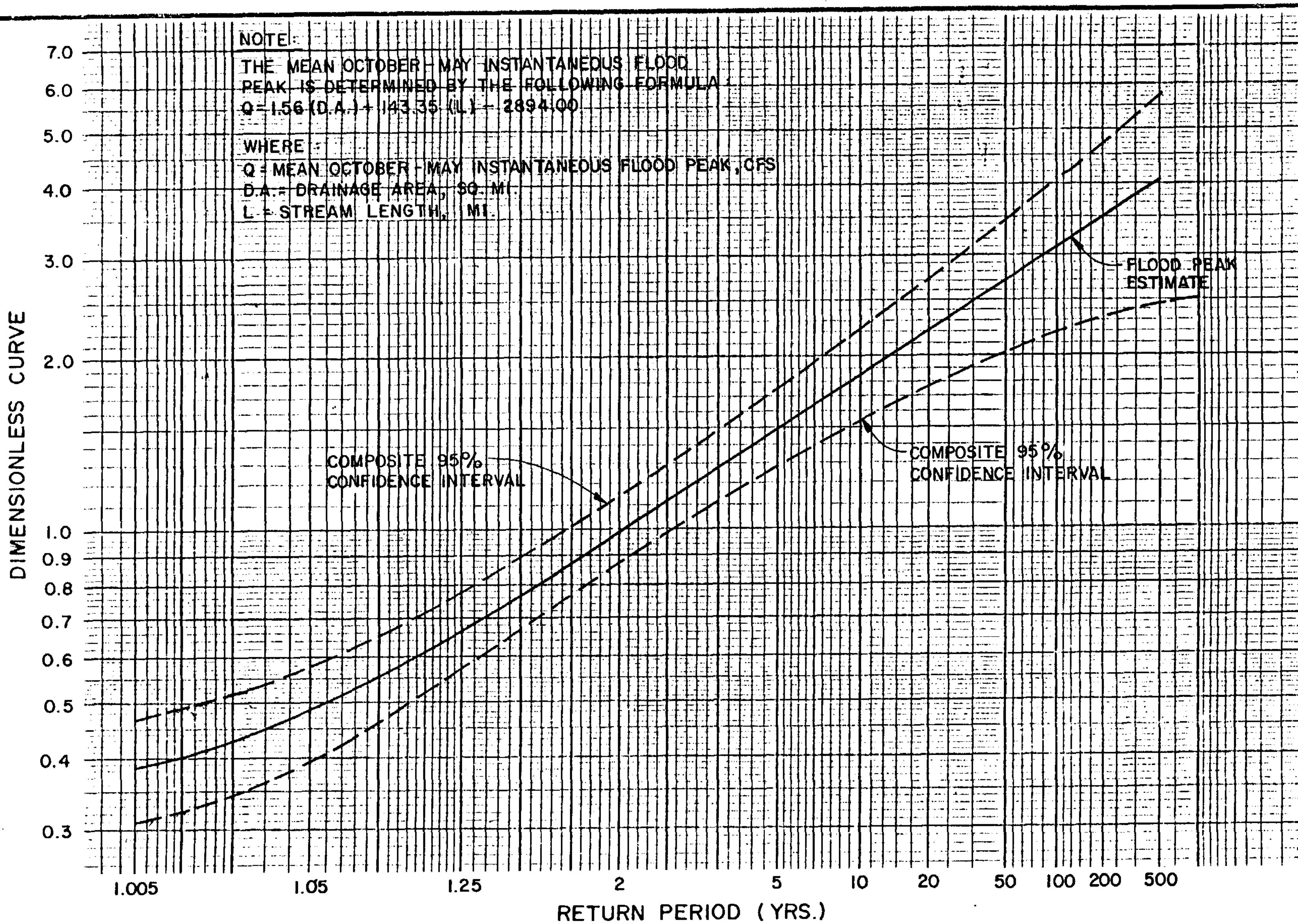
Prepared for:

R&M CONSULTANTS, INC.

DESIGN DIMENSIONLESS REGIONAL FREQUENCY CURVE
ANNUAL INSTANTANEOUS FLOOD PEAKS

FIGURE 3.1

ACRES



Prepared by:

R&M CONSULTANTS, INC.

DESIGN DIMENSIONLESS REGIONAL FREQUENCY CURVE

OCTOBER - MAY INSTANTANEOUS FLOOD PEAKS

FIGURE 3.2

Prepared for:

ACRES

4 - EVALUATION OF DESIGN FLOODS

Using Figures 3.1 and 3.2, annual instantaneous flood peaks and October-May instantaneous flood peaks can be predicted with a minimum of additional data. The figures will prove useful in assessing flood peaks at ungauged sites within the study area. The figures should not be used for basins with drainage areas smaller that 164 square miles, the smallest basin area included in the study. Use of the equations and figures for these smaller basins may result in unrealistic values. It is recommended that the regression equations developed by Freethey and Scully (1980) be used for determining flood peaks in these basins. Their analysis included basins as small as one square mile, and the equations have a smaller standard error than the regressiona equations developed by Lamke (1979), as seen in Table 3.9.

It is necessary to have information concerning the drainage area, the length of the main channel, the percent of the drainage area covered by glaciers, the mean annual precipitation, and the mean annual snowfall in order to predict the annual instantaneous flood peaks on drainage basins in the upper Susitna River region. It is also necessary to have information on drainage area and stream length to predict October-May instantaneous flood peaks in the upper Susitna region. When compiling this information, it is important that the information come from the same source, or at least represent the same precision, as the data used in the regression analyses.

Thus, the drainage area should be computed from U.S. Geological Survey topographic maps in the horizontal plane. Main channel slope is taken as the average slope between points 10% and 85% of the distance along the main stream from the lowest point of interest to the basin divide. The percent of glacial area is the total drainage area shown as glaciers on the topographic maps divided by the basin drainage area, as measured by the grid-sampling method or planimeters. The mean annual precipitation and mean annual snowfall are determined from isohyetal maps (NWS, 1972 or Lamke, 1979) using the grid sampling method. An example of the use of the figures for determining instantaneous flood peaks is given below.

Suppose it is desired to obtain the annual instantaneous flood peak with a 50-year recurrence interval on an ungaged basin in the upper Susitna River basin. The following drainage basin characteristics were determined.

Area of Drainage Basin = 164 sq. mi.
Stream Length = 25.0 miles
Percent Area of Glaciers = 0 percent
Mean Annual Precipitation = 40 inches
Mean Annual Snowfall = 90 inches

Using Equation (3.5), the mean annual instantaneous flood peak is determined to be 3269 cfs. Using Figure 3.1, the ratio of the 50-year peak to the mean annual peak is 2.04. Thus, the fifty year peak is

$$Q_{50} = 2.04\ (3{,}269\ \text{cfs})$$
$$Q_{50} = 6{,}670\ \text{cfs}$$

The confidence limits on this estimate could be found in the same manner by selecting the appropriate ratio from Figure 3.1. Thus the upper and lower 95% confidence interval are:

Upper 95% Confidence Interval
Q = 3.11 x 3269 = 10,170 cfs

Lower 95% Confidence Interval
Q = 1.01 x 3269 = 3,300 cfs

5 - EVALUATION OF TYPICAL FLOOD HYDROGRAPHS FOR SUSITNA RIVER AT GOLD CREEK

For the gaging station on the Susitna River at Gold Creek, typical flood hydrographs were developed from several measured hydrographs. The temporal distribution of annual maximum flood peaks was first determined, and is presented in Figure 5.1. The figure illustrates that the greatest frequency of floods (55%) occurs in June and the second highest frequency of floods (26%) occurs in August.

The five largest peak hydrographs were selected for two periods: May-July (rain-and-snowmelt floods), and August-October (rainfall floods). These were made dimensionless by dividing the flows by the peak daily mean discharge, centered about the peak with ±15 days and plotted on the same graph. The mean hydrograph is the arithmetic average of the five floods selected for each period. The five dimensionless hydrographs and the corresponding mean curve for each time period are depicted in Figures 5.2 and 5.3. These figures illustrate that the mean curves are typical of the general shape of the snowmelt and rainfall hydrographs, but that there is considerable variation from year to year.

The seasonal discharge frequency curves depicted in Figure 5.4 were derived by assuming that all floods from May through July are rain and snowmelt floods and that all floods from August through October are rainfall floods with high-altitude snowmelt. The seasonal daily peak discharges for each period are tabulated in Table 5.1. The corresponding published annual instantaneous peaks are listed in the respective seasonal period. The average ratios between instantaneous peaks (Q_I) and daily peaks (Q_D) for the snowmelt and rainfall floods were calculated by averaging all the ratios (Q_I/Q_D) for corresponding instantaneous and daily peaks. The calculated ratios (Q_I/Q_D) are 1.063 for snowmelt events and 1.052 for rainfall events. The missing instantaneous peaks were then computed by multiplying the daily peak by the appropriate (Q_I/Q_D) ratio. Using the three parameter log-normal frequency distribution and the instantaneous peaks from Table 5.1, the frequency curves for the May-July and August-October periods were computed. The annual instantaneous peak frequency curve is included on Figure 5.4 for comparison.

Fifty peak hydrographs were separated into the May-July and August-October periods and plotted. The base flows were estimated using standard techniques and subtracted from the hydrographs. The volume of each flood was estimated by planimetering the resulting hydrograph and tabulated in Table 5.2, together with the corresponding instantaneous peak. The flood volume frequency analysis for each period was conducted using the three parameter log-normal frequency distribution. The corresponding frequency curves with the 95% confidence levels are illustrated in Figures 5.5 and 5.6.

A power curve regression analysis was used to determine the correlation between the instantaneous peaks and the corresponding volumes. The correlation proved to be significant, with correlation coefficients of 0.794 and 0.825 for the May-July period and August-October period, respectively. The statistics are tabulated in Table 5.2 and illustrated graphically on Figures 5.7 and 5.8. As the correlation is acceptable, it allows for the development of the typical 100-, 500-, and 10,000-year flood hydrographs illustrated in Figures 5.9 and 5.10. These typical flood hydrographs were produced by using the general shape of the mean dimensionless hydrographs in Figures 5.2 and 5.3, and extrapolating the peaks and volumes for the 500- and 10,000-year floods from Figures 5.4, 5.5, and 5.6. The volumes beneath the flood hydrographs are those determined in the frequency analysis.

The typical hydrographs discussed here are qualitative indicators of flood hydrograph shapes. They should not be used for rigorous analytical calculations, but are intended to supplement them.

TABLE 5.1
DETERMINATION OF DAILY INSTANTANEOUS PEAK RATIO
SUSITNA RIVER AT GOLD CREEK

	May - July (Snowmelt Floods)			August - October (Rainfall Floods)		
Year	Daily Peaks (cfs)	Instant-aneous Peaks (cfs)	Ratio Q_I/Q_D	Daily Peaks (cfs)	Instant-aneous Peaks (cfs)	Ratio Q_I/Q_D
49	-	-	-	35,000	[38,700]	
50	34,000	(37,300)	1.097	27,600	[29,000]	
51	35,800	(37,400)	1.044	31,800	[33,500]	
52	43,300	(44,700)	1.032	41,900	[44,100]	
53	37,700	(38,400)	1.065	28,100	[29,600]	
54	30,100	[32,000]		41,000	(42,400)	1.034
55	39,000	[41,500]		56,900	(58,100)	1.021
56	51,500	(51,700)	1.004	31,000	[32,600]	
57	40,600	(42,200)	1.039	26,600	[28,000]	
58	28,000	[29,800]		47,800	(49,600)	1.038
59	39,600	[42,100]		59,700	(62,300)	1.044
60	39,300	[41,800]		40,100	(41,900)	1.045
61	54,000	(59,300)	1.098	26,000	[27,400]	
62	79,700	(80,600)	1.011	31,000	[32,600]	
63	49,000	(53,800)	1.098	35,000	[36,800]	
64	85,900	(90,700)	1.056	21,600	[22,800]	
65	39,900	(43,600)	1.093	33,600	[35,400]	
66	58,400	(63,600)	1.089	33,500	[35,200]	
67	50,000	[53,150]		76,000	(80,200)	1.055
68	39,700	(41,800)	1.053	21,800	[22,900]	
69	26,500	(28,400)	1.072	16,800	[17,700]	
70	30,800	[32,740]		31,600	(33,400)	1.057
71	66,300	[70,500]		77,700	(87,400)	1.125
72	70,700	(82,600)	1.168	26,400	[27,800]	
73	52,800	(54,100)	1.025	30,500	[32,100]	
74	33,600	(37,200)	1.107	22,300	[23,500]	
75	44,000	(47,300)	1.075	24,800	[26,100]	
76	33,300	(35,700)	1.072	32,000	[33,700]	
77	52,600	(54,300)	1.032	26,200	[27,600]	
78	24,300	(25,000)	1.029	20,800	[21,900]	
79	39,300	(41,300)	1.051	28,400	[29,900]	
80	49,700	(52,000)	1.046	31,100	[32,800]	
			Q_I/Q_D=X=1.063 S.D.=.034 N=23			Q_I/Q_D=X=1.052 S.D.=.032 N=8

Notes: ( ) Published instantaneous peaks

[ ] Instantaneous peaks computed by ratio.

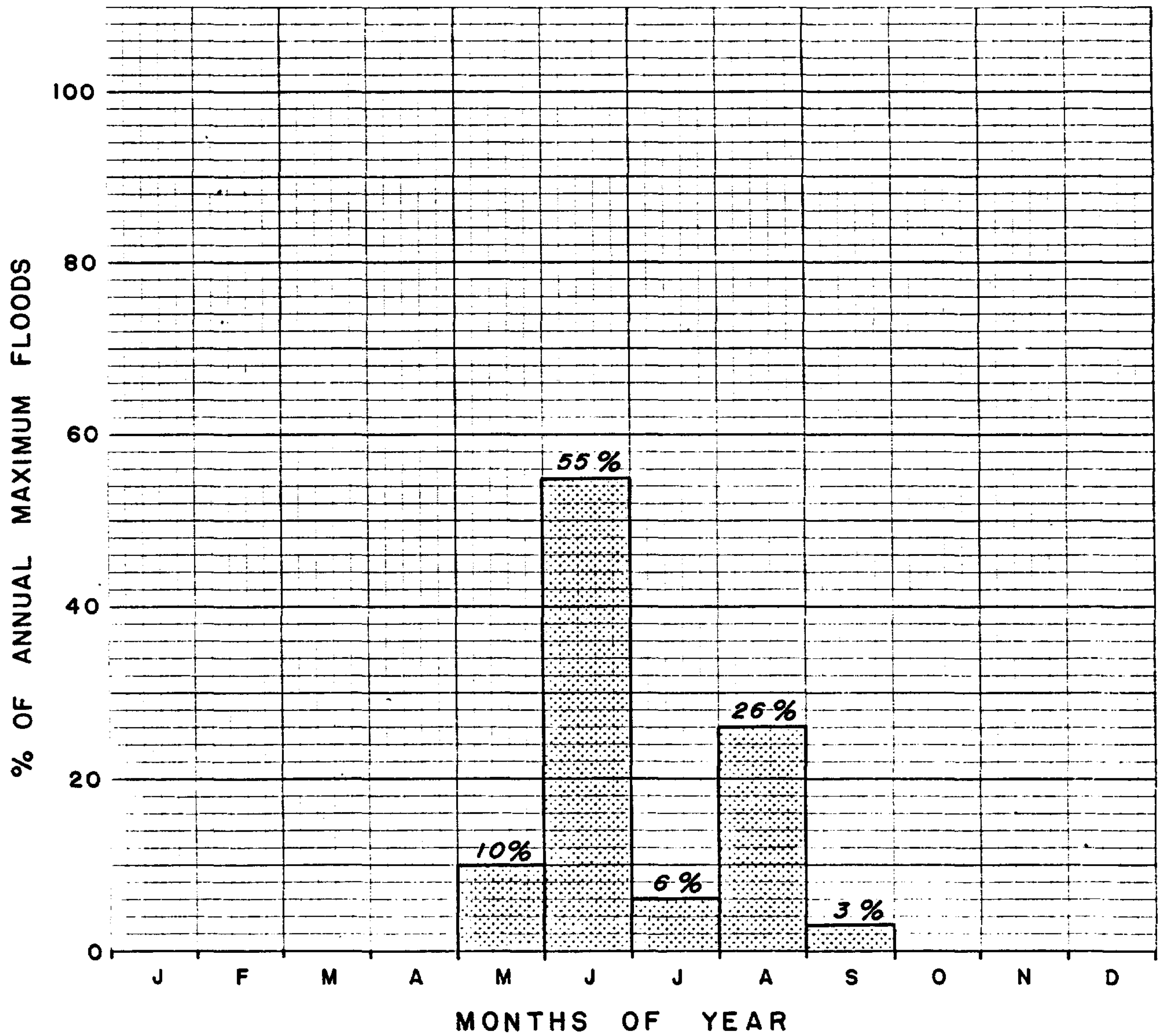
TABLE 5.2
TABULATION AND STATISTICS OF INSTANTANEOUS PEAKS VERSUS PEAK VOLUMES SUSITNA RIVER AT GOLD CREEK

Year	May - July (Snowmelt Floods) Instantaneous Peak, Q_p (cfs)	May - July (Snowmelt Floods) Peak Volume, V ($ft^3 \times 10^9$)	August - October (Rainfall Floods) Instantaneous Peak, Q_p (cfs)	August - October (Rainfall Floods) Peak Volume, V ($ft^3 \times 10^9$)
50	37,300	10.6	29,000	8.2
51	37,400	23.0	33,500	16.4
52	44,700	69.9	44,100	12.9
53	38,400	33.6	29,600	8.4
54	32,000	9.7	42,400	ND
55	41,500	38.0	58,100	19.0
56	51,700	33.8	32,600	ND
57	42,200	27.0	28,000	6.1
58	29,800	ND	49,600	19.0
59	42,100	28.4	62,300	37.6
60	41,800	18.4	41,900	10.3
61	59,300	30.8	27,400	ND
62	80,600	63.7	32,600	ND
63	53,800	26.7	36,800	5.7
64	90,700	83.4	22,800	6.5
65	43,600	35.6	35,400	17.7
66	63,600	30.8	35,200	12.5
67	53,150	19.9	80,200	30.3
68	41,800	32.2	22,900	UPH
69	28,400	11.8	17,700	3.9
70	32,740	16.1	33,400	7.7
71	70,500	50.1	87,400	27.5
72	82,600	82.8	27,800	UPH
73	54,100	36.8	32,100	14.9
74	37,200	23.9	23,500	9.3
75	47,300	28.0	26,100	UPH
76	35,700	18.8	33,700	11.5
77	54,300	45.9	27,600	3.2
78	25,000	12.9	21,900	UPH
79	41,300	12.6	29,900	UPH
80	52,000	NA	31,100	NA

STATISTICS

	May - July Q_p	May - July V	August - October Q_p	August - October V
Mean	48,441	32.9×10^9	40,090	13.7×10^9
Standard Deviation	16,104	20.1×10^9	18,214	9.0×10^9
Regression Equation	$V = 2820\ Q_p^{1.50}$		$V = 9840\ Q_p^{1.33}$	
Correlation Coefficient	r = 0.794		r = 0.825	
Sample Size	n = 29		n = 21	

Notes: ND = No data
UPH = Undefined peak hydrograph
NA = Not available



SUSITNA RIVER AT GOLD CREEK

PERIOD OF RECORD - 1950 - 1980

Prepared by:

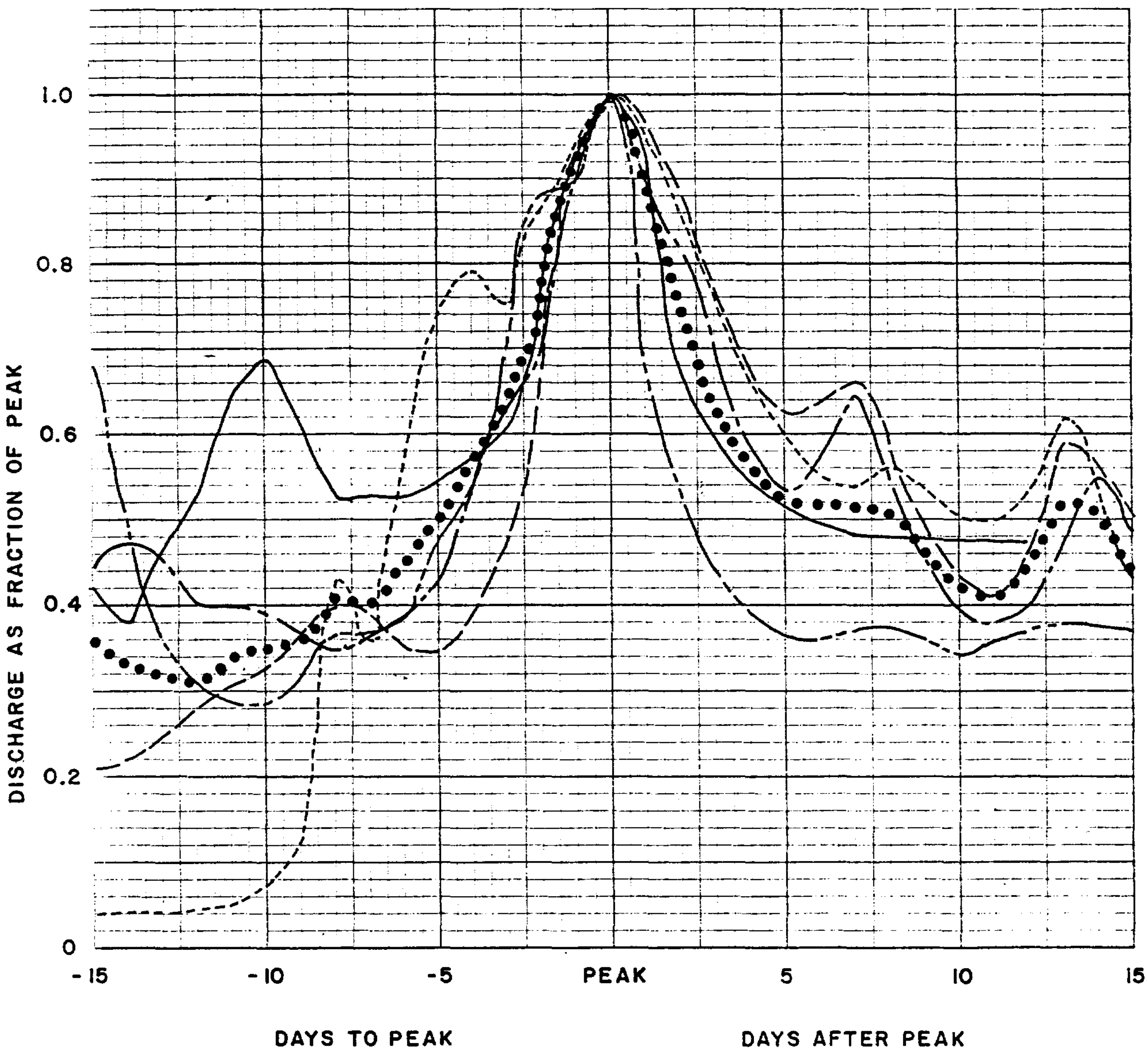
R&M CONSULTANTS, INC.

PERCENT OF ANNUAL MAXIMUM FLOODS

FIGURE 5.1

Prepared for:

ACRES



SUSITNA RIVER AT GOLD CREEK

LEGEND

	Date	Peak Discharge (cfs)
• • • • • • •	Mean Curve	
————————	June 23, 1961	54,000
——— - ———	June 15, 1962	79,900
- - - - - - - - -	June 7, 1964	85,900
— — — — —	June 6, 1966	58,400
——— - - ——— - -	June 17, 1972	70,700

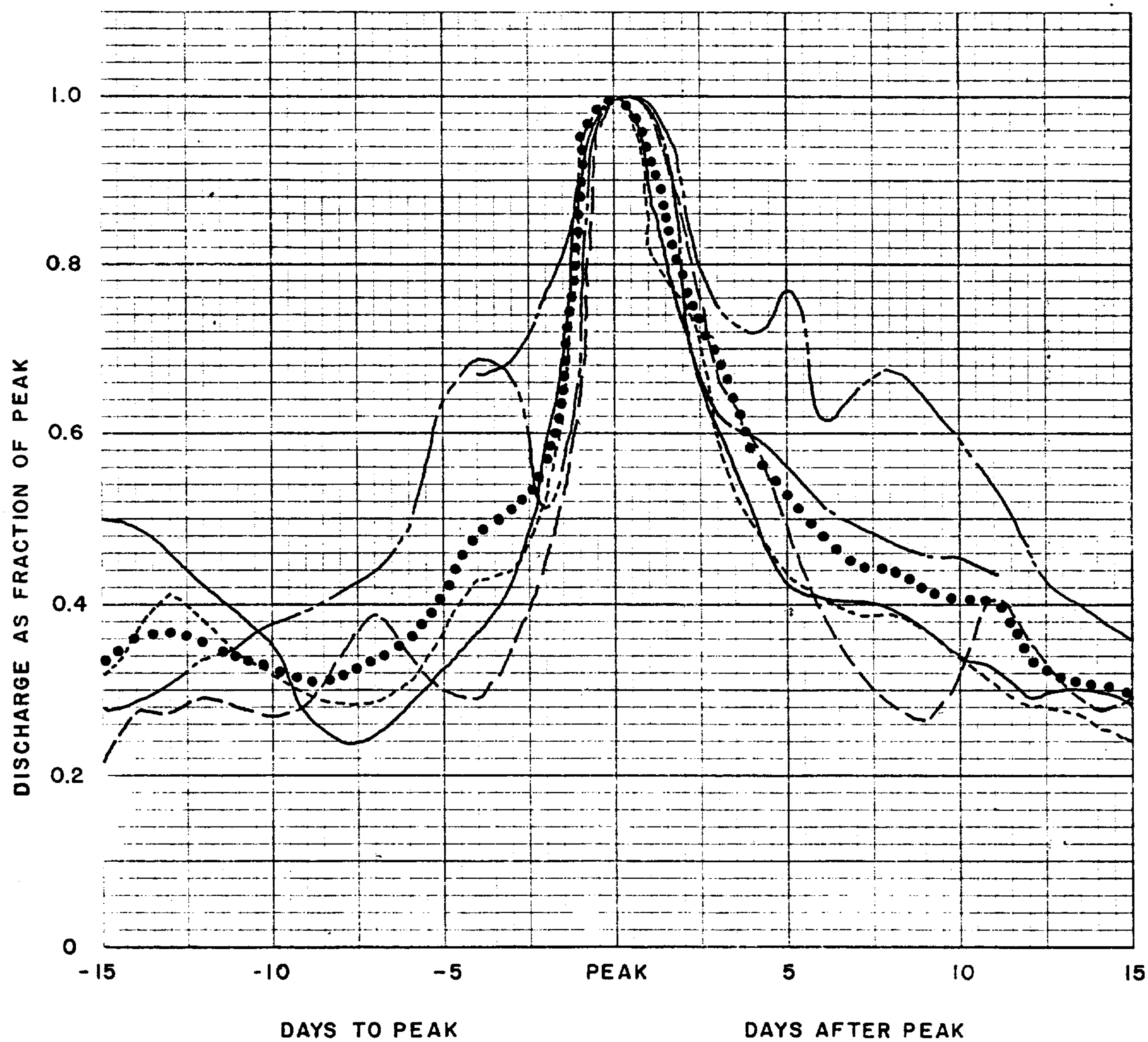
Prepared by: R&M CONSULTANTS, INC.

Prepared for: ACRES

DIMENSIONLESS HYDROGRAPHS

MAY - JULY

FIGURE 5.2



SUSITNA RIVER AT GOLD CREEK

LEGEND

	Date	Peak Discharge (cfs)
• • • • • • •	Mean Curve	
————————	Aug 26, 1955	56,900
——— · ——— ·	Aug 3, 1958	47,800
——— - - ——— - -	Aug 24, 1959	59,700
- - - - - - - - -	Aug 15, 1967	76,000
—— —— ——	Aug 10, 1971	77,700

Prepared by:

R&M CONSULTANTS, INC.

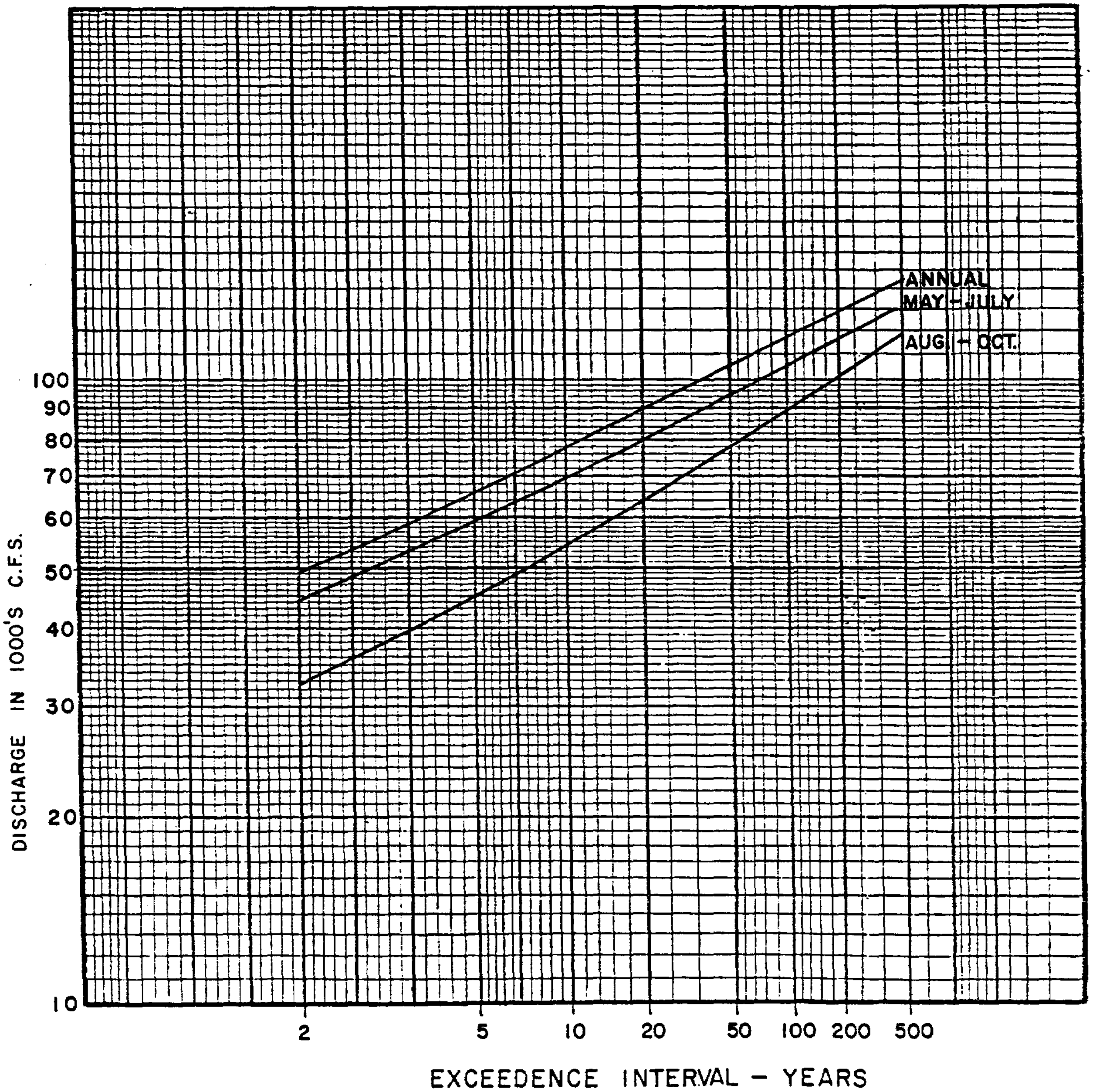
Prepared for:

ACRES

DIMENSIONLESS HYDROGRAPHS

AUG - OCT

FIGURE 5.3



SUSITNA RIVER AT GOLD CREEK

PERIOD OF RECORD - 1950-1980

ANNUAL SKEW IS 0.6830

MAY-JULY SKEW IS 1.130

AUG-OCT SKEW IS 1.134

Prepared by:

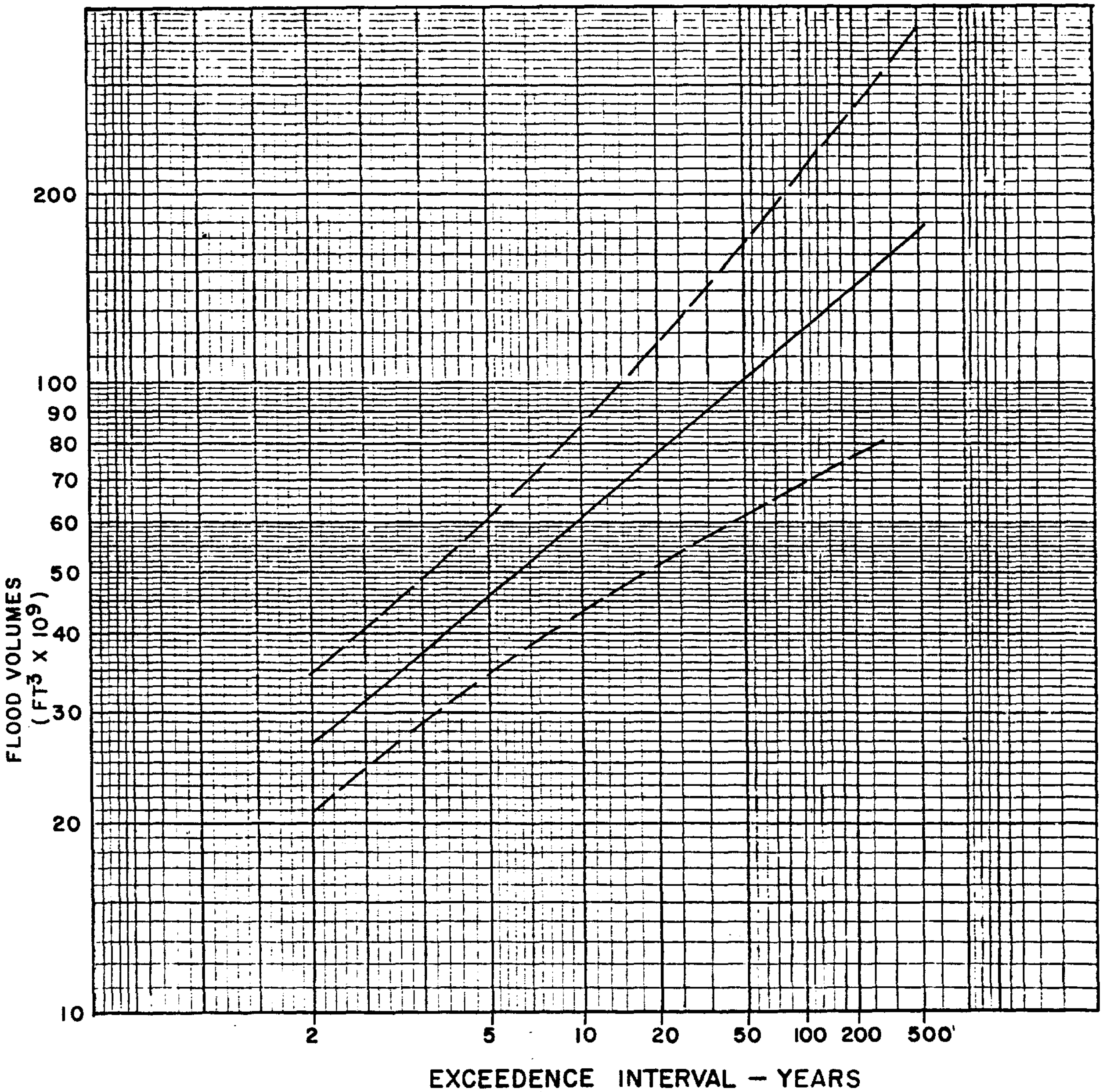
R&M CONSULTANTS, INC.

SEASONAL DISCHARGE FREQUENCY CURVES

Prepared for:

ACRES

FIGURE 5.4



SUSITNA RIVER AT GOLD CREEK

PERIOD OF RECORD - 29 yrs.

LEGEND

---- 95% CONFIDENCE LIMITS

—— VOLUME FREQUENCY CURVE

Prepared by:

R&M CONSULTANTS, INC.

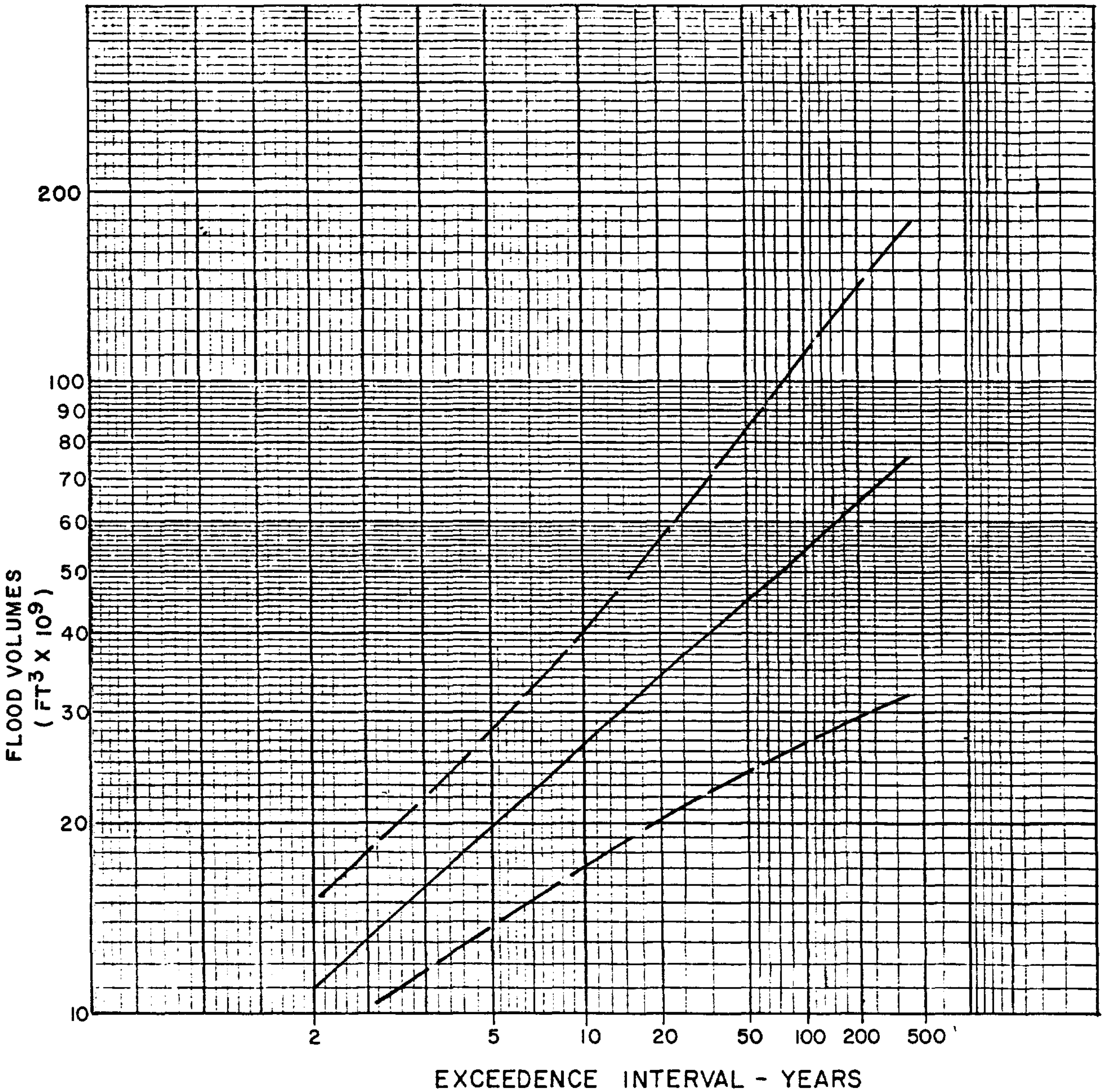
FLOOD VOLUME FREQUENCY CURVE

MAY-JULY

FIGURE 5.5

Prepared for:

ACRES



SUSITNA RIVER AT GOLD CREEK

PERIOD OF RECORD - 21 yrs.

LEGEND

---- 95 % CONFIDENCE LIMITS

—— VOLUME FREQUENCY CURVE

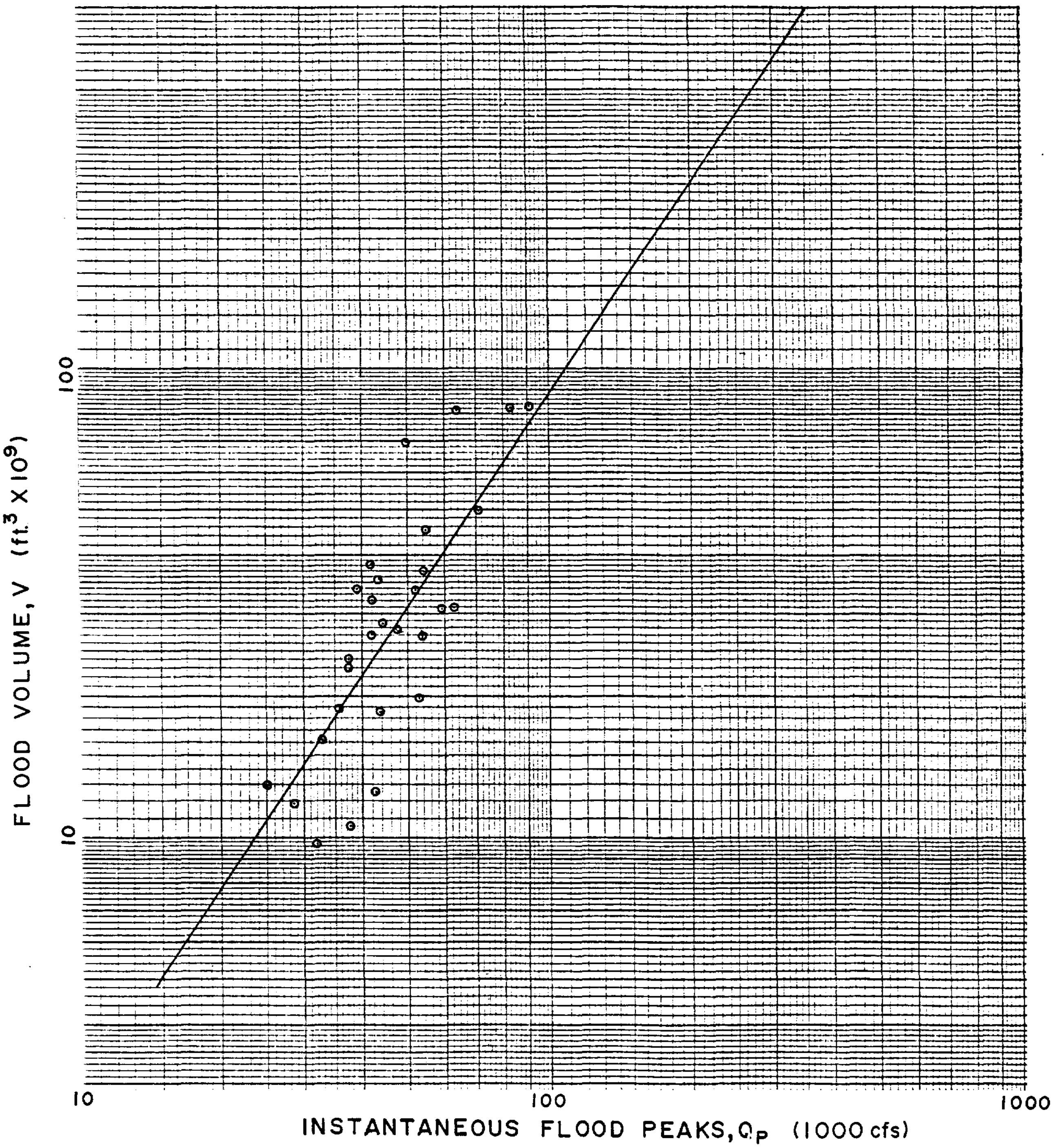
Prepared by: R&M CONSULTANTS, INC.

Prepared for: ACRES

FLOOD VOLUME FREQUENCY CURVE

AUG - OCT

FIGURE 5.6



SUSITNA RIVER AT GOLD CREEK

PERIOD OF RECORD - 29 YEARS

$V = 2820\ Q_P^{1.50}$

$r^2 = 0.63$

$n = 29$

Prepared by: Prepared for

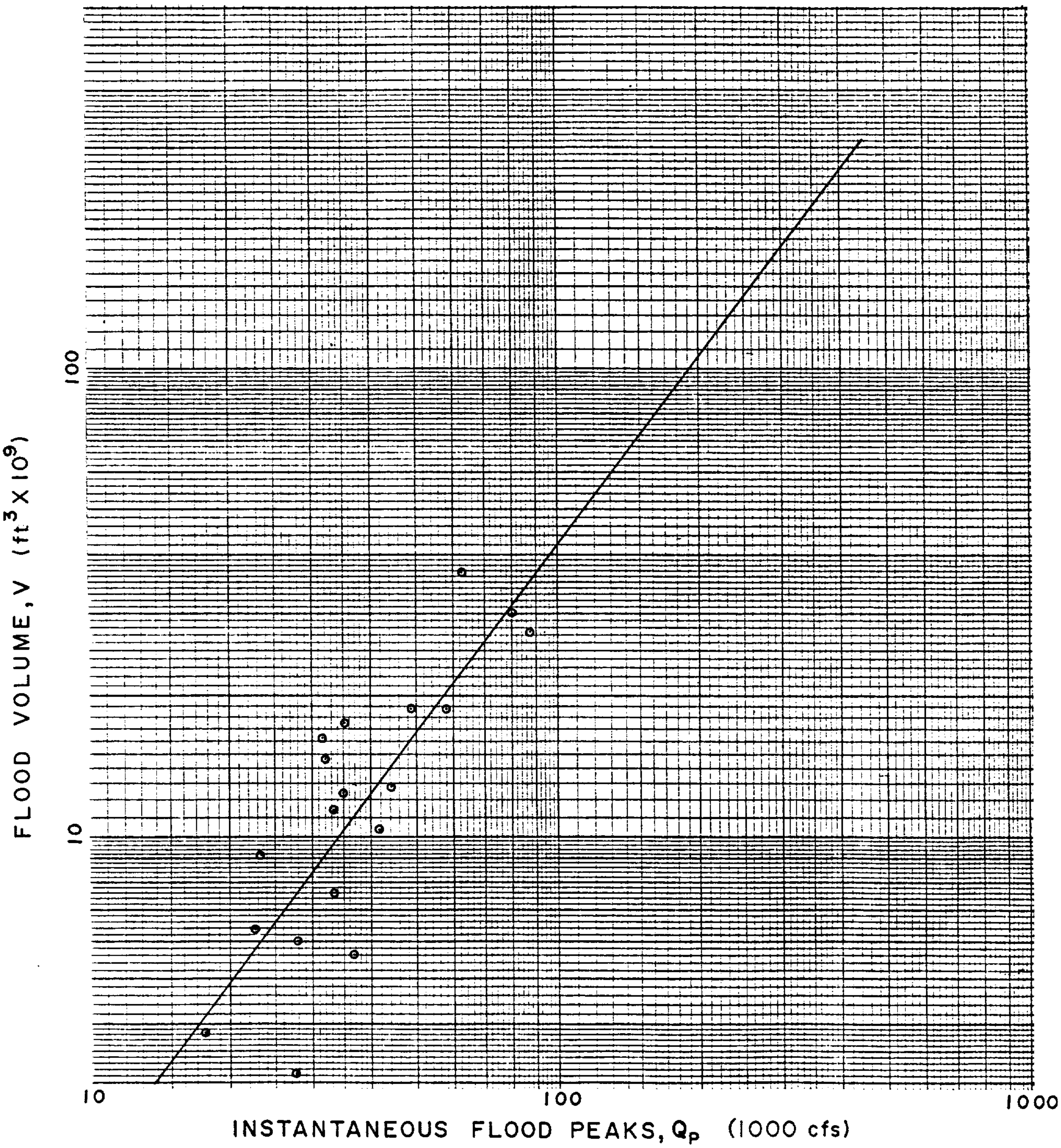
R&M CONSULTANTS, INC.

VOLUME vs. PEAK

MAY - JULY

FIGURE 5.7

ACRES



SUSITNA RIVER AT GOLD CREEK

PERIOD OF RECORD - 29 YEARS.

$V = 9840\,Q^{1.33}$

$r^2 = 0.68$

$n = 21$

Prepared by:

Prepared for:

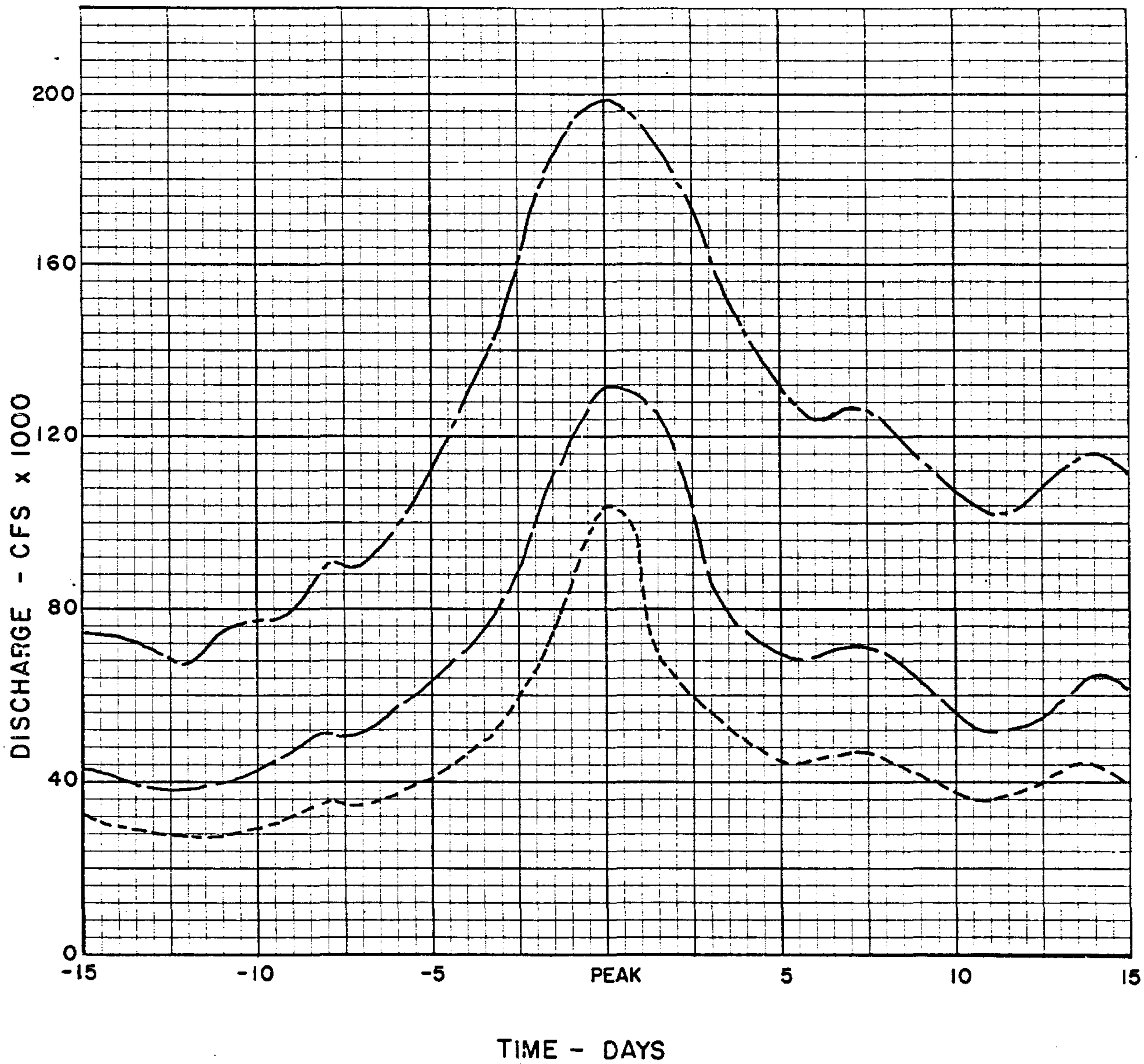
R&M CONSULTANTS, INC.

VOLUME VS. PEAK

AUG. — OCT.

FIGURE 5.8

ACRES



SUSITNA RIVER AT GOLD CREEK

100, 500, 10000 yr. FLOOD VOLUMES

LEGEND

	Flood Volume ft^3	Peak Discharge (cfs)
-----100 yr	122.3 X 10^9	104,550
— —500 yr	178.2 X 10^9	131,870
—·—10,000 y	310.0 X 10^9	198,000

Prepared by: Prepared for

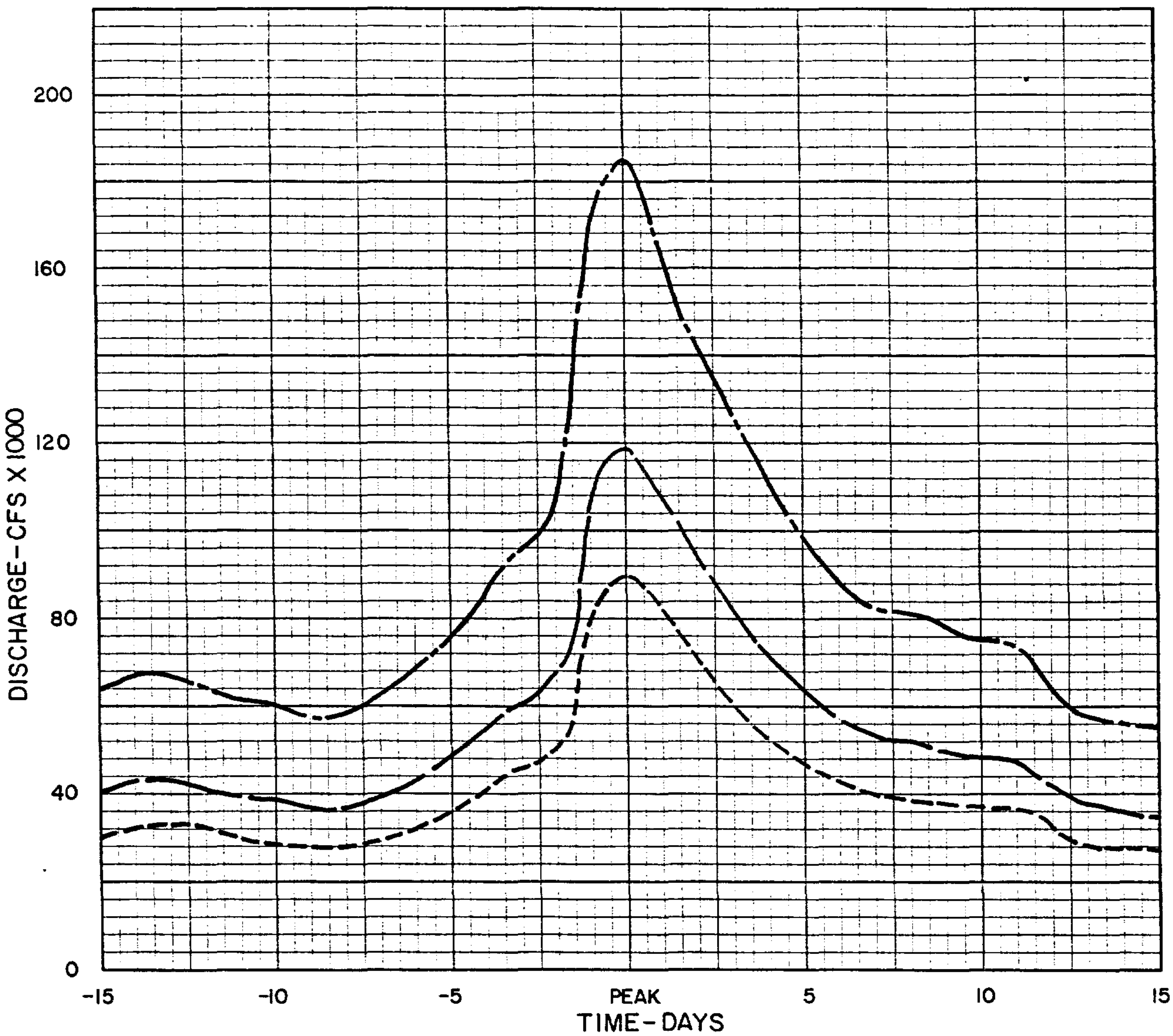
R&M CONSULTANTS, INC.

FLOOD HYDROGRAPHS

MAY - JULY

FIGURE 5.9

ACRES



SUSITNA RIVER AT GOLD CREEK

LEGEND

	Flood Volume ft^3	Peak Discharge (cfs)
---- 100 yr	53.8×10^9	90,140
—— 500 yr	78.8×10^9	119,430
—-- 10,000 yr	140.0×10^9	185,000

PREPARED BY:

R&M CONSULTANTS, INC.

PREPARED FOR:

ACRES

FLOOD HYDROGRAPHS

AUG - OCT

FIGURE 5.10

6 - FLOOD VOLUME-DURATION FREQUENCY ANALYSIS

To assist in designing temporary diversion structures and determining reservoir filling sequences, a flood volume-duration frequency analysis was conducted for May-July flows of the Susitna River at Gold Creek. Table 6.1 is a computer tabulation of May through July volume durations computed by the U.S. Geological Survey. The mean discharge for the 3-, 7-, 15- and 30-day durations were utilized with the three parameter log-normal frequency distribution to compute the volume-duration frequency curves illustrated on Figure 6.1.

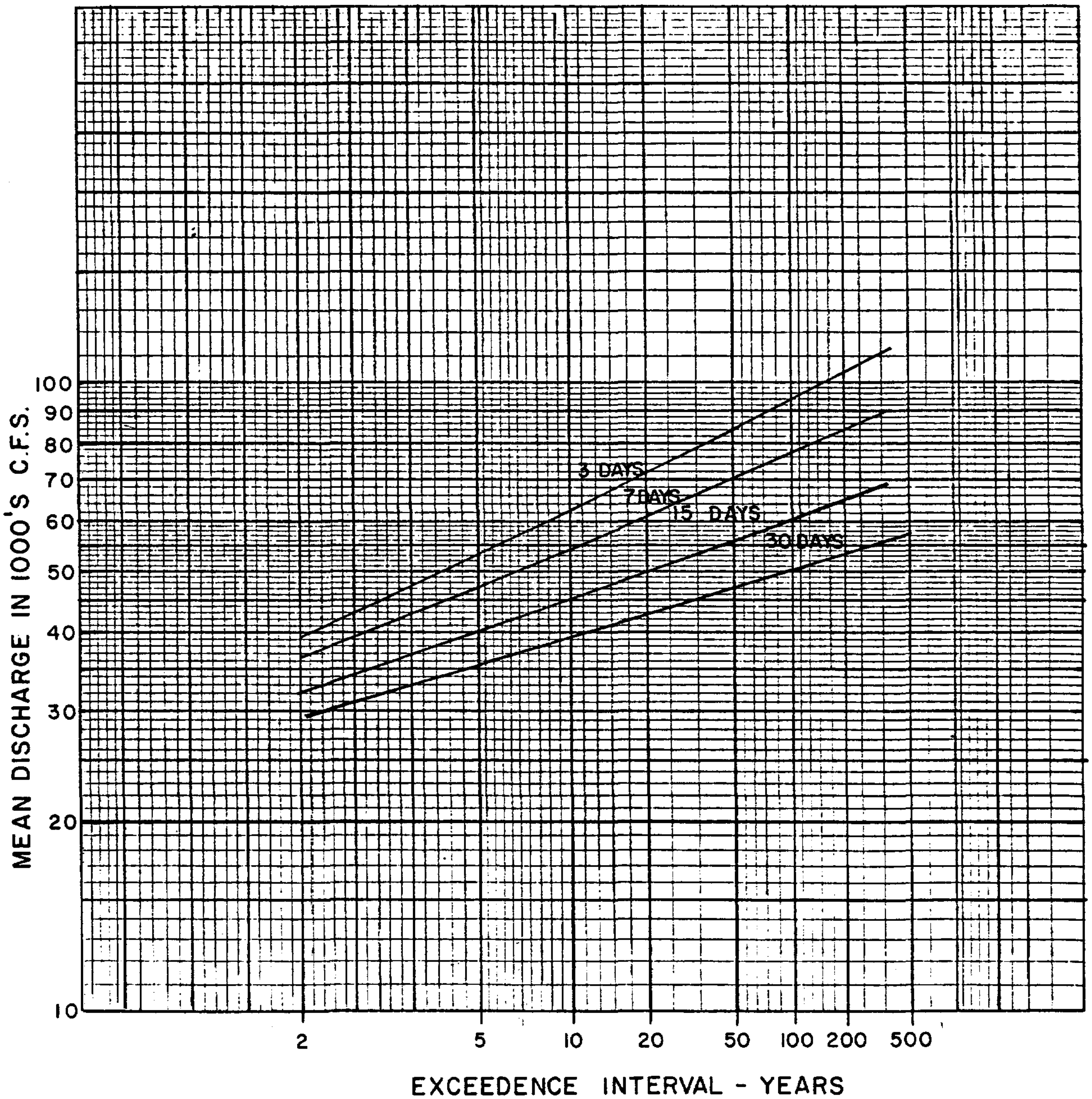
TABLE 6.1

SUSITNA RIVER AT GOLD CREEK

HIGHEST MEAN DISCHARGE (CFS) OF CONSECUTIVE DAYS FROM MAY THROUGH JULY

VOLUME DURATIONS COMPUTED BY U.S. GEOLOGICAL SURVEY

YEAR	1	3	7	15	30
1950	34000.0 23	32100.0 24	27000.0 28	24500.0 28	22700.0 27
1951	35800.0 22	32100.0 25	29800.0 24	25200.0 27	22700.0 28
1952	43300.0 13	42300.0 12	39500.0 11	37000.0 9	33000.0 10
1953	37700.0 21	37200.0 18	35500.0 17	31000.0 19	27400.0 19
1954	30100.0 28	29500.0 28	28800.0 25	26900.0 24	25700.0 22
1955	39000.0 20	38700.0 16	36600.0 16	35500.0 12	33800.0 8
1956	51500.0 9	49900.0 8	46800.0 7	40300.0 4	34500.0 7
1957	40600.0 14	39900.0 14	38400.0 13	35500.0 13	32300.0 13
1958	32400.0 26	32100.0 26	28000.0 26	28000.0 22	25800.0 21
1959	39600.0 18	37200.0 19	30700.0 22	27300.0 23	26200.0 20
1960	40000.0 15	36100.0 20	32900.0 19	26100.0 25	23100.0 26
1961	54000.0 6	52000.0 7	42700.0 9	36800.0 10	30800.0 14
1962	79900.0 2	75200.0 2	64700.0 2	53200.0 2	43300.0 2
1963	49000.0 11	46300.0 9	42900.0 8	39200.0 7	34900.0 6
1964	85900.0 1	81900.0 1	75000.0 1	63500.0 1	50700.0 1
1965	39900.0 16	37400.0 17	34100.0 18	31300.0 18	30500.0 15
1966	58400.0 5	56600.0 5	49200.0 4	39800.0 5	33000.0 9
1967	50000.0 10	46300.0 10	38900.0 12	32500.0 16	29900.0 16
1968	39700.0 17	38900.0 15	38100.0 14	36500.0 11	32400.0 11
1969	26500.0 29	24400.0 29	20500.0 30	17700.0 30	16700.0 30
1970	30800.0 27	30100.0 27	27100.0 27	25700.0 26	23800.0 24
1971	66300.0 4	59000.0 4	48300.0 5	38200.0 8	35400.0 5
1972	70700.0 3	65600.0 3	53500.0 3	39800.0 6	37300.0 4
1973	52800.0 7	45300.0 11	40900.0 10	34600.0 14	28600.0 18
1974	33600.0 24	33200.0 22	32400.0 21	29300.0 20	23200.0 25
1975	44000.0 12	42200.0 13	37100.0 15	33300.0 15	32300.0 12
1976	33300.0 25	32100.0 23	29800.0 23	28600.0 21	24500.0 23
1977	52600.0 8	52200.0 6	48300.0 6	41500.0 3	38000.0 3
1978	24300.0 30	23800.0 30	23100.0 29	22600.0 29	21700.0 29
1979	39300.0 19	34800.0 21	32600.0 20	31700.0 17	29100.0 17



SUSITNA RIVER AT GOLD CREEK

PERIOD OF RECORD - 1950 - 1979

Prepared by:

R&M CONSULTANTS, INC.

Prepared for:

ACRES

VOLUME DURATION
FREQUENCY CURVES
MAY - JULY

FIGURE 6.1

7 - REFERENCES

Acres American. 1977. Regional Flood Frequency Analysis. Prepared for the Canada - New Brunswick Flood Damage Reduction Program, Inland Water Directorate, Environment Canada.

Condie, R., Nix, G.A., and Boone, L.G. 1977. Flood Damage Reduction Program Flood Frequency Analysis. Engineering Hydrology Section, Water Planning and Management Branch, Inland Water Directorate, Environmental Canada, Ottawa.

Dalrymple. 1960. Flood Frequency Analyses. U.S. Geological Survey. Water Supply Paper 1543-A.

Dixon, W.J., Brown, M.B., Engelman, L., Frane, J.W., and Jennrich, R.I. 1977. Biomedical Computer Programs, P-Series. University of California Press, Berkeley. BMDP-77.

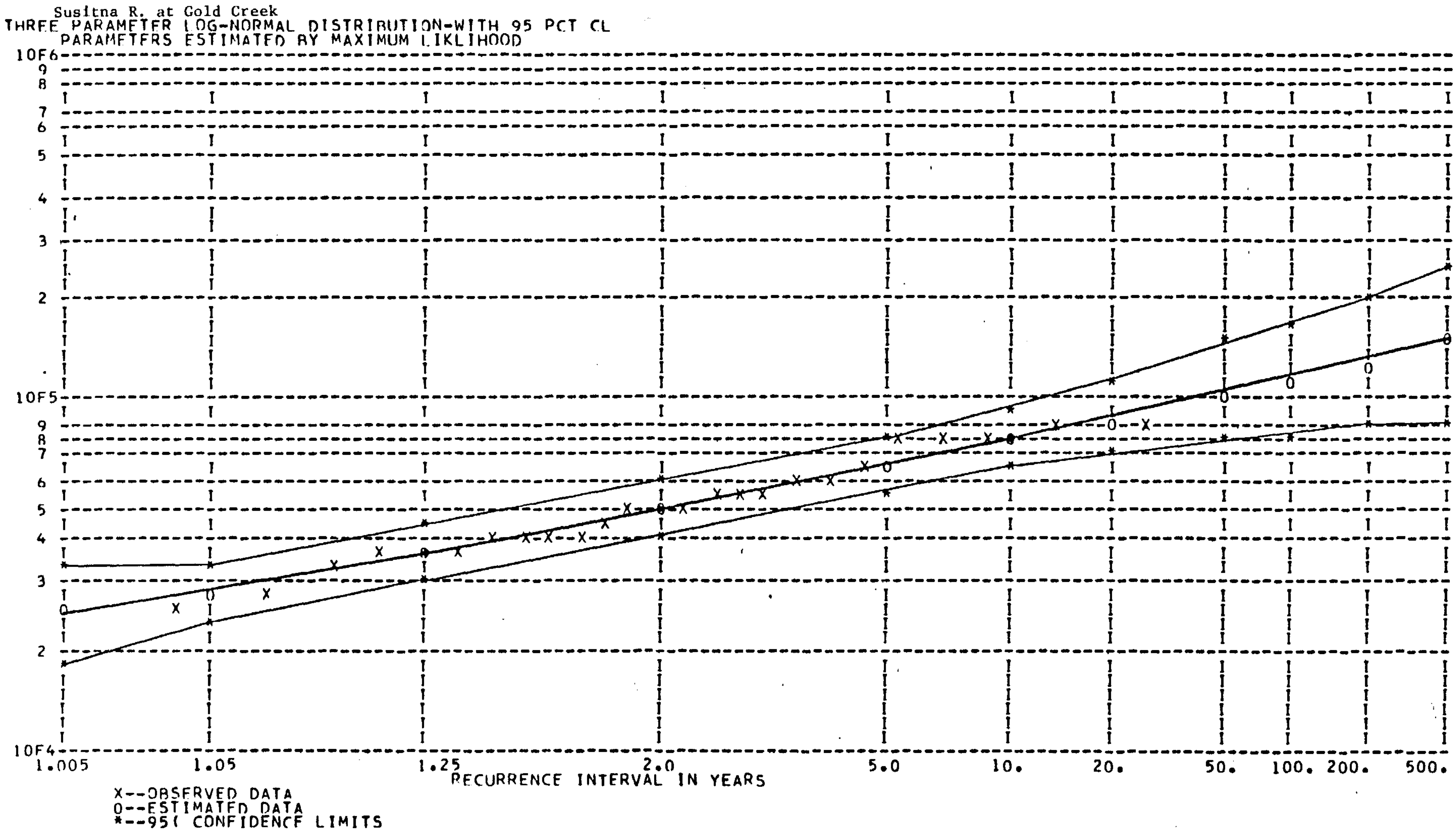
Freethey, G.W., and Scully, D.R. 1980. Water Resources of the Cook Inlet Basin, Alaska, U.S. Department of the Interior, Geological Survey, Hydrological Investigations Atlas HA-620, 4 sheets.

Lamke, R.D. 1979. Flood Characteristics of Alaskan Streams. U.S. Department of the Interior, Geological Survey, Water Resources Investigations 78-129, Anchorage, Alaska, 61 p.

National Weather Service. 1972. Mean Annual Precipitation -- Inches: National Weather Service [Alaska], map.

ATTACHMENT A

FLOOD FREQUENCY CURVES FOR ANNUAL
INSTANTANEOUS FLOOD PEAK SERIES,
INDIVIDUAL STATIONS



Prepared by:

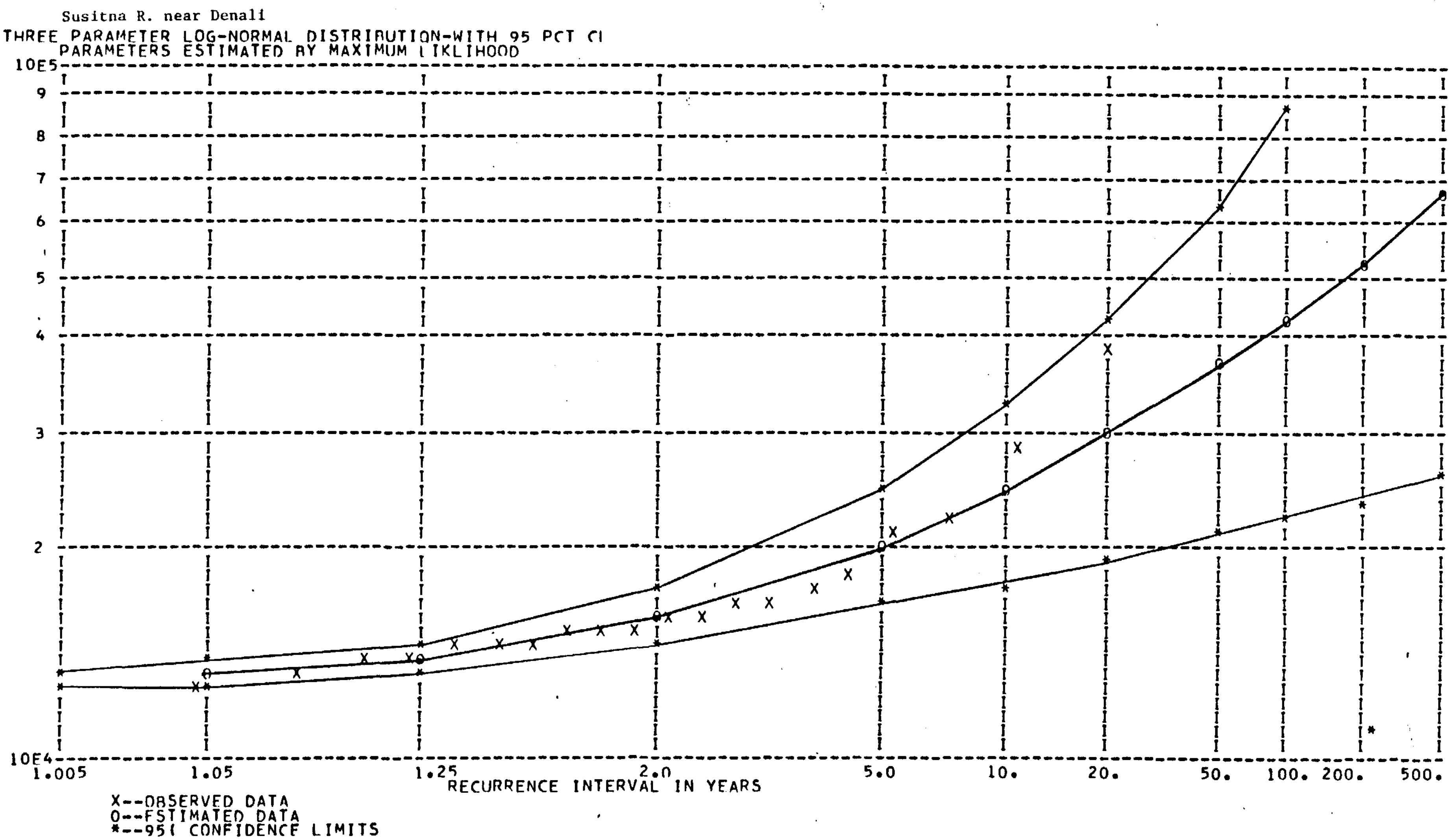
R&M CONSULTANTS, INC.

ANNUAL FLOOD FREQUENCY CURVE
SUSITNA RIVER AT GOLD CREEK

Prepared for:

ACRES

FIGURE: A.1



Prepared by:

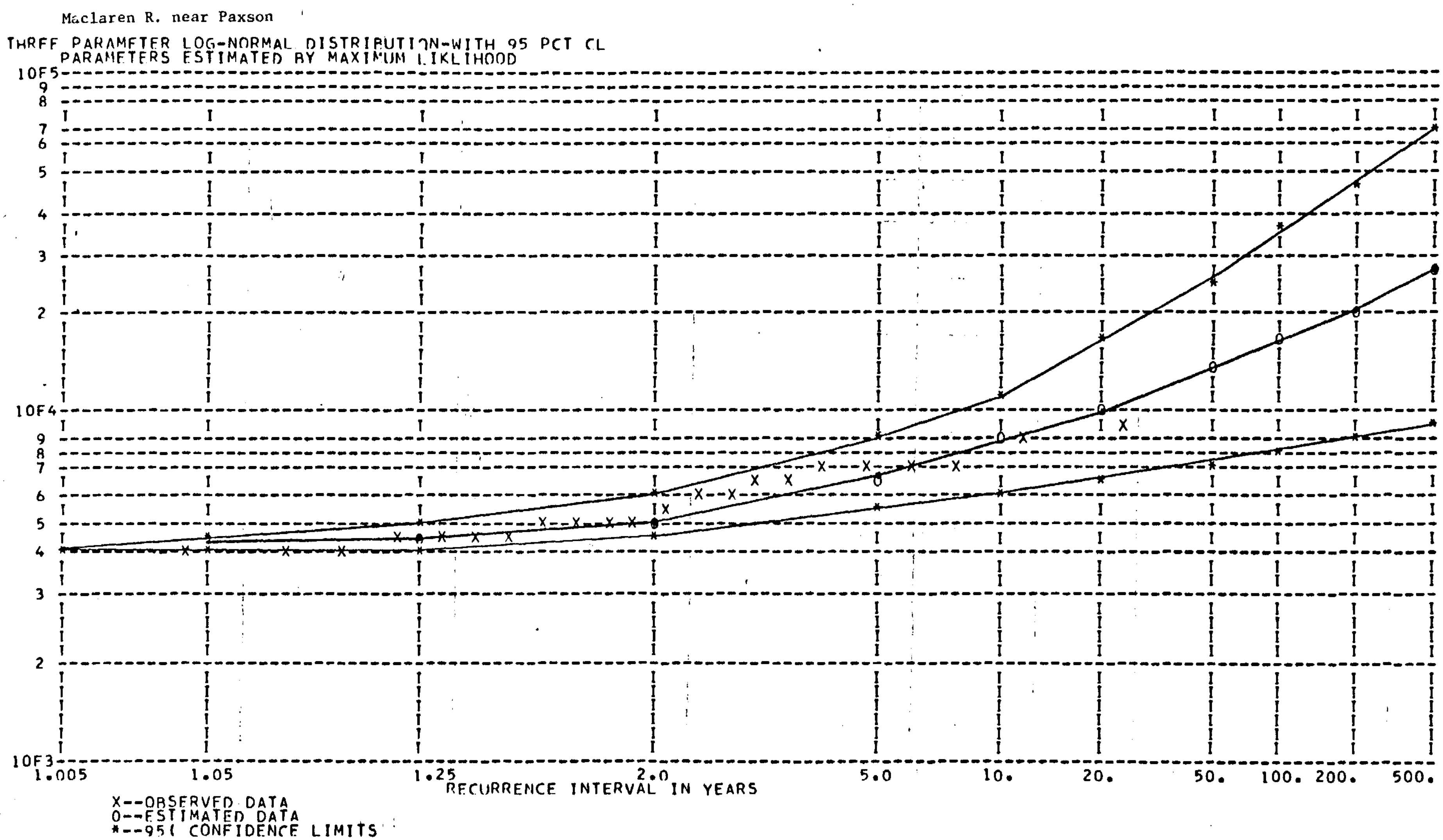
Prepared for:

R&M CONSULTANTS, INC.

ANNUAL FLOOD FREQUENCY CURVE
SUSITNA RIVER NEAR DENALI

FIGURE: A.2

ACRES



Prepared by:

R&M CONSULTANTS, INC.

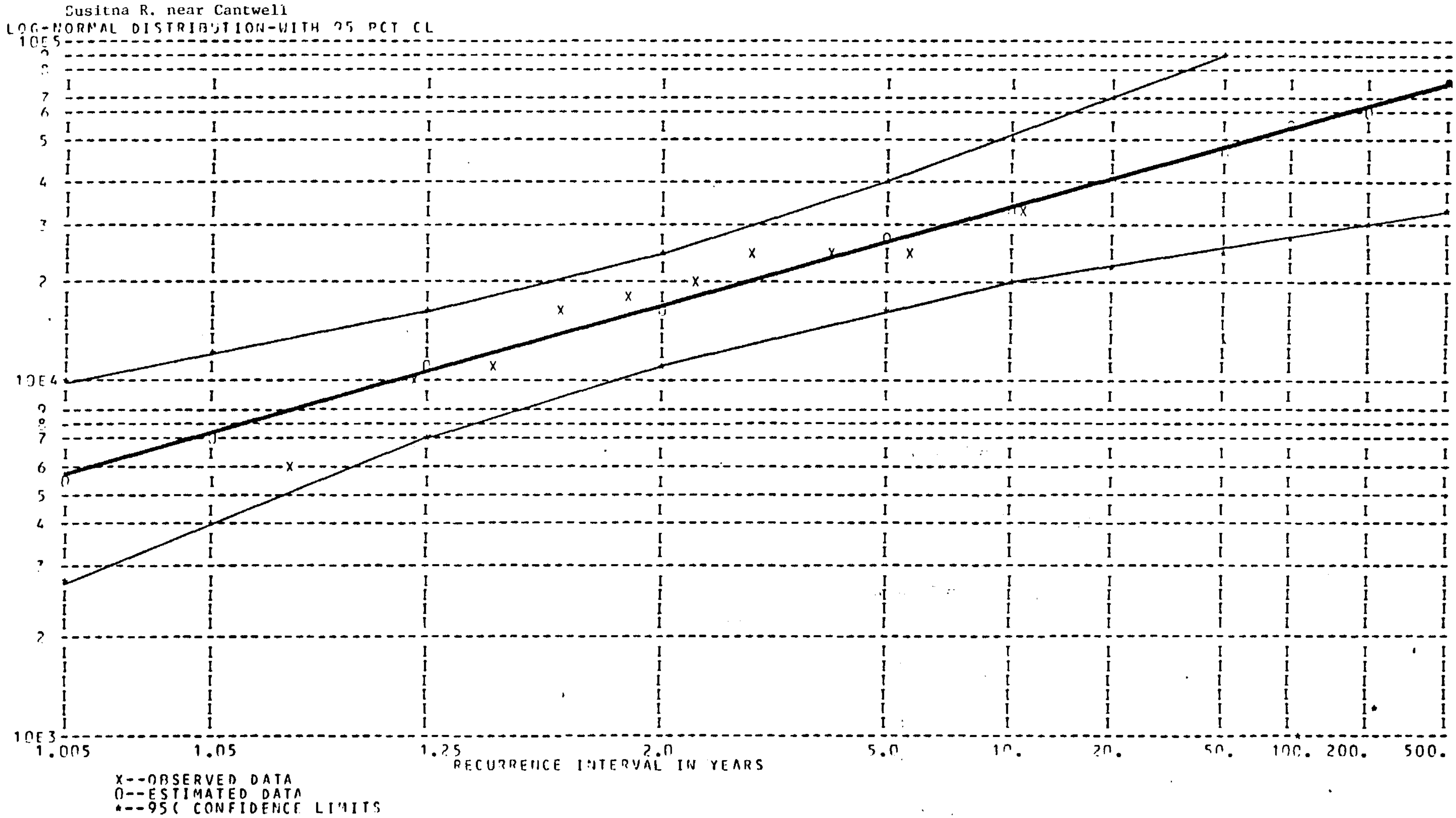
ANNUAL FLOOD FREQUENCY CURVE

MACLAREN RIVER NEAR PAXSON

Prepared for:

ACRES

FIGURE: A.3



Prepared by:

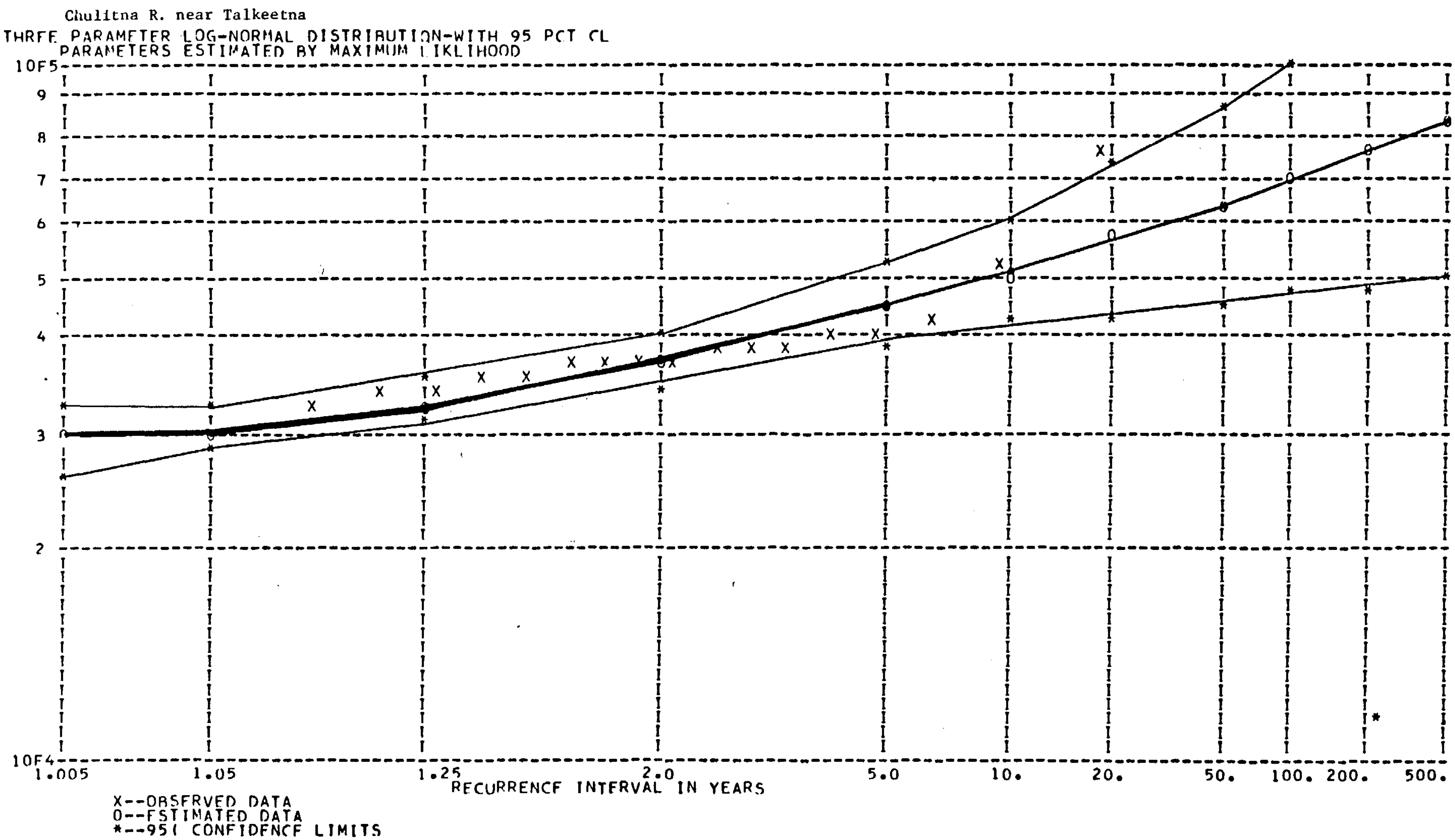
R&M CONSULTANTS, INC.

Prepared for:

ACRES

ANNUAL FLOOD FREQUENCY CURVE
SUSITNA RIVER NEAR CANTWELL

FIGURE: A.4



Prepared by:

R&M CONSULTANTS, INC.

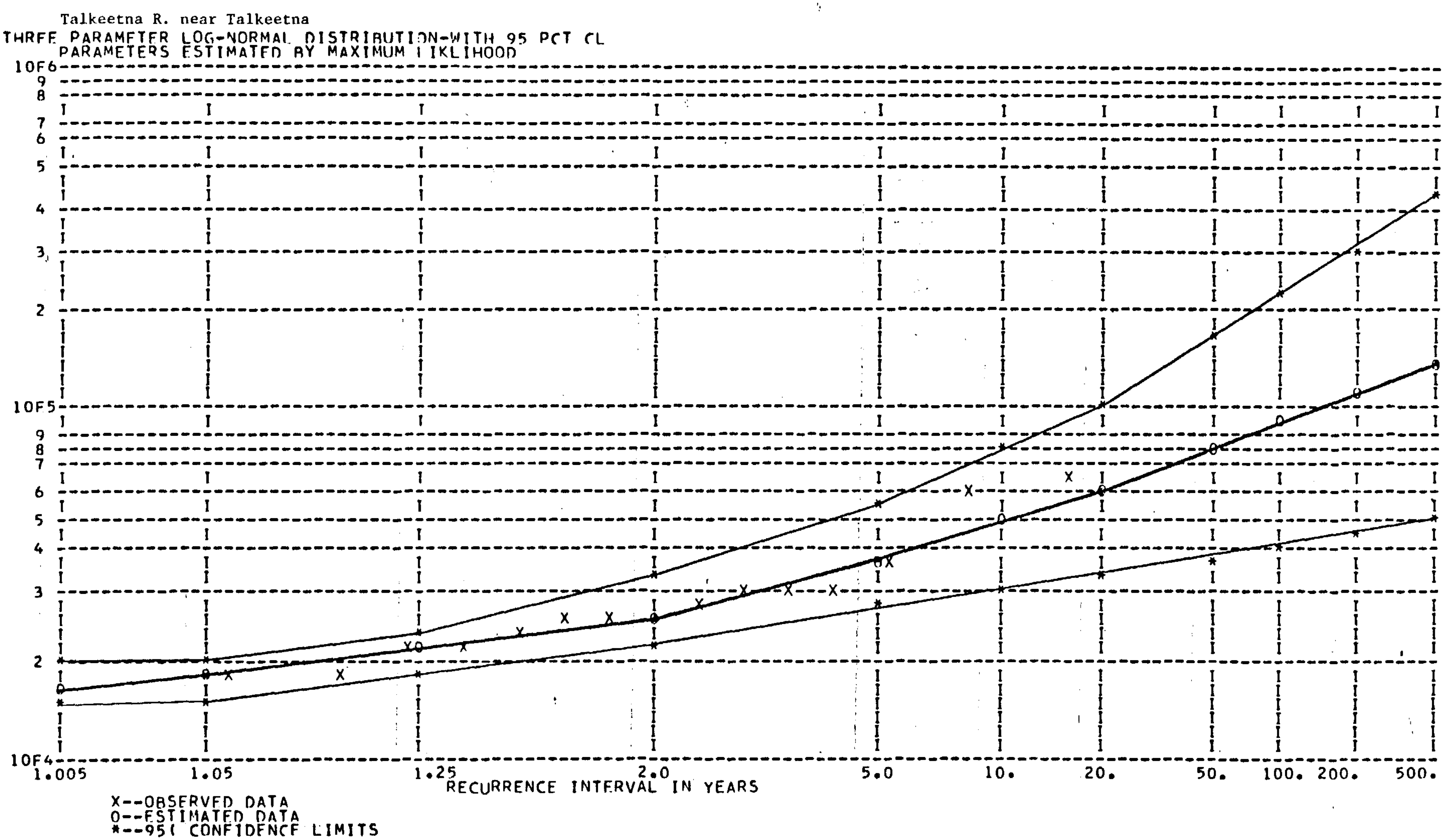
ANNUAL FLOOD FREQUENCY CURVE

CHULITNA RIVER NEAR TALKEETNA

Prepared for:

ACRES

FIGURE: A.5



Prepared by:

R&M CONSULTANTS, INC.

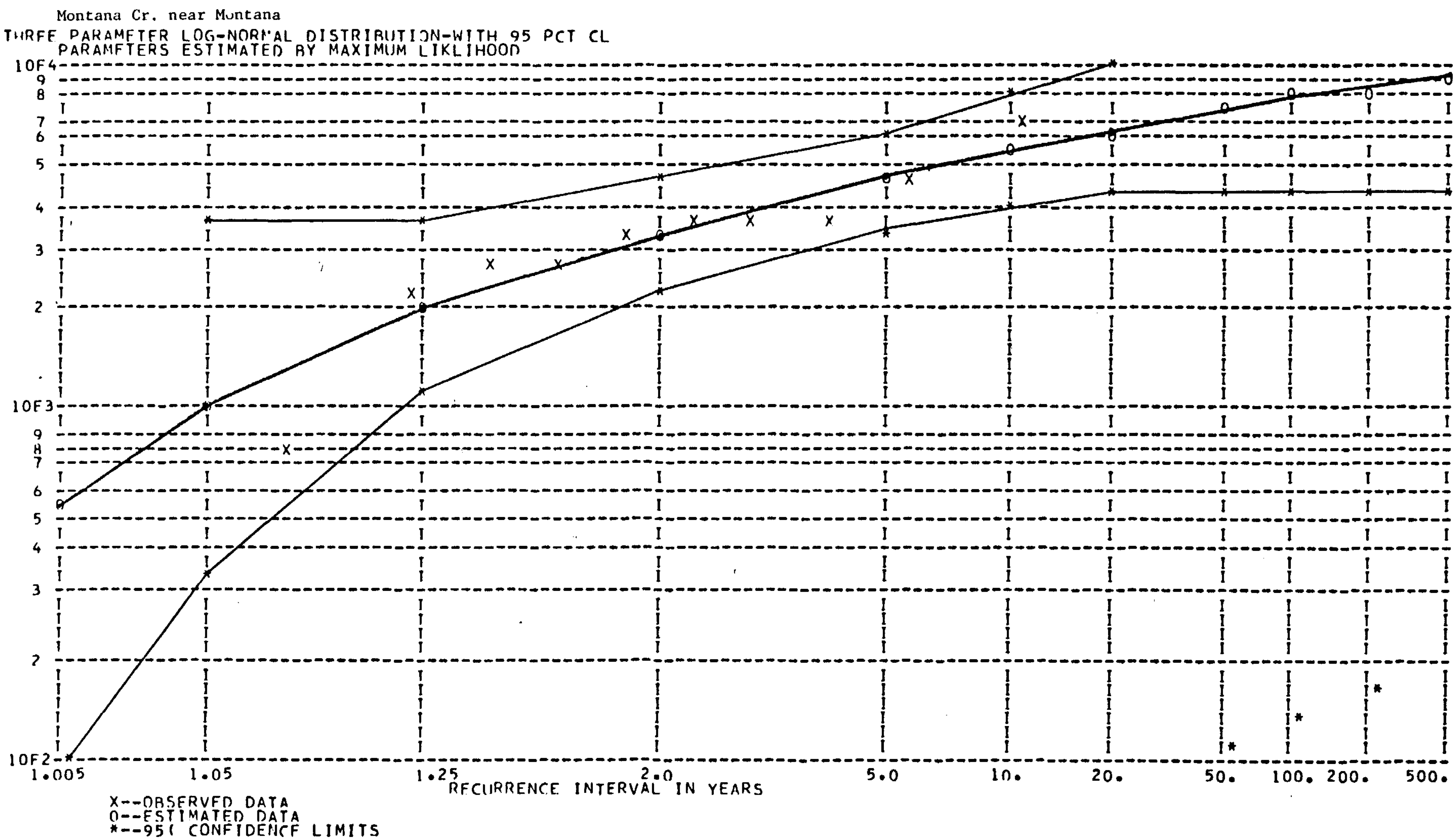
ANNUAL FLOOD FREQUENCY CURVE

TALKEETNA RIVER NEAR TALKEETNA

Prepared for:

ACRES

FIGURE: A.6



Prepared by:

R&M CONSULTANTS, INC.

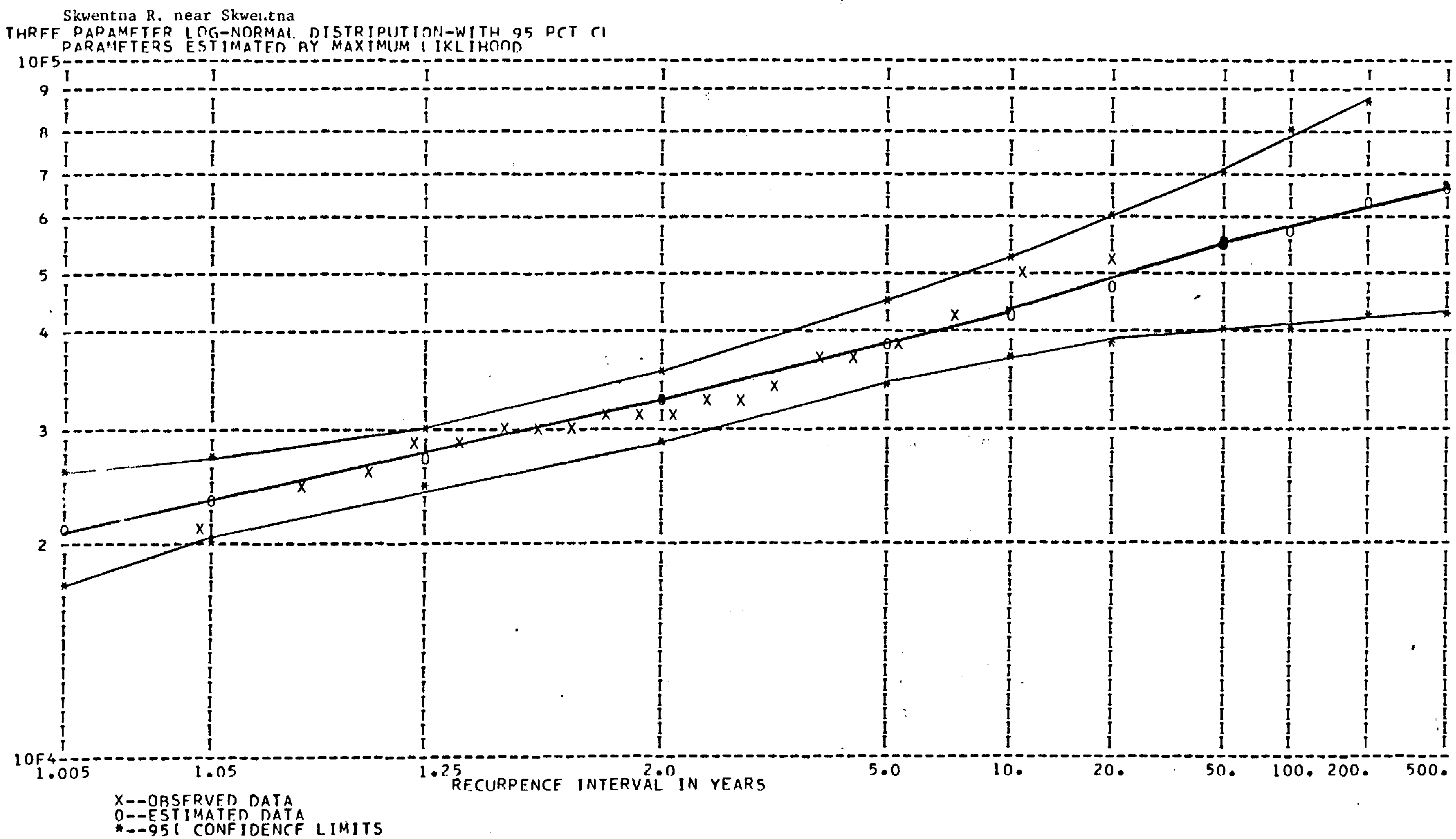
Prepared for:

ACRES

ANNUAL FLOOD FREQUENCY CURVE

MONTANA CREEK NEAR MONTANA

FIGURE: A.7



Prepared by:

R&M CONSULTANTS, INC.

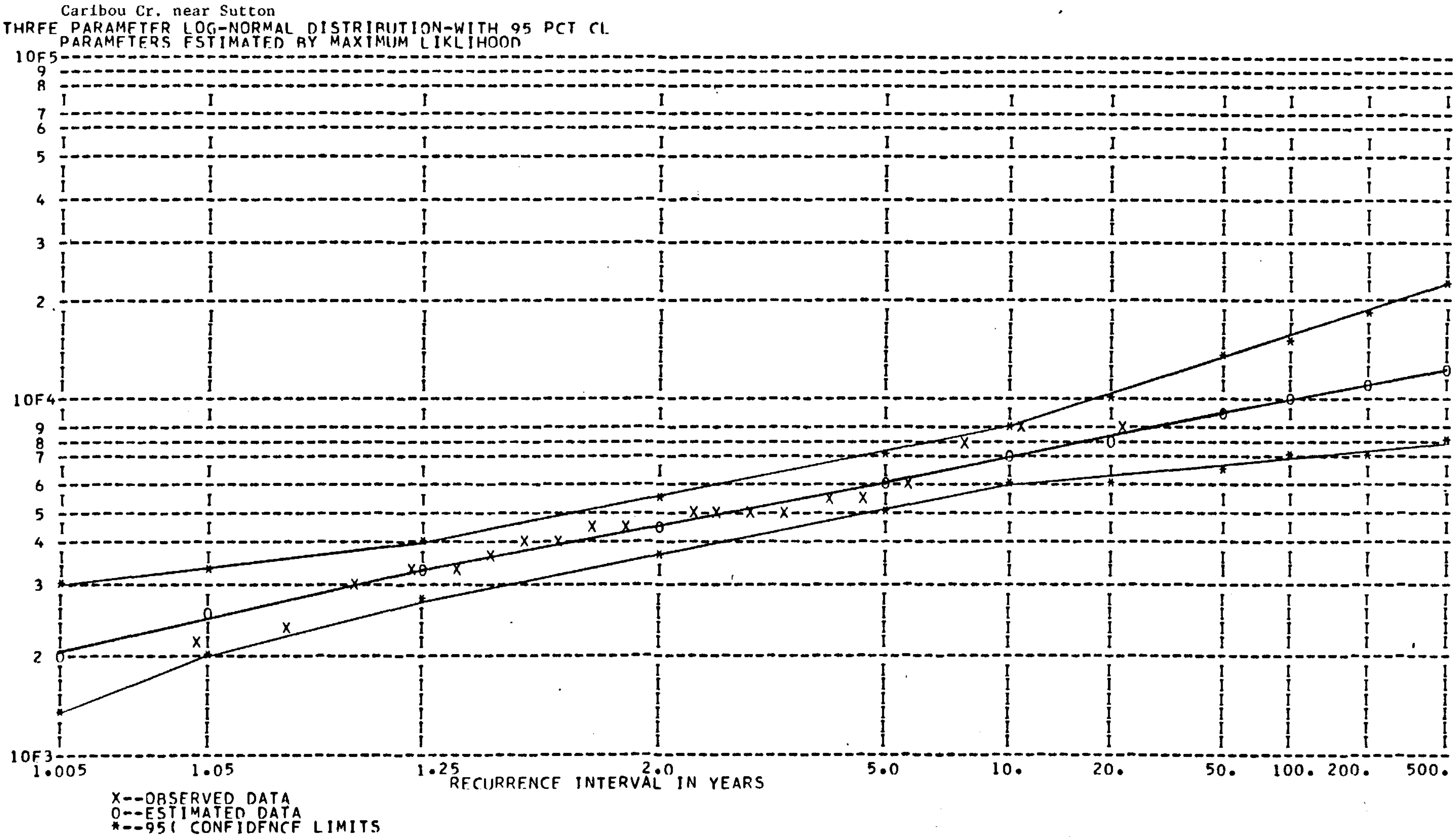
Prepared for:

ACRES

ANNUAL FLOOD FREQUENCY CURVE

SKWENTNA RIVER NEAR SKWENTNA

FIGURE: A.8



Prepared by:

R&M CONSULTANTS, INC.

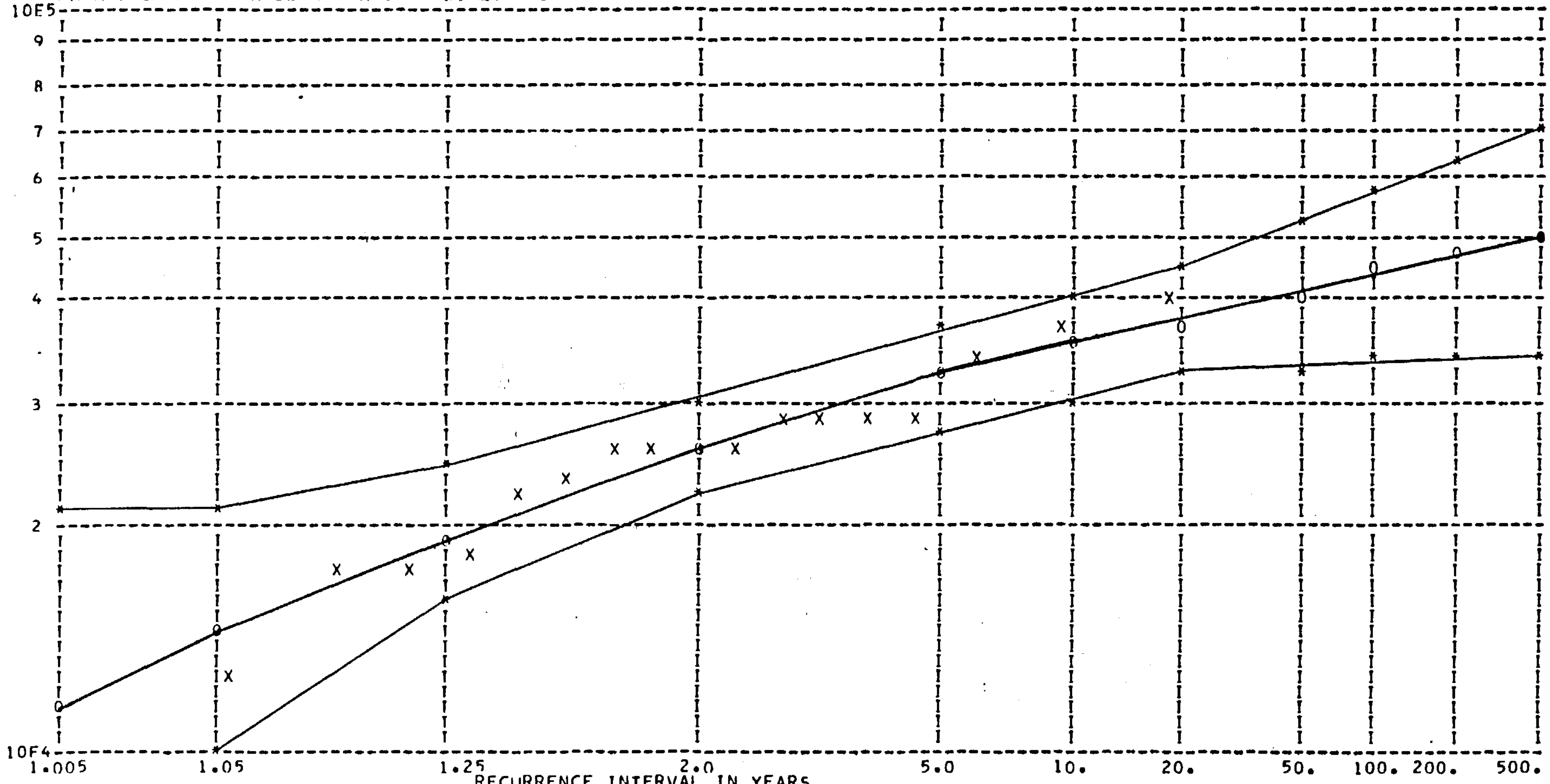
Prepared for:

ANNUAL FLOOD FREQUENCY CURVE

CARIBOU CREEK NEAR SUTTON

FIGURE: A.9

Matanuska R. at Palmer
THREE PARAMETER LOG-NORMAL DISTRIBUTION-WITH 95 PCT CL
PARAMETERS ESTIMATED BY MAXIMUM LIKLIHOOD



X--OBSERVED DATA
O--ESTIMATED DATA
*--95(CONFIDENCE LIMITS

Prepared by:

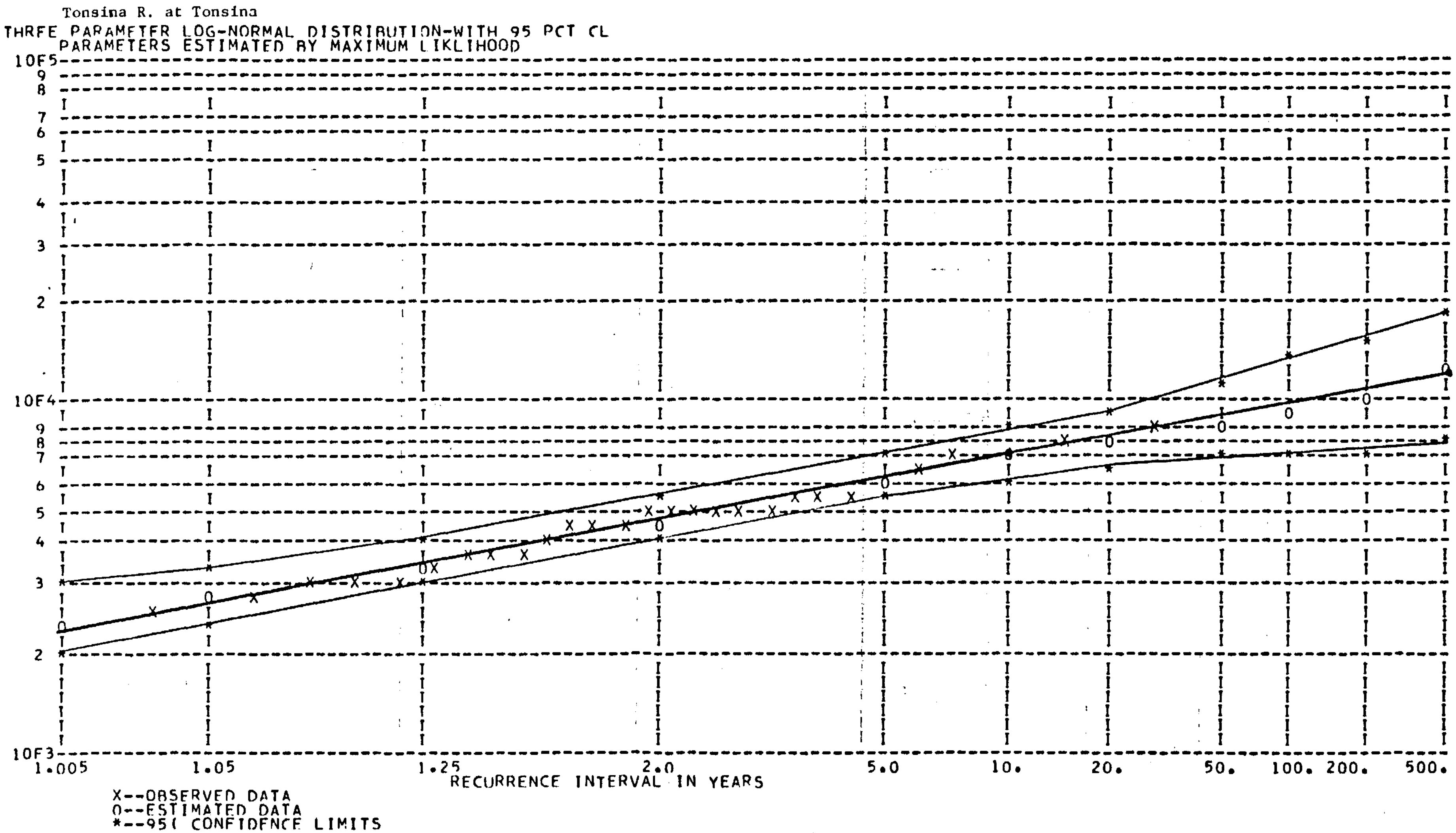
R&M CONSULTANTS, INC.

Prepared for:

ANNUAL FLOOD FREQUENCY CURVE

MATANUSKA RIVER AT PALMER

FIGURE: A.10



Prepared by:

R&M CONSULTANTS, INC.

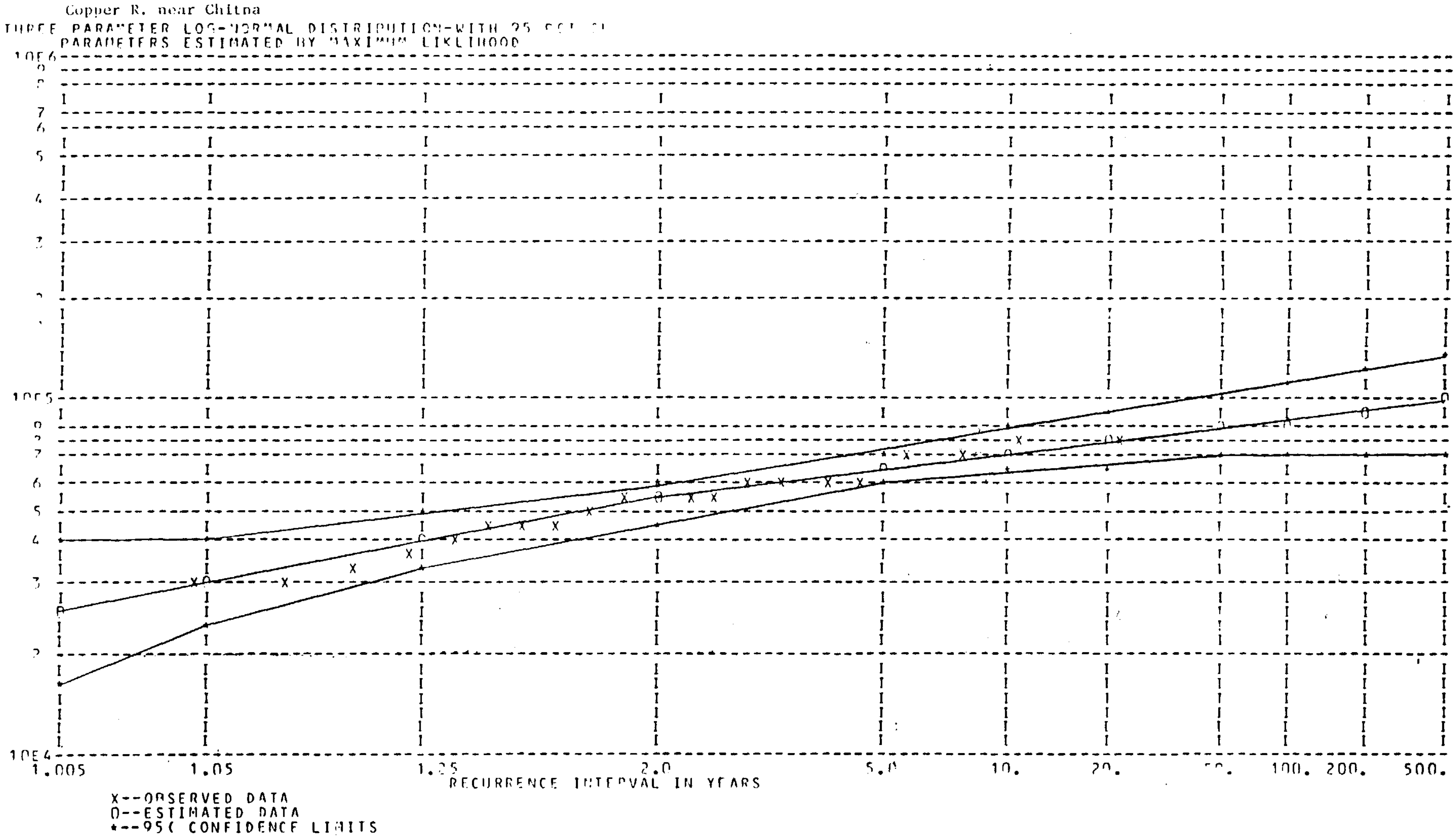
Prepared for:

ACRES

ANNUAL FLOOD FREQUENCY CURVE

TONSINA RIVER AT TONSINA

FIGURE: A.11



Prepared by:

R&M CONSULTANTS, INC.

Prepared for:

ACRES

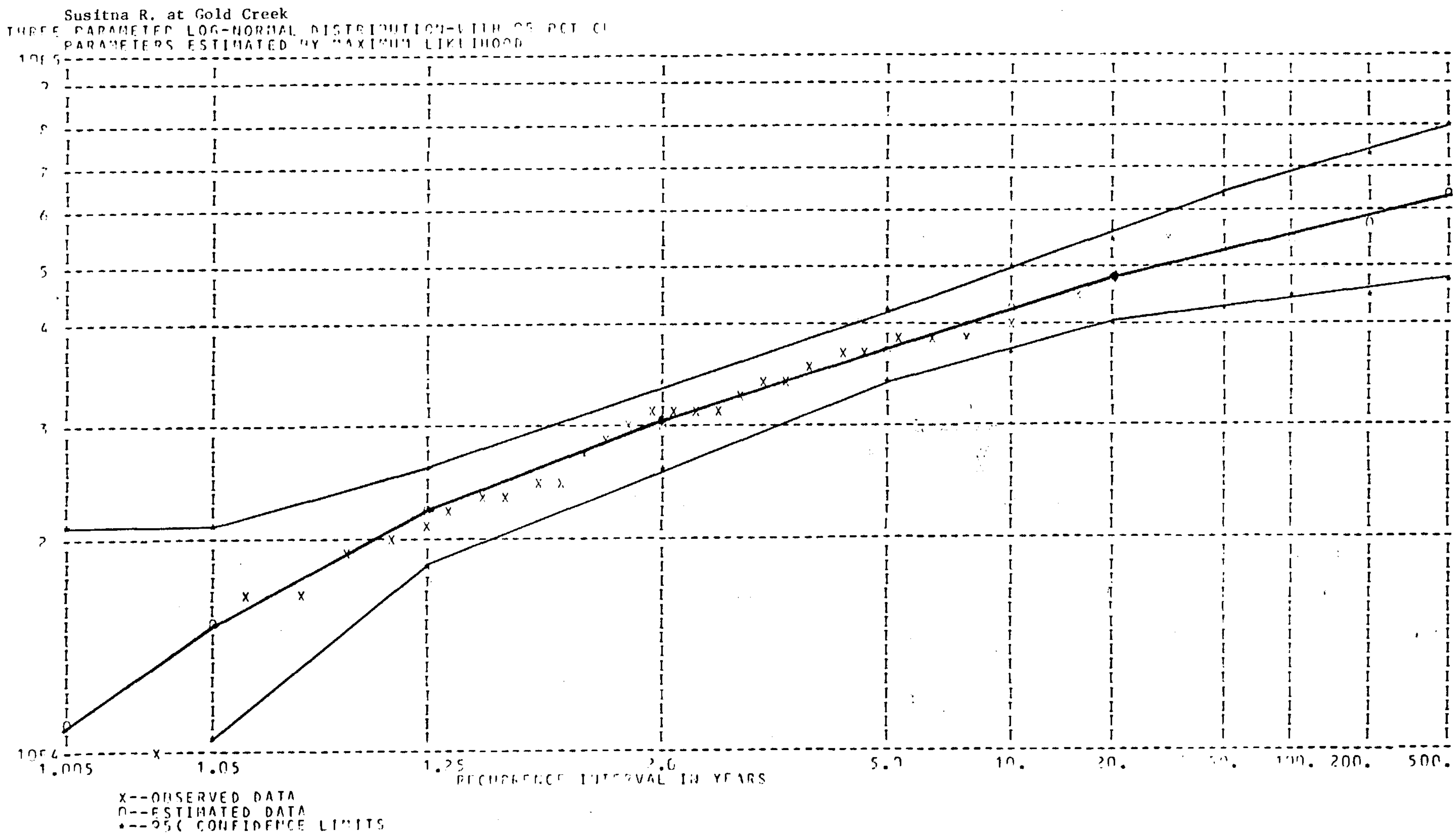
ANNUAL FLOOD FREQUENCY CURVE

COPPER RIVER NEAR CHITINA

FIGURE: A.12

ATTACHMENT B

FLOOD FREQUENCY CURVES FOR
MAXIMUM ANNUAL OCTOBER-MAY MEAN,
INDIVIDUAL STATION



Prepared by:

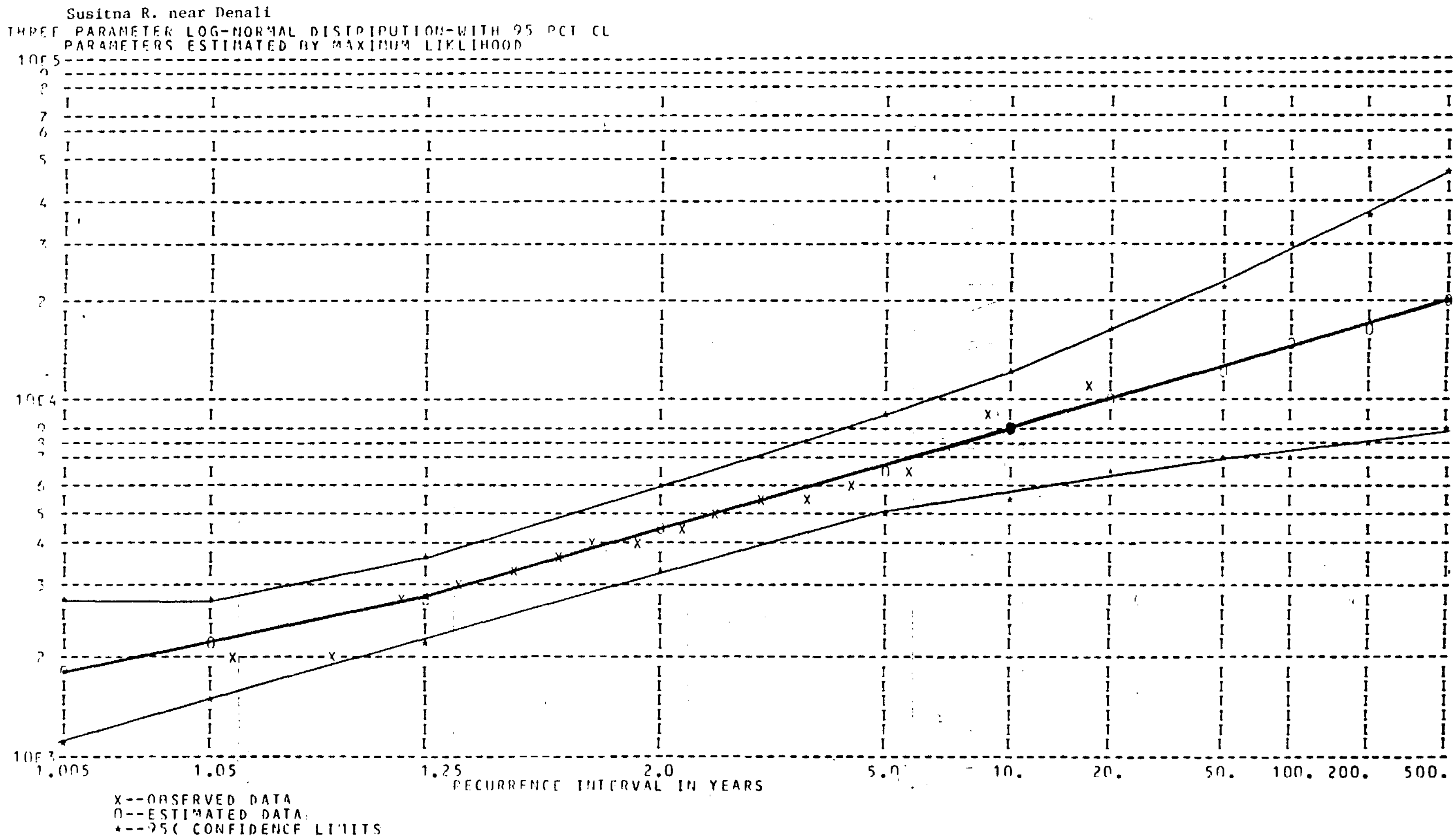
R&M CONSULTANTS, INC.

OCT-MAY FLOOD FREQUENCY CURVE
SUSITNA RIVER AT GOLD CREEK

Prepared for:

ACRES

FIGURE: B.1



Prepared by: R&M CONSULTANTS, INC.

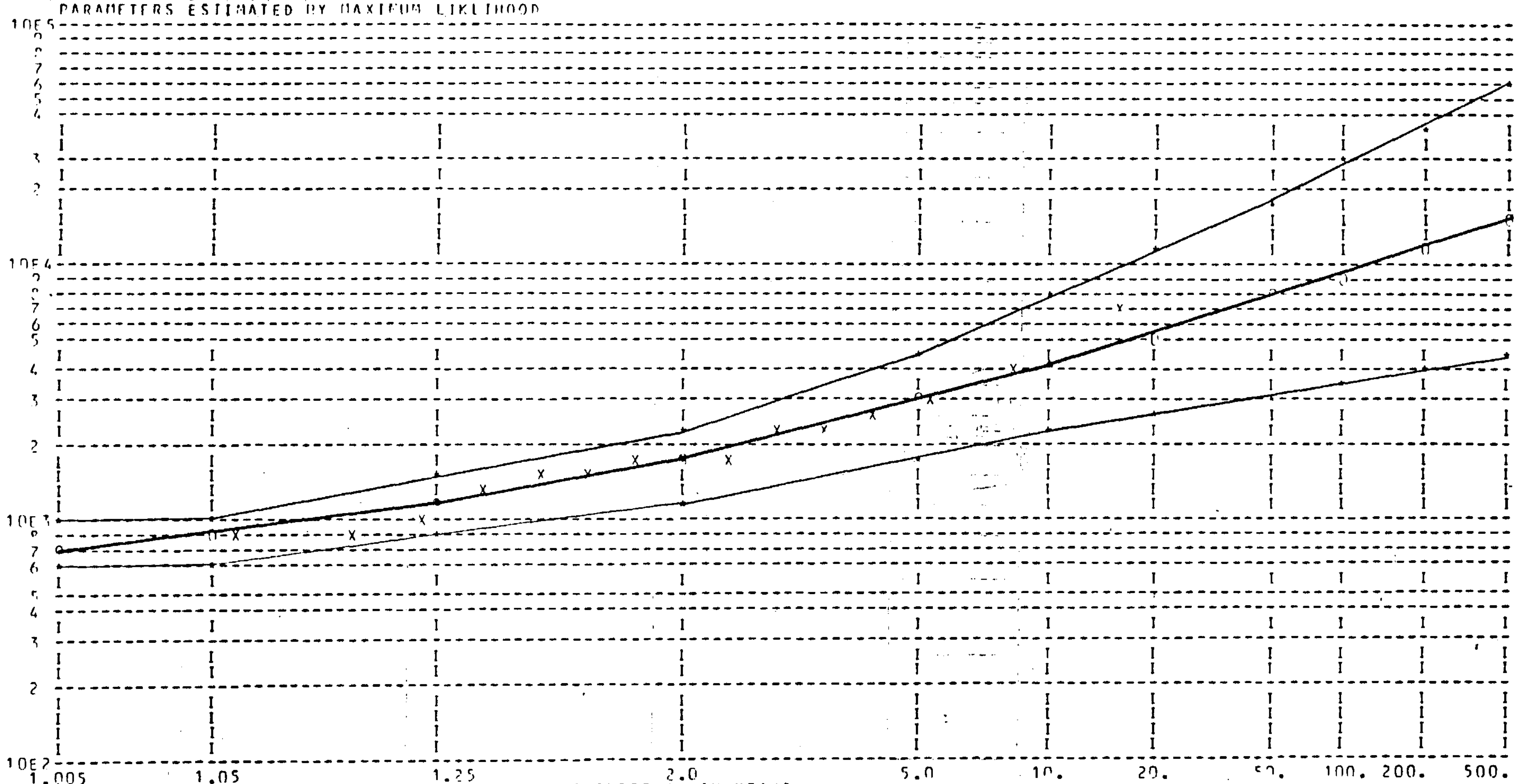
Prepared for: ACRES

OCT-MAY FLOOD FREQUENCY CURVE

SUSITNA RIVER NEAR DENALI

FIGURE: B.2

Maclaren R. near Paxson
THREE PARAMETER LOG-NORMAL DISTRIBUTION-WITH 95 PCT CL
PARAMETERS ESTIMATED BY MAXIMUM LIKLIHOOD



X--OBSERVED DATA
O--ESTIMATED DATA
*--95% CONFIDENCE LIMITS

Prepared by:

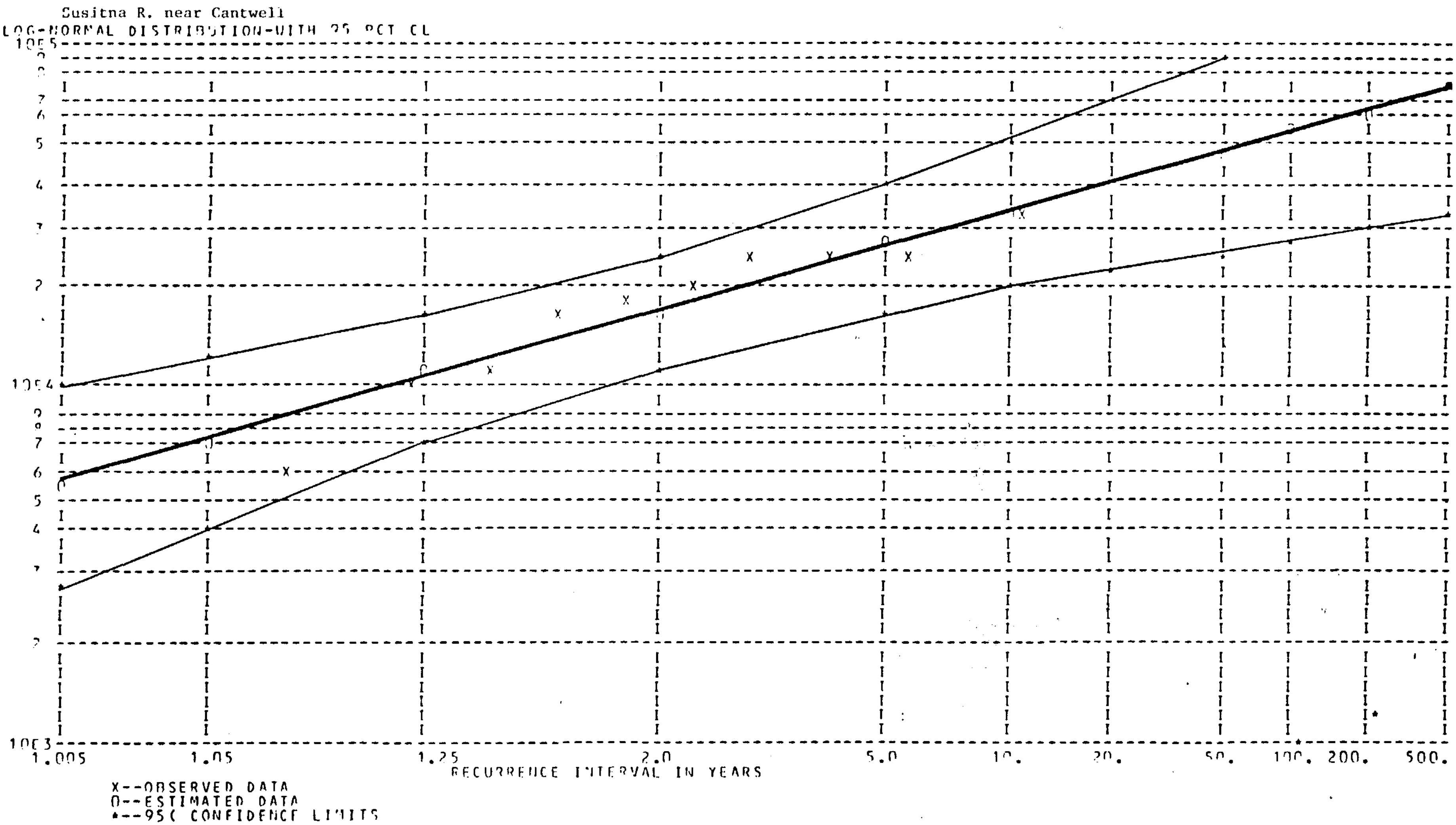
R&M CONSULTANTS, INC.

Prepared for:

ACRES

OCT-MAY FLOOD FREQUENCY CURVE
MACLAREN RIVER NEAR PAXSON

FIGURE: B.3



Prepared by:

R&M CONSULTANTS, INC.

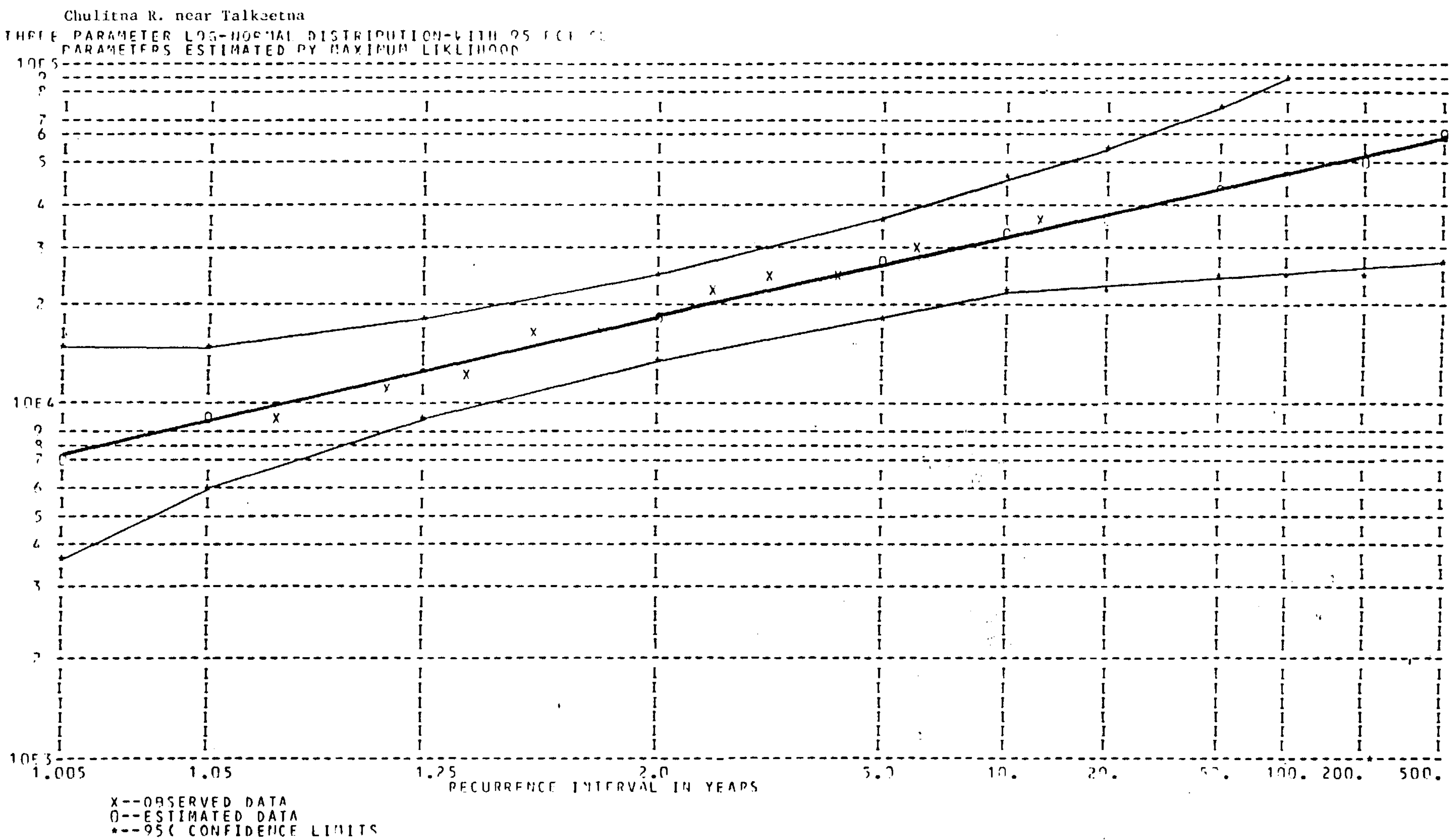
OCT-MAY FLOOD FREQUENCY CURVE

SUSITNA RIVER NEAR CANTWELL

Prepared for:

ACRES

FIGURE: B.4



Prepared by:

R&M CONSULTANTS, INC.

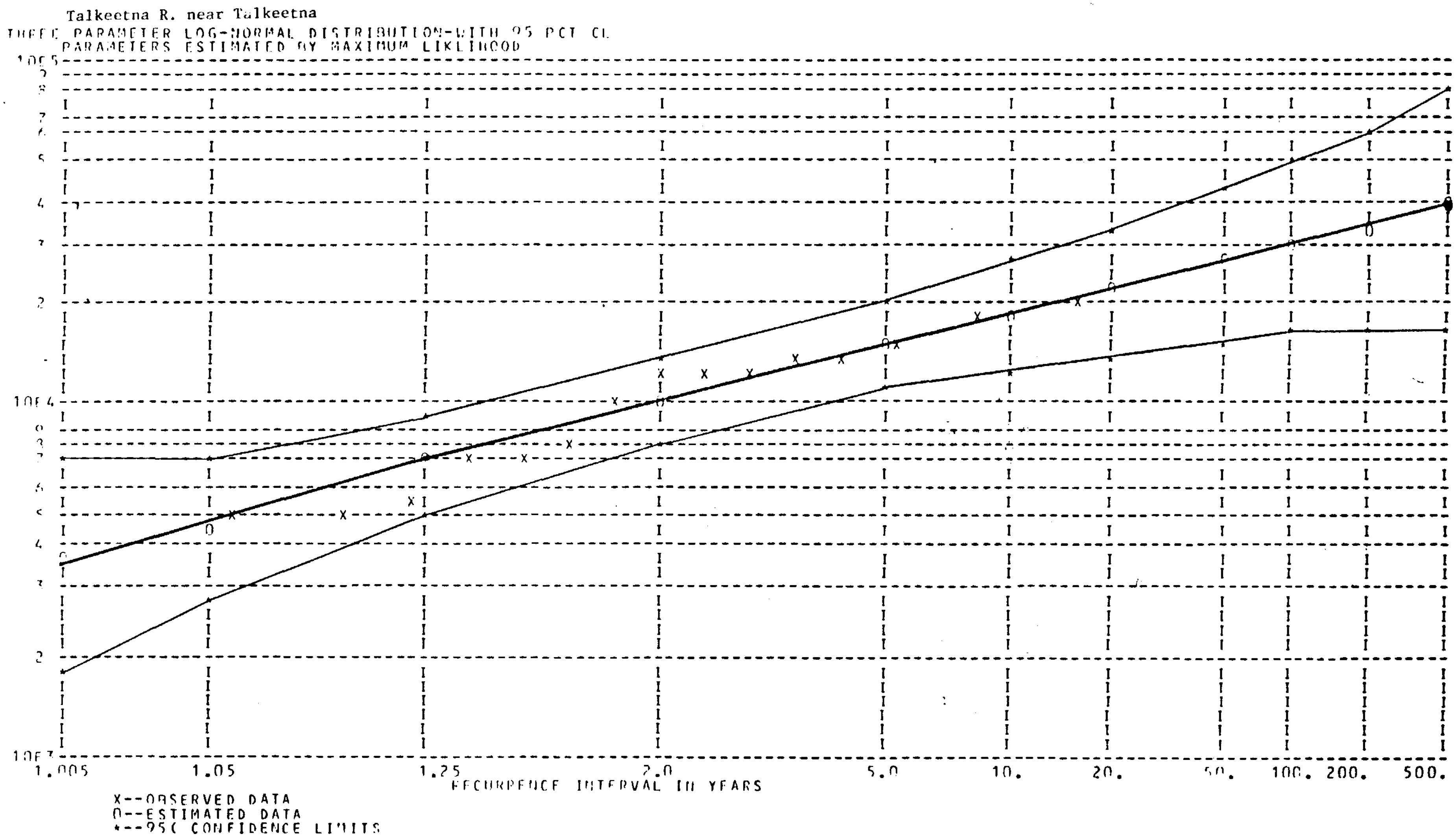
Prepared for:

ACRES

OCT-MAY FLOOD FREQUENCY CURVE

CHULITNA RIVER NEAR TALKEETNA

FIGURE: B.5



Prepared by:

R&M CONSULTANTS, INC.

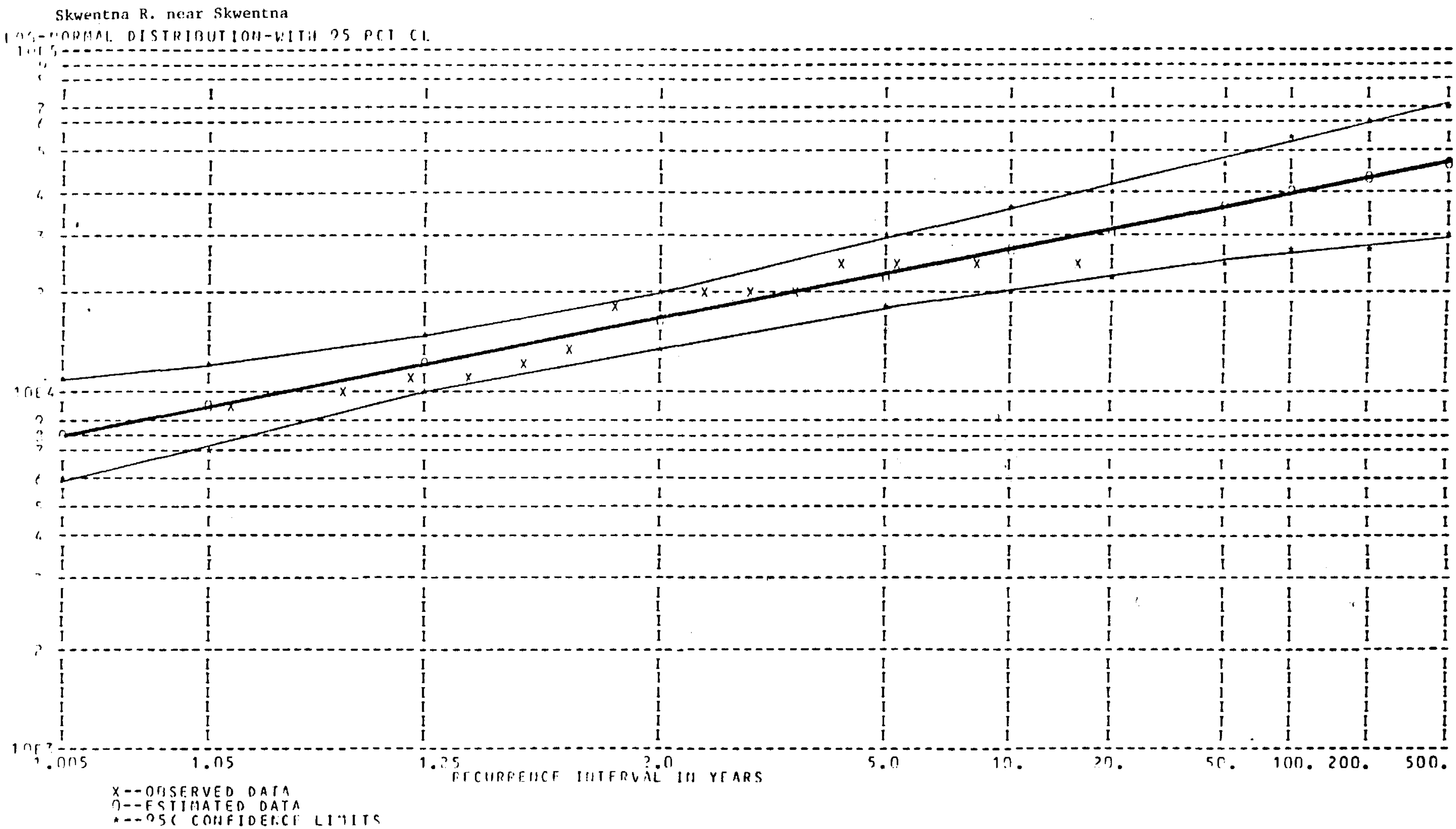
Prepared for:

ACRES

OCT-MAY FLOOD FREQUENCY CURVE

TALKEETNA RIVER NEAR TALKEETNA

FIGURE: B.6



Prepared by:

R&M CONSULTANTS, INC.

OCT-MAY FLOOD FREQUENCY CURVE

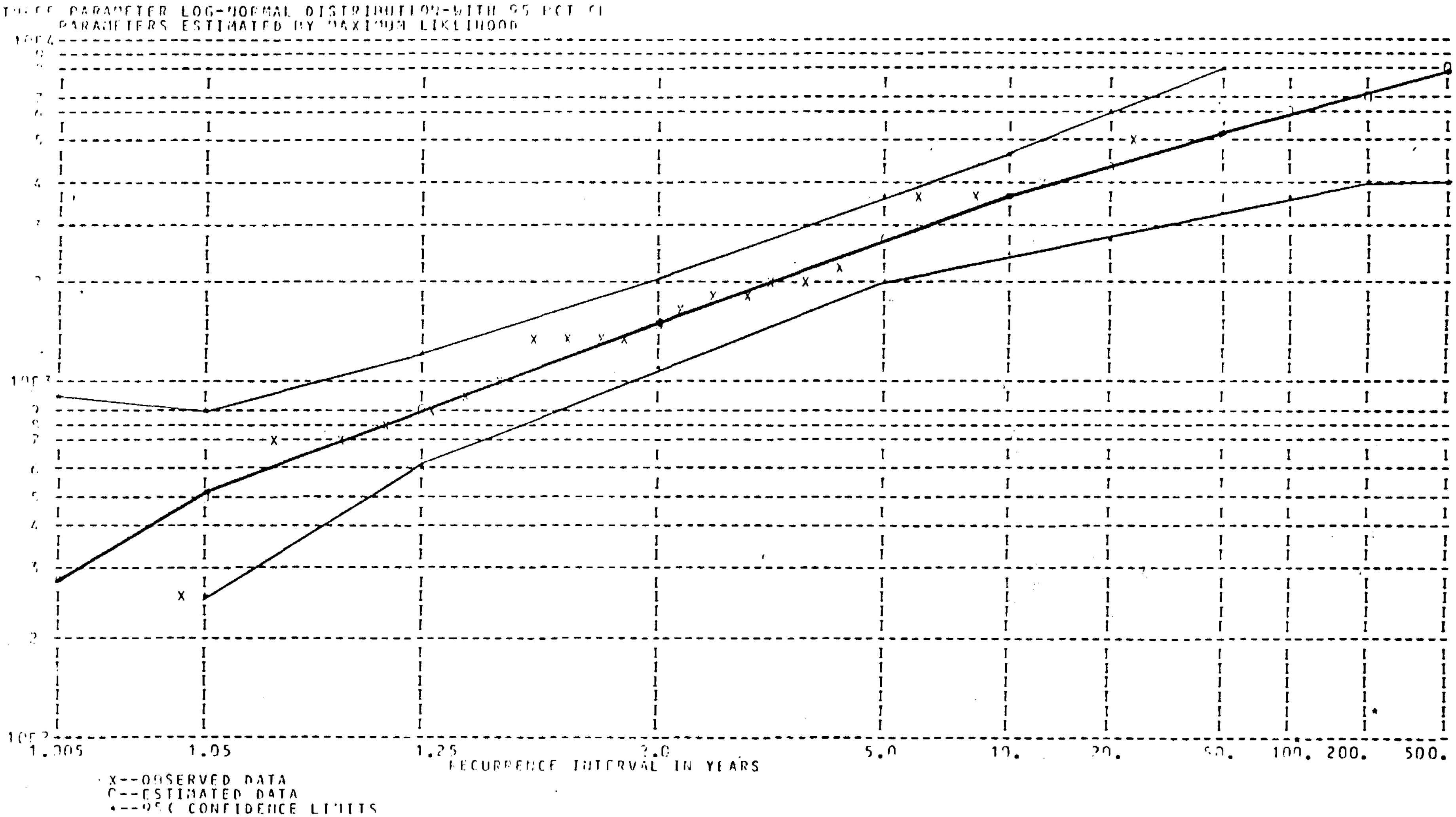
SKWENTNA RIVER NEAR SKWENTNA

Prepared for:

ACRES

FIGURE: B.7

Caribou Cr. near Sutton



Prepared by:

R&M CONSULTANTS, INC.

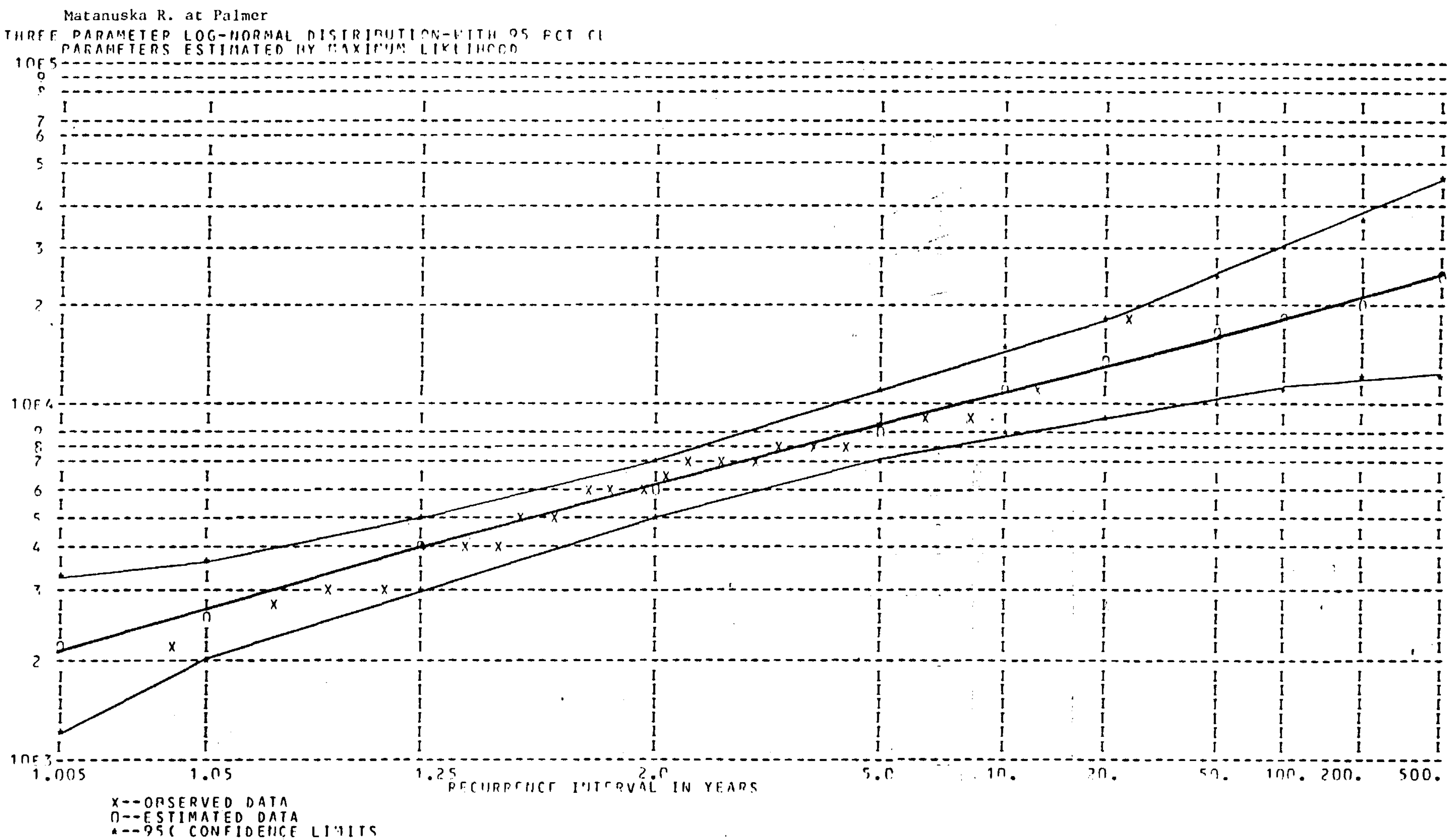
Prepared for:

ACRES

OCT-MAY FLOOD FREQUENCY CURVE

CARIBOU CREEK NEAR SUTTON

FIGURE: B.8



Prepared by:

R&M CONSULTANTS, INC.

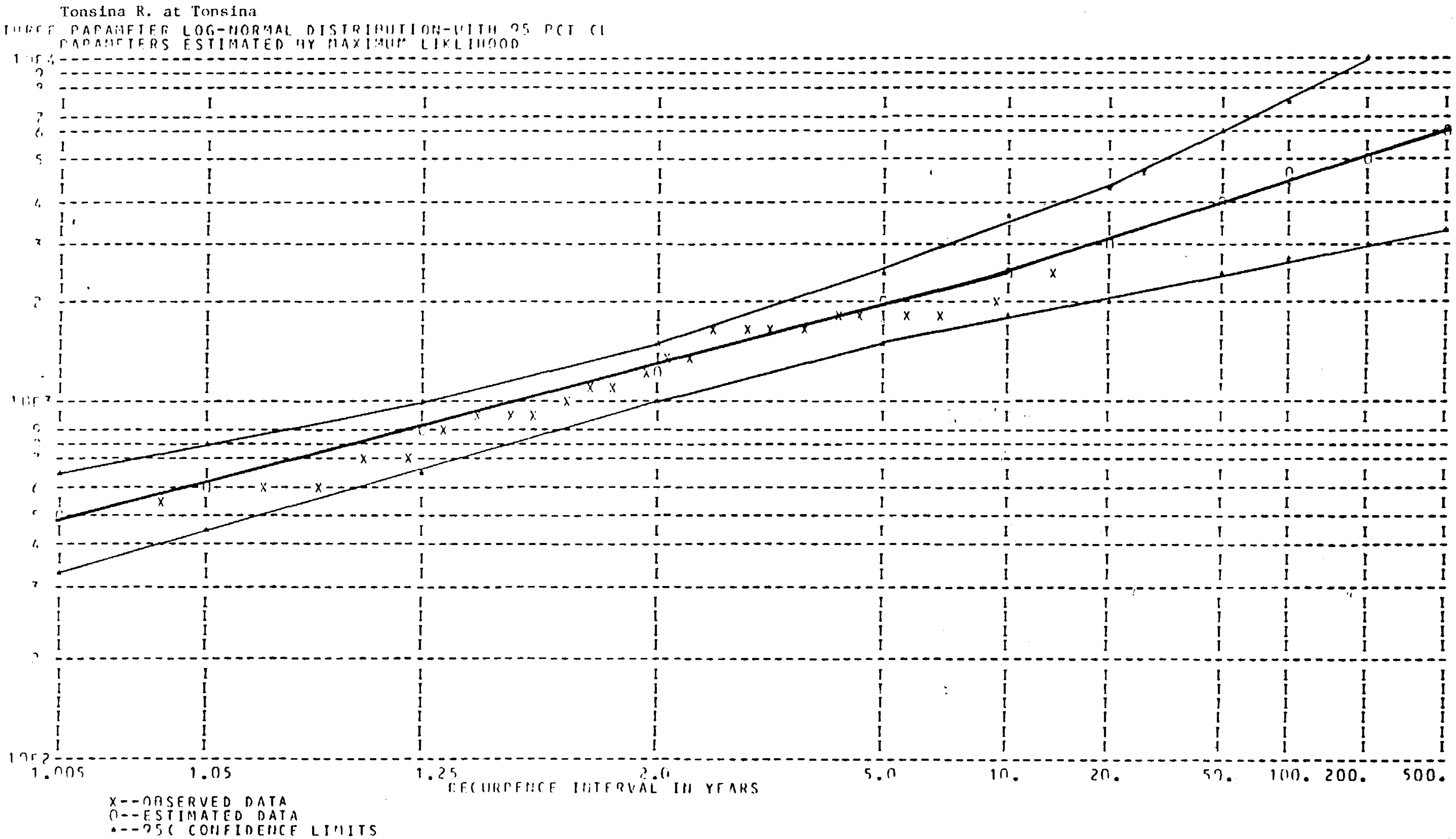
OCT-MAY FLOOD FREQUENCY CURVE

MATANUSKA RIVER AT PALMER

FIGURE: B.9

Prepared for:

ACRES



Prepared by:

R&M CONSULTANTS, INC.

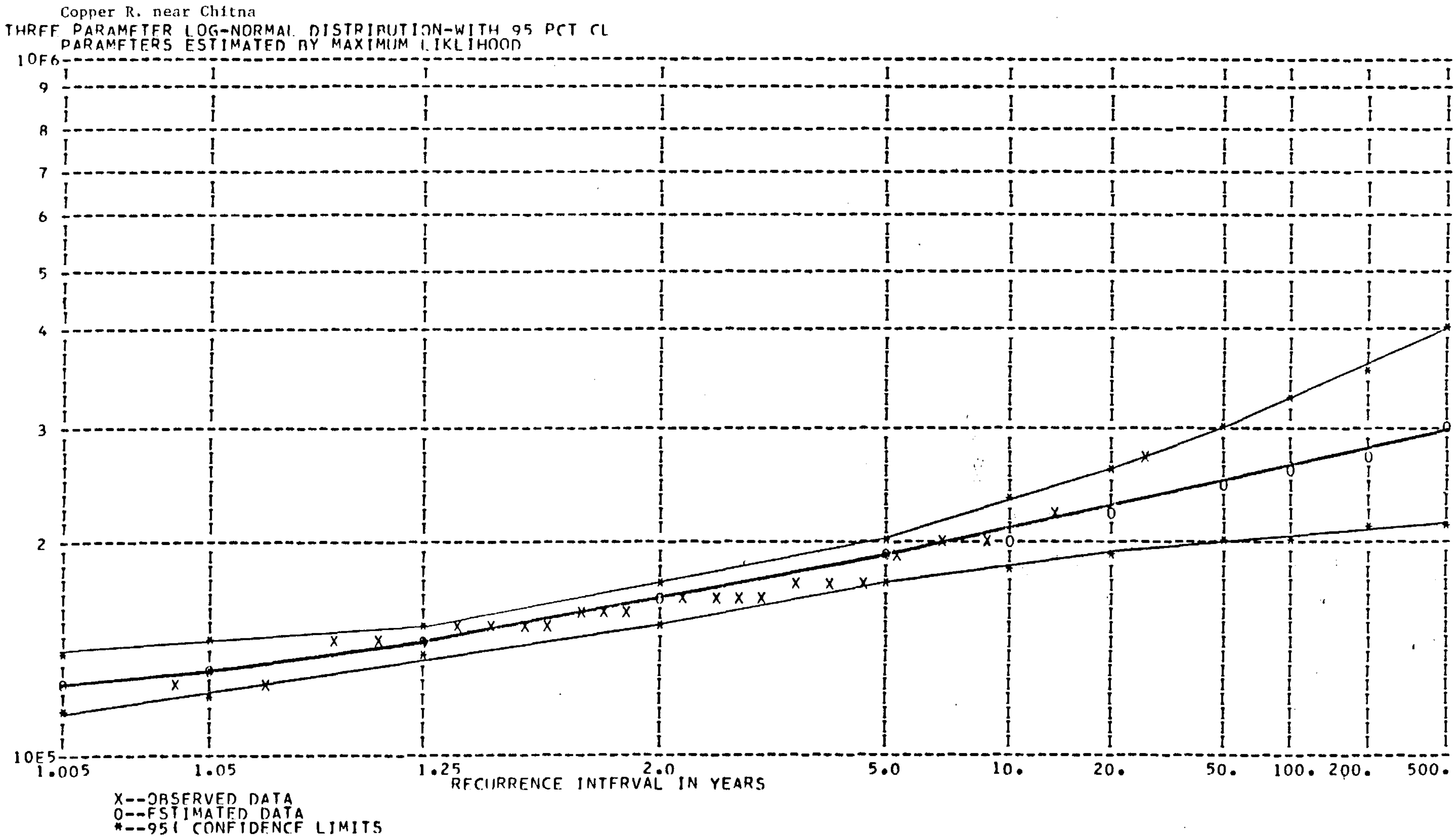
OCT-MAY FLOOD FREQUENCY CURVE

TONSINA RIVER AT TONSINA

Prepared for:

ACRES

FIGURE: B.10



Prepared by:

R&M CONSULTANTS, INC.

Prepared for:

ACRES

OCT-MAY FLOOD FREQUENCY CURVE

COPPER RIVER NEAR CHITINA

FIGURE: B.11

ATTACHMENT C:

COMPARISON OF SUSITNA REGIONAL FLOOD PEAK ESTIMATES WITH USGS METHODS

Station Location	Return Period (Yrs.)	Single[1] Station Estimate (CFS)	Susitna Regional Estimate (CFS)	USGS[2] Area II Regional Estimate (CFS)	USGS[3] Cook Inlet Regional Estimate (CFS)
Susitna River at Gold Creek	1.25	37,100	37,700	48,700	-
	2	49,500	49,000	59,200	43,800
	5	67,000	64,200	73,000	53,400
	10	79,000	74,500	83,400	55,300
	50	106,000	100,000	104,000	71,600
	100	118,000	110,000	115,000	-
Caribou Creek near Sutton	1.25	3,310	1,910	2,510	-
	2	4,500	2,480	3,620	2,670
	5	6,120	3,240	5,130	3,680
	10	7,170	3,760	6,280	4,200
	50	9,480	5,050	8,810	6,210
	100	10,500	5,570	10,500	-
Matanuska River at Palmer	1.25	19,700	20,800	20,400	-
	2	25,500	27,000	25,700	24,000
	5	31,800	35,400	32,500	30,500
	10	35,200	41,000	37,400	32,800
	50	41,600	55,100	47,300	44,600
	100	43,900	60,700	53,300	-
Susitna River at Denali	1.25	14,000	12,400	15,900	-
	2	15,900	16,100	21,700	18,100
	5	20,200	21,100	30,000	23,600
	10	24,100	24,500	36,500	25,700
	50	36,600	32,800	50,900	35,600
	100	43,600	36,200	59,700	-

ATTACHMENT C (Continued)

Station Location	Return Period (Yrs.)	Single[1] Station Estimate (CFS)	Susitna Regional Estimate (CFS)	USGS[2] Area II Regional Estimate (CFS)	USGS[3] Cook Inlet Regional Estimate (CFS)
MacLaren River near Paxson	1.25	4,450	3,760	4,880	-
	2	5,150	4,880	7,180	4,960
	5	6,800	6,390	10,600	6,790
	10	8,420	7,420	13,300	7,660
	50	13,700	9,960	19,800	11,200
	100	16,800	11,000	24,000	-
Susitna River near Cantwell	1.25	24,600	25,400	34,000	-
	2	32,300	33,000	42,500	29,800
	5	42,200	43,200	53,600	36,900
	10	48,400	50,100	61,900	38,400
	50	61,700	67,200	78,700	50,400
	100	67,100	74,200	88,500	-
Chulitna River near Talkeetna	1.25	33,100	28,500	28,200	-
	2	37,800	37,000	36,200	42,600
	5	45,100	48,500	47,100	53,400
	10	50,400	56,300	55,300	56,400
	50	63,100	75,500	72,600	75,200
	100	69,000	83,300	82,700	-
Talkeetna River near Talkeetna	1.25	20,300	20,900	30,000	-
	2	26,300	27,200	38,500	56,600
	5	38,500	35,600	50,100	71,400
	10	49,100	41,400	58,900	76,300
	50	80,100	55,500	77,400	103,000
	100	96,700	61,200	88,300	-

ATTACHMENT C (Continued)

Station Location	Return Period (Yrs.)	Single[1] Station Estimate (CFS)	Susitna Regional Estimate (CFS)	USGS[2] Area II Regional Estimate (CFS)	USGS[3] Cook Inlet Regional Estimate (CFS)
Montana Creek near Montana	1.25	2,040	2,520	1,130	-
	2	3,230	3,270	1,700	1,580
	5	4,670	4,280	2,500	2,220
	10	5,540	4,970	3,100	2,540
	50	7,290	6,670	4,490	3,770
	100	7,990	7,350	5,470	-
Skwentna River near Skwentna	1.25	26,800	23,600	15,700	-
	2	32,000	30,700	20,400	19,400
	5	38,900	40,200	26,500	24,600
	10	43,400	46,600	31,100	25,800
	50	53,200	62,500	40,400	34,300
	100	57,300	69,000	46,200	-
Tonsina River at Tonsina	1.25	3,540	4,820	2,130	-
	2	4,600	6,250	3,040	-
	5	6,040	8,190	4,260	-
	10	6,990	9,510	5,160	-
	50	9,090	12,800	7,130	-
	100	9,980	14,100	8,490	-
Copper River at Chitna	1.25	146,000	127,000	146,000	-
	2	164,000	164,000	165,000	-
	5	189,000	215,000	191,000	-
	10	206,000	250,000	210,000	-
	50	242,000	335,000	246,000	-
	100	257,000	370,000	265,000	-

1 Based on three parameter log normal distribution and shown to three significant figures

2 Lamke, R.D. (1979) Flood Characteristics of Alaskan Streams, USGS, Water Resources Investigation, 78-129

3 Freethey G.W. and D.R. Scully (1980) Water Resources of the Cook Inlet Basin, Alaska, USGS, Hydrological Investigations Atlas HA-620

ATTACHMENT D

REVIEW OF FLOOD FREQUENCY ANALYSIS,
CONDUCTED BY DR. ROBERT F. CARLSON,
UNIVERSITY OF ALASKA, FAIRBANKS

UNIVERSITY OF ALASKA
FAIRBANKS, ALASKA 99701

MEMORANDUM REPORT

To: John Lawrence, Acres American Inc.
Steve Bredthauer, R&M Consultants, Inc.

From: Robert F. Carlson

Date: June 11, 1981

Subject: Susitna Hydroelectric Project

This report is in response to John D. Lawrence's letter of April 3, 1981, asking me to review the regional flood analysis conducted by R&M Consultants. The review is meant to include:

a) Validity of gaging stations selected for the regional analysis and their representation of the hydrologic region analyzed.

b) Adequacy and limitations of the analysis in development of regression expressions and the assumed 3-parameter log normal distribution.

c) Validity of the shape, peak, and volume of the design flood hydrographs as developed.

d) Discussion of review findings with Acres and R&M.

The review is based on three reports which have been transmitted from R&M to Acres:

a) Two letters from James Aldrich to Ian Hutchinson, Re: Susitna Regional Flood Peak Analysis, Project No. 052305, dated October 27, and December 22, 1980.

b) A letter from Brent Drage to Ian Hutchison, Re: Susitna Regional Flood Analysis, Subtask 3.05, dated March 9, 1981.

The time and budget constraints of the review contract did not permit me to conduct an independent computation and verification of the values contained in the report. Therefore, the review is based on the material as presented by R&M. Nevertheless, several key values could be checked by comparison with published information.

Part (a). Validity of selected gaging stations.

The stations selected for regional analysis represent the transitional-continental climate zone of the Susitna basin. The Susitna basin's outstanding geographic characteristic is the combination of drainage from the south side of the Alaska range, the north side of the Talkeenta mountains and the large flat boggy sub-basin north of Lake Louise. It is doubtful whether any other basin faithfully represents this type of hydrologic region. Of the twelve stations chosen for the regional analysis, the Susitna's hydrologic regime is best represented by:

1. Susitna at Gold Creek.
2. Susitna near Denali.
3. Maclaren near Paxson.
4. Susitna near Cantwell.
5. Chulitna near Talkeetna.
6. Skewnta near Skewnta.
7. Montana near Montana.
8. Talkeetna near Talkeetna.

Stations that are not as closely representative are:

1. Matanuska at Palmer.
2. Tonsina at Tonsina.
3. Copper near Chitina.
4. Caribou near Sutton.

The second group has been selected primarily on the basis of station distance from the Susitna basin and a different exposure to the coastal maritime climate. I do not feel the differences are great enough to warrant their exclusion from the regional analysis.

Part (b). Adequacy of the regression expressions and the assumed 3-parameter log normal distribution.

The assumed 3-parameter log normal distribution: Given the very sparse data base of the Susitna area streamflow records in combination with the great variability of extreme values, an attempt should be made to model or fit the sample data with a theoretical distribution of simple construction and few parameters. The analysis indicates that either the log-normal (LN) or the three-parameter log-normal (3PLN) distributions are nearly equally satisfactory. The 3PLN distribution has the advantage of further adjusting for the skew by inserting a lower truncation limit. I feel that, in view of the slight difference in predictability between the two distributions, the LN is preferred because of its simplicity. The analysis is not greatly compromised by using a 3PLN distribution, but the small reduction of the total deviation does not seem to warrant the additional complexity. An inspection of rough frequency plots shows a good agreement between the fitted distribution and the sample points for both the LN and the 3PLN distributions. In summary, my preference for a frequency distribution would be the LN, but I do not see any great disadvantage in using the 3PLN.

The regression analysis: The regression analysis which attempts to predict the mean annual peak flow from watershed parameters has been carried out in a standard manner. A standard step-wise regression program has been used with up to twelve watershed parameters. Of the twelve, five parameters (drainage area, stream length, glacier area, mean annual precipitation, and mean annual snowfall) were shown to be statistically significant predictors of the mean annual instantaneous peak flow. Of these five, only the first three are directly related to basin parameters. The last two are estimated values and must be calculated from nearby gages or yet other basin parameters. Of the first three, the stream length and glacier area are potentially strongly related to drainage area. Larger areas are expected to be longer and, in the Susitna area, they should be strongly related to higher elevations and glaciers. Therefore, since drainage area is the most obvious predictor and far outweighs the others, it should be retained as the only independent predictor. The same reasoning holds for predicting the mean October-May peak flow.

There is one aspect of the regression analysis which is puzzling. The usual reason for an analysis of mean annual flood versus drainage basin characteristics is to allow a regional estimation equation to be developed. Yet I can find no evidence of the completion of this equation or of its intended use. When using the 3PLN frequency model, three values of the sample must somehow be estimated (the mean, standard deviation, and skewness of the sample) or the three parameters of the distribution must be calculated (in this case the truncation level, the mean of the logs, and the standard deviation of the logs). I can find no estimates of the other two and only the Susitna at Gold Creek is used in the third memorandum.

My recommendation would be to estimate the mean annual flood (or May-October flood) from the drainage area and to use a pooled regional standard deviation and skewness to complete the description of the regional curve. The great sparseness of the data base must be constantly kept in mind and the most variable parameters pooled whenever possible.

In summary, unless some use is made of the regression exercise, which is not apparent in the three memorandums, I would not recommend its inclusion in the final report.

Part (c). Validity of the shape, peak, and volume of the design flood hydrograph.

The first step, a dimensionless comparison of the five largest hydrographs, seems to be straightforward and correct. I think the mean curve should be smoothed out a bit more, perhaps with a moving average method.

The time base (which determines the volume) is not clear. Also, whether the base flow was removed from the peak prior to the plot is not clearly indicated. I was not furnished with Enclosure 3 (the fifty peak hydrographs), so it is difficult for me to make an accurate assessment.

Although a flood peak versus volume relationship was established in Figure 7 of Memorandum 3, it is not clear whether the flood volumes were estimated from this graph or established independently through a separate frequency analysis. I assume a separate analysis has been made and the peaks and volumes, say for a 50-year return period, are matched to form the hydorgraph. That seems to be a logical procedure, but the volume under the stated flood peak hydrograph should equal the corresponding estimated flood volume. There is no clear indication that this comparison has been made.

In summary, the flood peak-volume analysis has been carried out in a satisfactory way, but the several points mentioned above should be cleared up for the final report.

Part (d). Discussion of review findings with Acres and R&M.

I had preliminary discussions with Brent Drage and Tim Renschler of R&M Consultants about the analysis. My comments were essentially the same as those I have presented here. In late May, I had a meeting with Steve Bredthauer of R&M Consultants during which we discussed the three memorandum reports in some detail. Again, the substance of my remarks has been presented here.

Part (e). Some additional items for discussion.

The instantaneous-daily flow ratio analysis seems to be logical and consistent. An average value of 1.1 for all stations would seem to be appropriate. The mean daily values should be used for the frequency analysis since they are stable and available in every case. Then the calculated ratio should be used when required.

A comparison of the predicted values of mean daily floods for the 100-year return period from four sources compares reasonably well. The values are:

Lamke's U.S.G.S. Report	120,000 cfs
U.S. Corp's Interim Feasibility Report	110,000 cfs
R&M's Lognormal Estimate	112,625 cfs
R&M's 3-Parameter Lognormal	117,782 cfs

These values are reasonably close, given the general vagueness which is a part of every flood frequency analysis. One can be fairly sure that the flood frequency analysis has been carried out correctly.

Part (f). Concluding remarks.

This memorandum report completes my review of the Susitna flood frequency report. I hope the comments will be useful for understanding the application of the frequency analysis and for preparation of this final report. I will be willing to assist in any additional analysis which may be required or to answer questions about my comments.